WILLIAM BONVILLIAN: So this is the great groups class. Let me do a quick background here to get us up to where we are at the moment. And then, I'll just do a quick overview of the William Rosen book on the Industrial Revolution. And I'll do just a summary the Bennis and Biederman rules. And then it's your class.

So, quick background, you remember these characters Solo, Robert Solo, and Paul Romer, and we'll just do a quick recap. But Solo, essentially, taught us that technological and related innovation is the dominant causative factor of growth. Romer taught us that behind that, in effect, R&D system is what he calls human capital engaged in research. In other words, it's the talent base that's in that system, that these are to direct innovation factors.

And then, there's a whole set in this complex ecosystem of innovation. There's a whole set of direct and indirect factors. So, Solo and Romer, we just talked about, then innovation occurs in a complex kind of ecosystem of different factors. Some are direct, like talent and R&D. Some are much less direct. Some are set by the private sector. Some are set by government.

And you can see here that rich list of kind of factors that aren't as central, that aren't as critical, but still must be accounted for. In looking at that system, they do play within that innovation system. And then, a third question, which has been at the heart of a lot of what we've been talking about in class, is there a third direct innovation factor? And arguably, the organization of science and technology is that factor.

So, we talked about how the US innovation system evolved and kind of told the story of its evolution in that World War II time table. The Rad Lab at MIT was an important foundational moment. Vannevar Bush was the author of that kind of leading tract on what the US post-war innovation system was going to look like. And his model led to the creation in-- and the continuation, really starting in World War II, it started in World War II, of the federally funded research university, and then the plethora of basic science research agencies in the US.

So, that's innovation on the institutional level. But, as we've talked about before people innovate, not institutions, which is really the topic of today's class. And we're going to run through a series of great innovation groups. We'll run through five of them. So, we'll lay out Edison and Bardeen, Oppenheimer, the Xerox PARC group, Boyer and Swanson, and Craig Venter. So, we'll do a group of three that sort of came out of the earlier physical sciences side into the IT side, and then we'll do two life science leaders and groups.

Just as background, William Rosen wrote this book called *The Industrial Revolution in Britain,* and he has important lessons for us on the process of innovation, and I'll just recap. I'll just pull out of that book some thoughts that may help us think a little bit in the big picture kind of way about some of these issues.

First, he identifies something called the intelligent hand. And that concept is taken from Charles Bell, but it really originates in Immanuel Kant who identified the hand as a window in the world. And since MIT's model is mind and hand, in other words, in many ways, it's learning by doing, that's an important conceptual framework when we begin to think about innovation that's clearly not mind only. It is clearly mind and hand. It's the combination of the ability to do things physically and in a tactile way, carry them out as well as think those great conceptual organizing thoughts.

Davinci combines, and I've just been reading a biography of him, but he amazingly in his thousands of pages of notebooks combines his incredible ability to do art and draw with his highly inventive skill set of imagining all kinds of new machines, right, that were unimagined in the context of the 1500's when he's writing. Helicopters, as one example.

His ability to see and conceptually see and draw helps enable him to invent these big conceptual ideas. So that's another way of looking at mind and hand. Right. Another way of looking at the intelligent hand. So Rosen argues that the visual, and the tactile, and the mind, and the eye, and the hand, are all critical in this innovation invention process.

Just to quote-- to take a few moments here and pull moments out of his book, one is what he calls the flash of insight problem. And the example he provides is James Watt is walking on the green of Glasgow. And in that moment, and, of course, it's Scotland, so he's walking past the golf shack. Right. Where else? Right. He has the idea for condensation in achieving a much higher level of efficiency of steam power.

So, there are steam engines working in mines prior to Watt, but it's that walk on the green where he writes that the inside came together. But, we have to put this into the context. His insight, as he's walking next to the golf shack, appears effortless, but it's built on a long term project of understanding how steam power worked.

And Watt is an interesting figure because he comes out of a poor background in Scotland. He gets-- he's a skilled artisan. He becomes an instrument maker. So, he's working on early scientific, and navigational, and astronomy instruments. And he works in London, and he's exposed to the finest skilled artisans working on those early scientific instruments. He comes back to Glasgow. He's blocked by the local Guild from setting up his own instrument shop.

What's he going to do? He takes a job at the University of Edinburgh and actually becomes quite a close friend of Adam Smith who's inventing economics at the same time. And he digs into, in depth, into steam engines, and begins to develop concepts of how they actually function and work. I mean, this is pre-thermodynamics. But Watt is developing a lot of those early idea concepts that will lead to that conceptual kind of framework.

And he spends 10 years on that project before he has the walk on the green. Right. Doing these various projects. So it's that 10 years that enables the insight. So, Anders Ericsson who Rosen also writes about develops the expert performance model. Its time on task. It's not talent alone. So, it's really important to do those 10,000 hours of practicing before you can pretend to be a serious musician. Right.

So, you may appear musically fluent, but those 10,000 hours of practice turn out to be absolutely critical foundations. So, it's this combination of expert performance, Anders Ericsson Ericsson would argue, with that intellectual capability that's very key here. Michael Polanyi, a philosopher and psychologist thinks about learning by doing. What does that process look like?

And he develops a whole concept of tactile knowing, that it's a combination of knowledge and skills, actual physical tactile kinds of skills. Eric Kandel begins the work in neuroscience and beginning to tell us how learning can occur. And he's there great Columbia neuroscientist Nobel winner. He tells us how the brain chemistry changes in the course of actual tactile experience. Right. Which helps us understand why that-- its mind and hand in combination.

So, let me let me leave those there. And then, turn to Warren Bennis and Patricia Ward Biederman who wrote this book called *Organizing Genius* back in 1997. So Bennis had been an MIT faculty member. He became president of a university in Ohio. He then moved to teach business at USC, which is where he's writing this book from along with Patricia Biderman from

USC.

And they, after watching closely a lot of innovation groups, as you all saw, they develop the idea that these groups seem to operate on rule systems. That there are kind of rules to govern a group. And that these different innovation groups share a lot of rules. So, that's the key concept here that we're going to be playing when we discuss our great groups here in class.

And they run through-- I'll just run through some of the basic rules that you all, you know, by now are familiar with, but they argue that greatness starts with superb people. And they quote Bob Taylor of Xerox PARC, you can't pile together enough good people to make a great one. That great groups and great leaders both need each other, and create each other, and enable each other, that it's not leadership alone, it's the group and the group needs leadership. But the leadership have got to be able to play off of and interact with a group.

And we'll see different leadership styles in putting these great groups together as we talk about these groups today. Great group leaders love talent and know how to find it. Right. That's to create a great group you got have great talent in it. And a role of the great group leader is to find that talent.

The talent in great groups can work together. And in the Oppenheimer story, Beth, you're going to tell us some of the dissonance points I'm sure in that great group. And certainly-- and Martin and the Bardeen, Brattain, and Shockley story, you're going to tell us about some of the dissidents in that great group that kind of blew it up.

Great groups like to think they're on a mission from God. In other words, they have to believe that this is the most important mission that could ever possibly happen. Otherwise, they never get anywhere. So they have enormous zeal. Right. And it's almost a kind of religious zeal as they embark on their projects.

They wear blinders. In other words, they can focus only on their project. They can stay on task And make that their entire focus. Otherwise, again, would they get there? They are optimistic. They are not realistic. So, if they were realistic about what they were attempting, they would never try it. But, because they are optimists, they have the willingness to persevere in the expectation that something is going to happen.

Great groups are islands, but they have a bridge to the mainland. So, Luyao, when she tells us about the Xerox PARC story, is going to tell us the classic island bridge story. But typically, great groups need to get put on an island, a protected island, out of the control of bureaucracies, out of the control of the suits, where they can do their own thing, where they can come up with their inventions and then innovations.

But, nothing happens to those innovations unless they have a bridge back to decision makers that enable those technologies to get effectuated, to be put into place. Great groups have an enemy. Probably the most famous in your time, maybe you're all too young for this, remember those big blue commercials that Steve Jobs ran during super bowls? You know attacking IBM and its minions who were wearing suits in this kind of dark Orwellian advertisement talking about Apple is up against this, you know, authoritarian IBM enemy. Right. It was a shocking ad at the time. But it gives you a very good example of just how it felt to be at Apple pushing up against IBM's PC trying to get your Mac out the door.

Great groups have the right person in the right job. They have to avoid what we could call Hollywood syndrome, right, where everybody is a star. They've got to find ways by which everybody contributes, and has a critical area that they can handle. The groups give their talent whatever they need to thrive, and they free them from anything else.

The group needs protection from the outside forces. Typically these groups are very high morale. They're having a wonderful time. They're having the time of their lives. It is , funny and exciting, and it's 24/7, but they're having the times of the lives. And when they write later about what it was like, these are high points in their lives.

Tyranny destroys the collaboration. So, in a way, they've got to be, and we'll see different leadership styles because it's by no means always democratic, but there's got to be an ability to pitch in and contribute. Yeah, Max?

AUDIENCE: Yeah, I was just going to ask how does Apple fit in there?

WILLIAM BONVILLIAN: Yeah, well, it's going to be a very interesting set of questions.

MARTIN: Yeah.

WILLIAM BONVILLIAN: And maybe we'll raise that when we think about how Thomas Edison operates as a leader in that kind of 19th century leadership context, which is different than our era.

Teams are collaborative. They need to be flat and non-hierarchical, and pretty democratic. A lot of these rules we start to see in the Rad Lab, this is kind of how the Rad Lab functions in developing the first federally funded research and development center, creating the model for that.

The Rad Lab follows a lot of these rules. They use the challenge mission, challenge model. In other words, they've got to be solving a really big problem. This is not curiosity driven research. This is problem solving. It's solving a challenge. You have to ship. In other words, there comes a time when you have to get something out of the door. You've got to be able to set a time frame and move out your technology within a plausible time period to actually get into a market. Xerox PARC has a lot of trouble with this rule. You know, as we'll talk about when we get to Xerox PARC.

The group needs to have a continuous learning environment. So, in other words, they're all learning from each other, and they need to have a setting by which they can bring out each other's skill sets and teach each other on a continuous kind of basis. And Oppenheimer provides some interesting insights on this.

I think those are kind of key rules. And then, we're going to turn now to our colleagues to present their particular great group. So, we'll get the three kind of earlier great groups will each of you all will present on those and kind of get those out on the table. And you've got about 10 minutes or so to tell their story and explain their rule set and what additional rules they kind of came up with that are relevant here. Clear so far?

All right. So, Martin, why don't we do Edison first?

MARTIN: [INAUDIBLE]

WILLIAM BONVILLIAN: There's Edison.

MARTIN: I think with Edison, it's important to kind of look at him as an individual first, and then also the organization and group he created after. So, Edison came from a relatively poor family. He kind of made his own ways. He's kind of like the original self-made American inventor. He started off self-taught because he was kind of deaf, so he couldn't really learn in a school setting. So, his self-taught him math at home.

And so, that also gives him an original way of looking at problems. He's not really used to following social construct as well. And then, he gets a job on the railroad where as he's going on the railroad he sees a lot of different things. So, he's somebody who kind of becomes street smart as time evolves. And he is inventing things and learning while he's on the railroad. So, there's a funny story about him having his own little mini lab on a railroad which, you know, it's pretty funny. And so people wouldn't steal certain chemicals, he would like list them as poison.

And then, so that's kind of like his development into adolescence. And as he grows up and kind of becomes an adult, he gets relatively lucky. But he has all these hours of experience of inventing, and he invents this thing called the-- let me get the name here-- it's like the quadruple telegraph which what he sells for what would be the equivalent of $200,000 today. And that's what he uses as the initial money investment to make his lab at Menlo Park, which is considered, I think, one of the first great American research labs.

So, for him, it's pretty interesting because he's relatively street smart understands, the technology, understands what he doesn't know about the science, and understands the individuals. So, as he comes in, he is kind of a strong leader. But what he does that's unique is he finds different people with different talents. Not just academic, but also people who can build things. People that have experience shipping. People have leadership abilities because he's kind of had this kind of-- His 10,000 hours isn't just science, it's also been the ability to interact with a variety of people and see how they actually work in a real-life setting.

So I think what would be interesting with him was to go through the Bennis. Kind of some of the characteristics of strong groups and kind of relate them to how he did it at Menlo Park. Let me see if I can find this. OK. So, need certain conditions. Focus. So, Menlo Park was really a ranch that he originally bought with his house in the back.

So, being the leader, he kind of took it upon himself to place it near his home. But, he actually rarely went into his house. So, his wife lived in the back, and he would always be in the shop of Menlo Park always working with the people there. To the point that one time, he walked into his house and his wife hadn't seen him in about a week. So, she thought it was an intruder. So that kind of focus. Just to give it--

WILLIAM BONVILLIAN: She almost shot him. Right?

MARTIN: Yeah. Yeah. Yeah, I mean, I don't want to imply, but yeah.

[INTERPOSING VOICES]

MARTIN: Light bulb moment. Have everyone in one place. As I mentioned, they're there in Menlo Park. And he has these great individuals. Isolate them. They are kind of isolated in their own skill set, but they can always collaborate. It is a flat model. There's only really two floors I think in Menlo Park. And then, he did choose to expand slightly later, but it wasn't highly isolated.

No distractions. They were away from what I would say like other people. So it was an island. Atmosphere stress, they did have stress because they did have deadlines. And they're also very prolific. I forget how many patents. You might know the number. I know Edison has around 1000 patents by time of his death. I think-- I don't want to give a wrong number because it's hard to find, but I know that they're very prolific in terms of assuming a patent like a week. Something like that.

Because the talent, but also like I mentioned, Edison was street smart, so they knew but things are kind of ready to invent and put out there right away. So, most of the patents were all utility based in terms of mechanical, electrical, magnetism. And a lot of them-- I think there's only 14 patents for Menlo Park for something that was design related. So, it's very much focusing on what they were good at, which was kind of this applied science area.

Island with bridge to mainland. They were the island. The ability to sell, Edison already knew from past inventions, so that wasn't as much of a problem. But it does fit that framework roughly. I would say.

Winning underdogs. They did have competitors. They're not as famous as, you know, apples competitors or other companies. But they did know that at this time period, a lot of different people were making inventions to run electricity, and it was a market that there was a lot of competitors coming in, and you really had to fight to win. Even though they were utilities, the dynamics of the markets weren't as they are now.

Have an enemy. That goes back to their opponents optimism. And not really realistic. They would just try things to try things, to see if they would work. And sometimes, they would work or would not work out.

Right person for the right job. Give them what they need. They had a ton of resources. Let me bring up a example. A newspaper article printed in 1887 reveals the seriousness of his claim saying the lab contain 8,000 kinds of chemicals, every kind of screw made, every size of needle every kind of quarter wired, hair of humans, horses, hogs, cows, rabbits, goats, minxes, camels, so silk in every texture, cocoons, various kinds of hooves, shark's teeth, deer's horns, tortoise shells, cork resin, varnish and oil, ostrich feathers, peacock tails, jet, amber, rubber, all auras, and the list goes on. So I mean that--

AUDIENCE: Why?

AUDIENCE: He was a hoarder.

[LAUGHTER]

[INTERPOSING VOICES]

MARTIN: Yeah, well, at the time there's different theories of science. Right. So, they weren't as refined, so they would try different things. And also, he probably left room for things that weren't mainstream science at the time to try different theories because if you have an expert that says, oh, I know how to do this and this, but it's not explained by the current theory of science, he would still give them a shot usually.

WILLIAM BONVILLIAN: So, these presumably are all for filaments to get across the two electrical poles. He's got to find the right filament that's--

MARTIN: And I think what the right problem at the right time. Like Edison wasn't the first person to create the light bulb. He perfected the design so it can last longer than, I forget if it was five seconds or five minutes, so it could last for extended periods of time. So, that's another gamble, finding the right problem at the right time.

And it's something that we see in tech a lot. Like the I think the Newton from Apple was like an original was pretty much the iPad, but it just was the wrong time. Also, I think Oracle came out with something that was like the book like in the late 90s, and it didn't sell because it was too early. And not a lot of people on the internet yet, and there wasn't Wi-Fi.

So, I think those kind of showcase some of the examples of how Menlo Park was run. It was definitely kind of like a hierarchy where Edison kind of made the decisions, but he would make more hard decisions, which is important as well because it gets rid of complexity. And allows people-- usually, if you make a quick decision, it's better group because you'll go that way, and if it doesn't work you just move on to the next thing, but people aren't debating about, oh, let's do this or that for a long period of time. So, there's also when you're there, just focusing on doing the work.

So, those are some of the characteristics of this great group in Menlo Park.

WILLIAM BONVILLIAN: You know, maybe we ought to do Q&A now rather than kind of bunch these up. Let me just share a couple of thoughts with you from these photographs. That's the invention factory. And then, back behind this is the house, the old farmhouse where Edison theoretically lived with his wife, although he's spending almost all his time here. And that's the team. Right. That's the group. And there's the group, right, on the first floor of this building.

And it's an interesting amalgam of talents. So, there's some engineers and scientists in here, but there's tremendous artisans. Since they have to invent the vacuum tube, in effect, they have a great glass blower. Right. So, it's a very interesting mix of we call them experimentalists and theoreticians are, you know, combined in this space. But a remarkable ability to work together, and Martin has well described some of the rules that apply to them.

They're having a good time. So, they're often up ridiculous hours of day and night. And they have a, you know, they have an old stove. And after midnight, they gather around the stove. So, rap has not been invented, but they shout doggerel poetry to each other that's humorous at the top of their lungs. And Mrs. Edison brings by cherry pies. All right. So, they feast around the old pot-bellied stove eating pie and shouting doggerel poetry at each other. It gives you an idea of the kind of adventure that they were having together.

And on the island bridge point that Martin made, a key set of relationships that Edison was able to form was that telegraphing in effect like quadruplexing by telegraph. The ability to send multiple messages over the same line. That really enables the stock ticker and a tremendous amount of exchange of financial information for stock exchanges.

So, buying could occur at a distance. You could place orders from all over the country, which really is foundational for Wall Street. So, people like JP Morgan completely understood the power of this and have a relationship with Edison. So, the Edison crowd is all off in this rural farm on an island, but Edison has got a bridge back to JP Morgan. So, when they figure out the light bulb, and the system that goes with it, which I'll get to in a second, he's got a way to reach a decision maker who can actually stand up to technology. Right.

And that's really crucial. So, that invention earlier that he came up with is really the enabler for this whole project. They have to ship because, as Martin says, they've got a limited amount of money, which they're burning through by purchasing every bizarre thing you can think of, as you just ran through the great list of.

So, it's driven by the need to ship. They're going to have to get this thing done before their money runs out. So, they're working all hours with incredible intensity to try and do it.

This is not just the invention of the light bulb. They have to invent-- a light bulb is worthless without an electrical system to go with it. So, one of the things that Edison and his crew figure out they essentially have to invent the entire public utility model. So, they got a light bulb, which is a useless product unless you have an electrical system go with it.

So, they have to think through power systems. They have to think through safety. They have to figure out generators. They have to figure out the organizational model for utilities in order to understand how this whole thing is going to work. So, they've got a dream product that's going to displace, you know, gas lighting, which was incredibly dangerous, blew up all the time, with a much safer, inherently safer system, which provided much better quality light.

So, they've got a dream product, but it doesn't work unless they do the entire innovation system for electricity along with it, which is really what their accomplishment is. Right. It's understanding and being able to put into place the whole system, and then using their bridge back to the financial world to get it financed.

So, those are just a few points building on Martin's, you know, good summary, but let's do some questions on the Edison group.

AUDIENCE: [INAUDIBLE]

WILLIAM BONVILLIAN: Yeah, why don't you fire some out? OK.

MARTIN: How effective would an Edison-style research lab be today? So, there's like a really good show called pure genius right now where it's a billionaire who like makes a hospital where he kind of does something like this. But I just wonder if anybody had any interesting thoughts.

AUDIENCE: I feel like it definitely depends on the application. Like, what they're interested in working on.

Because I feel like this translates well when the capital expenses are lower, but if you're trying to do research on energy or large infrastructure stuff, I feel like it would be hard for a single person to finance that today. Like, even this is pretty impressive that you could build such a complex company from a garage basically.

But, I mean we see like Apple essentially started a similar process. So, that's something that kind of can start small and grow. I think it could still work today.

AUDIENCE: I don't really see very many differences between this and Facebook. It seems very similar very-- well, but again it follows that model of the quote unquote great group because it's everyone's focused, you've got a ton of people that are only working on the project. They've got all the resources they need. And they just like to work, and they have a great time.

MARTIN: So, say like somebody is trying to do this for like fusion, like instead of the Manhattan Project, it's the Manhattan Project 2.0 where they're trying to figure out a fusion energy device. Do you think a small group of talented people will be able to do it?

MAX: I think it'd be awesome, and I'd love to do it.

WILLIAM BONVILLIAN: You know, Max, I think you're right. This is the iconic picture. That's the group. And it's all in a room, and they're all in rich communication with each other. I think that picture gets carried through into most of the great groups that we're going to talk about.

MARTIN: And then another question I had based on this group was, do you think universities should focus on getting a variety of skill sets to interact with the researchers? Because usually it's academics, or they're used to doing research, but they only see a problem a certain way.

Versus somebody who would be more street smart or has a more technical ability to just build things, they would-- it might lead to richer solutions.

MAX: So what's the question?

MARTIN: So should universities focus on getting people that aren't from universities that are talented in science? So it could be electricians. It can be material scientists.

MAX: Oh, so [INAUDIBLE]

MARTIN: People who do things, rather than just people who have gone to college.

AUDIENCE: To teach, is that what you mean?

MARTIN: No, not to teach. To collaborate in a research setting.

AUDIENCE: OK, OK.

WILLIAM BONVILLIAN: I think it's really an important question, because we've begun to talk about the increasing economic role of universities, through the Bayh-Dole Act, for example, and the fact that universities now control patents on the-- and the researchers control the patents on their federally-funded research.

And the pressure's on universities to play more and more of an economic role. As the old historic industrial labs come down, the university role grows. If this is the iconic picture, are there settings in universities that look like this, or is it only two or three people in the room? I think that's a really intriguing question. Martin, what do you think?

MARTIN: I think you should probably have people, just because a lot of things, in theory-- well, and another is, if you think about the world in terms of theories that we haven't discovered yet or things we haven't discovered and our theories aren't perfect.

The way I would see it is somebody who has-- say somebody who's built an electrical grid and played around with different materials, they have 10,000 hours in things that might not have a theory for it yet-- they just know it happens. So they might be able to say, well, you think, theoretically, this is going to happen. This is what you're certain of. But based on some of the stuff I've seen-- I've seen this. Maybe we should just try it out. And I think that might be a really interesting proposition.

AUDIENCE: I wonder if it makes a difference though whether you're inventing a scientific advancement, or if it's just a product with maybe no new technology, but putting things together that consumers want. So I think with Facebook, I consider it more like a product not necessarily invented something new.

Whereas with Edison, they said he had an intuitive understanding of Ohm's law and putting together the light bulb. But I feel like now it's probably even more of a challenge to make scientific advancements just from tinkering around, just because a lot has already been done.

MARTIN: Yeah. But I would say there's also an opportunity, because if you look at-- there's waves of technology, like it's STS theme or certain ways of doing things come into fashion, and then they don't. So a lot of the great scientists of the 1800s built things, and would just build things and not really try to come up with a mathematical theory.

Versus today, you come up with a mathematical theory, and then go and try it. So there's less people just trying random things. So there might be a huge opportunity there because, with all the new insights and all the new data, you could try interesting things.

WILLIAM BONVILLIAN: All right, so why don't we leave Edison and shift over to Beth, who is going to do Oppenheimer?

BETH: OK, so again before I go into the Manhattan Project specifically, I wanted to talk a little bit about Robert Oppenheimer a person. He had a pretty fascinating life-- a little bit tragic, but he really contributed a lot. So he went to Harvard and finished his chemistry degree in three years, and then started on a PhD in physics at Cambridge under JJ Thompson, who maybe is someone you've heard of.

But completed his painting in Germany, where he had the opportunity to meet a lot of really famous scientists of the day-- Bohr, Heisenberg, [INAUDIBLE], et cetera. After that, he went to work at Berkeley as a professor. So he was really building his network and knew really all the preeminent physicists of his day worked there [INAUDIBLE]

Something that will continue to haunt him and affect how he works is that he did have multiple affiliations left organizations while he was-- especially while he was younger. So as the Red Scare comes about in the '50s, and even as he's working on the Manhattan Project, there are a lot of times that these affiliations come into question, and people doubt his loyalties.

So that's something that-- it's just interesting to note. And obviously, he was selected to lead the development of the atomic bombs at Los Alamos. I do just want to talk a little bit about what happened to him after the war, before we spent the majority of the time talking about his war efforts.

So in 1947, after the war, he started working in Princeton at the Institute for Advanced Studies. So that's where Einstein was, as well. So he was working with a bunch of really smart people. But then in 1949, he's called to the House Un-American Activities Committee. And in 1953, his security clearance was revoked.

So a lot of scientists did come speak out on his behalf, including Vannevar Bush, Edward Teller, who will make an appearance later in my discussion-- said some comments that weren't expressly negative, but were very much did not hold Oppenheimer's cause at all.

WILLIAM BONVILLIAN: It really led to his downfall.

BETH: Yeah. They were kind of wishy-washy in what he actually said, but it was used against him a lot, and eventually it really contributed to the fact that he was no longer allowed to have a security clearance and really was pushed out of the political field of science. So as a result of that, he withdrew from political activity-- kind of because he was forced to.

So he moved to the US Virgin Islands. And he worked a little bit independently on the nuclear field, but lost a lot of his influence outside of the scientific community. So within the scientific community, I think a lot of people still held him in high regard, but his opinions and his work wasn't really listened to by people outside.

Finally, in 1963, he got a political rehabilitation when JFK awarded him the Enrico Fermi Award. This obviously didn't leave him much time to contribute after that, because unfortunately, he was diagnosed with lung cancer and died a few years after. Yeah, he was a bit of a chain smoker, unforunately. But it's kind of sad to see this downfall of, as well discuss in the next slides, a great leader who stepped up to the job in a time of crisis.

All right, so now for the main focus, the Manhattan Project. So the picture on the left is an aerial view the Los Alamos laboratory, and on the right and some famous names of people who worked there, including Bohr, Feynman, and Fermi. So the Manhattan Project's goal, as I think most people are aware of, is-- was to build the nuclear bomb, essentially before the Nazis did. That was the ultimate motivation.

And it really is an example of a great group. As I'll go through the next slide, it really ticks off a bunch of the boxes, because in a very short amount of time, with pretty young group working really hard, they were able to achieve this. And obviously, the nuclear bomb comes laden with a lot of ethical and values questions, which I think would be interesting to spend most of this time talking on.

Bennis mentions in his work that professor described that you do run into this potential challenge of, what if a great group comes together to do something that is not very great? And so from the perspective of Americans, we can view this achievement as purely great, but-- or at the time, it was perceived as great.

Now, it's obviously murkier. But had this great group been a group of German scientists at the time, it would have been a much scarier position for us. So I'll come back to that. I just wanted to tick off a few of the elements of a great group, and talk about Oppenheimer's role specifically.

First, Oppenheimer really was a charismatic leader. Before this, he hadn't really had much leadership experience outside of his lab itself-- so overseeing graduate students. And a lot of people questioned his choice as the leader in this project. They weren't sure he had the right temperament or experience to do it.

And a lot of his colleagues and people who worked there did see a noticeable change in how he worked before versus how he worked at Los Alamos, that he really kind of stepped up to the task and was able to be a very influential and effective leader in this position. Since he knew basically everyone in the physics field, he was able to attract some really great talent, and definitely wasn't concerned with finding people who might have more knowledge in one area than he did.

He really emphasized the open access to information. So they would have meetings-- I forget if it was weekly or monthly-- I think weekly-- where people would share their research with each other so that everyone had an idea of what was going on. Some of the other hands-off approaches were the flexible working hours and the freedom to work on things you're passionate about.

So Teller, the guy from the previous slide, really wanted to develop the H bomb, and was pretty distracted from his work that was really applicable to the work that they were doing at hand. But Oppenheimer realized that the way he was going to be most effective was to just let Teller go off and work on what he cared about. And so he allowed people some freedom in judging what they should be doing.

With this example, there is a clear mission, and there is a clear adversary, so that was a very strong motivating factor. There was a sense of camaraderie between the scientists. It did help that they had a lot in common. It was mostly young men interested in science.

I think the average age was 25, so it was just a-- kind of the same thing of hanging out around the stove. They all lived and were pretty isolated in Los Alamos without much interaction.

MAX: That's something I thought that was odd. If they're all age 25, doesn't that mean that a lot of them don't even have their PhD yet?

BETH: So I think, from my interpretation, people used to get their PhDs slightly faster and younger. So Oppenheimer had his at 23. So I don't know--

MAX: He graduated in three years though.

BETH: Yeah.

MARTIN: He went college early.

AUDIENCE: Maybe a lot of them are graduate students too, because a lot of the people at the Rad Lab were graduate students who are brought in by the-- Lawrence and--

WILLIAM BONVILLIAN: [INAUDIBLE]

AUDIENCE: They brought their graduate students with them. 20 or 21.

BETH: Yeah, so young group of people who had a lot of energy and enthusiasm, and really didn't have much else that they could do, because they're in the middle of somewhat nowhere in New Mexico.

WILLIAM BONVILLIAN: They're on a mesa top.

BETH: Yeah.

AUDIENCE: Island.

BETH: Yeah, very much so an island.

WILLIAM BONVILLIAN: Yes, the ultimate island.

BETH: Both for security purposes and to keep them focused. I do think they had a bit of the underdog attitude, as well. Whether it was true or not, they perceived that they were behind the Germans in development of the bomb, and so they were very motivated to try to catch up and to become the top dog.

It did have a pretty casual atmosphere. It wasn't very hierarchical. There was a little division as possible. I think the book mentioned that Oppenheimer wrote out his ideal sketch on a piece of paper, and someone asked how it should be organized. So it was pretty freeform.

And lastly, he did a lot to maintain enthusiasm and to keep people excited about working there, both the scientists themselves and the families that they brought with them. So part of that was everyone had to take some days off, so that had some semblance of work life balance.

There were a lot of social events. Oppenheimer hosted some parties. And I think something really interesting that he did was to help the women that were brought to Los Alamos, mostly as spouses-- a few scientists, but mostly spouses-- to get more engaging jobs than they might have been able to otherwise.

So rather than having them stuck at home, isolated as housewives, he would bring in people who would do the house chores for them, so that they could get jobs as administrators, or more challenging work that would keep them happier to be there, as well. But this work obviously raised many ethical questions. And these are four scientists that I picked out who discussed some of these.

So first is Niels Bohr. He escaped from Denmark and came over to the Allies during World War II. And he very much supported the idea of open access to information, not just between Britain and the US, but including the Soviet Union in there, as well. He was afraid that leaving the Soviet Union out of all of this work was going to lead to an arms race after World War II. He was probably correct.

Another interesting person working on this is Joseph Rotblat. So he quit Los Alamos after the-- not after the war that should say-- after Germany was defeated, because he thought that there was no purpose to continue to study the bomb, if that was their goal was to have the bomb before Germany did, to protect themselves. He didn't think that developing the bomb further was necessary after Germany was defeated.

And then both Wilson and Feynman, I think, are quoted again in that Bennis article. So when they do the first successful test at Trinity, everyone's out there celebrating. This is the culmination of all their work, so they're really excited about this. But Feynman sees Robert Wilson, and he's like desponded. It's a terrible thing that we made.

And Feynman points out that they all got caught up in this excitement, this enthusiasm for achieving their goal, that they kind of lost sight of what their goal would do. And so that's, I think, a very important part of the story that makes it a little different from some of the other ones that we'll study today, is that there are a lot of potential downsides to the work that this great group did.

I think it's pretty clear that it was great in its characteristics, but I think it'd be interesting to discuss what the repercussions of that could be. So one question before we go too much into the ethical debate about Oppenheimer himself-- so as I mentioned, a lot of people didn't have much faith that Oppenheimer would be an effective leader. And it didn't seem like there was a little bit of a learning curve for him to understand what was realistic in what could work.

And so one question that came to my mind was, how long should a trial period be for a leader in a situation? How do you decide this person's not cutting it, we need to replace him, versus ruling out people just because they haven't adapted really quickly? So if you have any thoughts on that--

MAX: Well, I suppose it depends on the situation. But here, if you're in a war scenario where you have a couple of years, and that could be the difference-- and even a couple of months could be the difference between today and *Man in the High Castle.* For those who don't know, it's an alternate universe where Nazi Germany wins.

So I guess in that case, I would have given him like two months to figure out can he change, is showing improvement? If he isn't ideally suited at the beginning, can he adapt to the situation? And even then even, if he can adapt, can adapt quickly enough--

AUDIENCE: Could I ask-- who would conduct a performance review?

BETH: In this situation, he was kind of subject to the Army's approval, as well. He was working kind of paired up with General Groves, so I think that he would have had a lot of say, if he thought Oppenheimer was doing a terrible job. But as far as who his ultimate boss was--

MAX: [INAUDIBLE] I'd say some of his other-- his subordinates would also definitely have some weight because then-- they're all very accomplished scientists in their field, so their opinions certainly have meaning. So I think, if they worked with Groves, they could-- if they wanted to, they could get him pushed out.

AUDIENCE: Also going off that point, I think, as a leader, it's really important to recognize when you might have some deficiencies, and really learn how to delegate to other people. In the beginning, I think the article mentioned he wasn't very good at budgeting things or managing the logistics of establishing the town.

So maybe if he could recognize really early on, oh, I can't do this, I need to appoint someone else to do it, I think that's also an important part of being a good leader. And to be honest, it's something that probably should be established early on, especially in such a time-sensitive project.

WILLIAM BONVILLIAN: That's just a thought to contribute here on his leadership style. Martin brought us through Edison, and in some ways, Edison is a 19th century figure with a certain kind of-- who believes in his own seniority, his own kind of authority. And he's something of an authoritarian figure with that community.

They do share things and they are all up late at night together, but there's no questioning about who the leader is. Oppenheimer's got a very different leadership style. And correct me, Beth, if you've got a different view on this. But there was a phrase in the book reading about him, which was, he was like a bee spreading pollen.

In the words, he had the ability to go from group to group to group-- because this is organized with teams working on particular parts of the project-- help them think of their core ideas, and then share ideas other groups that would help influence them. And I think that turned out to be a really critical-- this is a large operation. This is not going to fit in one room.

Now, he did, as you mentioned, Beth, pull them together into the auditorium weekly for really in-depth exchanges and presentations so that they all kind of knew what was going on, they were all in on what was happening. But he plays a critical role in moving from team to team, trading the ideas back and forth that will help move them along and help advance them. And in some ways, that's the critical function that I think he plays. Does that add up with your views?

BETH: Yeah. I was thinking of one other point in the book where it said his talent was finding the talents of other people and using those effectively. So yeah.

WILLIAM BONVILLIAN: Right. So that's a different leadership model, but in this setting, an absolutely critical one, I think. Because all of these pieces have to work together, and unless they're all advancing, it's not going to happen. And he plays a really critical role in getting those pieces advancing together.

BETH: [INAUDIBLE]

WILLIAM BONVILLIAN: Yeah, absolutely.

BETH: So again, going back to what Bennis talked about with these great groups that may be towing a dangerous line. How could one stop the seemingly runaway tendency of great groups that they start crossing an ethical or moral line? It seems like they have so much momentum going. What responsibility do the scientists within have-- or anyone within it, not scientists-- to slow it down and rethink it?

How would you go about doing that?

AUDIENCE: Well, I almost think it's in the eye of the beholder, because this one is pretty-- well, even this is murky-- but it's pretty cut and dried. They made it a huge killing device. But I'm presenting on Craig Venter and the decoding of the human genome, and a lot of people might argue that that is an out-of-control topic, as well. So I think it's kind of your perspective that you're coming from.

MARTIN: I think also, we-- especially in this presentation, you kind of glanced over Heisenberg. So it wasn't just, we're building a gun so we can shoot somebody. It's like, somebody else is building gun and they're about to shoot us, and we should be the-- we need to be the first ones to be ready.

Because Heisenberg seemed way more prepared. They were getting reports. There's this great documentary called "Oppenheimer vs Heisenberg" by *American Genius* where they go over how they thought Heisenberg was much farther ahead, and sometimes they would fake reports to make it seem-- so for them, yeah, there were these ethical questions.

And the interesting thing about this great group is that most the people that joined the group were very much pacifists or left. So they weren't people who wanted to build weapons. But at this time period, the stresses around them influence them to have to build this because they knew that, if they-- even though my beliefs are this, if I don't do this, it could affect people that I do care about.

And it's just because of my beliefs, so maybe I should change my beliefs to do this. I think the ethical question was very much after they figured out Heisenberg wasn't-- his lab had already blown up and it wasn't working out. Why didn't they stop?

And a lot of it is that they already had come into-- they had so much momentum that they wanted to be prepared. But also how are you defining a horrible weapon? It's a weapon that can take down cities, and how many times had it ultimately been used since the time period? And how many deaths have been created because of it compared to other things too?

I think there's a huge focus on it because it's a weapon of high magnitude, so it's under a higher scrutiny. But also I'd want to look into the data of how many people have actually being killed by nuclear arms compared to other--

AUDIENCE: Or it can be a weapon or a source of energy. The human genome can be a source of biological weaponry or a huge source of knowledge for science. So you have these caveats with a lot of the things that the great groups have done.

MAX: That's kind of the point of science. Science is morally neutral. You're just learning about the nature of atoms, the nature of nuclei, and what kind of chain reaction exists. That just depends on the people that actually have it, and who discovers it, and how they decide to fund it and use it. So that's going to happen with any technology that exists.

WILLIAM BONVILLIAN: But Max, we're moving here from science to a very clear, specific technology project. But I think, Martin, you make an important point. This physics community before World War II is a relatively small community, and the group that gets assembled here, they all know each other. They've all been in communication prior to the war.

And they knew Heisenberg very well, and they knew how unbelievably talented he was. And they thought he had at least a couple of years head start. And I think they all realized that if Heisenberg was successful in doing this-- we talked about the Rad Lab as a war-winning technology-- radar. This is war-ending.

If Germany developed this first, the war would be over like that. It would be over. And now is an option which I think the group certainly, as a whole, felt was completely unacceptable. So that motivates everything up until April. And then what's going to happen?

So that's a critical moment, but it's not really until after the actual use of the weapon that I think this community begins to think hard about this and about the consequences. There are some exceptions, like Rothblat. But that's when Oppenheimer has to confront what the implications are and begin to think about how to-- because they've all been involved in development of it.

The physics community comes together as a political body, in a way, and starts to try and push the government to think about how we're going to deal with these staggering technologies and their implications. Does that add up, Beth?

BETH: Yeah. It does.

WILLIAM BONVILLIAN: Do want to give us some closing thoughts about Oppenheimer and what's important about the group?

BETH: Sure. So Oppenheimer's experience is definitely quintessential for when-- for how effective technology advancements can be under more pressures. So I think we discussed a few weeks ago, is it possible to replicate this sense of urgency and this progress under times of peace? And if we had a Los Alamos of fusion, would we be able to get it to work?

Would we ever be able to even get funding to do that without some kind of wartime need? It's definitely something I've been thinking about. They had so much money, so many resources, and so much talent in a small area, working hard, and they were able to achieve something. But again, it was mostly motivated-- pretty much entirely motivated by the war. And I think we just keep coming back to how can we make these advancements when we don't have that same impetus?

WILLIAM BONVILLIAN: Right. Good point to close on.

AUDIENCE: So today I'm going to present on the several groups that get involved in the process of inventing interactive computers. So in the very beginning, when the first computer was invented, it was so big, expensive, and only accessible to scientists and engineers that there's no one that ever imagined something like this before us will be so much-- no one imagined we would be so much relying on these devices.

But then Vannevar Bush was the one-- had this mission that computer can be some kind of intimate supplement to memory, that he named as [INAUDIBLE] vision. And he presented it in front of all the scientists at the summit and he kind of inspired one of the scientists in Philippines named Douglas Engelbart.

WILLIAM BONVILLIAN: Yes, Doug Engelbart.

AUDIENCE: Engelbart.

WILLIAM BONVILLIAN: Right.

AUDIENCE: And they got funding from NASA, and they started to get hands on images on how to have this interactivity between computer and the users. Then the invention of Windows, and the mouse, and the screen was successful by 1968.

Bob Taylor and Alan Kay had this group at Palo Alto Research Center. They were under the ax-- I don't know how to pronounce it.

AUDIENCE: Xerox?

WILLIAM BONVILLIAN: Xerox, yes.

AUDIENCE: Xerox, yeah. Xerox a corporation with already having a lot of scientific investment. So PARC, P-A-R-C, was under Xerox, and today we're going to focus on their principles on [their recruitment of this great group.

So Bob Taylor had-- was the real boss of PARC lab and the principal that he was is existing on is that there's no good scientists-- there's only great ones. So he had very strict selection of scientists and participants. The way that he built this team bonding-- team spirit is that, during the selection of scientists, he also requests participants-- the applicants to present in front of the whole staff, so people who are already part of this group will find oh, this is an interesting person and we would like to have him in our team.

And so whoever get assigned in this team would feel this sense of recognition. And I think this is something that might be lacking in a lot of science groups today because there's always this fear of having new members coming in, and they're so talented that they will replace the previous members.

And this kind of fear might hinder the next round of innovation. And the other principle that Taylor has the mobility of talents. He introduced market mechanism where they are now selecting projects, but they're-- they're not selecting the talents, but they're selecting the projects where, in a sense, whoever finds this project interesting can drop whatever they're doing and join the other product.

So the interesting projects get more talent and get moved on, and those less interesting ones you get [INAUDIBLE]. And another key feature of his team is that the structure of the team was also flat. There's no influence of politics in this group of science.

Another feature they had is this group meeting every week. So it is the only compulsory thing, that you have to attend this kind of weekly meeting where you bring your beanbags and every project will present their recent discoveries. And some of the lessons learned in one project might be crucial to the things going on in another team. And they exchange these ideas, and really helped the entire lab to develop.

That is the beanbags. Just I will mention the role of the leader, and how good he can serve the group of talents in his team and be loyal to-- be responsible to the needs of the team is also very important. For PARC, there's a time that they wanted to have access to different hardwares where the-- Xerox--

WILLIAM BONVILLIAN Xerox.

AUDIENCE: Xerox--

WILLIAM BONVILLIAN: Xerox, yes.

AUDIENCE: --didn't really wanted to give the permission, bit the leader was very assertive his demand, and really threaten if you didn't allow-- if you don't allow us to have-- to invent our own hardwares, I will just quit. And eventually, they get permission and they design their own hardwares and softwares.

And of course, this team was-- they're group of scientists that's really into whatever they're doing, that they don't see how they want to ship this to the mainland. They don't see how this can be-- should be commercialized. Therefore, some other team picked up this really well, and it's Apple, Steve Jobs.

So Steve Jobs saw this opportunity of having this interactive and easy, the user-friendly version of computer being commercialized in the market. And he understand that that is the future of computing, and inspired his team to just do this in a very [INAUDIBLE]

So Steve Jobs was able to inspire his team that they're-- in a way that they are doing something secretive. They cannot tell anyone else what they are doing. And they were working like 100 hours per week that's really intense, and also escalated.

He also has this obsession, the elegance of this design. I think that also explains how Apple users are so loyal to this company. Then there's this also saying that Steve Jobs criticism to his employer sometimes can be abusive. And maybe it helped to build this innovative environment and give the pressure to get things done, but in a way that maybe he's also driving people away.

So there's the downsides of his management principles, also this breaking down of marriage and other relationships. It can be argued that maybe this personality also helped to get this delivery of Macintosh to the market.

But I would like to hear your voice. And there's some question that's really-- that's been popping up in my mind while I was doing these readings. What is your view? Are some inventions or technical advancements that-- they are inevitable for human revolution?

Maybe the invention of fire or the use of tools in hunting are so crucial to human survival that they will eventually be discovered. But there are other things like maybe the desired computer. Maybe Vannevar Bush didn't point or have this vision of personal computer, but it's something entirely different, but equally amazing.

Maybe we are having an entirely different way of communicating and transporting everything, but so much different. So do you think there are this category of innovations that some of them are crucial and inevitable, there are other things that are still-- we can still be without? What are your thoughts?

MAX: So thinking back-- I think this goes back to the previous reading that was talking about how-- the 10,000 hours thing. So a lot of inventions, they seem to come by chance, but they're not actually by chance. They come from people dedicating thousands and thousands of hours and years, and completely restructuring their very lives just so they can try to make some sort of development.

So I guess my first-- the first example comes to mind is penicillin. Everyone's heard the story of how he accidentally made it and how he actually found out that it works, because he spilled some on a sandwich that had mold on it or something. That's the story I heard anyway.

So sometimes, maybe occasionally chance will help us find the invention or hear about it more quickly. For example, what's his face-- who made the phone? Graham Bell, thank you.

MARTIN: [INAUDIBLE]

MAX: Yeah, yeah. Actually, apparently, he was at the World Fair. This is actually a story I really love. He was at the World's Fair, and he-- when he was there, he happened to get there really late, so he couldn't get a table in the electrical section. So he had to get into some sort of botany section that was in this musky attic somewhere. And no one ever actually saw his project, because it was out of the way.

And apparently there was a guy, some prince. And Graham Bell used to teach at a school for the deaf, because I think his father was deaf or something. This prince was the one who was leading the judges around at the World's Fair.

The judges were tired at the end of the day, and they decided, OK, we'll look at one more project and go home. And the prince happened to see Bell, and they-- the prince obviously, he greeted Bell. He was like, oh, yeah, it's great to see you again.

And then Bell showed off his invention, and the rest is history. So sometimes it's chance, but I feel like chance-- the invention isn't necessarily chance, but rather the-- its rapid development and commercialization, that might be a little bit.

WILLIAM BONVILLIAN: Let me draw on some of the things, Luyao, that you raised, and tie it back to Max for a second. So let me just go through some of your interesting points with some additional perspectives. So one, the point you started with was the Memex and Vannever Bush's role in creating the Memex, which was really a fast retrieval system for it microfilm knowledge bases.

We could look at it now and think about Windows and search engines as derivative technologies, but that's really what he was driving at. And so it put a picture up of something that computing might be able to undertake for us. It's not that he was able to achieve it.

So that was, I think, a very interesting point to start from. Then you took us through the story of Doug Engelbart, just briefly. We talked last week about-- and we'll talk more-- about JCR Licklider and the role of DARPA in creating these great group communities.

Engelbart is at Stanford Research Institute, SRI, and Licklider funds him. And Engelbart is clearly a remarkable talent. Licklider has the ability at DARPA to pick great groups and support them, and Engelbart is one that he comes up with. SRI couldn't understand what he was doing. They were pretty dismissive. But Licklider understood back at the DARPA office, and kept him funded.

So he does a demonstration, as you point out, of 1968, which is called the mother of all demos. And it was to a group of computer freaks and computer scientists. And they're all gathered in a room, and Engelbart runs this series of demonstrations about what computing is going to be able to do, and shows hypertext, and he shows the mouse, and he shows just a whole set of capabilities that computing is going to be able to lead to-- which none have ever seen compiled before. So that was a critical visualization moment.

Bob Taylor also worked for Licklider. So he was a project manager in DARPA-- again, another one of the talents that Licklider identified. And Taylor goes out to Xerox PARC and is running what we would call the personal computing team. And they develop-- Luyao, would you go to the slide of the early Apple, the early Mac? Yeah, that one.

They develop something called the Alto at Xerox PARC. It does look a fair amount like this. It's got a cathode ray screen. It's got a computer keyboard. But it has all these capabilities that, in some ways, they have-- it has all of Engelbart's capabilities and more-- and remarkable ability to do data visualization. It's fun to use, it's-- there having a great time with it.

But because, as you pointed out, of this island-bridge problem-- in other words, Xerox PARC Palo Alto Research Center is out there in California-- Xerox is in Rochester, New York. It's making copying machines. There just is no connection between-- as you suggested, between the group making copiers in New York and these wild computer scientists living on beanbags.

And they just don't-- it doesn't happen. The technology doesn't transfer. Xerox has no idea really what these-- what this incredible Xerox PARC team visualized here has accomplished. They don't know how to translate it in the marketplace, so they miss the opportunity of being Apple, and therefore, the largest company in the world at the moment.

So it's a painful island-bridge problem that they are never able to resolve. The head of R&D at Xerox PARC-- at Xerox, who had set up Xerox PARC to begin with, isn't able to help them make that transition. So it's the ultimate story of the island-bridge not working.

And then, just to kind of carry this story through, it's-- Jobs buys the rights to essentially walk through Xerox PARC, and see the Alto, and see what it's accomplished. And he and his team go through in the course of the afternoon. It's not that they take the technology. They don't get the rights to take the technology.

What they do is see what the Alto is capable of doing. And then they have a picture of what's possible, and then they work on putting the Mac together to realize that picture. So there's great technical accomplishment and what they achieve. But they do get the visions on what gets put together.

So Luyao has led us in this interesting track of Vannevar Bush and Memex to Doug Engelbart to-- I would throw in DARPA here because they played such role-- but then to Bob Taylor comes out of DARPA to lead Xerox PARC, and then to Steve Jobs. So there's a whole continuity.

And there's something worth remembering, which is that all of these groups stand on each other's shoulders. These incredible technology achievements that lead to personal computing just build, build, build, and build. And there's a series of remarkable great groups here. Is that a fair summary?

OK, now, let's get back to your-- let me come to you in a second, Steph. But I think Luyao's question is a really key one, that there are inventions that we have to have, and then there's other stuff. And how do we create that drive to create the other stuff, like computing?

We didn't have to have personal computing. The world got along with it for a few million years without it. What is it enables us to put that on the list as a necessity and really drive towards it? How does that happen? Is that a fair summary of your question? OK.

AUDIENCE: [INAUDIBLE] I think that's where I disagree with Max-- that I don't think it's so much about an inevitability, because I think it's much more about what Bill just stated, that we stand on the shoulders of giants, and that necessitates the continuance of a momentum toward a direction of something.

And I feel like we had been going towards the direction of the personal computer for a very long time, beginning with the Gutenberg press, and then the personal typewriter that you could carry around, and that people certainly did carry around. And then that gave people the impression that there could be something better and that there was a next step.

So I don't think it's so much about inevitability or-- and I do think sometimes chance does play a role, but I think it's more so about the continuation of that momentum. And that's why I think it's important to analyze where we are and where we've been going, and to think about the interesting visions that we can have within the confines of that direction in which we're moving forward to.

WILLIAM BONVILLIAN: So in a way, I think what you're both saying is that-- and we'll tie it back into Beth's discussion of Oppenheimer-- you build up this momentum on a technology pathway, and you can't turn back the clock. And that's what Oppenheimer found.

When that project reached culmination, he probably wanted to turn back the clock, but there was no way. That technology would keep going on a pathway. And maybe that's a way of answering your question, Luyao, that there's certain-- there becomes a certain inevitability about, once you start launching down a technology pathway, that it's going to have its own momentum, whether it's a necessity or not. What do you think?

AUDIENCE: I think this is getting philosophical-- whether or not there's alternatives to history. I realize there's another part I didn't touch. So this-- a lot of principles we introduced in these great groups doesn't really act as models. It's just these factors adding together make these things successful.

But how applicable are these principles to the world today? Personally, I find there's over-commercialization of a lot of [INAUDIBLE] inventions. And I don't know if it's true. Also I saw a question in our summary asking with these lessons learned from previous great groups, how can these lessons be applied to different scales of production?

The great groups I assessed are smaller groups, and they're in the beginning of figuring out how computer-- personal computer can work. But in terms of bigger companies like Google or Facebook, are they-- how applicable are these lessons to these bigger groups that also requires innovation, but having a more complex politics in these groups?

WILLIAM BONVILLIAN: Yeah. Look, I think that's a crucial question. And related to it is, once you create a great group, does it only do one thing, or can I keep moving on to ongoing innovations? And the number of times that happens is not big. But how could you create a culture, particularly within the larger corporate organization, that keeps innovating. It's really a tricky problem.

AUDIENCE: We also hope that these models can be independent of the leader and their personality, and can be cated in other fields. Otherwise, it will always be reliant on that leaders to lead us [INAUDIBLE]

AUDIENCE: So when I was reading this, and in Bennis's whole description of great groups, I definitely have a lot of concerns with how the groups come about. Like at PARC especially, it was-- I forget. Taylor was his name?

AUDIENCE: Bob Taylor.

WILLIAM BONVILLIAN: Bob Taylor.

AUDIENCE: He was picking people whose personalities meshed well with the group, and stuff like that. And then Bennis emphasizes so much about how great groups can really affect people's family life. It seems like they kind of exclude a lot of people.

If you don't fit with the leader of the group, even if you could have contributed, you have a different personality type, you might not get picked to be in a great group. Or if you're a woman who is expected to see her children once in a while, how are you going to hang in the great group?

WILLIAM BONVILLIAN: Sometimes fathers see their children occasionally.

AUDIENCE: I know, but I think there's still a societal expectation of women being somewhat more present in their families-- whether that will persist, who knows. I don't know. It makes me nervous when we talk about perpetuating great groups, when they seem kind of exclusionary, exclusive.

AUDIENCE: There's an amazing point that you have brought up, that I will touch on in a second, the first one of which is that I don't think that-- or rather, your analysis, I think, applies well to the Tuxedo Park reading that we did maybe two or three classes ago about how-- what was his name, Alfred Loomis?

WILLIAM BONVILLIAN: Loomis.

AUDIENCE: Loomis was hand-selecting people that he liked to work in his lab. That doesn't seem to me to be very far from what he was doing in his private lab, which is obviously a point of concern, in terms of including diversity in your perspective-- [INAUDIBLE] perspectives, not to say anything of racial diversity, and affirmative action right, and including populations that can be underrepresented in science and technology. But furthermore, also while I was reading this, I felt like it was almost presupposed that all of these people were going to be white male.

WILLIAM BONVILLIAN: So let's go back to the beanbag slide.

AUDIENCE: There's a girl.

WILLIAM BONVILLIAN: There's two.

AUDIENCE: In the reading, they only mentioned one woman explicitly, and that was the woman who was the graphic designer at Apple, and so she didn't have any technical capabilities and didn't have much of a role to play within the organizational structure. And thus, her influence was very low. So I really call into question precisely what Beth is saying, but would almost say that it's not something that makes me nervous. It's something I find outrageous.

MAX: So I would say actually to somewhat counter that-- definitely I agree, women in STEM fields-- that we definitely need more representation. But it's possible that, at the time, there was less of an emphasis on STEM education, which would mean--

AUDIENCE: Oh, no. So I totally agree with the reasons-- or rather, I understand the reasons as to why it happened. But as being these scholars are thinking about organizational structure, they're not adding in any caveats about the roles in which these social factors have to play.

And furthermore, they're not making recommendations as to how they could be resolved. Because if they are not the ones addressing these holes within organizational structure and how people can-- people's perspectives can be meaningfully included, then you're just glossing over that as an issue and leaving it for someone else to resolve.

And so that was my concern with this reading, in particular. I can have a concern writ large with sexism in the workplace, but I try to focus my concerns generally with the literature with which we are engaging.

AUDIENCE: So you're saying this was an omission from [INAUDIBLE] writing?

AUDIENCE: Correct. Yes, specifically.

AUDIENCE: [INAUDIBLE]

MARTIN: I would counter, in terms of-- because it is a question of our time. I think that there will be an organization that is more prone to females that does better [INAUDIBLE] doing it or there's an organization that's all-female because of the structure being different. Because it's something that I started seeing when I did work as a diplomat in Mexico.

Their social structure was much more extreme. So if a daughter was seen working with a man, the parents would like, ugh. So they started making special groups just for these females so they can move forward and get an education. And I think that's a problem that can be more prevalent outside the US than in the US.

But also, if you give a good answer and have really good talent-- because these people are really more competing for talent. And you find a way of accessing it and changing your structure. Because it might be that this structure of always being very intense. Being on location is a problem women with children, so maybe changing the structure around-- Yahoo try to do this, [INAUDIBLE] ability to work from home or choose specific days so you can hang out with your children.

Also because most-- more organizations are going to try to become-- they want this model. I think there's going to be companies that are going to be very intense and then mix vacation time, because they know work life balance [INAUDIBLE]-- well, it's not working. So you have to find a way of mixing it.

So it's like, OK, you have this problem, you have this project, you've got a deadline, and then you have two, three days off. Because you need to have a certain intensity for a certain amount of time, but that you can kind of relax. And that's going to lead to less turnover in employees.

Because that's a big issue. If you have employees that are working very hard and they don't get a break-- if you have a cord be too tight, it snaps, and so you want to make some loosening and tightening to get a right cord.

AUDIENCE: I also wonder how applicable this is to the context outside the West and outside the United States. In terms of work culture and organizational structure, I think a lot of other countries culturally or just society have different senses of obligation to family and community at large.

So I think that this is definitely a very Western, maybe very US-centric approach to how analyze great groups.

WILLIAM BONVILLIAN: Yes. Sanam, I think that's an important point. This great group series that we're doing really does reflect an American culture. And how does that great group theory translate into other cultures? I think that's a really an important underlying question.

And as we said a couple of weeks ago, I am open to other great groups. So when you all have candidates that open up-- is the 1970s. That's as far as we've gotten. We've covered the 1940s pretty well and '50s. Now, we're at the '70s. Not much has changed.

And I'm not sure much changes in any of the groups that we're going to talk about today. I think it starts to get better in places like Genentech and Craig Venter's operation. And the problem is you've got to find a technology that's taken off so you can prove that the group accomplished something. So if you all would help me with this and find examples that I can include in the group, it'll be--

MARTIN: [INAUDIBLE] is capitalism and technology so that's going to be a group-- it is going to be pretty much white males. If we redefined it as the top working groups in different fields-- so it can be like music, like soul music. How do they stretch themselves? We might be able to find [INAUDIBLE]--

WILLIAM BONVILLIAN: Yeah, you tried to raise this last week, Martin.

MARTIN: Yeah.

WILLIAM BONVILLIAN: I still wanted technology though.

MARTIN: [INAUDIBLE] or maybe you can go back in time [INAUDIBLE] different countries.

WILLIAM BONVILLIAN: I don't know. I think things are starting to change. We'll see.

MARTIN: We're also looking at the popular ones. So maybe we can look at top technology in like India, top technology groups in other countries.

WILLIAM BONVILLIAN: Right.

AUDIENCE: I think we already did Japan. The thing that I remember kicking myself for not bringing up, when you were talking about Japan and how incredibly prolific they were, and the-- their economic growth is that they created effectively a workplace culture that relied on two factors-- one, devoting your entire life to your job-- one job you choose. You're with a company for the rest of your time there.

And then two, that if your entire self-worth as an individual is tied to your success within this company or the success of the company generally, then if you fail or if the company fails, you feel like you're effectively threatened. And what I mentioned to Bill, and something that you may know, is that there's an incredibly high suicide rate amongst Japanese workers.

So what does that mean if the culture that we are trying to create here is effectively trying to emulate Japan's, because we want to achieve their level of economic growth, if it is that they have reached the sort of peak human? Is that what we have to aspire to? And what might be some lessons for us to learn from that country, as a great group?

WILLIAM BONVILLIAN: OK, that's fair enough. So Luyao, do you want to give us a couple of closing thoughts about the groups you looked at?

AUDIENCE: Yeah, I think definitely these lessons learned [INAUDIBLE] I'm amazed, as a Chinese background student, with this flat structure of a lab. That would never happen in Chinese culture. It is always hierarchical.

I think other things that's been changing better in China is the sense of female scientists' position in China has been actually leading in all these other countries. We have a larger number of female scientists, I think-- we are highly ranked. And there are lessons to be learned from different countries and from across history.