President's Council of Advisors on Science and Technology (PCAST)

Public Meeting Transcript

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Welcome from PCAST Co-Chairs

JOHN HOLDREN>> Okay. We should come to order. Welcome everybody, welcome to the members to the PCAST, to the OSTP staff who joined us, and to members of the wider community of folks interested in science, technology, and innovation who have joined us both in the room and for the live stream on the Web. Very happy to have you all here. As I think everybody knows, this is the last meeting of the full PCAST of the Obama administration. We will be reviewing a little later in the morning the whole history of PCAST, the number of times we've met, the number of reports we've produced, some discussion, impacts we've had, some thoughts about the challenges ahead, but for now, aside from those words of welcome, I want to turn it over to my co-chair Eric Lander for any initial comments he might want to make and then we will launch right into a discussion of some new reports that we have prepared and are ready for the vote of the group as to whether they are approved.

Eric?

ERIC LANDER>> I want to use this chance to express my deep thanks to all the members of PCAST. We'll talk, as John says, a little bit later in this meeting about the bigger picture of what PCAST has done over the last eight years, but I want to say to all of the members of PCAST how much we appreciate everyone's service, their incredible hard work, and the fact that even up to this last meeting, people are dedicated to working on bringing final studies to closure. It is a remarkable group and I want to say thank you.

I also want to make a point to say thank you to our staff. Ashley Predith and Jen Michael have continued to support this group and we have been blessed with an amazing staff over the course of eight years, and we could not possibly have done this without you and our colleagues in OSTP. So I want to start the meeting just recognizing how much everybody has put into it, and we'll turn to our agenda and we'll have a chance to return to this point, but thank you to everybody and thank you to everybody on the Web who has been watching, to people who have been attending, to all the people who will watch some day in the future because it's all archived, if it turns out that folks have an interest in looking back at what was accomplished and discussed over this period, we've created something of a record of things that people can turn to. So thank you.

JOHN HOLDREN>> Thank you, Eric.

Semiconductors Update & Vote

>>JOHN HOLDREN: We have no public comment for this meeting. We had decided we would have the public comment session at the beginning, but there are not any scheduled. So we will move straight to a presentation and discussion of the first study that's up for a vote, and that is the study on semiconductor challenges. The working group that produced that report was co-chaired by Paul Otellini, the former CEO of Intel, and by me. Paul was not able to join us for this meeting, but another real expert in this domain, which I am not, Craig Mundie, PCAST member, was an extremely active member of that working group and had a lot to do with, on relatively short notice, our ability to drive that study to a successful conclusion. So I'm going to ask Craig to present it this morning.

So, Craig, the floor is yours.

>>CRAIG MUNDIE: Thanks, John.

So let me begin, a little context and motivation for the study. Obviously semiconductors are a key component of the life and world we live in today, and the United States has for many decades been a leader in the development of that. At various times in the past the country has faced potential losses of leadership in these areas, but through a variety of strategies, always managed to recover and remain in an important position, even as the world has changed substantially.

But right now we face two significant problems. One is that the natural technological evolution remember as you see some slowing in the relatively near future, things people call Moore's law, the famous doubling of chip densities and attendant performance benefits every 18 months or so, is starting to slow down. The cost of building these fabrication environments is getting very high.

We also see other countries, notably China, who recognize the importance of this, and also recognize that China, for example, will be a substantial fraction of the total world market for semiconductor consumption in the course of the next ten or 20 years. So they've embarked on strong industrial policy targeting this industry with a substantial investment toward that. The goal of this study was to determine what the United States should do to try to ensure that its leadership in this key area remains strong.

The slides here, I just passed, show the representation on this committee and included many key people who have been involved in the semiconductor industry for a long time directly, as well as economists and other people who understand this from a national security standpoint.

As I said, the two biggest issues if you summarize them are the change in the technological landscape and the competition that's going to come from China. As we thought about the study, we ended up with six guiding principles. Perhaps the most important is that you cannot win this by playing defense only. And, in fact, when the U.S. has prevailed in previous challenge periods, it did so because, either by strategy or serendipity, we evolved what was important in semiconductors at a time that other countries were investing in the previous concepts. So our goal here in the report is to encourage the country and private sector to think collectively about doing that with real intent this time.

We want to focus principally on leading edge semiconductor technologies. This is

another substantial variance from what we've seen in the past in that today the diversity of use of semiconductors, which ranges from the smallest of small things, the Internet of things as it's emerging, to the very largest computers that we know, produce both an opportunity and requirement for a very different approach in many cases to what semiconductors provide, and so with that comes an opportunity to bring a larger part of the technological capacity of the country to bear on advancing in this area.

We do think the U.S. has strengths that don't yet exist elsewhere in the world, including in China. So rather than, you know, doing what might be a knee-jerk reaction, which is to try to think, well, if China has an industrial policy, should the U.S. should the US suddenly decide it needs an industrial policy. You know, that of course is not something that has been favored conceptually for this or any other area in the United States and similarly now we think that that would be the wrong approach.

We do expect as we begin to take steps to ensure an equitable playing field as China makes these policy based investments, and we begin to see the United States respond to those, that there will be obvious responses, but we think those have to be well considered and measured on both sides. It's clear while China will make advances, a reflexive response to the progress they do make, if it diminishes our ability to advance toward a new concept would probably not be the best strategy. So we have to make sure we maintain balance on that. And of course we want to enforce trade and investment rules, such that where there are norms and legal obligations on both sides and with other countries, that we maintain our focus on supporting those.

So in order to do that, we came up with a set of recommendations. The first one was to, in fact, find a way to bring a set of industrial expertise and make it available to the government, so that as they face questions about strategy or action on the international stage, that they can be well-informed. Because it's a complex technological area, it does continue to move quickly. So we think that we have to build that capability as well.

The next thing we want to talk about is really this question of sort of maintaining the balance, and I'll say the level playing field, if you will, on an international basis. The U.S. has a range of tools at its disposal when it feels that there's a threat, an unnatural threat of some kind. So things like the CFIUS mechanism for controlling investment, when it affects national security, the long history of the potential for export controls, some of which are in effect today on certain key manufacturing equipment, these things all remain in place, but as China in particular, and potentially other countries enact measures to try to improve their own lot relative to this critical and strategic industry, we will have to be cognizant that those policies and tools may need to be adjusted in order to ensure they're effective in the current geopolitical and technical environments.

Toward that end we think it's going to be important to boost transparency of what's happening globally with respect to these activities. We think it's going to be important to bring that together and monitor it and talk about it. We think it's going to be very important to maintain an active dialogue with China. What they're doing is completely in the open from a policy and investment point of view, and so we need to make sure that we understand, and that they understand, you know, what we think the issues are around this.

To the extent that the tools that we have need to be reshaped, you know, we need to be sure that's done in a timely way.

The third is also to recognize that the U.S. has a number of natural allies, other countries and companies essentially that work on a global basis in this domain, and that they too would be concerned if they saw an unnatural consolidation, or sort of nontrade based ways of it I think of tipping the playing field in some way. So we think that it will be very important that diplomacy is applied here with respect to other countries who share a natural concern, and that we use that to both boost the transparency and make sure we have common cause with respect to these kind of controls.

The next area that we focused on is trying to make sure we create an optimal environment in the United States for the companies that want to invest to build this next generation of capabilities. And the U.S. has of course long been a favorable place for this to happen, and we have a long history here, but many of the companies that are the world leaders in both the semiconductor industry itself and the related computing areas are very global companies, and at this point, you know, the global market, in fact, the market for their products is larger outside the United States in most cases than it is inside the United States, and so there's a natural tension and some concern if the U.S. in any way is just even less favorable let alone hostile to these kind of investments, then there will be a lot of implicit pressure for the countries to be neutral or less concerned about this evolution in the market. But we also know that if policy is leading toward consolidation, the companies would find themselves at risk in the long-term, and so I think there's certainly an area of our collaboration around these issues.

So we made a number of recommendations. One, not new as a general concept for this group, PCAST, is the importance of STEM education and the development of the talent pool. Immigration reform continues to be a key issue in this area. Lots of the academic research work and other things that underpin this is done outside the United States, particularly in Europe as well as in Asia. So we have to pay close attention to the talent pipeline.

We want to continue to invest in precompetitive research. That is part of the fuel that makes all this run. But notably as you'll see in the next section, we believe that the window to create this next generation of semiconductors is a fairly narrow one. Perhaps the next ten years being the principal time of opportunity. And as such we can't begin to look for new research to do this. The time horizon would be too long. So we have to really continue to invest for the future, but the principal focus as this report will show has to be to harvest a lot of the fundamental science that has been done in the United States and around the world, and begin to invest to bring it to market, and recognize that to do that we have to overcome a number of implicit risks that would otherwise deter that.

We think there are other specific things that could be done, maybe some changes from a tax reform point of view, strengthening R&D tax credits. All of these just basically create a more favorable environment for a large investment, particularly capital investments required in order to develop these capabilities.

There are some areas where the semiconductor companies in particular want some attention paid both at the state level and potentially at the EPA federal level, and that relates to the permitting processes associated with these complicated fabs that produce the products. These processes have a lot of complex chemical properties. Those properties have resulted in a lot of regulatory scrutiny in the construction of the fabs, and that permitting process is becoming a longer and longer part of the total cycle time, as the technological capability to build the fabs has actually shortened their construction time to put them into operation. Time

is money in this case, and the permitting process needs to be at least made as expedited as possible.

Finally, and perhaps the real key in this report, is a recommend strategy for how the country should approach creating, you know, the next big thing in semiconductor or related component technologies. Normally there might be a temptation to respond to the policy action on the part, or the investment action on the part of China or other countries, but our strong view in this group, I think unanimous view was that unless the country can establish some very broad goals that tend to move us in a direction that is not incremental improvement of the current production capability, that it's unlikely the U.S. would sustain the advantages that have accrued from being a leader in this domain. So the report goes on to propose a series of moonshots, but here the goal is not a moon shot specifically to solve the problem that you find on the title of the moonshot. The goal is to use these important problems as a way to galvanize collective action between the public and private sector and across a range of domains and technologies that might not otherwise be brought to bear. So there are activities in these cases where people would say, we're already trying to do some of that, but they would all be being done within a problem domain using the currently available technologies. So here the goal is actually the reciprocal, which is to look for a radical approach that if achieved would, in fact, be a benefit but where the by-product is with the intention to produce breakthroughs in the underlying computing and semiconductor technology. This will require a mix of private and public participation. And if you read the report in detail you'll see we actually identify some problem domains where businesses are likely to invest heavily to pursue them any way, but there's a fairly substantial set of areas important to the overall economy but where the computing and semiconductor industries would not naturally take a leadership role in trying to prosecute them. So some of these things are going to require more government investment and activity to bootstrap them, while others might be the government has to ride along on what will otherwise be initiatives at scale by industry itself.

So we wrote three sample moonshots in the appendix, we identify a very broad inventory of what we call component technology vectors that we think are all harvestable within this ten-year window. And each of which represents a potential tool with which to attack a moonshot class problem. But to show, you know, how we think this mechanism would work, we actually wrote hypothetically three moonshots in order to guide this process. The first was the development of a zero day bio threat detection network. PCAST recently did a report on bio hazards and one of the things of course recognized is downstream with the emergence of synthetic biology and other things, it's hard to predict what, and from what quarter we might see a biological threat. Whether with malintent or otherwise. So, you know, it's a very difficult problem, in general one we don't know how to solve, but it requires a new class of sensing and a new class computing in order to be able to do this because it would be a defense environment in a world where by this time we might expect to see the emergence of quantum computation, it requires we bring a whole new security model forward in the solution as well. This basically is an example of a problem that would be valuable to solve. We either don't have a good solution to, or would like a much better solution to this and which would require advances in many of these areas in order to have a complete offering.

The second one, well, so what do we want, let's see. That got out of order maybe.

I guess that was just one example. There were two others. One was essentially a focus

on high resolution weather modeling, one kilometer global resolution. This is something that currently is unachievable, and the current approach is in excess scale computation. You know, basically require power levels that are quite limiting in terms of when and how many of these we might be able to deploy. So in the proposal, we look at much more aggressive way of approaching this using new methods and techniques and notably not focused on using a classic C moss based technological system. And the third is basically one to develop a new model of high scale zero carbon energy production, another important goal, and one where we think, without breakthroughs in both materials and chemistry, we probably won't get there. So the goal suggests we should develop a quantum computation capability commercially that could be deployed against the materials and chemistry problems, and from that potentially bootstrap a different class of energy solution.

So we then suggested that we need to see these things formalized and orchestrated. Perhaps there should be other moonshots in order to complete, get a complete cover set of the important technologies, and so we recommend that there should be a subcommittee under the NSTC that would be put in place in order to administer this kind of activity.

So that's a quick summary of what's in the report and I'm happy to take questions.

>>JOHN HOLDREN: Thanks very much, Craig, for that excellent summary. The floor is now open to PCAST members with the usual protocol of raising your flag when you would like to comment, and Bill Press is the first flag.

>>WILLIAM PRESS: Thanks, Craig. I think this is a very important report. I think it has a heritage that comes substantially out of real industry experts as well as academics and I hope it's very influential.

My question is on the moonshots, I'm visualizing it as kind of Column A and Column B, and Column A is what are the important problems that we think that different kinds of computing, more advanced computing will be able to solve, and Column B is this list of technology vectors that are currently underexploited and could be exploited. My question is in deciding which vectors go with which problems, are you viewing that as prescriptive, is that the final answer, or if a corporation or academic research group had an idea that they could mix and match from those two columns differently, is that as good of solution?

>>CRAIG MUNDIE: Yeah, as we said, we offered these as an example, more to stimulate thinking and get people recognizing, much like the original put the man on the moon moonshot, nobody knew exactly how we were going to do it when Kennedy got up and said let's do that, but the country brought its assets together and achieved that in a ten-year period. So I think the moonshot term applies in that regard. Here we thought there were a set of important things, some of them, for example, in recognizing we want more and more interaction in the biologics area. In some sense that's not classic semiconductors, and yet went to see a hybridization. We constructed the three examples to try to show how you could get a cover set of things, but we don't intend to be totally prescriptive. In fact, we published the whole set of technology vectors that came out of the inventory largely to encourage either more moonshots to be developed or people to take a different approach.

>>JOHN HOLDREN: Chad Mirkin.

>>CHAD MIRKIN Craig, I think that was a fantastic summary.

Looking at the moonshots, I think they're just a beautiful compilation of the challenge here and the opportunity because it is a nice example of the importance of convergence in creating a competitive advantage, bringing fields into the semiconductor arena that traditionally are not impacting them to create much higher value items.

The one moonshot you described in detail, it seems that the groups of folks that would be interested could be expanded. I'm curious why IARPA and DHS, for example, wouldn't be called out there as well because it seems like a very obvious set of agencies that would take an interest in the one that you describe in detail.

>>CRAIG MUNDIE: I think you're right, I mean, we, both in terms of how you approach this and which government agencies might be interested or involved, that's all up for grabs. It's why we said these are examples. These aren't the specific answer, and why there should be a committee who looks at this in more depth and with a real understanding in the next administration in particular of what the areas of focus might be agency by agency. But we did think it would be important that there be an obvious lead agency, you know, or a couple of lead agencies whose natural mission requirement, you know, would focus in these areas. And we tried to identify those. But I certainly wouldn't deem that as comprehensive, or that it should seclude any of the other agencies who have a natural interest in participation.

>>JOHN HOLDREN: Other questions or comments for Craig? I know a number of the other members of PCAST were themselves paying close attention to this study, but it seems that Craig's summary has satisfied all interested and concerns.

That being so, I would like to call for a vote as to PCAST approval of the report on semiconductors, as usual subject to final minor edits. All those in favor please raise your hand.

All those opposed? Those abstaining? The ayes have it unanimously. The semiconductor report is approved and will be transmitted due course to the President and posted on the PCAST Webpage.

Thank you again, Craig, and thanks by remote control to all of the members of the working group who included, as Craig noted, an extraordinary array of both industry and academic experts on the array of issues raised by these semiconductor challenges.

NNI Update & Vote

>>JOHN HOLDREN: Let us move now to the National Nanotechnology Initiative update and vote, and Michael McQuade I believe will be leading that discussion.

Michael, the floor is yours. Please remember to press your microphone.

>>MICHAEL McQUADE: Thank you very much.

I'll make just, this is pretty short. I'll make some brief comments and then, Mark, maybe give you a heads up to prepare a little bit too.

This is the sixth review of the National Nanotechnology Initiative. Just to provide a little background, NNI has been substantiated since 2001. In that time, the U.S. Government has spent approximately $24 billion on the National Nanotechnology Initiative. The peek funding was about 1.8 or $9 billion a couple of years ago. It's about $1.5 billion in the current fiscal year. And just then to come from the other direction, the latest estimates from commercial research reports are there are in excess of a trillion dollars of nanotechnology enabled products and services in the marketplace today. So it is substantial investment we have made, and it has had substantial return.

This is the sixth review. We and NRC are both currently statutorily reviewed to require the NN on a periodic basis. We have done that every two to three years as has the NRC. We should say that in the recent competitive acts funding of 2016, based on the success of both the program and the review process, we very pleased that Congress has changed the review process from both agencies to every four years, and one of our recommendations will be how to offset that.

There are two primary recommendations in this report. The report is quite short based on the comprehensive review done in late 2014 by PCAST, and the recently released NRC report. The NRC report in particular continued to focus on many of the same issues that had been highlighted in our 2014 report. In particular, for those of you will who will recall in 2014, one of our major reports or recommendations was to initiate the structure of grand challenges. A very similar discussion to what we have just been having. Challenge problems that to first order are of significance, they have scale, and a belief that nanotechnology of some kind can be an important mechanism in solving those grand challenges.

We were very pleased that under Lloyd Whitman's leadership, the NNI community came forward last year with its first grand challenge, nano-inspired grand challenge, related to highly efficient computation at the scale that would reproduce the energy efficiency of a computational system related to brain capability in hums. Tied to both a nano initiative and the brain initiative.

Our first recommendation in the report this year is that in keeping with the impact of grand challenges and the success of the initial grand challenges, we recommend that NSET continue that process, and announce in the next year to a year and a half, two more challenges to be owned and operated by the National Nanotechnology Initiative.

That's our primary technical recommendation. We further then endorse the recommendations again from the 2014 report, noting that nothing substantially has changed in that time period. Those recommendations are still valid and have been endorsed by the NRC.

Finally, we recommend that the next comprehensive review by PCAST be done in 2018, and that subsequently PCAST doing its review and NRC doing its review are offset by every two years. So we are not doing a review every year of the program any longer, it's being done every two years and each agency would be on a four year clock cycle. That's the sort of sum and total of the report. Now I'd like to turn it over to Mark for some additional comments.

>>MARK GORENBERG: Mike, thank you, and I particularly wanted to thank and praise Mike for his leadership here on this report, and particularly call out Ashley Predith for her work not just in this cycle but in the cycle report when this report came together, because this is really a continuation of the work we did in 2014 to review and look at what's happened in the

last two years since that happened. And people believe that these reviews are fairly routine, essentially report cards, but I would say that the review in 2014 was clearly not standard. You know, if anything, the NNI had gone through a period where it was primarily a coordinating body, and by 2014 many people here in the government and outside wondered if the NNI had run its course and we looked at it, we looked at that seriously as Maxine challenged us, but we also looked at it another way, which is that nanotechnology is really just in its very early beginnings. It is not a specific technology. It's not tied to any particular industry or discipline or any agency, any agency silo. It's clearly a revolution in how we work with atoms. We're at those very early innings, and we saw a great opportunity to move from coordination to leadership, and that leadership took on this concept of the grand challenges, and if anything Lloyd has redeemed our thoughts there by doing such an exemplar job in bringing this forward and if anything it's our belief that, and I'll speak for all of us on this, that the NNI probably is more important now because of that than it has been in its last five examples viewing this coordination. We've moved to this place now where if anything we're extremely enthusiastic about the importance of the NNI and perhaps that's the more important thing we're voting on today rather than this review is our continued belief in the importance of the NNI. So we're very honored to have as part of PCAST by the way, one of the experts Chad Mirkin from Northwestern, but I can tell you our leading universities are seeing this as the starting point. I know this is the No. 1 thing that MIT is doing today, building in the center of campus, and it is the number one thing they are funding today. I think we're seeing just the very beginning of something that can change the human health for the good, and change the health of the planet for the good, and so very enthusiastically support the recommendations here. The.

>>MAXINE SAVITZ: I just want to add, want to thank Michael and Mark, and this is a initiative as Michael said, began, 2001, 2000, you can actually go to the Clinton library and see the initial speech that he gave at Cal Tech to introduce this. This has been a really bipartisan program, both from the Congress and the administration of carrying it through starting with five agencies and expanding now to 20-some agencies. It's been part of their missions but also with the private sector. But through this it's been very important that the Federal Government's role continue in the fundamental research area, which it has done and to degrees it moves through applied programs and also to ensure U.S. leadership. So it's been sort of exciting to see products on the market and nano has become a common word that everybody uses, maybe not correctly but it's, and I think some of the biggest advances and Chad has been in the healthcare area that were not necessarily anticipated at the beginning. But I think it's really a tribute to all the researchers, the industry itself, and also the government in sustaining a program that can lead from research to products that we become the lead in.

>>JOHN HOLDREN: Chad?

>>CHAD MIRKIN: Yeah, kudos to putting together a great report and great, I think, summary and analysis of the situation, because I think everything you've said is right on the mark.

As we think about going forward, I think you guys have done a beautiful job of emphasizing the importance of creating grand challenges to create a convergence of all these

capabilities that can impact almost every field. We've seen it really impact almost every agency and every group of scientists working under the purview of those agencies. How do we plan for the future, and the next set of grand challenges? Is there a process in place? Do we have ideas on how the next set of grand challenges are going to be selected and are there some thoughts in that regard?

>>MICHAEL McQUADE: Yeah, I think I'll speak for Lloyd who's sitting right behind you. I think the process that was used to select the first grand challenges, it was in many ways what we envisioned when we did the last report. If you recall in that report we focused, and I'm going to draw an analogy to what Greg just said we focused on the grand challenge but also the process of bringing the community together to instantiate and decide what the grand challenge is. Lloyd ran this as part of the council. There were significant public meetings held. There was a request for proposals. Not sure if I get whether it was an RFP or an FOA, or whatever the mechanism used but there was a very strong engagement with the community and then the council ultimately selected what this particular grand challenge was. I think we would envision the same process running again and that's what we had suggested when we did the recommendations last time. I don't know, you're sitting in the back, I don't know if you want to say anything or Lloyd?

>> (Away from microphone).

>>JOHN HOLDREN: Seeing no other flags up, I think we can move to a vote on approving this latest update of our review of the National Nanotechnology Initiative taking into account the comments made that we are really voting in a sense on the culmination of a longer and broader effort to focus and advance this particular initiative, and again, before we vote I would want to add my congratulations and thanks to the team, both the PCAST team and the extraordinary staff who have worked to advance this initiative.

So all those in favor of approving this installment and endorsing our long effort, hands up.

Opposed? Abstain?

Chad abstains I think because of his connections to an important part of the initiative, not through any reluctance.

>>ERIC LANDER: No. As he has consistently on each nano-report, Chad has followed that policy and we respect that.

>>JOHN HOLDREN: So the report is approved.

Forensics Update

>>JOHN HOLDREN: And we move now to the third new piece of PCAST work to be discussed here, and that is the update or addendum to the forensic science report that the group released in September. For that I will call on my PCAST co-chair but also the chair of the forensic science working group, Eric Lander.

>>ERIC LANDER: Great. Thank you, John.

So I'll give a brief update. PCAST has produced an addendum that we bring forward for the approval of the group today. To the report we had, just to remind us without revisiting the entirety of 174 page report, the basic point of the report was that forensic methods, in order to be considered reliable, which is the standard they must meet to be admissible in court, have to have been tested empirically. That's pretty much a summary of the 174 pages. If you haven't got empirical test that something is reliable, you can't know that it's reliable. So we undertook a very extensive review of the literature. We looked at more than 2,000 papers to cover a wide variety of fields, seven fields in all and found that in some cases there was really convincing evidence that people had done empirical studies, demonstrated reliability, could actually measure reliability, if you can't put at least some rough number to it you haven't measured it. And in other cases, at the extreme there were no studies whatsoever that had ever been done that demonstrated reliability. So it's covered the whole spectrum there. We recognize that within the field of forensics there's a growing group of people who see themselves committed to the necessity of empirical studies, and we applaud them and we also strongly stand by the notion that it's not just a good idea but it's a necessary idea to have empirical evidence.

So we wrote this report, shared it broadly, and in response to the report we got lots of feedback from many people in the community but two that were particularly important pieces of feedback. Some groups asserted that empirical evidence was indeed the best way to show something was reliable, but suggested that maybe you could show things were reliable without empirical evidence, so that no one actually suggested how you might do that.

The other was that there was a suggestion particularly from the Department of Justice, that perhaps PCAST had failed to note some studies that met our criteria for properly designed empirical studies that demonstrated the reliability and scientific validity of some of the methods because we are empiricists and scientists and technologists, we take such issues seriously, so we wrote to a number of organizations, including the Department of Justice itself asking if people could point us to actual empirical studies of the forensic methods we had reviewed that met the criteria of being a properly designed study and that had not been considered in the course of the PCAST report. We received replies back on all of that, which we've sifted through. We got a couple hundred papers that people pointed to as being of interesting to look at. We looked at all of those. NIST even suggested to be comprehensive we looked at interpolls, web based resource of 8,000 forensic papers we happily sorted by discipline. We did that as well. And we've written a short eight or nine page addendum to the report we bring forward to PCAST today that basically points to a handful of conclusions. Number one is that there is no way to demonstrate reliability without actually empirically testing reliability. You can't make a conclusion that something is reliable without trying it out. I have to underscore does not in any way diminish the importance of many other things. People point to the importance of professional organizations in forensic science and accreditation and certification. Those are all really important things, but don't in themselves say anything about reliability. People point to large bodies of peer-reviewed literature that show patterns, fingerprints, footprints, et cetera, differ and that therefore you might hope to be able to identify things based on those differences. It's a very important body of work to know that it's worth trying to develop a method but the existence of differences between things doesn't mean that you have a reliable method for associating items with their sources that you can only

tell by empirically doing it. So on considering this we found that we could not imagine, I guess, science is premised on the idea that conclusions that a method of reliable empirical testing, and that no one could provide us any suggestion of any way that one could know that something was reliable without empirically testing it. So we've discussed that in the summary.

We also reported on the various possibilities of were there any studies that had been missed that were actual empirical demonstrations of the reliability any of the methods which we had fell short of or completely missed that standard, and the short answer was no, we could find none. I note that in particular we had been moved to do it because the Department of Justice had raised this possibility. In the end, the Department of Justice did not send us any such studies and we reached out particularly and spoke to the office of the Deputy Attorney General and we were told that on reflection the department had no such studies to bring forward to PCAST. So we very much appreciate their raising the possibility and we were heartened to find they too could not find then give us any studies that met PCAST standards and demonstrated reliability. But we felt it was important to add to the report by saying those things. And then finally, another point that was raised was with all of our focus on empirical studies to demonstrate reliability, there was concern expressed we shouldn't forget about the importance of other studies, like ways to understand why people make errors, not just measuring error rates but understanding the process by which people make errors, or technology efforts to convert subjective methods to objective methods, and there was concern that a focus on reliability alone might divert attention from those important efforts to advance forensic science. We have tremendous respect for those studies. The first, they're called white box studies to see what's going on inside the black box, and these efforts to create objective technologies, and in no way would we want the absolute essentiality of empirical studies to diminish from the other work going on. I don't think we think that there is a need for that. There should be funding for both, and it's a very important thing that we learn those things because that's how technologies will continue to advance. We've written a summary of that. It stands as an addendum we bring to PCAST to our longer report, and that's pretty much my report on the subject.

>>JOHN HOLDREN: Thank you, Eric.

Do we have questions? Comments?

Jim Gates who has himself been a key member of that working group and involved in these issues in other fora as well.

>>JAMES GATES: Thank you, John, and first of all, thank you, Eric for the tremendous amount of work that this was completed on. It was also of course, we thank all of the people work you with like Tania Simoncelli and your staff members with OSTP staff. I think the most important thing you have said very well and since this is a public session I think it bears some repeating. No less a person than Albert Einstein essentially said that Galileo was the father, not just of physics but all science and the reason I ascribe this to Galileo, he said, and this is his phrase, Galileo drummed it into our heads that science must be based on empirical observation. Until this idea was accepted, it would be impossible for the western birth of science to have occurred. This is an essential point about science, it's not a faith based belief system, it's a system grounded in the fact we have to refer to nature in order to be assured we

are doing science. This also means, of course, that we are particularly aware of our limitations, and as science gets codified and error bars and level states of confidence and what have you, and the message that I think the report is attempting to deliver again to the forensic science community is if you are a science, then you must adhere to this basic principle about what it means to be science. Like you, I have confidence that there are members of this community who understand this intrinsically and are pushing forward with it. I recently partly, as you well know have become in the Defense Science Standards Board as a member working with this community to make sure we keep focus on this effort, and I've met forensic scientists who are absolutely the people who will drive this forward. I think this report empowers and encourages them. I think that's a very important function. And the other thing I would let it be known is that some of our previous discussion here and within PCAST itself was resulted in ongoing discussions about moving some of the technology from subjective observation to actually IT based, and modern computer technology to replace subjectivity. So this report has already started discussions. I commend you, as I said, for your leadership. Very happy to be part of the working group, and I will continue to be part of this other community as a consequence and continue to try to drive this message. So thank you.

>>JOHN HOLDREN: Thank you for your continued service in the various capacities on this forensic community. Are there other questions or comments on the addendum to the forensic science report? I see none. To, again, with thanks to who contributed led by Eric Lander,

>>ERIC LANDER: With very valuable contributions by staff. And I really want to call out Tonya and Diana Pankevich whose no longer with us and Ashley and others, and Jen Michael who's putting together all of these documents so we'll have them up on the Web on time, it's no easy feat to wrangle so many different papers, so this was a team effort.

>>JOHN HOLDREN: I echo that and call for the vote. All those in favor of approving this addendum, hands up, please?

Those opposed, those abstaining?

The ayes have it unanimously again.

Congratulations to the team as well as thanks.

PCAST Accomplishments and Vision for the Future

>>JOHN HOLDREN: We are now actually somewhat ahead of schedule. I think we can move rather than taking such an early break, I think we can move to the next topic, which is PCAST accomplishments and vision for the future, and I believe we have some slides to start that discussion. I will make a few initial observations based on those slides, and then we will open it up for a wider discussion.

Just a very quick recapitulation of the history of this operation. I should say that PCAST as an institution goes back many, many years. Really all the way back to the Eisenhower administration when it was called the president's science advisory committee, PSAC, but had

the same function as PCAST has today, which is to support the President's science and technology advisor and the OSTP in ensuring that the president gets the most objective and independent science and technology advice available, and in the process of doing so, that there is a mechanism that reaches out to the wider community of scientists, engineers, and innovators across academia, industry, civil society, because as all of the members know and probably everyone in the room knows, the members of PCAST other than the President's science advisor, which at the moment is myself, keep their day jobs, and as a general matter tend to have very demanding day jobs but nonetheless contribute their time, energy, and intellects to ensuring the connectivity of the stream of advice that goes to the President with that wider community, that that advice reflects the insights of that broader community. President Obama announced the members of his PCAST at the annual meeting of the National Academy of Sciences on April 27th, 2009, just a few months after his inauguration in the first term, and the picture here shows the President meeting shortly thereafter with his PCAST in the Roosevelt room.

We currently have 19 members on PCAST, a total of 25 people have served as PCAST members during this administration. Fifteen of them from the very beginning, and these slides will be posted if some of the print is a little small for reading around the room, these slides will be posted, but this shows the members and the terms in which they served.

Today's meeting marks the fiftieth public meeting of PCAST over the course of the Obama administration. Forty-five in-person meetings at various locations, although I would say a majority of them at the National Academy of Sciences, to which we are very grateful for the support and assistance in PCAST's work provided by the use of the Academy's excellent facilities, five public teleconferences took place as well, all announced as required by law in the Federal Register.

By the end of the administration, which is imminent, we will have published 39 PCAST reports, 37 of them unclassified, two classified as noted here the average page count is 80. I'm not sure that's a distinction, but

>>ERIC LANDER: It's a widespread.

>>JOHN HOLDREN: It is fortunate that we have worked for a president who is not only interested and enthusiastic about the application of science, technology, and innovation, to national goals ranging from the economy, to public health, to the environment, to energy to national and homeland security, but a president who is a voracious reader, and therefore the large average size of the PCAST reports has not been a deterrent to the President's absorbing their content and embracing a remarkable fraction of the recommendation of the PCAST reports and embodying them into administration policy.

The recommendations total, I can't believe whether it was Ashley or Jen or in combination who counted them up, but over 440 recommendations in those 39 reports.

Again, I'm not sure why we stressed the length, but the longest ones

>>ERIC LANDER: We had to write every page.

>>JOHN HOLDREN: Yeah, I guess it's sort of both a celebration and a recollection of pain

past that the 2012 report to the President on Realizing the Full Potential of Government Held Spectrum to Spur Economic Growth, 192 pages. The report to which we just approved an addendum, the report on Forensic Science in Criminal Courts, ensuring scientific validity of feature comparison methods, that was 174 pages, and I believe entailed the review of several thousand articles, studies, and reports by others to make sure we had overlooked no insight available from the literature on that topic.

The 2010 report to the president and Congress on Designing a Digital Future, federally funded research and development in networking and information technology, 148 pages. The shortest report, eight pages, a triumph of compression and Rosina and Michael and Maxine who led that study deserve and are taking I can see by their expressions and gestures credit for producing,

>>ERIC LANDER: Hearing aids was pretty short too.

>>JOHN HOLDREN: Eight pages. But, again, notable for its impact out of proportion to its length, in terms of the embrace not only by the president but by the community affected of the recommendations on closer engagement of the Federal Government with the private sector on adaptation to the changes in climate that are ongoing and will continue despite our best efforts at mitigation.

This gets really hard to read, but this is just a listing in order of the reports produced by PCAST. First term reports and then the second term reports. Obviously I'm not going to read you the list, but it will, again, be up on the Web. Those reports are all themselves posted on the PCAST Webpage in their entirety, along with the press releases that accompanied them at the time.

So that's the quick statistical overview of what this group has been about for these eight years. As Eric already noted in his opening remarks, a lot of thanks and credit are due not only to the members of PCAST itself, but to the PCAST secretariat, and to members of the OSTP staff, and indeed to scientists, technologists, and innovators across the federal government and society who have taken part, have fed insights into, have participated in these PCAST studies, this has really been the work of a much larger body of people than those sitting around this table.

>>ERIC LANDER: More than 100 people served as working group members let alone all the other contributors.

>>JOHN HOLDREN: Let alone all the other consultations and interactions that took place. In my view this group has fulfilled its obligation to ensure that the science, technology, and innovation advice that goes to the President reflects the insights of the wider community, and not just the folks who happen to be working full time at the moment in the Federal Government. So we would like now to expand a little bit on some of these achievements, and entertain as well comments from members of PCAST about the path forward, how we think about the role of science, technology, and innovation in government after this particular administration and this particular PCAST have passed from the scene. I think I'm going to turn it

over to Eric Lander to lead that particular discussion, because I know he's ever ready to do so.

>>ERIC LANDER: There are lots of different topics we worked on, and I think it would be a fitting thing to close our meeting to just talk a bit about the topics and their impacts. I note that the impacts we've sought to have are sometimes within the Federal Government, and sometimes outside the Federal Government. We're always providing advice to the President but sometimes the advice we're providing are about things that the Federal Government itself can undertake, or things that the federal government can undertake in partnership with the private sector, and in some cases we're providing insights about how one might think about the problem to the President, but those insights are intended for a broader community as well and very frequently it's others outside the Federal Government who are in the position to pick up and run with those insights, and we've seen that happen again and again and again. So with no particularly planned order but a little bit of focus here, I thought I might turn to a few of our colleagues and ask them to say a few words about some of these studies. I'm going to pick on Mark Gorenberg first, because the spectrum policy study that PCAST undertook and published in July of 2012 was a particularly impactful report and one I think that surprised us by its impact. When we started that study there was a broad agreement amongst the group that was doing it and leadership of PCAST that it was unlikely to,it was likely to fall upon deaf ears that people didn't want this message, and in fact it turned out not to be the case at all.

Mark?

>>MARK GORENBERG: I think the timing of it was actually very good. I give Craig Mundie a lot of credit for coming up with the idea to pursue this for exactly that reason. This was really quite a team effort by both PCAST and the working group. PCAST members Craig, Eric Schmidt played a big role, as well as Jim Gates, Maxine, and Bill Press in terms of our work and really we called on everyone who all pitched in, had a hand. And the reason why this was timely was because spectrums been allocated to the government and industry in the same way now for 100 years, really since the sinking of the Titanic when we understood the importance of communication, and that's been this idea of finally dividing it into exclusive frequency assignments and allocating to those particular assignments which is not very efficient, and also is very difficult once you're changing industries as we've seen now from TV broadcasting to wireless just the whole movement to that is extremely difficult. And at the same time the Federal Government is doing their mission in many bands, probably well over 50 percent of the spectrum has been allocated. The spectrum now has reached a point with this wireless revolution of not being available and not being reproducible. You can't just expand on it. So we looked at this 100 year change of creating a new model. Effectively this model of dynamically sharing it with the commercial and federal sector, and that has a number of reasons of positiveness but one is it can increase the efficiency and effectively capacity use of spectrum by thousands of times, and economically in what is being produced now that could lead to potentially worldwide trillions of dollars. So it had a lot of impact.

I think what surprised us was how quickly both the U.S. Government and industry has responded to the report that came out in 2013, follow the President's report in 2012 and the President's memorandum that came out in 2013 which is that through tremendous work, the FCC commissioners approved the rule making which was a painstaking process finally in April of

2016 but something that they voted unanimously to start just after our report in December 2012. And that created a whole new concept of a band called the innovation band, the citizen broadband radio service. That was 150 megahertz that had been put aside that the government and industry had given up on basically for sharing. And that's now on its way. The DOD has been a leading force in its opinion to move towards sharing. They created the National Spectrum Consortium which now has 115 industry members and a lot of funding to look at new technologies, and the White House has really embraced the launch of the Advanced Wireless Research Initiative which is really being led today by the NSF. But industry has been a huge positive sway in moving from the early incumbents of spectrum around voice to really this notion of data and IOT and whole new sets of services that are important for wireless, and the core of our report was the creation of what we called spectrum access system, which was the idea of a three-tier model of allowing the government to have an incumbency allowing people to have license spectrum in the middle layer and allowing the bottom layer to be general access. It had the best of both worlds of both quality of service at the license level, and innovation at the general access level following the innovation we've seen on unlicensed spectrum.

Seven vendors and industry have come forward to build spectrum access systems just in this short period of time. Both alphabet and federated wireless are ready to go. Also even done interoperability studies between spectrum access systems so they know this will all work. Chips are being developed for this already by companies like Qualcomm and the 3.5 band. The Wireless Innovation Forum which has 100 industry members was the first endorser of the report now has 277 participants working on this concept and have regular calls, and 200 engineers were on their last regular call. So industry really is responding in the work they're doing to make protocols and procedures for device operation real. A new group was formed called the CBRS, being the name of the band alliance, 24 members now. They're going to be performing joint trials in the next 18 months.

And then the third piece of this is how this is affecting the rest of the world, how this U.S. leadership is affecting the rest of the world, which is OFFCOM which is the FCC equivalent in the UK has called for comments now to implement this in the UK spectrum as well, 400 megahertz available, and they're going through that process today. And China Mobile is working with the U.S. FCC to be able to harmonize the band and the beauty of that is that it will open up another huge market so people who are developing chips and devices will have a huge market to build into. That will really expand the industry.

I think the most important point I wanted to make here was the report really worked towards the idea that spectrum was really scarce, but that doesn't mean that the spectrum itself should become the investment, the value. What we wanted to do was come up with a way that made spectrum effectively so abundant that everything on top of it created the value, created a whole new industry, again, where trillion dollars as opposed to potentially the money that the government could make by reselling spectrum, and we believe this has the impetus to change the 21st century for communications of all kinds. With that I'll turn that over.

>>ERIC LANDER: Fantastic. and thank you for your tremendous efforts in this area.

So I'm going to suggest, I'm going to touch on hearing aids. Chris Cassel should do this by all rights because she was the driving force but she's unable to be here this morning due to a

personal obligation, and then just to give a little advanced warning, I'm going to ask Maxine to touch on advanced manufacturing. The I'm going to turn if it's okay to Susan Graham to say something about big data and privacy and about the NITRD reports we've done, and then I'll give advance warning to a few more people. I'm going to turn back to Mark Gorenberg to talk about cities. That's a little advanced warning, I'll keep giving a little advanced warning since we haven't orchestrated all of this in advance.

Hearing aids was perhaps one of the most impactful reports we've done and I think the most impactful report per page that we've done. It was an extremely short report, and it provoked a tremendous amount of action, which we've seen just in the past couple of months. Problems are very straightforward. 30 million Americans need hearing aids. They need assistance. If they do not get their hearing aids, there are really serious medical consequence, social isolation, falls, cognitive decline, and yet more than 2/3 of the people who need them don't get them. Why? Because they're extraordinarily expensive and difficult to get.

These devices if you need one in both ears, as many people do, can run 4,000 to $5,000 and it's not covered by Medicare. It's not covered by Medicare because they cost you 4,000 to $5,000, and if you multiply that by 30 million Americans it's not affordable but when you take a hearing aide out of the ear and look at it, it's a piece of plastic with not an awful lot of technology in it. You look at all the amazing advances that happen in consumer electronics today, and you say why isn't this thing that cost ten times more than my iPhone at least as smart as my iPhone. There's a big market for these things, why isn't it something where I can put it in my ear and I can tune it with software on my phone, for example, and optimize it and have feedback there. Why aren't there all sorts of innovative companies jumping into this market to serve Americans and others around the world with really advanced devices that are smart, listening to the noise that's out there, filtering it in smart ways, tuning it to what your own personal hearing needs are. Well, it turned out the reasons are that we have a set of constraints, a set of regulations that were put in place in a different era when they made a lot of sense, but they don't anymore. These devices which should be like consumer electronics devices, at least in the case of basic hearing needs, we're not talking about severe medical problems, implantable devices, we're talking about the thing you put in your ear externally, these audio conduction devices, air conduction devices, these things should be innovating faster but they're regarded as a prescription device. You've got to get a prescription from an audiologist or sign a waiver that you haven't got a prescription. They have to be approved by the FDA in particular ways, they have to satisfy good manufacturing procedures. This shouldn't be. We wrote a short and simple report that said for basic mild to moderate age related bilateral hearing loss, these should be over the counter devices that do not require a physician's prescription. National Academy of Sciences, NRC conducted a study that came out several months after ours that was very similar in its conclusions and to its enormous credit the FDA has heard this loud and clear. They've already taken the action of essentially abolishing the need for an audiologist test the way the FDA does that is it says it's going to exercise its regulatory discretion not to enforce the requirement, but that basically means you don't have to go to an audiologist start now, and they're beginning the process to make this an over the counter device. It's a fabulous example of a case where the Federal Government is able to step in, recognize that the industry has changed, that we need to open it up to lots of innovation, and to do so in a remarkably rapid and thoughtful way. So I think we all feel really good about

it not at least because, selfishly but at least because all members of PCAST are at risk for needing hearing aids at some point in the future because, you know, as one ages, almost everybody's going to need them. So in this one case we're going to reap a benefit, but so will so many people around us, our parents right now. So that was the effort. And it all arose from a broader project that PCAST was engaged in involving technology and aging. Chris Cassel who's our PCAST member who's a gerontologist had pushed the really great importance of focusing on a technology could help aging Americans, and this larger report from which this nugget was produced rapidly as a letter report, this larger report covers a number of other subjects, including, just to pick one nugget out of that one, banking. The idea that as people get older, there's a great deal of risk of fraud in their bank accounts. The if you're using your credit card and there are funny transactions on your credit card, there are all sorts of software that can say that was a funny transaction, I'm going to hold it up and make sure that you actually meant to make that transaction.

If somebody was draining your bank account, an elderly person who wasn't on top of all of that, someone was draining your bank account with a series of unusual transactions, there are not either the software algorithms in place to monitor that nor the general expectation in the industry that banks should be looking after that on behalf of their customers. The banking industry has embraced the fact that is a customer service that is technologically quite feasible. You can recognize at least in many cases bogus suspicious transactions. You can delay them to make sure they really were authorized, and I think the banking industry increasingly says we want to provide that service to customers. So that is happening and in this case it's not clear that government regulation is going to be needed. It's the government stimulation that's going to be needed. Although it may come to a point at some point in fact there are rules adopted that people should do it, but we're seeing much faster market adoption. There are many other things in this report on aging as well and I think we should be very proud of that.

I'd like to turn to Maxine on advanced manufacturing and then I've got Susan and Mark and then I'm going to turn to Chris Chyba to talk about microbiological threats.

>>MAXINE SAVITZ: Thank you.

As everybody knows in 2009 we were recovering from major recession and in 2011 PCAST decided there was, or looked at there was a need for a concerted whole government effort to increase the footprint of applied research and development in advanced manufacturing and cross the gap for how to you scale these technologies that are often beyond the risk limit of large manufacturing firms and particularly the smaller manufacturing firms. There was a study in 2011 co-chaired by Eric Schmidt who unfortunately couldn't be here today and Shirley Ann Jackson, President of RPI who had previously been on PCAST. And there have been two subsequent studies in 2012 and 2014 that have been co-chaired by Alex Alvarez, the CEO of Dow and the President of MIT first Susan Hockfield and then now Rafael Reif. It's really a joint, the idea was to have a joint academic industry partnerships. It was decided to create the National Network for Manufacturing Innovative Program. It's now called Manufacturing USA and it was also decided this would be tried out by three major agencies, Department of Defense, which really needs the newest of technologies, Department of Energy, and the Department of Commerce, which has its role and NIST as part of the Department of Commerce is coordinating role but also a major coordination by OSTP and the economic council. Really

been a very collaborative government program. In the four years that the program has been in existence, the establishment of one institute in Youngstown Ohio by the Department of Defense, there are now 13 institutes. One was just announced this past week and the Federal Government has committed for these five year programs, $920 million, and the private sector and state and local governments have committed $190 million. The intent is for five years if they are to continue it will be purely all non Federal Government funding. In addition in 2015, there's a bipartisan action by Congress passed the revitalized American Manufacturing and Innovation to formally authorize the program. They're very exciting activities. One they're chaired by a nonprofit. Some could be a smart manufacturing institute or other consortium group, and then their active participation by many different universities and also large spectrum of industries, both small and large. And city and local governments and they provide, there's a new one getting started that is sort of managed by UCLA for smart manufacturing. There's a smart manufacturing alliance that was sort of a lead of the nonprofits, but you have UCLA and the city of Los Angeles providing facility in the downtown area where actually there can be testing of some of the scale outs testing of non-disruptive evaluation, all sorts of parts that will go into manufacturing, and to the whole value creation of manufacturing, not just the end product but also supply chain and then regional areas and that one there's five regional areas that again will consist of universities and industry led RPIs. One of them Pacific Northwest lab, so you get various participation by also the national lab. And these have already, groups have started to attract new manufacturing investment in the region. The oldest one in Youngstown Ohio has, which is looking at 3D printing, has attracted $32 million from GE for a printing hub, and ALCOA has invested 60 million in New Kensington, Pennsylvania to do 3D printing with metal powders. It's really taking advantage of its mission and really pushing new technologies and manufacturing, not just making, trying to revitalize the traditional manufacturing institute. So we look forward. There will be coming out in the next month an evaluation of some of those programs, but just talking to some of the people the enthusiasm and the real spinoffs are very, it's a very successful concept in how all these players can work together successfully.

>>ERIC LANDER: That's great. Thank you. And it's just amazing to see these 13 hubs that are just buzzing right now. I think there's a recognition that manufacturers, when we started there was a great concern that manufacturing in the United States was perhaps lost to us, and I think what came out of that PCAST report was a recognition that low end manufacturing where the cost of labor was the major part of the goods was going to be a tough thing for America to compete on because there were low wage countries that would be able to manufacturer things cheaply, but, boy, there's just such an explosion we've seen in high-end advanced manufacturing that can't move elsewhere nor frankly where the wages are not the largest component of the goods, and therefore there's not a downward pressure on wages in the way that there are in straightforward manufacturing. So these are good jobs and good wages, the sort of things we've wanted to have in manufacturing. We noted early in that report that Germany had gotten really good at doing that, and there was no particular reason why the U.S. The Fraunhofer Institutes. There's no reason why the United States shouldn't be a world leader in that manufacturing and one could imagine that will lead to a very large number of jobs. Whether that will ever replace the whole number of jobs we had in the 1950s, who knows, but I

suspect it's already the case that there's a lot more of that that is going to be appearing in this country than we even imagined when we were writing the report. Thank you to everybody who worked on that.

According to my list, we're going to turn to Susan to talk about whichever order she would want. The big data and privacy report from a technical perspective and the multiple reports that PCAST has done on a topic we call NITRD or Networking and Information Technology Research and Development.

>>SUSAN GRAHAM: I'd like to start with NITRD, the NITRD Program, the Networking and Information Technology Research and Development Program, was started in the early 1990s during the Clinton administration, and it was created by congressional legislation to coordinate investments in information technology over the various government agencies that had an interest in IT.

The program about ten years later, so the legislation said there was to be a biannual review of the program, and there was to be an advisory function from the nongovernment community.

About ten years later that responsibility was assigned to PCAST. So in the beginning of this PCAST, a working group was created to do the review of the NITRD program, was co-chaired by David Shaw who was then a member of PCAST and Ed Lazowska who was the chair of the Computing Community Consortium. I participated in that review. The review had two components. One was to review the coordination. The other part was to review the investment, what the R&D investment of the Federal Government was in network and information technology. And in the investment part we laid out various emerging areas that we thought the government should be paying due attention to. One of those areas was privacy, and we said that privacy is not the same as cyber security, as more and more information is digitized, it's going to be an important issue for society and the research community should be paying some attention.

We then did an update report in 2013. Peter Lee and I chaired that. And we looked at the recommendations from the previous report and we said, well, some of these are getting appropriate attention, some are not. Privacy is one of the areas in that, in which you didn't listen to us. We then did a review that came out in early 2015, which again looked at the coordination process, looked at the areas of investment and the emerging important areas of research, and in addition looked at the way that we understood what the investments were, which had to do with the way the reporting was done by the various agencies, and we recommended some modernization of the reporting structure. And we go the very good response, particularly in this last report, things changed in response to our recommendations, which was very satisfying. So that's the NITRD situation. The coordination continues. Over the years the agencies have learned to work together rather well, and I would regard that program as a success story, which we have continued to monitor. I also might point out that the legislation says that the review should occur every two years. That's a little bit often and that we now expect it's going to shift to every three years which makes more sense.

So it was frustrating to some of us that we had twice recommended there a there be more research in privacy and it didn't seem to be happening and then in January 2014, well, in the fall of 2013 the whole Snowden affair erupted and then in January 2014 the president gave

a speech in which he said we need to pay some attention to privacy, we need to find some ways of addressing this threat, and he asked for two reports. He asked PCAST to report on the science and technology of privacy and privacy protection, and he asked other people in the White House to report on the policy implications of threats to privacy and what policy might be put in place. And he told us our role was not to talk about the policy issues, but to talk about the science and technology of privacy protection.

And he wanted a response in 90 days. So we put together a group, Craig was part of that group, Bill was part, I apologize, I don't remember who else among our PCAST members were parts of the group, and we set out to learn everything we could about privacy and to explain it in a report. Which we actually did in 90 days. Part of that report was really a tutorial to the larger community about how the threat to privacy had emerged because of information technology primarily. That more and more personal information is in digital form.

People volunteer personal information because there's an implicit contract that if they tell this Web site something about themselves they'll get services in response that are services that they want, and some of them volunteer that information without really thinking about what they're giving away and to whom they're giving it away. And in addition, there's an increasingly powerful way to combine information from different sources, and so you think you're only telling somebody what your gender is and what your age is, and yet that can be combined by your ZIP code and lots of other information and we have increasingly powerful ways of analyzing data so in fact as a society, we can learn an enormous amount about people.

And we made a bunch of recommendations. We had a fair bit of exchange with the other group that was making policy recommendations. One of the key observations that our report made, and this was an outgrowth of a paper that Craig had written, was that you can't really prevent the collection of this data.

As I said, there are good reasons why the government collects some data, and good reasons why people volunteer data in return for services. And in some sense every time you volunteer information you're doing a risk assessment in which most people decide it's worth the risk to get the services.

So the data is going to be out there, and the analysis is going to be out there. What you can control is the way personal information is used. In principle you can control the way it's used. In order to do that you have to again come back to using IT to help to control the use together with policy that says certain uses are not appropriate or not legal.

And in doing that you need to take into account the fact that different people have different views of what they regard as private information about themselves and their families, so you need some way to be able to have different degrees of control depending on people's different value systems, and there are some parts of that problem that we as a science and technology community know how to solve now and there's some parts of that problem which we again throw back to the research community to say figure out how to institute these controls in a way that we can manage them, in a way that they're affordable in a way that we can check whether they're actually being applied or not.

So because we didn't make policy recommendations, we can't say that there was legislation in response to our recommendations, and yet there's been an enormous increase in consciousness, increase in knowledge, and increase in the ways that the commercial sector is able to grapple with the policy issues.

>>ERIC LANDER: Can you say a little more about the way these ideas are rippling out in the communities and in companies and things.

>>SUSAN GRAHAM: Well there are now courses that use this report as part of their text material, and in that sense we're educating the next generation, we're educating lawyers, we're educating people who work on policy, and we're educating the technical community.

What was the other half of your question?

>>ERIC LANDER: That's fundamentally it. The it really has now, the framing of the report but I think Craig distilled into it's not productive to regulate collection regulate use, or control use was I think really important framing because there was and still is in some places a notion that placing the controls at the point of collection would even be feasible. You can't tell at the point of collection what all these pieces are going to be good for. They may look all minor.

>>SUSAN GRAHAM: The other part that I should have pointed out is that a lot of the collection is not visible to us or under our control. For example, if you think about the pervasiveness of cameras in our environment, we're photographed all the time. The face recognition is getting better and better, and yet most of the time we're not consciously aware that we're being photographed and even if we were, there's no issue of consent. If you're in public, it's perfectly legal and okay for you to be photographed.

>>ERIC LANDER: It's a good example of I think trying to reframe these issues in a way that both policymakers and technologists could work with them. Thank you.

Let me turn to Mark on cities again and then I'm going to turn to Chris Chyba on microbiology, and Bill Press on cyber security.

>>MARK GORENBERG: Eric, thank you. So again the city's reported came out of the brainchild again of Craig Mundie and I hope Craig will add some comments after I'm done with these sort of the introductory comments. In terms of studying what's happening in cities and how they're transforming and how the Federal Government can be helpful in that regard by policy to the technology. So Craig and Eric Schmidt were co-chairs on this report. Huge credit to Marjorie Blumenthal who sat on top of this for frankly a year working on it with us. But this is a report that was co-chaired by almost all of PCAST. We did our first meeting publicly together in February of 2015 to pick a working group out in Palo Alto, and clearly everybody was involved and people stayed involved. People like Jim Gates were on every single call for about a year. Susan did a final review through the way, and everybody added their part because this is so just interdisciplinary in its work.

And the interdisciplinary tone of this set the stage for some of our recommendations, the need to break down the silos of government to become much more interagency, the need to create competitions, the need to look at cities through the lens of a district, to be able to have something that is large enough to have meaning but small enough to experiment on, the ability to look at this in terms of districts improving on the dimensions of being more green, being more mobile, being more connected, effectively solving issues such as poverty and so we also looked at the necessity of this to share information and came up with a concept in the

report of the city Web that is how to share information and insights across cities because some of the larger cities are actually working on these problems today but the smaller ones just don't have the budgets to do that and can learn tremendously from each other.

The timing of this that really is the reason why it has potential for great impact is that we're really entering into a fourth era of cities. I mean, we went from the era of the steam engine, to the electric grid, to then the personal automobile and that's been true now since really before World War II, but particularly after World War II with the creation of the highway system.

And that's the way funding has been put in place. But now we're seeing this change, and that's because urban planning is transforming frankly into urban science. It's because there's a demand that is appealing to 80 percent of our population live, in cities, 90 percent of our country's GDP centers around cities and this change happened around 2011 with the start of this sort of sharing economy with millennials frankly and Baby Boomers coming back to the city and changing their norms of behavior, rallying around a shared economy, rallying around the concepts of access instead of ownership, rallying around the idea of living in less space, and rallying around the idea of more walkability and bikability, and sort of less transit movement. And at the same time we saw cities starting to get instrumented in terms of data and sensors and we saw technologies all transforming together, like transportation, I mean, everybody knows about autonomous vehicles that are coming and it's actually real within the next five years. New energy systems, new building and housing systems, new district water systems. Maxine talked about in the manufacturing report new concepts around urban manufacturing. And we even see urban farming.

So when you put all this together, you have the ability to really transform cities and to make a point of this in a way that's thinkable. About 25 percent of our downtowns now are used up for parking, and tied to our old transportation system. And if you put in autonomous vehicles and you can get that 25 percent back, frankly 80 percent in some of the districts of downtown Los Angeles, you can transform housing into very different district kind of housing. One you create new housing around that, you can create new district energy systems. You can create new district water systems. You can really transform the whole makeup of these cities of the districts of these cities, which has huge opportunity for revenue growth and huge opportunity for cost savings, and huge opportunity for competition and we're actually falling behind. The Asian Import Bank is spending $18 billion a year on this. The UK has created essentially a cabinet member, a minister of cities, and cities like Stockholm and Hamburg and Amsterdam are transforming in public-private partnerships to a whole new model far ahead of us, a chance for us to fall behind but also an opportunity to work together.

So the report came out in February of 2016, and we had a lot of conversations with both industry and agencies along the way. So a lot of this work started happening towards the end of our report cycle, but also since that report cycle, one of our key recommendations was around implementing competitions. The Department of Transportation has really taken a tremendous lead here with their smart cities challenge. They ended up getting 78 city proposals, far more than they expected, seven finalists came out of that, and all of them by the way are working on their proposals, although the winner, Columbus Ohio was the one that was funded by the federal government with $40 million from the Department of Transportation which by the way then leveraged into another $100 million of private funding alongside of that.

They chose four districts for change, with the implementation of autonomous vehicles and battery research, electric charging stations, buses to cars, new types of shuttles. But what was interesting about it was that they're also trying to solve the issue of infant mortality. The infant mortality level in Columbus Ohio is four times the national average, and that's because of the lack of accessibility of doctors and transportation and to many parts of the city, so part of these competitions again was to look at things like making cities more green around electric vehicles and electric charging stations, and the DOE worked with DOT on this, but also this idea of changing and fixing some of the poverty and connected issues of some make our cities more inclusive. What I find most interesting about this competition is it got so many people involved, although only Columbus was the one that was funded. 1400 people participated in these DOT Webinars, and 800 people participated in forums, and 300 industry companies joined in their proposals, so they and the other six finalists are all working on it today because of a small amount of money that had a huge amount of leverage. In fact DOT has kind of doubled down on this now because of its success where at the Frontiers Conference this past October, they gave out another 65 million in grants. That led to another 100 million in private sector funding, and they've now committed as part of the fast act 240 million over the next four years in this area. Beyond the Department of Transportation, NIST has moved forward with their global cities team challenge. They, working with U.S. Ignite, hosted their super cluster kickoff. 150 cities and 400 new companies around the world working on these issues. The White House, towards the end of our report, put together their first smart cities initiative in September of 2015 and they did their second round this year in 2016 of 80 million in funding from federal investments led by new ideas in the NSF, 60 million from the NSF, 15 million from DOE, with the impact on 70 different city communities, and they also grew their Metro lab network we really think is a model for how city CTOs and universities can partner to solve some of these issues around urban innovation, and now there are 51 universities and 38 cities working together in pairs to solve some of these horrible issues.

We also called for cooperation, our coordination of research across the different agencies and that is well under way now and we're expecting to see report for public comment in this next week on how to put research together for urban science and urban innovation. And also there is a federal blueprint being worked on sort of cross agency right now. We're hoping to see that come forward, if not before the end of this administration by people who remain, to put that together as a blueprint that we're very hopeful the next administration will pick up the ball on.

This is one of those studies and concepts that I particularly am very optimistic that the next administration will take charge of. The reason why is because I mean the president elect has already talked about a trillion dollars in infrastructure improvement. We're hopeful they'll look to the guidance here in how to spend some of that, but we think this is a multi trillion dollar business opportunity. We think it can create all kinds of new jobs and be actually one of those bright lights for creating jobs over the next few years. Can certainly enhance the quality of life for all city residents and we think it can improve infrastructure that's really critical for things like homeland security and resilience, climate change and disasters because that clearly is one of the tenets that can be implemented by these technologies, can be very impactful for our nation's cities. With that I wanted to turn it over to Craig and anybody else that may want to make comments.

>>CRAIG MUNDIE: Thanks, Mark. You were pretty comprehensive in covering many of the points but I'll emphasize a couple. One, there's been a lot of activity under the banner of smart cities which is more or less applying technology to improve the efficiency of existing city structures. I think one of the things we emphasized in this report which I think people are beginning to adapt to is that the steady progress in more of these infrastructural technologies like energy and transportation, in and of themselves cause cities to change. Their nature changes, what urban living means changes. These changes don't happen very often, but we believe they're about to happen again, and people oftentimes underestimate how quickly these transformational things happen. If you go back to the decade just before WWI, New York went from an all horse environment to all car environment in about twelve years.

More recently, my own experience visiting China in 1987 was an all bicycle environment in Beijing, less than 15 years later was essentially almost an all car environment, and the nature of those places change.

We see these kind of changes coming now. Certainly many of the infrastructures that created the urban evolution as we have known it for over 150 years in this country, were each individual technological advances, for example in energy or transportation, the car, but now we have all of them in sort of their earliest incarnations but the cities have lived on those for over 100 years. So many of them are basically being depleted or are going to be up for replacement any way, and therefore we wanted to signal to people that the investment that is going to have to be made needs to be made in anticipation of these new infrastructures, and not just a replacement of the old one in situ. Also the fact that we understand them as a system now is a very different way of thinking. The district approach and in talking about energy heating and cooling as one integrated thing, not set three different things, are very important ideas. None of these were emergent under the smart cities approach

Yet we see a lot of work in the governments who contemplate huge capital investments required to deal with aging infrastructures. The water problem we also wrote a report on is essentially a byproduct in many ways of degrading classic infrastructure. And so I think we wanted to get people to focus not just on tweaking cities at the margin, but recognize that fundamental is change, is coming, is necessary and we need to be prepared for that. I think that was a big delta from classic thinking that came from this report.

>>ERIC LANDER: Let's turn to Chris Chyba to talk about a constellation of reports that really emerge from various kinds of micro biological threats including the very first report the president asked us to do.

>>CHRISTOPHER CHYBA: Thank you, Eric. It's true there's been a kind of continuity through the eight years of PCAST with respect to attention to micro biological threats, going back to our very first report that Eric mentioned on influenza in 2009, and extending to one of our final reports on action needed to protect against biological attack. After our initial report on influenza in 2009, a year later we expanded, provided much more context for what the nation had faced with the H1N1 influenza pandemic in 2009 with a 2010 report on reengineering the vaccine production enterprise to meet the challenges of pandemic influenza. The issue was that the time scale of the declaration of an urgent need for a vaccine, and the

availability of a first limited doses of that vaccine had been 26 weeks, which was eight weeks after the start of the second wave of the pandemic in the United States. The PCAST 2010 report set as a goal and identified a suite of individual measures that could be taken towards that goal set as a goal to reduce a time line for vaccine production to about twelve weeks. There were a succession of other PCAST reports that were all in, all had either the theme or had a component of a theme for preparing for biological threats. In 2012 there was the PCAST report on compelling innovation and drug discovery which included, which examined issues of increasing the pace of development of therapeutic drugs, including the development of medical counter measures against infectious diseases, and then in 2014 PCAST released its report in combating antibiotic resistance. That report identified a suite of measures intended to increase the pace of development of new antibiotics, and also measures intent to protect the utility of existing antibiotics that is by slowing the rate of growth of antibiotic resistance. The report endorsed a one health approach which says that you have to examine the situation in animals as well as human beings. You have to conduct surveillance in both the human population and the animal population, and this has to be a part of a comprehensive strategy.

Most recently we had their letter report to the President which with one of our two reports that include a classified annex on protecting the United States against biological attack. I co-chaired that report with Wanda Austin. I think the continuity through years of PCAST on confronting micro biological threats shows the ongoing importance of these issues is clear looking forward that the importance of these issues is never going to go away. This is something our civilization has to face, and our country and our civilization has to face for the foreseeable future.

In fact, I think it's likely these challenges both with respect to natural disease and with respect to potential human made threats is only going to increase in the coming years.

Let me summarize the unclassified parts of our final report on actions needed to protect against biological attack. As has been often the case, almost always the case with PCAST reports we brought together working group of specialists, micro biologists and virologists, and we also had strong PCAST participation in addition to the co-chairs, Bill Press, Barbara Schaal, Eric Lander, John Holdren. The basic idea of the report and message is that advances in technology are now so important, both quantitatively. There's been a, if you define as your metric the time it takes to synthesize an oligonucleotide, a short strand of DNA, you see an exponential increase in bio-technological power that's comparable to computer power increased explained by Moore's law. That's the old Moore's law, not the new slower rate of Moore's law. But you also see qualitative jumps with new DNA technologies coming online. You put those trends together and the clear result is that the approaches we have taken towards biological security and in particular bio defense are no longer going to be entirely sufficient, no longer going to be sufficient to focus on a list of select agents and possible manipulation of those agents. There's going to be a potentially much broader landscape that an intelligent adversary could choose to engage on with respect to the creation of biological threats. Government is always inherently challenged to keep up with rapidly moving areas of technology, and that's because of people that are developing those technologies are primarily in the private sector and academia. And therefore we need to have mechanisms to constantly inform the government, and this has to be true in perpetuity, to make sure that government remains on top of these new technical developments. Our report divided our recommendations into immediate, medium term, and

long-term steps. All of those steps need to begin now because the things. We to have in place for long-term, say 15 years from now, need to begin now if they are going to be in place 15 years down the road. Absolutely crucial is the issue of leadership. White House leadership above all because this is such, this problem cuts across so many agencies. Leadership within a variety of agency and including most important perhaps is the intelligence community.

That leadership is going to have to establish, going to have to build on the already existing strategy for bio defense to ensure that it is routinely, annually updated taking into account new advances in the technology and the ramifications of those advances, and that leadership is going to have to hold to account the various agencies to make sure they are in fact fulfilling their responsibilities with respect to that strategy, and there has to be a kind of back and forth routine communication between the White House leadership and the various agencies engaged on this issue.

Another immediate step that we called for was the creation of the Public Health Emergency Response Fund. Congress eventually appropriated $7.7 billion for the 2009 H1N1 influenza outbreak. It appropriated $5.5 billion to combat Ebola. There is no question when there is a major outbreak in the United States or internationally presenting a clear threat to the United States that substantial funds are going to be appropriated. What one wants the Federal Government to be able to do is be able to move out of the gate quickly, to get out in front as fast as possible. That will in fact minimize the amount of spending required by the Federal Government as well as of course minimize the impact on the health of Americans and health of people around the world. We have an analogy, an analogue for this, which is the Federal Emergency Management Agency's disaster relief fund. When there is a hurricane or tornadoes, executive branch doesn't have to go to Congress, FEMA doesn't have to go to Congress and ask for a new appropriation to allow them to respond to that catastrophe. The money exists, already appropriated and FEMA can immediately draw on. It has to report monthly to Congress as it spends that fund down and as the fund is spent down, Congress replaces the funding. The important thing is one can act immediately.

By analogy we call for a public health response fund that the executive would be able to draw on immediately in the event of a major pandemic, rather than having to wait for a particular crisis. And again, rather than having to wait for a particular appropriation. And again we know historically those monies will be appropriated. Those are congressional research service numbers for the H1N1 and Ebola outbreak. Substantial funding will be appropriated. The amount of funding required will be less if we can move out faster.

In the medium term we need to continue to increase our ability to conduct bio surveillance. Again, taking a one health approach. This has to happen both with respect to agriculture and with respect to human health. We note that the Centers for Disease Control domestically and internationally both the CDC and Departments of Defense are improving bio surveillance and are adapting or adopting genomic approach to surveillance. One wants to rapidly understand the genetic diversity of whatever organism one is facing, look at the various strains of the organism, and determine whether the organism has been modified, intentionally modified. You want that to be able to happen as quickly as possible. So bio surveillance needs to be a continuing area of emphasis and the already underway movement of bio surveillance towards the ability to apply modern genomic techniques needs to be continued.

We also, in both the medium and long-term, set goals for improvements in medical

counter measures. Once you recognize that something is underway, whether it's a naturally threat, a naturally occurring threat or a human engineered threat we have to be able to respond quickly. If we look down the road at what's, will be increasingly available to potential adversaries, whether we're talking about non-state actors or state actors, with the technology and the ability to manipulate organisms, we had better be able to act increasingly rapidly with respect to medical counter measures. Therefore we set two ambitious goals, very ambitious goals in the PCAST letter report to the President. One is that on a time scale of a decade, the United States needs to be in the position where it could have the ability to accomplish in a six month period the complete development, manufacture, clinical testing, and licensure of a vaccine against a new threat. Everyone recognizes that is a very heavy lift, but yet in the world that we are entering, it's one that we need to work towards rapidly.

And then in a longer time scale, we need to be able to respond even more quickly with medical counter measures, with at least therapeutics to outbreaks. Ultimately that's something we want to have the ability to have therapeutics available to the American population within days of their recognition of a new threat. That is a kind of blue sky requirement, but it is one that one can already begin to identify a handful of possible approaches to pursue, and it's time to get underway with trying to make those a reality.

So in conclusion, Eric, I'll just say that, I'll reiterate that PCAST has recognized there's been a kind of steady drum beat on a kind of biannual basis on this recognition of the microbial threat. There was a time decades ago when people talked about a post infectious disease era that was in respective a kind of naive hope. Microbes in the natural world evolve, and we now know that even if microbes are eliminated from the natural world, that human beings as a consequence of biotechnology, which has brought so many advances and gives us so many opportunities to protect ourselves, but those technologies have also brought with them the ability to recreate microbes that were once eliminated from the natural world, this is a challenge we will face forever. I'll conclude by saying I need to say something about, even though it's such early days with this report, something about reaction in the community, I will note that in addition to great interest in the Executive branch there has been clearance on Capitol Hill. We have briefed staff from a half a dozen different Congressional committees on this report. This is clearly a bipartisan issues, and one we all recognize we'll face through the future.

>>ERIC LANDER: Thanks so much, Chris. That's very helpful.

We'll take just a couple more of these because I think we're getting the sense of it. The goal is not to be comprehensive, but I asked Bill to say something about the cyber security report. Rosina if you would just take a couple of minutes on the water report, we'll keep it brief, and Jim Gates, if you would just say a couple of minutes about this whole series of education reports we've done, that might bring us to the point where I think we've covered enough to get a representative flavor of what has flowed through apart from then turning to our chair, our co-chair here, John to talk I thought would be fittingly last about climate and energy.

>>WILLIAM PRESS: So the subject is cyber security. There are some national problems that are so difficult and so fast moving that even PCAST was not able to solve them in the eight

year period that we were engaged in this issue.

I said that a little bit jocularly but only because if you opened up your newspaper headlines today or yesterday or the day before, cyber security dominates those headlines. I think it's important that we recall this has all happened in the last eight years, or much of this has happened on the time that we've been on deck here. If you can think back eight years ago, cyber security was something that the guys and gals in the IT department worried about a little bit, and mid level management in corporations worried about it a little bit, and to the average citizen the kind of issue was how do I stop all the spam I'm getting in my e-mail and, oh yes, there's this idea that maybe my computer is being co-opted for somebody's bad use but that's not very likely. Now fast forward to today when people's identities are stolen, people's bank accounts are drained, this is an issue that has gone from being arcane and specialized to literally at the forefront of American government, and as we have seen to much regret American politics. So where has PCAST been in all of this? But thing's also a lot of necessary context here because it isn't purely a technical problem. The question of allow we as a nation defend our self against cyber threat, against crucial attack is something that stresses our whole notion of what is the dividing line between what government is responsible for, and what the private sector is responsible for.

You know, if you think of cyber attack, particularly cyber attack from abroad, as being an attack on us as a nation, then you would conclude there a we ought to be defended down to the level of every individual citizen by our military.

In fact, if you go back more than 100 years in American history, the military was used to defend within the borders of the United States. It was not a very happy in period in American history. The military was defending primarily white settlers of the west against indigenous populations whose land was being taken away. That's not the point. The point is the Federal Government accepted that the military should defend its citizens even within the borders of the United States.

So the modern analogue would be an agency like NSA or DOD that has extremely capability defensive cyber security capabilities. But we by national policy limit the use of those capabilities to defending a very small circle of intrinsically governmental things. The NSA defends, roughly speaking the dot.mil network by executive order the government turns to the Department of Homeland Security to defend by and large the dot.gov network. There's then kind of a gray area much debated of what is critical infrastructure which lies in the private sector but whose disruption would be so fundamental to our economy, to our life that government does have a clear role. That starts being things like the financial sector, power, electricity, but even here the government starts in effect turning over the responsibility for this defense to the private sector itself. And then when you finally get down to almost all of our economy, the government basically says by policy you're the private sector, this is not really different from you should build your own fences or put your own locks on your doors and windows to defend your business. The role of government is limited to prosecuting crime. It comes down to the FBI point of view.

So I know from having participated in discussions with people from other countries that other countries don't view this as a rational division of labor to cyber security. They say, why aren't you using your best talents all the way down the chain as it were, or all the way up the value chain. Interestingly of course this goes back in American history to the election of

Rutherford B. Hayes in 1876. I don't know if my colleagues know this, because in part of the compromise between Republicans and Democrats, then quite different parties from today, that put Rutherford B. Hayes into office, there was an agreement to withdraw all federal troops from the south, and there was a law, the Posse Comitatus Act passed that forbid for all time, the use of federal troops of what we would say the military in a whole range of civilian defense functions which have come down to us today as including cyber defense other than in a very narrow defensive government, or presumably if there was a Pearl Harbor like event, a catastrophic event of a magnitude in which the President could invoke special powers.

So it's in that kind of a strange political context extending back a century that PCAST in the last eight years has tried to be helpful in its cyber security recommendations.

Let me give you examples of some of them and try to assess whether we've done any good.

In our principal unclassified cyber security report, the overarching finding was that cyber security could not be achieved by any set of static precautions, whether taken by the government or taken by industry. Static checklist approaches to cyber security were doomed to fail. Rather, a national approach to cyber security at all the levels I've described, has to be a set of processes that continuously couple information about an evolving threat to defensive reactions and responses.

And I would say that recommendation which we issued about the middle of our tenure in the last eight years certainly stands the test of time. I think we all think that that's true today. I think that the government organizations that I've described, particularly Department of Homeland Security, are coming around to that view, coming around to the view that you don't try to draw a line and say above this line is critical infrastructure and we're going to regulate critical infrastructure by giving them a checklist of mandated things they must do, and below this line good luck.

Instead what we want to do is say, and NIST as a government agency has been the most active in this, NIST have said let's bring in industry people at these different levels, some in critical infrastructure, some in simply the economy at large, and let's get the individual industries discussing what are the appropriate level of cyber security measures that they can take, and much more importantly as our overarching finding says, what is the process by which we will continue to evolve this framework so that as the threat evolves the accepted standards for any given industry also evolve.

When we issued or cyber security report, one of the things we did I know Craig and I remember this vividly, was go and visit the folks at the SEC, the Security Exchange Commission. Why the SEC? Because the SEC is almost the only federal agency that can ask, can require the whole economy or some very large part of it, that is to say all publicly held companies, to do things. And we said to the SEC, here's our cybersecurity report, it's advice to the President, they said to us, go away kids, we don't take advice from the president, we're an independent regulatory agency. I'm paraphrasing what they said of course. And we said, we only want to be helpful, and we think that this threat is moving so fast that you will be drawn into this space, that your mission of protecting a level playing field for investors is going to draw you into the cyber security space. And they said, well, okay, leave a copy of your report and maybe we'll think about it.

Over the next, I guess it's now been three to five years, the SEC and several other

government agencies have moved into this space, and have moved into it in a way I think we find reassuring. I think that maybe we weren't the right people to be advising the SEC, but the cascade of events is sufficiently compelling that cybersecurity is on the agenda in every boardroom of every publicly held company in America now, and with an approach that is by and large moving away from checklists and towards the kind of continuous improvement that you first saw.

>>ERIC LANDER: I realize our time has drawn short. I'm actually going to ask that Rosina give a five sentence summary of the high points of water. Jim Gates, it's the staff of life or something, Jim Gates can give a five sentence version, and then I want to make sure John has a chance to comment on climate and energy.

>>ROSINA BIERBAUM: I had quite a bit of opportunity at the last meeting to have you approve our recommendation. Let me give you a very quick update. The full report in all its glory was delivered on December 19th, kind of a Christmas present to the administration, but there had been a number of positive things that have happened. I mentioned that we thought about short-term as well as long-term and let me just say some of the short-term things that are happening. One, EPA released its Drinking Water Action plan, which is very synchronous with our recommendations. Two, Congress passed the Water Infrastructure Improvement for the Nation Act which allocates 200 million in low interest loans to upgrade infrastructure across the nation as well as 100 million to Flint. And some of our short-term recommendations are actually being implemented even as we speak or very soon. One was that we suggested EPA revisit the idea that if only fewer than 10 percent of your samples exceed 15 parts per billion, all was okay. Of course that means there can be some very high number, and as they are revising the Lead and Copper Act, they are taking this under advisement and we expect that will change.

Citizen Science was one of our recommendations, and a number of agencies through their coordinators are already coming up with new ideas for citizen, science, and water, and finally we discovered three multi-agency groups focused on water, and they have come together and are coordinating existing data and working through two existing portals to make it more accessible to the public. So we feel in only a few weeks we've already had some big successes.

>>ERIC LANDER: Fantastic. Jim Gates?

>>JAMES GATES: Thank you. And I will indeed be brief.

First of all, there were a sequence of four reports that PCAST did on STEM education, the first one being Prepare and Aspire, the next one, Engage to Excel we did a report on IT, and a final report on jobs and skills.

I think probably for me the high points that I would like the public to take away as well as our PCAST members is that the I'm sorry, the Every Student Succeeds Act which was passed in December of last year, was heavily impacted by our discussions of stem. There are parts of that report, particularly section 4107 where you will find there a ideas that were in our report have been passed. This represents I think something that's rather interesting in the past few

years. This is a bipartisan victory for PCAST recommendations which I find just extraordinary as an accomplishment.

The other thing I would tell you is I would point back to the involvement and feedback of teachers. One of the things that was passed in there was support for a concept that came from teachers themselves. This is the Stem Master Teacher Core, a state led effort, and this was called out to PCAST by the teachers who had been awarded the President's Award for Excellence in math and science teaching, so this is a closed loop where a group of citizens spoke to the government and impacted the law. I will just end by reminding some of you that perhaps in your childhood you too saw the Alphabet Rock on a bill going to Congress and becoming a real accomplishment. We did it, folks.

>>ERIC LANDER: Very good. John, we're going to give you the last word on a topic that is very important, and one that you've played such a central role in of energy and climate.

>>JOHN HOLDREN: So on energy and climate, PCAST certainly played a very substantial role in helping to shape this administration's response to those interlocking challenges.

The November 2010 PCAST report on Energy, Technology, and Innovation in the context of a comprehensive energy strategy led the Department of Energy to produce the first quadrennial technology , a year later in November 2011 and a second one appropriately four years after that in late 2015. The these have been the most comprehensive and in-depth looks ever at the array of energy supply and energy end use technologies, their status, the possibilities for accelerated innovation, what would be needed in the way of road maps to move the needle with respect to the availability of the more advanced technologies. The November 2010 report also recommend an interagency quadrennial energy review modeled in some respects after the quadrennial defense review. That has also now been put in training. The first install of the quadrennial energy review appeared last year. The second installment was rolled out this morning, focused on the electricity system from harvesting of raw energy sources to the end uses of electricity across our society and what needs to be done to improve the resilience, the reliability, the efficiency the economy of the electricity system going forward looking out to 2040. The letter report on near term actions on clean energy and climate change that PCAST produced for the President in early 2013 had a profound effect on everything on the thinking that went into the President's climate action plan that was released in late June of that year, and continues to be implemented in virtually all of its elements going forward. Of course, as they say, success has many parents while failure is an orphan. I would not want to suggest that PCAST input on this topic was the only input. There was a very large effort related to the climate action plan that included the Department of Energy, the Environmental Protection Agency, the Department of Interior, and NOAA and NASA and many others, but again I would argue if you go back and look at the PCAST reports on those topics and then look at what has emerged in this administration's policies, certainly PCAST played a very important catalytic and intellectual role in that development, and I would mention also even though we did at the beginning of this session, because it was one of our shorter reports, the influence of the report that Rosina and Maxine and Michael led on increased cooperation between the private sector and the government on preparedness and resilience against climate change. I think the record on that topic is extraordinary. Some other studies that we did that impinge on parts of it, I

would mention. The study of ecosystem services and how influence on ecosystem services and the valuation of those services needs to be part of government decision making, ecosystem services are of course at serious risk from climate change. That is also in a larger sense a part of PCAST contributions to the climate change agenda. In the interest of time I will stop there.

>>ERIC LANDER: Well done.

>>JOHN HOLDREN: And we will moving to our closing, closing remarks.

Closing Remarks

>>ERIC LANDER: All right. Well, well done.

I think it's clear just from the conversation we've had that a lot went on. We didn't have time to rehearse, and we didn't intend to rehearse every single thing that had come out. As John mentioned there were 39 reports, 440 recommendations. We didn't want to recite them, all but I think just telling some of the stories of what went on over the last eight years underscore one very important message. America has been the single place in the world and in history that has best understood this magical interaction between public goods and private goods, and this is informed so much of what PCAST has done that we need an incredibly vibrant private sector in this country creating innovative businesses to develop the science and technology and innovation that has given rise to so much of our GDP growth, our wealth, our prosperity over the course of the last century. We've done that better than any other country or any other time in history, not just though because we have a great private sector. Because almost all that rests on public goods that is to say things that a private enterprise can't themselves invest in and reap the full benefit of. And therefore would necessarily under-invest in. These include education. Companies aren't going to invest in basic education of their workers because they can't reap their return. They include fundamental research where you can't say where it's going to go, and in any case the investor couldn't possibly reap all of the benefits that could come out of it. They include creating the kinds of common grounds such as this advanced manufacturing efforts or efforts in cities or spectrum, all of which are going to generate huge amounts of economic activity, and the government will make its investments back in the form of the prosperity and health of its citizens, and the taxes they pay that they could reinvest in creating that ecosystem. It's a poorly understood thing. We don't do a good enough job of explaining it, that the partnership between public and private, and the great investment in this country, several percent of our GDP in research and development going on in both public and private, and the care and tending of that ecosystem is what undergirds our prosperity. I'm very proud to have seen so many different reports that have had at their core that fundamental understanding. It's an important one to pass on. Each administration thinks about how it's going to interact with science and technology. I think this has been a remarkably broad and bipartisan effort to see this power of science and technology and how it helps, and how one has to steward to get things done and then to unlock just the creativity of the market, of the small start-up that's going to make the hearing aids or things like that. So it's been a great honor and great privilege to serve the President, to serve the nation, to work with all of

you on PCAST and on these reports and I think the reports will have legs far beyond what occurs in these eight years, the next eight years and the next decades ahead. I think these, they're ideas that will have long-term impact and I want to thank everybody for it and I will turn as usual for the last word to my co-chair John Holdren.

>>JOHN HOLDREN: Well, practical everything has been said although not everything has been said by everybody so I will make just a few further remarks. First, I think that the degree of success and influence that this PCAST has had which has been extraordinary, was enabled above all by the characteristics of our boss, by the characteristics of President Obama who was an exceptionally astute and willing enabler and listener and embracer of findings and recommendations about the ways science, technology, and innovation could improve our economy, could improve public health, could help protect the environment, could produce a cleaner energy future, could contribute to national and homeland security. His awareness, and he brought that awareness to office. I sometimes inappropriately get credit for having somehow turned him into a geek, a techno nerd. He was one when he came. He had a deep understanding when he arrived at the presidency of how and why science, technology, and innovation matter. And that made our job as PCAST, both an enormous pleasure and an effective influence on public policy because our boss was so prepared to take on board insights and ideas from the wider science, technology, and innovation community. I have said publicly on previous occasion, I'll say again, I think President Obama is the most science savvy president since Thomas Jefferson, with the qualifier that there's a lot more science to be savvy about today than when Thomas Jefferson was the president. That has been I think to the great advantage of our nation that we had a leader who had figured this out and who empowered all of us in PCAST, all of us in OSTP, all of the scientists, technologies, mathematician, innovators across the Federal Government. As I mentioned before was prepared to draw on the insights of the full science, technology, and innovation community. We have had a great run. I have had a great run in my position as his science advisors and co-chair of PCAST. I have had in this group the most amazing set of partners that any presidential science advisor could want, led by the extraordinary Eric Lander who devoted a fraction of his energies to this operation that is to me unimaginable, given the demands of his day job but somehow he did it. And I think all of us in PCAST recognize that Eric's fingerprints are in one way or another on virtually one way or another of the 39 studies that we did and I am enormously grateful as I know the president is. But again one must mention the PCAST secretariat represented here now by Ashley Predith and Jennifer Michael and their predecessors who deserve great credit as well. All of OSTP who worked seamlessly with PCAST in its efforts, and I want to mention as well Trinh Lieu and Laura Sosa who have been doing the logistics work and meeting planning.

[APPLAUSE] They have spent a lot of early mornings, a lot of late nights, a lot of last minute requests. Always with the smiles that you're seeing now. We are very grateful to them as well, and finally of course to the extremely attentive and resilient representatives of the wider community who have attended our meeting and watched them online we are grateful for your interest as well, and with that we adjourn the last meeting of President Obama's PCAST. Thank you all.

[APPLAUSE]