PCAST Meeting - May 9, 2014

Welcome & Antimicrobial Resistance

>> John Holdren: Well, good morning everybody, welcome to the members of PCAST, to the staff, members of OSTP and STPI and welcome to the members of the wider science and technology and science and technology-interested community who are attending in person, and of course welcome to those who are watching on the web. We have a heavy schedule today, there's a lot going on in the domain of science and technology policy, PCAST is in the thick of much of it, as will become apparent in the course of the morning's discussions. So without further ado I'm going to turn it over to my Co-Chair, Dr. Eric Lander. Eric?

>> Eric Lander: Well, welcome to everybody here. Thank you to the members of PCAST for all the hard work you've been doing on a lot of studies, one of which is going to come for approval to PCAST today, on Systems Engineering and Healthcare. And welcome to everybody who is in the room with us and to everyone who is watching the PCAST meeting on the web either in real time or sometime in the near or distant future. So we've got a number of topics. The first will be relatively brief, which is just a brief update on the Antimicrobial Resistance Report that's being worked on by a working group and a subgroup of PCAST. We spoke at length about it last time and I'm not going to review all of that, other than to remind everyone that this is a very serious and growing problem, with now 15 different bacteria that are serious -- urgent or serious threats as defined by the CDC. And this problem has been getting just tremendously worse because of a combination of factors. Antibiotics are increasingly becoming less and less useful because of resistance being developed, due to a number of factors, and we are not producing the new antibiotics that we would need, or new alternatives to antibiotics that we would need, in order to really have that equation go in our favor to continue to stay ahead of evolution. We're never going to beat bacteria, they're good at what they do, they evolve in response to our antibiotics, but we can stay ahead of them if we can combine good stewardship in health care and agriculture and elsewhere, with real innovation. Industrial innovation to produce new therapeutics. The thing I wanted to emphasize, I'm not sure I emphasized enough last time, is the third leg of the stool, which is surveillance. That anything as complex and serious as understanding how bacteria are changing in response to our antibiotic usage, we can't succeed without extraordinary information. We can't answer today the most basic questions. If 10 patients in a hospital all are infected or colonized with the same type of antibiotic-resistant bacteria, carbapenem resistant enterococcus, let's say, we can't answer the simple question, are those 10 independent cases that entered the hospital from different places? Or did they come from one patient spreading to 9 others? That has very different consequences for what the hospital's practice should be. If the hospital could know that it was spreading that bacterium, it should do something very different than if these were 10 cases that were coming and you could trace them back to -- I don't know, let's pick New York or something like that. We know the answer to those questions, usually. We can't answer the question if you think you've cleared an infection in a patient, and then three months later the patient develops an infection again with that resistant bug, was that a new, independent infection or did you really fail to clear the infection? We can't answer that question today in most settings. We can't answer

the question: do antibiotic resistant bacteria that we encounter in health care setting originate from overuse of that health care setting? Did they originate, say, due to agricultural use? Did they enter this country from some other country? We have no idea. It is fighting a war blind. The lack of situational awareness of the problem is really serious. But happily, here, technology has given us the tools to know these questions. The very crude characterization, here's a bacteria that grows up and it's resistant, doesn't allow us to tell whether it's the same bacteria, to tell its provenance, where it came from. But complete DNA sequence does. When organisms continue to divide and grow, random DNA changes occur in their genomes. And those random DNA changes are telltale fingerprints; they're little breadcrumbs of the provenance of the bacteria. And you can tell whether or not two patients have gotten the infection from exactly the same source because the genome sequences of those bacteria are almost identical. And if they came from different sources, they differ. We can suddenly enter a world of serious data here in antibiotic resistance and we need to. It used to be inconceivable to think about collecting data of that scale, but federal investments and things like the human genome project and related projects have driven down the cost of DNA sequencing from, well, $3 billion to sequence one human genome to by next year #1,000 to sequence a human genome. And since a bacterial genome is a thousand times smaller than a human, you might say in principle that's a buck a sample. Now, there is sample preparation costs and other things, so it won't really be a buck a sample, but it certainly should be under 10 bucks a sample. And with appropriate sample preparation and other techniques it may get under a buck a sample. And if you got to that point you could do rather comprehensive surveillance in health care settings. You could also do comprehensive surveillance or at least extensive surveillance in agricultural settings and environmental settings, in international settings in collaboration with our international partners. So it's becoming clearer to us as we discuss this that information is going to be an important backbone here, a backbone of overall policy, and a backbone of actions to be taken by individual players, individual hospitals for example, within the health care system. So I wanted to add that as a bit of a coda to our discussion. Last time, it's clear that we can do this technologically but we need an infrastructure. We've got to have some kind of network of laboratories that are able to perform these tests efficiently. We need to have reference sequences in order to do it. A couple thousand reference sequences from each of the major bacteria publicly available, CDC has those collections. These are the sorts of issues that are continuing to be discussed by the group and are being clarified, and I thought that it might be useful just to add that to the discussion we had last time. I'm not planning to really say much more because I think the questions and the thinking of the group are still largely around the topics we discussed before and that's all on the web, but I wanted to first turn to my cochair on this Chris Chyba to see if he had anything to add, then ask members of PCAST if they have anything further to add.

>> Christopher Chyba: I'd just say that I think, Eric, your point that resistance is an intrinsic part of what microbes do is very important. Over a decade ago. Joshua Letterberg a emphasized that point and argued that metaphors of war, with respect to the war against microbes or the war against microbial resistance are misplaced because of that. Instead, we need to think of this in terms of an ongoing relationship. And as a relationship, it's something we need to manage, not that we'll ever have total victory. And it's a relationship we need to manage for as far as we can see into the future. The dilemma is that right now is we're not managing it very well. As you've already emphasized even with respect to surveillance, even the most basic surveillance for antimicrobial resistance at the level of state public health, is insufficient. Then

building on that, there's -- looking forward, there's much more sophisticated kind of surveillance that we should think about putting into place. But not only are we not -- do we not have a situational awareness that you mentioned but we're not doing a good job with respect to stewardship and we're not doing a good enough job with respect to antibiotic development. So if we're going to manage this relationship for as far as the eye can see this problem is never going to go away. We need to put into place the foundation now to be doing well, to be managing well with respect to all those components.

>> Eric Lander: And the problem will never go away, as long as we're on the front side of that problem, where we have more working antibiotics and the rate at which things are going away is lower, we're winning temporarily. Victory here is a long series of temporary wins across these, and we can shift those rates. Other questions from PCAST? Bill Press.

>> William Press: So as microbes develop resistance to antibiotics we move to other antibiotics. But there are only a fairly small number of families of antibiotics, and so I wonder, is there a kind of a longer term even bigger danger that even with development of antibiotics, if they're all in the same family, we'll run out of families because of cross- resistance.

>> Eric Lander: Well, that's exactly right. Many drugs have cillin in their name, penicillin, amoxycillin, and other cillins are closely related and when a bug becomes resistant to one it will maybe become resistant to others. So we have many fewer families, of antibiotics, classes of antibiotics they call them, than specific molecules. I think there are really two things to say here. One, the development of antibiotics has focused often on broad spectrum antibiotics, which means you need to have a molecule that's going to work in many, different species of bacteria. And there may be only a limited number of such targets that are really good for that. If you're interested in developing a more narrow spectrum antibiotics that might affect a particular type of bacteria, you might have a lot more choices of where will to shoot at. So one way to solve the problem might be to have a larger collection of targeted, more narrow spectrum antibiotics. Another would be a technology that is entirely different. Technologies that didn't involve the traditional small molecule chemistry but might exploit the immune system in certain ways or might give you immunity in other ways. And I think we need to examine both the traditional chemistry, but in new and much more efficient ways, and maybe more targeted ways. And then. You know. Completely different approaches. Obviously, vaccines are very effective in some cases. If you could have a vaccine against a particular type of bacteria, bacterial infection, it might not care whether that bacterial infection was sensitive or drug resistant, the immune system wasn't using a drug against it. We need, it's pretty clear, a broader research attack on this. There's a real role for fundamental research here that brings creativity to the whole question. And then of course there's a real role for industrial development to actually turn any of these ideas into effective therapies. Jim Gates.

>> James Gates: Thank you, Eric. In fact, you anticipated my question talking about long term technologies. I was wondering, now this is a bit pie in the sky, but do you see a role where, for example, information theorists and computer scientists might think about modeling some of these pathogens in such a way that we get a deeper insight into basically exploiting their failure modes?

>> Eric Lander: Well, yes, if we're ever going to model anything, any life really well, it wouldn't be unreasonable to think we'd start with bacteria which are certainly much simpler in their structures. They typically have only a few thousand genes. Now, even small things with a few thousand genes turn out to be insidiously difficult to model well and they're designed to be especially tricky in interacting with the human body. But there are people who think about systems biology approaches where you can ask about how all the parts interact and what might be a particularly effective place to target a bacterium. Now, in fairness there is a debate amongst the people working on this as to whether simply random screening of molecules to look for things that kill bacteria may be as effective as knowledge-based systems biology approach. And I think we need the portfolio because we don't know which is better, whether knowledge or randomness will be better. I suspect we'll need both of those things at our disposal. A lot of -- this is why we really need to revive interest in academia and in the industry on the wide variety of different approaches you could use to create new antibiotics and nontraditional approaches. Dan Schrag?

>> Daniel Schrag: Thanks, Eric. I guess this follows up on the statement that both approaches are necessary. It seems to me if you look at the community of scientists and biologists and chemists working in this space, there are many more focused on the synthetic approach, which is how we take knowledge together and create molecules that might be effective as opposed to the natural products approach, going out into the environment in unusual soils and situations, and looking at natural antimicrobial elements, that plants, that other microbes produce, that might -- we might be able to harness and use even though it's, of course, the latter that's the foundation for our antibiotics.

>> Eric Lander: That is to say we didn't invent penicillin, we discovered that fungi had invented penicillin.

>> Daniel Schrag: Exactly. The question is, is a there reallocation necessary in terms of the effort. My impression is there's far fewer scientists today doing natural products chemistry than the other way around.

>> Eric Lander: There's an interesting revival of interest here through new approaches, including through these genomic approaches. Natural products are a weird complicated molecules that have a lot of stuff going on in them and they take a lot of work to make any one of them. But as you say, organisms out in the environment that have been producing these things for a long time, and the synthetic pathways by which they make those molecules are encoded in their genomes. So one approach that's going on is people are sequencing lots of organisms that are out in the environment, and by bio-informatic analysis, recognizing the genes that encode the proteins that run the biosynthetic pathways, and then using those DNA sequences and taking them into a given friendly organism and expressing them. And say we can own -- I don't mean in the IP sense, we can now possess in the scientific sense, all of the enzymes that are used to make these cool modifications and string them together in new ways. There actually is a lot of interest in doing things like that. So whereas the traditional natural products approaches would involve, you know, sailing the south seas and going into the tropical jungles and coming back and screening for molecules, that's still a good thing, but some of it may be able to go much more deeply by finding molecules produced by organisms that we can't even culture in the laboratory but whose genomes we can sequence. So I think there too there's a need for enrichment of these approaches. Ed Penhoet?

>> Ed Penhoet: Well, speaking of wandering into the scenes, et cetera, there's likely to be an important secondary use of the technology that's developed for better surveillance. Which is in the environment.

>> Eric Lander: Yes.

>> Ed Penhoet: Because many people believe that if you want to study environmental change in somewhat something approaching realtime, you need populations of organisms that respond to change, and quickly, and bacteria are the best examples of that. So many people believe that monitoring bacterial populations is a good way to assess environmental change in somewhat realtime, because of the life cycle of bacteria, which is on minutes to hours, as opposed to elephants, which is in hundreds of years. So I think that the technology that you're talking about to broadly assess and to survey these bacterial populations could in fact have secondary uses in the environmental study.

>> Eric Lander: What a great point. I think we're talking about a world where we move toward real molecular level surveillance, genomic level surveillance will probably have a lot of benefits in addition to the antibiotic resistance. You raised one, in monitoring the environment. You can think of another which is in human nutrition, many of the nutrition studies look at what you eat, and maybe they might look at your own genes. But we know that the bacteria that colonize your own gut probably play an important role with regard to nutrition and disease. And if it became routine to survey what people called the microbe biome, the collection of microbes that could live in your own gut, one would be able to do correlational studies there that might help bring a whole renaissance to nutritional studies there. So I think it's really a question of moving to that world routinely where we have capabilities to look. My guess is 10, 15 years from now we'll look back and say how did we think we could do any of these problems without actually being able to collect, you know, real discriminating data that could tell the difference between hypotheses, you know, otherwise we're just reduced to very weak correlations and trying to draw inferences. When now -- here's a good analogy. It's a little bit like DNA fingerprinting. When DNA fingerprinting came along it was possible to definitively say whether this sample, in a case, a blood sample, sperm sample, came from a particular individual with near certainty, if the technology was done well. And that's taught us all sorts of things. It's taught us, you know, how to identify the correct suspect, and how to make sure we don't include the incorrect person there. And it's taught us that our criminal justice system makes mistakes. We can definitively say it makes mistakes, even putting people on death row. Information, molecular information about genotype is powerful, and I bet we're only scratching the surface of the ways that we'll be able to use that in various different applications. I don't see any other questions. What a fun topic. I thought this was a very short update, but such great questions here on PCAST. I suspect there are questions out there on the web, too, and people are welcome to, you know, write in with suggestions to PCAST there because it's a topic of great interest to us.

Advanced Manufacturing Partnership

Eric Lander: Shirley, are you going to lead us through our next topic, which is the Advanced Manufacturing Partnership 2.0. Upgraded from our previous Advanced Manufacturing Partnership, 1.0.

>> Shirley Jackson: Thank you. I'm here just to provide a bit of an update on the Advanced Manufacturing Partnership 2.0, and I have to tell you that this update build-out from very excellent work by Jason Miller who is Deputy Director of the National Economic Council and Special Assistant to the President for Manufacturing Policy, and then JJ Raynor, who is a Policy Advisor at the NEC, and she works very closely with the -- as we call it, the AMP 2.0, where her focus is on business competitiveness and the manufacturing portfolios. So let me just give you a bit of context, you know, the Advanced Manufacturing Partnership 2.0 builds out from the recommendations that came from what was the original AMP or Advanced Manufacturing Partnership made up of corporate CEOs, university presidents, and labor leaders looking at issues of manufacturing and U.S. competitiveness. And the creation of the Advanced Manufacturing Partnership was an outcome of a PCAST report on advanced manufacturing that we issued in 2011. And so the work of AMP 2.0 has had a focus in two major areas: in innovation, and questions of workforce, manufacturing workforce. And that work has gone on through the creation of five working teams whose work is overseen by an operating committee that then supports, and reports to the overall steering committee. PCAST has a role in providing oversight and ultimately approving recommendations that will come from the steering committee. So these working teams that focused in these five areas in transformative manufacturing technologies, ones that are broadly undergirding and/or are important for certain industries. They've been looking at demand-driven workforce development. A particular initiative proposed by the President in his 2013 State of the Union speech on creating a national network for manufacturing innovation, which I'll come back to. Looking at scale up policies as they affect new high tech startups and as well as small and medium sized enterprises and the image of manufacturing, you might find that an interesting one. So if you look at those five areas, they naturally group into those that focus on innovation with the transformative manufacturing technologies, the NNMIs, the centers, the institutes created under that initiative naturally are innovation focused as well as scale up. The workforce focus has been on demand-driven workforce skills and the image of manufacturing. But I will say to you that some of the key challenges that the working group and the AMP 2.0 generally has focused on is how to articulate and embed recommendations for actions. And with public-private collaboration, how do things get done that don't always take huge government funding. In the manufacturing technology area, there's been a focus on digital manufacturing, advanced sensing, control and platforms for manufacturing, and advanced materials manufacturing with a particular focus in areas that relate to structural composites and more recently on biomanufacturing because there's some interesting things about that, and ultimately it may even relate to the earlier discussions. But as well, the group has been looking at what they considered to be undergirding requirements such as database standards, reliability standards, and manufacturing, and so on. Vis-a-vis workforce development, while there's been a particular focus on demand-driven meaning what does industry need, what do businesses need, the group has been looking to try to create and think about workforce development as an ecosystem from high school through college. What kinds of enablers in terms of background and training are important that can go across industries, and across disciplines. There's been a special focus on so-called stackable credentials. Credentials that come from different experiences that people have, as well as specific training. And looking at particularly at what role apprenticeships might play. And there is there's been a special focus on veterans looking at the kinds of skills veterans bring from their military experience, how they can be certified, how can those skills be repurposed, and if there's any additional retraining that may need to occur. And there's a strong partnership with the Veterans Administration in order to do that. Now, I have

mentioned the -- this national network for manufacturing innovation, and the idea was to create institutes around the country for manufacturing innovation with a particular technology focus that would leverage the industry, the research, and institutional strength of a given region, but ultimately to have these institutes be part of a national network. And the plan is to have ultimately 15 such regional institutes. Three, plus a pilot so far, have been formed, with a $1 billion initial investment. Now, what's interesting about these is that the actual specific funding comes from different agencies and departments which create the opportunity to cover a broad range of technologies. But it does raise some governance issues that I'll mention in a second. So there was an original pilot, such institute called America Makes, that had a specific focus on additive manufacturing. And it was set up in Ohio, emanating from Youngstown. Since then there's been an institute created in Illinois, linked to the University of Illinois, on digital manufacturing and design innovation. One on lightweight and modern metals that emanates from Michigan, you might expect why. And then one on mixed generation power electronics centered at North Carolina State University, but involving a range of companies and industries. While all of this has been going on, there's been an interagency process, in fact there's an interagency advanced manufacturing national program office that's supported out of the Department of Commerce that has done extensive outreach to solicit input from manufacturers, universities, and community colleges around the country, and local and regional governmental bodies on how to bridge gaps and address market failures relative to advanced manufacturing. Now, advanced manufacturing, as you may recall, has two meanings, as was articulated in our original report. One, of course, had to do with the manufacturing that emanates from technological breakthroughs and innovations, be they be in nano, bio, and other arenas. But the other had to do with applying advanced techniques, computational techniques, sensing et cetera, to improve and make more competitive existing manufactures, and even to improve products. So the focus that the larger group has had, having to do with the NNMI institutes, has been on, interestingly enough, intellectual property, in terms of its ownership. Questions of data rights, and those are subtle differences that will emerge more as things become even more data-centric. Questions of publications and revenue models. And overall, how to harmonize the governance structure. Because the advantage of having different agencies support these, again, allows the coverage of different technologies, but then it raises questions about how one makes sure there are some consistent policies and questions of membership, while at the same time looking at differentiation by industry. A big problem, particularly as it relates to startups has to do with scale-up. And as has been identified, and even was identified in PCAST's original report, this whole question about venture funding has always been there, particularly to help enterprises cross the so-called valley of death. But one that has emerged more recently has to do with corporate strategic funding, and how does one -- you know, how do we provide incentives to get the kind of investments that companies need, whether it's through tax credit or some other means. There have been discussions and some recommendations vis-a-vis public-private investment funds following models that exist across the government and other arenas. And then of course shared infrastructure, particularly for startup companies. But even existing manufacturers, particularly the smaller ones, have issues because there are banking gaps inhibit their ability to innovate and to move and to scale up. So a big issue for them is connection to various financing sources. But a particular challenge that's been identified are broad technologies that might benefit industry as a whole, or even a particular industry as a whole, but not a specific company. And that's where the classic kind of market failure occurs. And so people are discussing various strategies for that. Now, you know, there's this image of manufacturing, because of so many

changes, that people have developed, that people refer to as the four Ds. That manufacturing is dark, dirty, dangerous, and declining. And so there's a campaign afoot to change that, to have people understand that there's innovation in manufacturing, that it can be, you know, sexy, et cetera and therefore to consider manufacturing as a career. Well, one, again, kind of underlying kind of issue is if there's a demand-driven focus relative to workforce skills, how does that play against the transferability of those skills so people may feel they're not just locked into a given enterprise or type of industry. There's a plan to have a national media campaign to work with the professional organizations with academic institutions, and even various STEM initiatives to increase awareness of the importance of manufacturing and the opportunities today. And there's going to be a national manufacturing day, and there is what is called the maker movement. And people, the intent is to take advantage of those movements. So going forward, the work will continue in these areas, but over the early summer the intent is to gather and refine all of these recommendations, to have them reviewed by the overall AMP 2.0 steering committee, and then once those -- that's done, to actually then bring them to PCAST for review, and the issuance of a formal report. And so with that, I'm happy to entertain any suggestions, cries of outrage, to steal a word from our leader, John Holdren, or questions.

>> John Holdren: All right, I see Barbara Schaal and Maxine Savitz. And Barbara.

>> Barbara Schaal: One of the aspects of this that you talked about was workforce, workforce training and development for advanced manufacturing, and clearly that's a challenge, because as in many different domains there's very rapid advances. And PCAST, in a previous report it talked about online education, IT education, particularly in MOOCS. But clearly there's also some discussion about the workforce training aspects of online education. There's many opportunities. And I think there are many different groups, including PCAST, which is exploring that. So I wondered if your group had begun to explore that realm as well, and how that affects the training of the work force.

>> Shirley Jackson: Yes, but I would say that the efforts are a little more nascent. So I think we have an opportunity to link the EdIT efforts, the educational information technology efforts, that focused on MOOCS and SPOCS and that kind of thing. Craig Mundie has been a big proponent relative to the role of educational IT in re-skilling and training. And Craig, you might want to make some comments in that regard.

>> Craig Mundie: Thanks, Shirley. I think as we've looked at the role of technology and education going forward, and also tried to prognosticate a little bit about what the manufacturing and sort of technology assisted workplace of the future is going to look like, we see the trend that says many of the classical middle skill jobs are going to need to be taught in a different way and updated much more frequently. And so that's where we're investigating the intersection now between the technologies that are emerging out of higher education, but for online and high-scale capability, and their potential application in this domain. You know, I think there's promise there, and we hope to produce a report in that area.

>> Shirley Jackson: If you look at the sort of balance of educational IT for updating, training, reskilling, et cetera, and you look at apprenticeships on the other hand, you end up with what has been perhaps a model, and the AMP 2.0 is kind of compiling a database of best practices and approaches to -- that can be

deployed to kind of keep that balance so that people on the one hand have relevant training and education, and it's relevant to the companies and what they need, but that there's a baseline background that gives them an ability to move. But then to have the online education provides the specific pathway for that kind of movement. Jim, I don't know if you wanted to say --

>> James Gates: Thank you, Shirley. As Craig mentioned, there are some of us who are engaged right now in the study to try to figure out how to take -- how to put in place a national system that would respond in much the way for example that the weather service is able to make predictions, and we all then carry our umbrellas. You might imagine a system that can project a bit out into the future about the job opportunities that are there. That could inform educational institutions as well as organizations that have to do retraining and the re-skilling. So we have a holistic approach that we're trying to bring to the table here. And as Craig said, we look forward to presenting the results of our study at some point in the not too distant future.

>> Shirley Jackson: And since I've had the privilege of working with the two of you, rest assured I'm injecting this into AMP 2.0.

>> Maxine Savitz: I've got a different line on the manufacturing, one of the Ds is decline here, but with all the recent discoveries and use of shale oil and gas, industry is starting to come back here again, particularly the energy intensive ones, like chemicals, and the composite one relates to that. So as part of looking at the manufacturing, are you also going to in that area be considering -- and I know the Department of Energy is part of it -- new novel energy efficient technologies that will also address, you know, that aspect of. So we're getting more product per BTU of energy, and so we can accomplish two things. More manufacturing, more energy efficiency, which will lead to more facilities even being built here.

>> Shirley Jackson: Right, I think as you know there's an RFI and RFP type process that works for these NNMI institutes, and they are a foci on energy-related innovations. And -- but what you raise is a very important one because it's not just having greater availability of cheaper energy, but in fact take energy intensity out of manufacturing. And that in fact, ironically, I think relates to things like advanced sensing and better control processes, computationally driven manufacturing processes and even design of materials, as you've pointed out.

>> Barbara Schaal: (inaudible)

>> Shirley Jackson: That's right.

>> Chad Mirkin: So a wonderful presentation. In looking back on this I think one of the most innovative things that came out of this were the NNMIs, and one of the most substantive impactful outputs of the whole first entre into this area. You kind of articulated some of the opportunities, and I think the exciting things going on with those structures. There are also some challenges. The challenges laid out were dealt with, intellectual property, and how to deal with this unique collaboration between industry and academia. Are those challenges being met with the first centers. If they're not, what is the path going forward. And then the second challenge is area, and it seems to me it's really critical, and by area there

are two meanings to that. One is where the place these, and also what topical areas to pick. Are we making the right bets, do we have the right strategies to go out with the rollout of the next 10 or 11.

>> Shirley Jackson: You know, I mentioned the transformative manufacturing technologies that AMP 2.0 has been focused on. Well, this is a subset of a larger set of technology that the original AMP discussed. So in fact the steering committee has given guidance to the working committee and the groups that we need to have a more linkage between the NNMIs and these identified technology areas. And then the question about geographically where they may be, that's a set of -- you know, issues that are addressed as a part of evaluating the quality and so on of the various proposals that are promulgated. And then I would say yes, there is work on intellectual property that is progressing because what has happened is the national program office extracts from the various institutes and the various regions, where people see the issues and problems. And so there's beginning to be a coalescence, consensus, being developed about how to deal with issues of intellectual property and so on, and that will be part of the ultimate report that comes out.

>> Eric Lander: Great, I don't see any other flags up. Are there any other PCAST members who wish to comment or question? If not, I know we're looking forward to hearing more about the Advanced Manufacturing Partnership 2.0. Perhaps even at our next meeting over the summer I think there's lots of activity there and we're looking forward to getting a report.

Systems Engineering and Healthcare

Eric Lander: We'll turn now to the third topic on our agenda. This is a topic that the council has been engaged in for awhile and we've had some interim updates on having to do with systems engineering and health care. And I believe today we actually have a report coming to PCAST for an actual approval with a vote. And so I'm going to turn it over to my colleague, Chris Cassel, who will lead us through this report on Better Health Care and Lower Costs: Accelerating Improvement Through Systems Engineering. Chris, all yours.

>> Christine Cassel: Thank you, Eric. Yes indeed, this report is completed and ready for PCAST to consider for approval today. It has been the work of a number of people from the broad health care world and from engineering disciplines, coming together to talk about actually very practical and proven ways that we can actually achieve these goals of better health and better health care and lower cost. And I'll at the end acknowledge and show you the working group that produced -- helped us produce this report. But I also want to particularly thank my Co-Chairs Maxine Savitz and Ed Penhoet, and so I will present the recommendations of the report and the context for it, but also welcome their thoughts afterwards. So here's the context. We have a health care system that is nothing if not complex. It's both public and private, there are multiple different sources of payment, businesses are involved as purchasers of health care, we have state-based programs in multiple states and different communities. And we have a large federal program, as well. So it, by definition, is a complex system with lots of different variables. We have made enormous progress in the last few years, and particularly this year, with the success in more than 8 million Americans signing up in the federal health insurance market places, but also many millions more

in the other avenues that people have to access health care coverage. So this is very good news, we're getting to a place where almost everyone will have access through health insurance to the health care system. But it also needs to be affordable. I will remind PCAST that the Affordable Care Act the first word is affordable, and that that's essential to be affordable not only to the nation going forward, as we look at the rising costs, but also, and probably even more importantly, to families, and people, consumers, who are purchasing health insurance and who also have lots of expenses out-of-pocket. So that's the context. And there's also some very real challenges. In spite of the progress that we've made, there still are gaps in quality and safety and identified, clearly identified waste in the health care system. Now, I want to make clear that advances have been made, especially in recent years, in reducing errors in health care and improving quality, but we still have 20 to 30 percent of hospitalized patients who experience some kind of medical error, often minor, but tragically sometimes not so minor. And at least half of these are preventable through rigorous approaches in reliability science that come from systems engineering. We also have gaps in quality in many places, errors of omission because people go to multiple doctors, multiple hospitals, have different information systems. We sometimes miss a diagnosis because we didn't have all the information at our fingertips or a patient gets lost to follow-up. And now that we can measure outcomes of care better and better, we're finding that the outcomes are not as reliably good as possible. And that ought to be achievable with the pieces that have been put in place with health care reform. Also, there's waste. So this is in some ways good news, because reducing expenditures does not mean reducing anything that's necessary or important or personalized in care of patients. Quite to the contrary, it means identifying waste and finding ways to make the system of care more efficient. And I would add more centered around the patient, which is the next bullet, that in many systems designs you start with the consumer, the customer, the person who is at the center of whatever the enterprise is. But health care has kind of grown up over the years so that we make our plans around what -- how does the hospital work, what's the doctor's schedule, how do the different specialists like to work according to their traditional ways that they do things, rather than the more creatively destructive approach that comes from many systems engineering approaches, where you start with what the patient and family need, and then you build a system that works around them. And you can do that especially well now because of advances in information science. We also have -- and this is leading to the first and our major recommendation -- a payment system structure that does not reward efficiency. As a matter of fact, much of our health care system is built around a fee for service model where more is better, we pay for volume rather than for value, and people don't have any incentive to get more efficient. And quite the contrary, are actually creating models where the inefficiency may be rewarded. So that's not a surprise to anybody in health care, and we're well on our way to moving in a direction that will solve that problem. And systems engineering is the tool that doctors and hospitals and health systems can adopt and use so that switching to these new approaches of value based purchasing actually can be done more -- less painfully and more effectively. So, what is systems engineering? Just a little bit about that, it's kind of a jargony term. The working group struggled with trying to find some more popular language to describe this, and we have been unsuccessful of that, but we welcome people's additional suggestions because it does sound kind of wonky but it is actually a discipline of quality improvement science that is used throughout all kinds of industries, throughout the kinds of industries actually Shirley was talking about in her report where you start with a complex system, you identify the goal that you want to achieve in that complex system, and then you use complexity science to identify ways to get to the goal and to reduce waste towards that goal.

It's a suite of tools, some of you have heard of Lean the Toyota Lean system or Six Sigma, and some of those approaches which has been used very successfully in manufacturing, in aviation, which has drastically reduced errors in aviation through these same methods. These tools, I want to point out that this is not a brand new idea. These ideas have been around for actually a couple of decades, championed by early innovators, but more recently, really accelerated with some of the programs within the Innovation Center within CMS, that is leading some of the reengineering processes that are in the Affordable Care Act. But nonetheless, those successes have not spread fast enough, and have not spread widely enough. So here is four examples. The circle you see in this slide is sort of centered around improving care for patients and families, and talks about assessing what worked, defining the problem, modeling the system, analyzing the information, in realtime, and implementing constant iterative improvements as you identify what's needed. So as you can imagine you're going to need constant input from patients and families, but also from the workforce in health care that's going to be highly dependent on being able to access reliable data and make sense of it and act on it. So here's, four examples from very different parts of the country that have done this. Denver Health, a remarkable safety net health care system in Denver that takes care of a large number of vulnerable populations, actually redesigned their operations beginning in 2006 and have saved a total of $200 million. But what's probably even more important is Denver Health has ranked at the top of every quality ranking, and patient safety ranking, in the nation over that period of time. Virginia Mason is a health care system in Seattle that similarly adopted the Lean methodology to try to reduce waste in their health care system. They have demonstrated the lowest rates of hospital-acquired infections and falls, and their medical malpractice liability has been reduced by almost 40 percent. So that's another important aspect of affordability. Kaiser Permanente, which is a big system in 13 states and about 9 million members, has had many successes using systems engineering approaches, but more -- most recently, they've identified -- been able to identify sepsis, which is a potentially lethal disease related to infections, and related to the kind of resistant infections, Eric, that you were talking about earlier, and actually cut mortality rates by half, by 50 percent, within the last two years. And then finally, the Vermont Blueprint for Health which is based on an outpatient model of patient centered medical homes interacting with community health teams. And this is a really important part that not everything that makes health care more efficient happens in the hospital or in the doctor's office. Much of it can happen and does happen at the community level, and that's also part of what we learned in the committee's work. So what are the barriers to adopting these systems which have been demonstrated to work so well. I've mentioned the misaligned payment incentive structure, that we still predominantly pay for procedures and for volume of things that you do, rather than for the outcome that is demonstrated for the patient. We also have had limited availability of the right kind of data. And the ability to turn that data into meaningful information at the site of care when the doctors and nurses and patients need it, which we refer to as analytics. Many physicians and nurses and even hospital administrators are not really trained in systems engineering the way people who come from engineering backgrounds are. And so some of them have learned these skills and adapted it to their practices. Particularly in much of the country, physicians still are in small practices, they're not in big systems, they tend not to think of themselves as a system. They think of themselves as I'm a doctor, I have an office, I have patients, and not looking at who is the population of patients I have to care for, reaching out and identifying the patient who doesn't come through your door who might need a flu shot or who might need to have some kind of checkup that could even be done remotely. So that's just a different way of thinking

about your practice as a system. Also, as part of that leadership and culture, that increasingly we need more people in health care who understand this kind of science, who can speak the language of medicine and health care, but who are also leaders in showing how this can be done and how the positive effects require a change in culture. And that relates to workforce competencies that, and when we think about the training of physicians, nurses and others, there's a lot that could easily be applied to help create a whole new cadre generation of medical professionals and providers who understand this kind of science and know how to apply it. So our recommendations are 6, and they're here, and I'm going to spend a little time on each one of them. The first is to accelerate the alignment of payment systems with the desired outcome. Just what I mentioned earlier. The second, increase access to relevant data and to the analytics to make that into useful information. The third, to provide technical assistance in systems engineering approaches to people who are currently in practice. The fourth, to involve communities in improving health care delivery and bring patients in at every step of the way. Five, to share lessons learned and celebrate successes. And six, to train health professionals forward to create a pipeline of leaders in this area. So a little bit more about the first recommendation. This has already -- I want to emphasize that many of these things have already started within the innovation models and the innovation center, and within the private sector, in the work of private payers both insurance companies and employers. But our recommendation is to accelerate this work to align the incentives towards better outcomes at lower cost, and to accelerate the alignment of public and private programs, so that everybody is kind of signaling that this is the direction, and it will be appropriately rewarded. So we recommend the public and private payers be convened to discuss how to accelerate and align these kinds of improvements in payment; to promote transparency; to provide tools and congruent measures of outcomes, so that everybody is looking at the same scorecard, and that patients can see the value of what it is that they're buying. And actually, have a role in evaluating the quality of care that they're receiving. That is the second recommendation in this slide, which is that while we're headed towards having better outcome measures we don't really have the most -- the measures that are most meaningful to patients. We have a lot of technical measures often that are used within health care that can help these systems engineering approaches be adopted. But if we're really going to make transparency and a marketplace for health care drive improved quality and reduced cost, we need measures that are really meaningful. Functional measures. After you have your hip replacement can you go out and play golf six months later. And, you know, that's one easy to understand example, but outcomes that are really relevant to the lives that patients and their families want to live. So we need to get more quickly to better measures that then can be used, and identify gaps where measurement science can be advanced. Recommendation number two is to accelerate efforts to develop the nation's health data infrastructure. Now, again, this builds on the success of the High Tech Act of the really dramatic acceleration in the adoption of electronic health records in physician's offices and in hospitals now, PCAST issued a report in 2010 with our recommendations about how that might be accelerated, and in particular how data could be more interoperable, so that everything you need to know about a patient is not based in that particular hospital or that particular physician practice, but accessible to the person at the point of care that the patient is being seen. That set of recommendations was revisited this year in the JASON report to the Office of the National Coordinator of HIT, and has recently been released and has many of the same directions and some sort of innovative and additional technical recommendations about how that might be achieved. We're also suggesting that we need more, clearer national leadership around how vitally important health information is, both at the national level, at

looking at populations, but increasingly at the regional level and the local level, where health care really happens, and that HHS has a richness of health care data through all the different agencies, not just through HHS, and while there's great efforts going on within CMS to try to bring together all the data and make the analytics more available, we're recommending that HHS actually lift this up and make a more senior leadership position across HHS that would bring together FDA, the Centers for Disease Control, and the Agency for Health Care Research and Quality, as well as CMS Medicare and Medicaid information and to accelerate the ongoing efforts to release data, make it meaningful, and make it available to patients to make informed decisions as well, as making it available to the providers. And this is really key, with the kinds of analytics which I mentioned earlier, is a science that could -- the government could really offer assistance to providers as they try to adapt to making use of this information in a more effective way. And that actually relates to our fourth recommendation, which is to increase technical assistance to health care professionals and communities in applying these systems approaches. So we have the success stories in the health care system, but we have people who are struggling with how to shift from this fee for service model to this new model, how to use electronic data in doing that, and how to think of themselves as a system. Maybe even a virtual system, in a community, rather than part of a wholly integrated hospital-based system. So we have all these different kinds of models. We have success with this model of sort of boots on the ground technical assistance that has been demonstrated in the Department of Agriculture, in the Agriculture Extension Service, and in manufacturing, the same techniques have been applied. And as we rolled out the electronic health records program over the last four years, we have used that same model to help physicians and their offices learn how to use new electronic records. So there's actually a system in place of trained experts who could be repurposed or added to provide this kind of help. Now that we've got you using the electronic information, how can you actually use it to create a more efficient system. Recommendation number five is to support efforts to engage communities more systematically in these kinds of health care improvement efforts. So here we're recommending that state and local efforts to transform health care systems should continue to be supported as much as possible by federal programs, and I know a number of federal programs are doing this already. But think about it this way. If you have input from communities that is both -- hearing from them about what works for them, knowing where the gaps in care are, or where the people who are really struggling with their health care might be, being able to reach out, find those people, and help them. And also educate people who can access health information at home, at school, increasingly in the workplace, without having to always go to the doctor to make an appointment, or go to the emergency room, and find ways to help that kind of effort, both empower patients and families in their health care, reduce time away from work that often is unnecessary, and be able at the same time to be able to identify needs that really do need that higher level of attention. And not miss opportunities when people do need to come into the doctor's office or into the hospital. So these systems engineering approaches could be linked with needs assessment programs that are already required for many hospitals and systems as part of their nonprofit status, that they need to demonstrate community benefit, and they're being asked to assess the needs of communities. So this could very much interact with those efforts that are already underway. Recommendation six is to celebrate the successes. I mentioned that we've had a number of health care systems that have been very successful in this area, and with some of these approaches we think there will be many more. The government actually already has an award called the Malcolm Baldridge Award that was given by the Department of Commerce, and it was started in the 1980s to create recognition for companies that were adapting some of these systems

engineering, Lean engineering approaches to reduce waste and develop more reliable -- in the beginning it was automobiles really that started this, you know, has been, has been very successful. Increasingly, interestingly, over the last 10 years more and more health care systems have applied for and actually won the Baldridge Award. So it shows you that there's an appetite for people who recognize that this stuff really works in health care. We think that the Department of Commerce and the administration could lift up the visibility of these awards and create more recognition, perhaps expand the program, perhaps work together with HHS to make special awards for health care, you know, I think there's a lot of different ways that this could be done. But it is clear that recognizing success is a way to spread innovation. And then the last recommendation is to build the competencies and workforce for the future. Invest in the pipeline. And I want PCAST to understand this pipeline is not like out in the far distant future. That you can start new training programs in medical schools and nursing schools and have a workforce that's skilled in new skills within five to seven years. So this is something that would be a very good investment to begin now. So there's a wide range of ways in which the federal government funds education and training programs, and is a partner for many of the private sector educational institutions and academia. And so there are many ways in which developing curriculum and learning opportunities, bringing the learners into well-functioning systems, so that they can see how they're working, and how to disseminate that kind of knowledge. In addition, many of the federal agencies could develop grant programs for developing innovative approaches to this kind of curriculum that could be called implementation science as well as systems engineering, and have requirements for dissemination linked with it. But one very specific aspect of this is our recommendation that we develop centers of excellence. And here, I want to go back to two other successful areas, where new specialties of medicine were created by relatively modest investments at key points in time. One is the field of occupational medicine, which didn't exist in the 1970s, the government invested in around 8 or 10 centers of excellence around the country to train physicians in the science behind keeping people healthy in the workplace. And that field has now -- is now an established field and has had enormous impact in workplace safety as well as in the health of workers and actually undergirds a number of these attempts to have people get more and more of their health information and maintenance in the workplace to not have to lose time from work. The second example from the 1980s which I know personally is geriatric medicine, which did not exist in the United States. And the Veterans Administration, looking at the demography and anticipating aging of the population, wisely took a page from other countries that had developed a specialty of geriatric medicine and started fellowship training programs in the VA that have spawned a whole generation and created this whole new discipline of geriatric medicine. So we're imagining that we could build a robust pipeline of leaders and experts in health improvement science, for physicians, nurses, other health professionals, pharmacists are people who really understand the importance of reliability and systems of care, and other people who are part of the health care system. So this is the summary. Systems engineering is an important and as-yet underutilized tool to help the nation on our journey towards higher quality and more affordable health care. PCAST has identified a comprehensive set of recommendations to encourage the acceleration of these -- of the adoption of these tools, accelerating payment changes, increasing access to relevant health information, providing technical assistance, involving communities, sharing lessons learned, and recognizing successes and training health care professionals in new areas. So I want to just wind up by recognizing the working group that worked so hard and on such a rapid timeline to put this together, and did a great job, and I also, of course, want to recognize the excellent work of the PCAST staff in supporting

the effort. And for our -- the public there also are some references that are at the back of this report which are available.

>> Eric Lander: Maxine?

>> Maxine Savitz: Yeah, it's been an interesting journey as we've gotten the health professionals and the engineering people together and come with, I think, some very good recommendations and also building on things that are going on in other industries, and in the health care. I just want to elaborate on a couple things that Chris said with the data collection and analytics and creating a high position in HHS that wouldn't be controlling of all the data, they are now at least identifying in the report 11 different parts of HHS that collect data. And they don't collect just one part of data you can get sort of 40 or 50, so it's taking inventory. But we sort of modeled this after the Energy Information Administration which was set up when the Department of Energy was formed to serve as an objective and independent source of energy information. And it does this by regularly collecting data on supply, demand, some it's already published by others, it analyzes, it does surveys of its own in order to collect it, and then it runs an open model. As they go forward projecting it, those various analytics, and publishes regular products that are related. And so it does the analytics and also does policy analysis. So it follows -- it sets up an example, and it's well recognized both in this country and abroad by government, by industry, by academia, and by individuals. So it serves as a good model. And the other is in the technical assistance. We've had USCA for years for agriculture. And then NIST set up in the late 80s the manufacturing extension program, which was to help small and medium size businesses implement quality and systems engineering. And we've had some discussions with them about -- and there are 61 of them across the country, and these are not federal employees, they're by people who are trained in this field and go out and provide the service. And in some of the regional extension service groups that HHS has they might work collaboratively together. That's going on.

>> Eric Lander: Well, we'll turn then to PCAST to see who may have questions because this report is actually now ripe for approval. I think Bill reached for his flag first. But Craig. Craig succeeded in actually planting his flag. So I think it goes to Craig.

>> Craig Mundie: Mine was pre-prepared. I thought maybe we should discuss a little bit more in recommendation two about the health data infrastructure. As you pointed out we did have a report in 2010. Importantly I think that report talked both about the strategy for making the records more interoperable but also the privacy questions, both have certainly come to the fore even to a greater degree in recent times, and we just issued the report last week on that. You know, I think it might be useful to just explain a little bit to people what is the way that we think we get to an interoperable record. We're not really advocating that everybody has to use exactly the same method, I think that was one of the innovations and one that this report continues to reinforce, as the JASON report did. Bill may want to comment, since he participated in that. But I think, you know, it's very important for people to understand, both in PCAST and the public, that this forms the basis of taking the records we already have and putting them in a form that would allow these new systems-oriented engineering practices to be brought to the fore. Would you care to add a little to that?

>> Christine Cassel: Well, I think both your point and Maxine's are very important. The report does not recommend, you know, a centralized gathering of data, but rather the ability to use it in a way that ensures privacy, but that also can make the information then available for things like quality reporting and looking for areas where this greater outbreaks of certain infectious diseases and other kinds of things, that a local practice might need to know, and that could happen much more quickly, and then the system could be adapted to that. And so I just would refer people that report, that 2010 report, is available on the PCAST website, and I think the JASON report might also I'm not sure, Bill, we have to ask you about that. But I'm glad you brought that up, because it's important to clarify.

>> Eric Lander: And now Bill Press.

>> William Press: Thanks. Just to answer the previous point. The JASON report was commissioned by ONC and has been received by ONC and is available on their website. In terms of its relation to the PCAST 2010 report, it very much starts with the premises of that report. It actually -- JASON is a little bit more ambitious or may be more in politic, and the JASON report actually tries to sketch out just as an example what an architecture for health information exchange might look like. In part, to help inspire or prod, if you will, the community into saying no, that isn't right, but we can do a better job than that, and we hope that happens. I actually had a slightly different question. There are many different flavors of system engineering, and basically every application area develops its own flavor. And you've described a kind of a mid- or long-range future where we have educational programs that are specialized to health domain in this. But of course, it would be a mistake if we had to wait for all of that to transpire before we could get started. And I wonder, do you see that there are enough people trained in systems engineering in fields that are close enough that they can be inspired to move into the health arena and get this kind of approach going?

>> Christine Cassel: I do, Bill. And we heard this from our working group and actually from a couple of the roundtables that we held, hearing from much broader group of people, both from engineering and from health care. First of all there are beginning to be these programs at Vanderbilt and Georgia Tech and Dartmouth now and other places, where people from engineering backgrounds are focusing their research and their teaching on health care as a complex system, with a lot of opportunity for making a difference. So you're beginning to see that discipline emerge. And in the health care delivery system -- because I think it's really important that we not just depend on a new pipeline of leaders, but that we have to start now, and that's the extension service model or this idea of technical assistance on the ground. There are enough people who have done this successfully that I think that the nation could somehow draw on them or create incentives for them to work as consultants with existing practices and develop models that could be adapted. I mean, one of the wonderful lessons from systems engineering in health care is this idea of rapid cycle testing and change, that you take a microsystem like, let's say, an emergency department, or an intensive care unit, and you find places where there are problems and you address those problems and you have realtime feedback. And then you can adapt what you're doing you're not stuck doing it that same way, you know, for a year while a committee decides what you're going to do next. So it's very -- it's very much dependent on creativity of the workforce who are actually involved. And of getting patient input into that process.

>>Maine Savitz: The industry has used some of the examples Chris used like the Denver and used the Toyota system where people have actually set up consulting to do this. And it's applying the same processes, and electronic health records help you get the data because you need the data and you can feed it into the process and go back. So the training of people doesn't have to wait. What's the advantage of when you get people embedded in the organizations to know about it, it becomes part of the culture. And then it is used continually, you know, after it's done. But you need to learn it, too.

>> Christine Cassel: Right. For people who aren't familiar with this there is sort of a curriculum with some of these techniques where they use the analogy with martial arts and they call them black belts, you get a green belt or black belt. And General Electric started this actually within their -- and you actually -- you started it, right. Allied Signal started, we'll let you -- green belts and black belts. Anyway, the idea is within your nursing staff, within your medical staff, within the people who organize the information systems, you have people who get this extra training. And then they are the ones who are able to react in this realtime way, so you're not constantly having to bring in external consultants to say where do we go from here. So it really is a kind of a bottom up, grassroots model of institutional change that builds on the medical expertise but then adds this kind of different way to think of yourself as part of a system.

>> Eric Lander: Shirley.

>> Shirley Jackson: Thank you. Well, as you know, and you've mentioned some of them, a number of engineering schools have whole departments of systems engineering. So one quick thing would be, I think, to think about how you might create internship opportunities with students. You'd be amazed at what undergraduate engineering students from Rensselaer or MIT or any of these places could do, and they become your kind of counterpart of kind of innovation type fellows. But by definition then you're turning these folks and their thought and their application of their backgrounds to this particular area. The other is I think it's important, though, to emphasize -- and it's been embedded in what you all have been saying -- that at this moment there's this unique both need and opportunity to marry data and data analytics with the traditional systems engineering approaches, because that's where you really are going to make a big breakthrough. But again, by doing things like the internship kinds of things you both bring people in and you turn them to what you need them, but it has the concomitant effect on the curricula of the universities. And so I just thought I'd bring that up.

>> Eric Lander: All right, I did see more flags but I just do want to note for everyone who is listening to this, the thing I was most struck by in your report -- and it's really just a wonderful report -- is I think there's a sense on the part of most people that affordability in health care must come at the expense of -- health care. That is, you have to limit, ration, health care, to make it more affordable. But I think it's so clear in this report, and I hope everybody gets, is that in fact increasing quality and decreasing cost go together in all of these approaches. And that's something I realize in industry people really who engage in large complex manufacturing or other large complex systems have come to embrace. That, you know, you make your systems better, you understand how they work, you increase their quality, and you reap dividends in cost. But it's just not the sense most people have with regard to health care. And I think this report is incredibly important, because it points out concrete examples of how that plays out, and really how much low-hanging fruit we have to reach that affordable goal of the Affordable Care Act without, in fact, giving

up the health care that we all want. I see Mike McQuade just raised his flag in the midst of my statement, therefore I will turn to Mike.

>> Mike McQuade: It was not an intention for you to shorten the statement, it was just to follow on. I think a really good discussion on that, I don't want to get in the way of any of the process that ultimately delivers this capability in the health care systems. And to talk to Jackson's statement about taking students who are learning this for a living and for the companies and consultants who do this. But I wouldn't lose sight of the fact that there are large companies who buy an enormous amount of health care, who have very important quality systems and a vested interest in the short term in leveraging their capabilities. So this definition of public-private partnership, you know, raising a flag to say, with your local hospital, we could use some help. You know, I would look at that as an opportunity to engage at a really important, very quick level, in engaging expertise that already exists.

>> Eric Lander: And so from companies to undergraduates there is a range of talents we ought to be drawing on. And that's right, because this is actually an incredibly exciting problem.

>> Christine Cassel: Let me just say that the reason we can do this now in a way that we weren't able to, people are often saying health care is so backwards because all the other sectors of manufacturing and industry have adapted very quickly these techniques. But you know, we never had the information at our finger tips, it wasn't available. There was every different doctor's office, there was nothing electronic, you couldn't aggregate data. We now thankfully, in response in part, in major part to the high tech investment, we're now at a place where we're beginning to have that information. And that's what makes it all possible.

>> Eric Lander: I think if you combine information and incentives, economic incentives correctly, one unleashes a powerful force. I see no more flags up, I hear there to be great enthusiasm for this report, its description and its recommendations, and so I think it's time to call the question. Is there a motion to approve this?

>> So moved.

>> Eric Lander: Okay, those in favor?

>> Members: Aye

>> Eric Lander: Any opposed? -- The report is unanimously approved. As is our usual pattern, we will go through editorially to clean up the report and make sure it's in appropriate shape and then release it. Very good. Jim Gates:

>> James Gates: These last two suggestions were so great and I don't remember sort of seeing them, so are we going to massage --

>> Eric Lander: I think if we don't actually change the recommendations per se within the editorial cleanup we can certainly note those really great suggestions into the body of the report. Absolutely. I think they drop in nicely, but they should be said explicitly. That's great, okay. So the council has done its work in the

appropriate time. We're supposed to end by 10:30. It is 10:30, remarkably. And therefore we have earned a 15 minute break, and we'll be back at 10:45 for our new session. Thank you.

Directions and Implications of Science, Technology & Innovation in China

>> John Holdren: It is a particular pleasure for me to introduce the next session because both of the speakers are friends and colleagues with whom I've had the pleasure of working on issues related to innovation in China, clean energy technology in China and the like. Let me introduce them both and then they will do a hand-off across their presentations. Denis Simon is the Vice Provost for International Strategic Initiatives at Arizona State University. He also serves as Foundation Professor of Contemporary Chinese affairs in the School of Politics and Global studies. His research focuses on science technology and innovation in China and East Asia. The PCAST members have a longer bio in their materials, and if you haven't looked at it yet I strongly recommend that you do so. Denis has been a key figure in our innovation policy dialogue with China, and a key source of insight for me in this domain for a long time. Professor Kelly Simms Gallagher is the Director of the Center for International Environment and Resource Policy at the Fletcher School of Tufts University, and Associate Professor of Energy and Environmental Policy. She also directs the center's Energy Climate and Innovation Research Program, and she is also a senior associate at the Bellford Center for Science and International Affairs where she previously directed the energy technology innovation policy research group, which reported to me when I was on the Harvard faculty. And closely related to the topic of her presentation today, Kelly has a new book out which appeared on my chair, the Globalization of Clean Energy Technology, Lessons from China. So Denis, I understand you're going to speak first, and then hand off to Kelly, and we will hold questions until we've heard both presentations.

>> Denis Simon: Thank you. Thank you, Dr. Holdren, it's a great pleasure to be here and I want to thank PCAST for having the vision to take a closer look at what is going on in China in the innovation space and also to look at the broader implications in terms of the United States and our relationship with China as we look forward. The issues surrounding China have both something to do with our bilateral relationship, but I also would argue they are a part of a larger change in the international landscape, and that as we look at China we ought to think more broadly also about the implications with our relationships with other countries as the international S&T landscape begins to change. Just to give you a little bit of perspective, in July, 2012, the Chinese held a major international -- excuse me, domestic conference on their innovation policy, they had been faced with a bunch of problems and they organized this meeting right before they had a leadership change, which is usually unusual for them to do that. But they called this special conference and at the closing session they made this statement. They said that China missed the first industrial revolution, it only caught the tail end of the second industrial revolution because of the

cultural revolution. And now we're in the forefront of a third industrial revolution, which as far as China is concerned presents a rare strategic opportunity. The Chinese see both life sciences and clean energy are likely to be the two major building block technologies going forward into the 21st century, and they see these technologies as areas where they must make progress in order to keep pace with the international frontier, but also in order to help transition their economy to the next level as well. Similarly, right after the global financial crisis, Wen Jiabao, the former premier of China, was talking to the Chinese Academy of Sciences and he also made the following statement: Faced with the current international financial crisis, various countries are competing with each other to capture the science and technology commanding heights. The whole world will enter an unprecedented era of intensified innovation and industrial revitalization. I think these are two very, very important perspectives, because they give us a sense of the determination and the national political will that is now being put together in China in order to look at how China can catapult itself into the ranks of the advanced industrialized countries, and also again transition its economy from the manufacturing oriented or low end manufacturing oriented economy that drove most of its economy for the last 30 years, and moving into the era of China becoming a so-called knowledge economy. So what I want to do is talk a little bit about some of the things going on internally, but most importantly to talk about the external implications for what seems to be going on in terms of how China is reconfiguring and repositioning its international activity as a now more important country in the international science and technology space. So we see that the China now has shifted from a country that was once oriented in the direction of self-reliance to a policy that we've all heard about, a policy called indigenous innovation, in which China now wants their economy driven much more by the weight of innovation. Some 30 to 40 percent of growth is to be derived from this new knowledge economy, or what China calls high tech industry. And as those of us who have been reading about China understand, a lot of this is about changing the whole calculation of where growth will come from in China by virtue of many of the problems that Chinese have encountered. Kelly will talk about the environmental issues and the energy issues, in a little bit. But the last one, last couple of bullets here are very, very important. The one, Chinese perception about the growing protectionism in the international economy with respect to technology, a sense that with all of the pressure they're getting about IP protection et cetera that this may not be as an open era coming forward as they've seen over the last 30 years. Second, their concerns about national security, and we see with the increase in the Chinese military budget, and particularly the budget for advanced technology in the military sector, that this is also a concern of the Chinese, particularly after watching the American deployment of so-called smart weapons in the two gulf wars, the Chinese are very, very concerned about their ability to keep pace with U.S. defense technology. And finally, and I would argue perhaps maybe even more important than all, and that is the lethargic performance of their own R&D system. Over the last half a dozen years we've seen the Chinese substantially increase their spending in R&D by over 20 percent per year. It has made China now the number two spender in R&D in the world, and yet for all of the input that now China has more money, more people, and more infrastructure than they've ever had before and Chinese leaders are unhappy or anxious about the fact that they haven't gotten a big bang for their buck. So I think in contrast to a lot of people who see sort of a more arrogant China, I would argue that the Chinese are extremely apprehensive about what's going on. After putting all this effort in, they're not getting the results they wanted. So China has put in place basically what I would call a strategic innovation triangle, it's built basically on 3 legs. A 15 year medium and long-term science and technology plan that they have now just gone through their

first midterm evaluation. I was one of 12 international experts asked to sit in that evaluation, it was a very, very interesting process in which we critiqued a lot of the things going on, and that's the first time they've had such an open process for this kind of plan. That's joined by a medium and long-term plan for education, and a medium and long-term plan for talent. So resonating with some of the discussion that we had this morning about workforce preparation, et cetera, the Chinese are very, very much concerned that they will have sufficient number of high quality, talented individuals to staff this new knowledge economy as the economy goes forward. It may seem like an irony, given the fact that China graduates so many students every year, but actually the reality on the ground is that China may have a talent shortage, not a talent surplus. And this is something that they are -- they're trying to deal with. So we've seen the system go from what we would call then a system characterized by a high degree of resource shortage to what I would call a high degree of resource abundance. If you would have asked me in the 1980s what's the problem with the Chinese S&T system, I would have said not enough money, not enough people, very poor infrastructure. We look at the system in 2014, we would say more than enough money, more than enough people in some respects, and more than enough infrastructure, particularly 2010, 2011, these big investments in R&D went into modernizing the entire S&T infrastructure and we can see that in terms of the spending, again growing twice as fast as the economy. And that's why China today is now achieved over 2 percent of GDP on R&D spending. So it's something that we didn't expect to happen as quickly as it has, but now when you have a system of resource abundance or seeming resource abundance, the system operates in a very different way than it had been over the last 20 or 30 years. So the expectations are, this is from Battelle's work, that if the Chinese keep growing at the same rate in terms of their R&D spending, sometime around 2023 they will surpass both the United States and the EU in terms of their annual R&D spending. But one of the things that we know is that money doesn't guarantee innovation. And that's the problem the Chinese are facing now. They're trying to figure out what it is about the culture of their innovation system and the management of that system that is not yielding the results that they had anticipated. This all came to the surface in July 2011, again former premier Wen Jiabao in Chaussure, a communist party journal that gets published, it is a journal in which Chinese officials sometimes write, and Wen Jiabao presented a rather scathing criticism of the entire R&D system. And in this article he more or less said that the Chinese system is not prepared to meet the requirements of the economy, nor is it able to meet the requirements that are needed to sustain China to become a competitive force in the world economy in the years ahead. So coming from the Premier at the time using this kind of vehicle was a major statement that indicated just the severity of the problems. I tracked the movement of Chinese officials traveling around the country. We can see them constantly making speeches admonishing different localities, different institutions, they've got to improve their innovation performance. So this is something that's going on now on a regular basis. Now, this all translates into a different set of policies now for China on the international stage. We thought that with China's push towards indigenous innovation it was actually going to perhaps become a more closed economy. And I think we made a bad judgment. I think that what we will have seen if we would have looked more closely is that the move towards indigenous innovation was perfectly aligned with what China was doing on the other side of the equation in terms of repositioning itself to further utilize its international science and technology engagement to further push ahead its economy and further drive it to become a more innovation oriented kind of economic system. So in 2012 there was a very interesting report in Koji Raboue, the science and technology daily, in which they talked about basically now three major shifts that China is now engaged

in, in terms of its transition and thinking about how to conduct its international science and technology affairs. First, a shift from sort of going at it alone to now a more full-fledged kind of science and technology diplomacy. Second, on the road from what they call tracking and catching up to now more and more peer, or more and more parity based kind of cooperation. And third from being a so-called passive collaborator, now towards looking for relationships that are much more equal balanced more mutually beneficial and more win-win. So these are all designed to change the equation for how China relates to its both bilateral partners and also its engagement in the multilateral system of international S&T affairs. So we can see now that over the last 20 or 30 years China has built a major infrastructure in terms of utilizing its international S&T relationships for global engagement. And if you look at this, this is sort of a piece of all the different segments in which bilateral government- to-government collaboration has become an increasingly smaller part of this kind of international presence, and private sector, university-to-university, think tank-to-think tank all sorts of other kinds of collaborative mechanisms now have become much more the mainstay of China's international S&T relations. So even though we look at the bilateral S&T relationship as an important part of this, the reality is that our relationship with China has outgrown what the government is doing. And if we look more closely, our corporate to corporate ties are also becoming more and more expanded. So by early 2013 China now had established not just diplomatic relationships but in this case science and technology cooperation relations with 150 countries, it has over 100 international intergovernmental S&T agreements, it has now about 140 S&T diplomats in 70 institutions and 47 different countries. Its presence now is expanding widely. It is now becoming much more engaged in what the Chinese have called a format of science and technology diplomacy, not in just sort of dabbling in the international S&T system. And that also has implications not only for Chinese central government, but also for local governments at the provincial and municipal level as well. So what we've seen is we've seen also a devolution of authority going to municipal and provincial governments now, encouraging them directly to get engaged with their counterparts, through state to state, province to province relationships. These are all starting to again build and grow, particularly in terms of money availability. So these are just sort of some documentation and sort of growth in the budget for international science and technology cooperation at the central government level, particularly during 2010 and 2012, as I said, in the financial -- post financial crisis as part of their stimulus. Those two years are what we call booster years. But if you look at the graph, it's been growing steadily all the way up until this year, and we can see that in the same way in terms of international S&T cooperation projects. They've also been growing both projects going abroad and also projects coming into China. Now, all of this story seems very, very good. China is becoming more globally engaged, it's spending more money on its R&D system, everything seems to be in pretty good shape for the Chinese. In fact, if you look at China's high tech exports, you would say in fact China is indeed making the transition to this knowledge economy. High tech exports have been growing particularly over the last half dozen years very, very rapidly. And one would think that hey, you know, the Chinese are really on the road to success here. But a problem has emerged. If you look at this chart, this chart tells you who actually makes those foreign -- who makes those high tech exports. And in many cases, as much as 80 percent are actually contributed by foreign investment companies, and about 66 percent as of last year were coming from joint venture companies and wholly owned companies. So what we've started to see is we haven't seen a change in the derivation of where the technologies are coming from that support these high tech exports. For the most part they continue to be owned by foreign entities. This is a great disappointment to Chinese leaders, who want more and more of the intellectual capital, or

intellectual property, to be coming from their own domestic sources. They continue to be coming from foreign sources. And many of the things evaluated as coming from the Chinese side continues to be low value added. The best case that's been advertised recently was the case of the iPhone in which the Chinese get some 3 or 4 percent of the total value added versus the bulk of the revenue which accrues to Apple and a number of Apple suppliers in Japan and other places. So these are major problems, the way the Chinese see it. The problem looks even worse in a World Bank report that came out in 2012 using some 2009 data. They indicated that China had an IPR deficit in balance of payments of some $10 billion while the United States had a surplus of over $64 billion. So you can see what's getting Chinese officials apprehensive and nervous, they don't see a shifting of the tides in terms of the reality of where their technology position is. In fact, according to that World Bank report it says that using the Thomson Reuters survey of Chinese patent data -- and many of you know that China's patent data indicates rapid increases in the source of patents coming out of China, it says only about one fifth of the patent professionals believe that Chinese patents are of high quality. A smaller percentage than any other country in the world included in their survey. So there's some interesting sort of disconnecting. More money, more people, more equipment, not getting the bang for the buck. This means that engagement in international S&T affairs become even more and more important because it means if a domestic system is not producing the value, China has to plug in somewhere else to ensure a more steady flow into their knowledge bank coming from abroad, and therefore international S&T cooperation now is becoming even more important. Over the last period of -- over the last decade there have been two major conferences now, and this process has started going forward. In 2006 there was the national foreign scientific knowledge affairs conference in which the former minister Xu Guanhua oversaw the discussion or the beginning of discussion, about is China actually getting yield from these science and technology relationships on a bilateral and multilateral level. And they discussed now five major shifts, and this what we see today actually being played out. Again, the move from general cooperation to now cooperation that's focused on the needs or specific needs of this medium and long term plan. And in fact, in the evaluation process that I was engaged in there's one whole group now focused simply on is science and technology cooperation actually yielding benefit for the goals and objectives of the medium and long-term plan. Second, from project collaboration to integrating collaboration, and project talent and R&D. So what they want to make sure is that there's training, there's actual knowledge generation, and that these projects are actually yielding some results. Third, they want to make sure from sort of a technology import orientation that they are both going abroad, as well as bringing things into China. So you could see more and more activity now going on in the United States, more and more companies being set up, more and more think tanks being set up, more and more sort of listening posts on science and technology now being set up around the United States and Europe, et cetera, to bring knowledge back into China. Fourth, from just general cooperation driven by the government, to cooperation driven by more players, as I suggested before, and then finally, the fifth one, from bottom up to sort of top-down now. Much more guidance from the center about the types of projects that China ought to be engaged in, in terms of international cooperation. So we look at the bottom here, I think it's very instructive. China will change its position of working for other bosses, i.e., foreigners, as typified in the past cooperative activities through establishing dedicated funds through national S&T cooperation, supporting major S&T cooperation projects, raising China's position in international S&T cooperation, making China's participation in such cooperation on an equal footing, and realizing results, sharing and earning reciprocal benefits. So this all indicates again a

different kind of posture. And then again in August 2011 I would make the argument that this was sort of the follow-through from those admonitions. And we began to see actually some very, very concrete activities coming out. On the bottom you'll see minister Wan Gang with Madam Liu Yandong who is really the vice premier who is in charge of international science and technology affairs, sort of indicating they are very much concerned about these particular areas. Wan Gang at that meeting talked about a number of tasks, and just in the interest of time, most important, strengthening the level and design for scientific knowledge and cooperation between governments, and also making sure that China now enhances its role in major international S&T affairs. So what we've seen is China going from sort of a bystander on the side to now becoming much more active. And also, shifting its thinking, creating a whole series of new kind of platforms for collaboration, and also striking some new initiatives. Particularly in the case of the United States, something like CERC. Where CERC is seen by Minister Wan Gang as not only a pet project of his, but also presenting a new kind of model. So after 30 years of science and technology cooperation with China on a bilateral basis between U.S. and China, the Chinese are beginning to suggest that maybe it's time for some innovation in the relationship. Maybe it's time to revitalize and alter the basis of the relationship, because the global context has changed, and the relationship between the United States and China has changed, and also China's own S&T capabilities have changed. And so we've seen the seeds of a kind of a new game starting to be played. We see this also in terms of China's international presence more broadly in terms of international S&T organizations. China is involved in now some 20 or 30 major international S&T projects like ITER, for example, and it's starting to increase that effort to becoming much more engaged. In a recent discussion we had in Beijing, Chinese talked about bringing some major S&T organizations to China so that they'd set up their headquarters in China, and also enhancing their influence and their voice in the international S&T organizations in which they belong. And we're starting to see now training activities going on within the Chinese bureaucracy to basically create senior officials who can assume positions of leadership in these major international organizations. So we're starting to see a sea change come about. Now, along with this, of course, if you're going to ramp up and you're going to engage in more activity, you are going to -- you're going to run into problems if you're not prepared. And in some ways the aspiration is moving faster than the ability to deliver. And of course, that's always a problem, there's a disconnect, China's aspiration always moves somewhat faster than the ability of the system to deliver in reality. But what we've got now is we've got a recognition of those problems, we've got an understanding of those problems, and now there's a major new reform underfoot in China not only to fix the innovation system but also in this case to begin to fix the international S&T cooperation system, particularly in terms of personnel development, in order to be able to staff people across these international S&T organizations. Now, the last thing that I want to talk about, that is China's foreign R&D in China, which I think is a major area of growth that some people probably will find surprising. Right now at the end of the 2013 there were some almost 1400 foreign R&D centers that had been set up by foreign corporations in China. This is something, given China's ITR problems, most people figured would not happen. But major companies, some sitting around this table, some of the strongest ones, GE is a very good example, are not simply using these R&D centers to adapt products to Chinese markets. No, it's not Campbell soup saying do we want sweet or sour soup for the Chinese market, it is our companies now that are actually creating new innovation that is serving the global marketplace. And this is change that again is happening very, very quickly. A lot of return Chinese who would think twice perhaps about perhaps going back to China are now going back to work for foreign multinationals in their R&D

headquarters in China. And so in some ways the Chinese are talking about what they're calling now an internal brain drain. These people, maybe they're not staying abroad, but when they go back they're going back into the foreign sector, they're not going to work for the Chinese Academy of Sciences. What the consequences of this foreign R&D will be is very interesting. A lot of impacts right now are intangible on the soft science side: training, technology transfers, standards. But what they can potentially bring is something called brain circulation. Most Chinese, there's a saying I'd rather be the head of the chicken than the tail of the ox. So a lot of these individuals will work for big companies for awhile, and then they will go out and they will become the next wave of technologically entrepreneurship in China. This is similar to what happened in Taiwan in the late 70s, early 80s, and is likely to happen in China. And so this is perhaps maybe one of the saving graces for China, that these R&D establishments will train -- turn into valuable training ground for the foreign presence in China. So where does this all take us? So we have a very interesting transition going on. If you look at the picture here, China, 1980 was just simply -- was a marginally involved peripheral player in the global economy. It had limited participation. It was self-reliant in its orientation, and it basically was outside of the western S&T system. In 2014 we see a much more engaged China, a proactive or increasingly proactive stakeholder. One that's become now a favored site for foreign R&D activity, and has become a transnational collaborator. China now in terms of international collaboration on articles, on citations, on international projects, is becoming one of the major players now in science and technology affairs. So what's out there? If we look at particularly the international problems, again, we can see that not everything is working well, but we can see that this transition is becoming much more part or ingrained in what the Chinese are thinking about how they will play their role in the future. And in particular, the Chinese are thinking about how are they going to position their economy in the years ahead. This is a section from the Chinese Academy of Sciences, Science and Technology Roadmap 2050. And if you look near the bottom it sort of says that China must do this kind of long-term forecasting if it is going to have the ability to position itself in science and technology affairs so we can make the right investments and make the right choices. And this kind of foresighted anticipation of where the global economy is going, this is something that the Chinese consider essential in order to make sure that they're not off somewhere in left field. That's also why life sciences, clean energy, new materials, et cetera, are all high priorities for the Chinese. Remember, China is not a small little country, it is a continental sized economy. Continental sized economies have ambitions and aspirations that are different than small countries, and therefore China, whether it's nationalism, culturalism or just big power status, China is interested in restoring its place in the international economy. We can see this in terms of collaboration. This is Chinese science and technology ties in terms of research co-authorship. The good news is that the United States continues to be China's primary partner in terms of research collaboration, by far. And this is just some recent data over the last let's say six, seven years that we can see this really big increase in the role of the United States. So U.S. relationship with China continues to be China's most important S&T relationship but I would make the argument that we're not leveraging it enough. We're not being innovative and creative enough in terms of thinking about how do we utilize that relationship. Even in the areas of nanotechnology these relationships are beginning to pay off. The Chinese collaboration is growing, Chinese authors now account for some 21 percent of the over 800,000 SCI indexed articles that are published globally. The Chinese share has increased to some 27 percent, and the U.S. coauthors are by far the leading collaborators with Chinese authors. And we would find this in many fields. If we look at the international college, some of the work done by Caroline Wagner at Ohio State,

we see this kind of collaborative relationship with United States as the principal partner gives the United States a huge leverage. So where does this all take us. It's clear I think we've entered a key transition point in China's international science and technology relations. China is becoming more assertive, more proactive, more determined, and it's tying science and technology to its diplomacy. One can witness China in Africa as a very good example of the Chinese starting to go use science and technology as a tool to enhance their relationships with African countries. There's an effort to improve the performance of the system, and it's also an effort to raise the visibility and the image of China in both global and regional affairs. I think these all suggest that we're going to see a much more active China in international science and technology affairs. It doesn't necessarily mean it will be an adversarial relationship with the United States, but it also means that it will be a much more proactive relationship, and we're likely to bump heads with the Chinese more and more unless we figure out a way how to work collaboratively. I can think of no global international S&T problem that will not require close U.S.-China S&T cooperation. That being the reality I think we need to begin to think of how do we now take advantage of our understanding of this transition in Chinese S&T relationships abroad and how we utilize that to change the game to the next level in terms of our bilateral relationship. Thank you very much.

>> John Holdren: Thank you, Denis, you crammed a huge amount of material into a relatively short space. Let's go now to Kelly Gallagher, and then we'll come to questions for both of you after she's completed her presentation. Kelly.

>> Kelly Gallagher: Thank you very much. Okay, so we're going to go from the really big, total, cross sector perspective to essentially you can think of this as a case study, where I'll be talking about China's engagement in clean energy technologies and clean energy innovation and how it is sort of acquiring clean energy technologies from abroad, and then also utilizing export markets. I'll be presenting research from the recent book that John kindly waved around. But I'm also going to spend a little bit of time talking about recent trends on energy and climate policy, which I thought might also be of interest to you. Okay. So I'm not going to waste time talking about what's on the left-hand side, but one of the motivations for this research, why did I get involved in it, is worth breaking down into why clean energy, which I'm going to skip, and then why global diffusion. Why do we care about the movement of these cleaner technologies across borders. And here I just wanted to highlight that naturally we understand now that emissions are shifting from north to south. And I'm sure many of you know that China surpassed the United States in absolute terms as a global greenhouse gas emitter recently. And before too long in cumulative historical terms as well, China is estimated to surpass the United States. Clean energy can contribute to human development. We have finite global resources. This is a big motivator in China, as it's trying to become a more resource-efficient economy. Global peace and stability, cleaner air and water. Again, a big motivator in China, and I think one that has a lot of political salience, this is something that's changed in the last maybe two years. The just severe urban air pollution, anyone who has traveled there recently can attest to it, I think is now having real resonance in the Chinese context, and in the region, in the east Asian region as everybody downwind from China is having to cope with its pollution. Okay. So these are some of the motivations for my book research, and what I was interested in was some of the assertions that I was hearing both in the United States policy dialogue but also international policy dialogue. And here were some of the assertions that I heard. Repeatedly. First, that technology that's transferred or sold or

exported to -- usually the country referred to as China, will be stolen. Second, the costs of clean energy technologies are prohibitively high. Third, many barriers exist to the transfer of technology. That's actually in the text of the UN convention on climate change and the Kyoto protocol to that convention. And then also that access to clean energy is restricted to developing countries due to patent protections and other restrictions. And this is an argument that's been made vociferously by the Indian government. So I thought these were all really interesting, provocative assertions, and I really wanted to set out and try and uncover the empirical evidence. So these are my research questions as I dived into this research project, which took about three years. So the main overarching question is what are the main barriers to the cross-border movement of clean energy technologies. And conversely, what are the main incentives, what are the most important incentives to motivate the movement of these technologies. But also, I'm very interested in whether the diffusion of clean energy technologies differs from the diffusion of technologies in general. How does the theory hold up regarding international technology transfer to the evidence for clean energy, and then what do the conclusions imply for business and government policy. So I decided to go investigate these things in China, go into the dragon's den, so to speak. Why? Well, China is now the largest energy consumer in the world. It is the largest coal producing consumer, but paradoxically it is also now the largest clean energy consumer in the world. It's the second largest economy, we probably all read recently that it may soon be the largest economy in purchasing power parity terms. And it's been a rapid evolution of policy for clean energy. Both in energy innovation policy, but also more generally the market formation and deployment policy. The Chinese firms, as I discovered, have used every conceivable strategy for developing, acquiring and exporting the technology. So there's a lot to study. And then from the point of view of the IP question, China is the place, you know, everyone is most worried about. So that's what I -- why I wanted to study it. Attitudes towards climate change have really changed in China recently. There's been a really significant shift in tone, I would say in the last five years, and even more intensive in the last year. And these are exemplified by these two quotes, which I am going to take the time to read to you. The first one is from Xie Zhenhua, who is the main negotiator on international climate issues, but also governs climate policy and energy policy at the national development reform commission in China. He's quoted as saying "If Chinese per capita emissions of greenhouse gases reach U.S. levels it would be, quote, a disaster for the world. China will not follow the path of the United States, we want to reach the peak as soon as possible." This is a rather extraordinary statement that he has not made, you know, in the context of the international negotiation, but was quoted in a government newspaper.

>> Kelly, you could probably clarify what you mean by the peak. The peak emissions of greenhouse gases before they start to decline. Which is really important.

>> Kelly Gallagher: Yes, thank you, John. The second quote is from Wen Jiabao who is the former premier, and this was captured in a teleconference with local officials. And here he was trying to emphasize the importance that the central government was attaching to climate policy and clean energy to local government officials. So he said, "The party committees and governments at all levels must consider energy conservation and emissions reduction as the most -- the most -- important task for promoting scientific development, as the most important measure for transforming the economic development pattern, and as the most important measure -- or the most important index for evaluating cadres at all levels". This I think really shows how important climate change and clean energy are now to the central

government, which Denis mentioned already. But it also illustrates the relative lack of importance that I think some of the local governments and provincial level governments attach to these issues, so there's some internal tension on this question in China. And then quickly here, these are some of the recent policy updates in China with respect to clean energy, and I'm going to just add very recent addition in red here. So these are the key targets in China's 12th 5 year plan, I'll mention a few, I think you have these in your slides. China really is pursuing an all of the above strategy. One that President Obama has articulated but I think in China is really true. They have set a target for a percentage of non-fossil fuels in primary energy consumption of 11.4 percent, and they just recently upped that to 13 percent by 2017. They've got a carbon intensity target, an energy intensity target. They've set a very ambitious target for natural gas as a percentage of energy supply. Big renewable targets. China's nuclear energy capacity is growing very fast. And you probably heard recently that they've recently banned new coal-fired power plants in three regions in China. Beijing and the Yangtze and Pearl River delta regions. So quite a lot going on there, and I think there's strong consideration of a carbon tax in China along with experimentation with regional cap and trade programs around China. Okay, so to do my research I essentially focused on four case studies in China of four sectors. And here they are. Solar PV, natural gas turbines, coal gasification, and advanced batteries for vehicles. Let me just say a few words about these four although I won't have time to go into them in detail. The first point I'd like to make is within these four there's big unevenness, as Denis was explaining earlier, in the technological capabilities of the Chinese. So for example, with respect to gas turbines, one of the experts that I interviewed, he's actually the chief expert of the Ministry of Science and Technology working group on gas turbines, characterizes the Chinese as not even in nursery school. Very weak capabilities in this sector. And we can contrast that to coal gasification. And here I have a picture of the new Edwards Port plant in Indiana, and the Duke's new plant. And Duke has been in collaboration with a number of Chinese companies most notably Hwanong to develop coal gasification technologies. But in China here's a real classic case of technology catch up, where the Chinese started at a level that was very backwards and far behind in the 1980s, and over a period of many years has developed very strong coal gasification capabilities. And are now licensing to the United States. So, you know, contributing a little bit to deficit reduction in that regard. I'd characterize solar PV and batteries for advanced vehicles to be somewhere in the middle. Clearly the Chinese have acquired really excellent manufacturing capabilities in solar PV. In this sector they went from essentially no serious PV manufacturing a decade ago to now accounting for half of global exports. In 10 years, it's just an amazing story. That being said, I don't think they have deep technology capabilities in this area in terms of invention capabilities. But what they've become very sophisticated at is working with foreign universities, with foreign firms, and buying foreign firms when they needed to, in order to acquire and develop, further develop technology. The case for batteries for advanced vehicles, in some ways was the hardest for me to investigate, but I would characterize the Chinese as extremely determined to acquire capabilities in this space precisely because they want to leapfrog to a battery electric vehicle future. This is the official, you know, strategy and goal of the Chinese government now, which is saying something, because Wan Gang was a big advocate of fuel cell vehicles and he's sort of changed his mind over the years. And core to that, core to meeting that goal, is acquiring and developing strong battery capability. The Chinese use every conceivable mechanism for acquiring these technologies. I opened this book with an anecdote of touring a solar PV factory in China, and having spent about four hours touring the factory floor with the chief technology officer, who was educated abroad, one of those returning overseas Chinese, we went into the

cafeteria and we were going through the buffet line, and suddenly I realized that I wasn't hearing Chinese behind me, but in fact was hearing German. And I turned around, and the entire cafeteria, we're talking hundreds of people, were German workers in their coveralls. Not a Chinese worker to be seen. And I said who are these people and what are they doing here. And they were all German workers that had been brought to the factory to assemble a parallel production line, and they had brought their manufacturing technology with them and they were assembling the line. So essentially the whole thing was outsourced to the Germans, and that was really an “aha” moment for me about what they were doing, and how they were doing it. I'd like to point out as you look at this slide that most of the mechanisms here are private sector mechanisms. And really, I think in clean energy the government has been a relatively small player in terms of how the Chinese have acquired these technologies and also how they've been leveraging export markets. It's interesting in the solar PV case, for example, that when the Chinese firms set up their businesses, they were planning to use China's export-led economic model. They never did intend to sell to the Chinese market, at that time there were no market formation policies. Feed-in tariffs, or renewable portfolio standards, nothing like that in China. They were looking at foreign markets, most specifically Germany, Spain Italy, and believing that they could compete in those markets. And then it was not until later that the Chinese government kind of came from behind then and actually, you know, it's worth pointing out, not until the cost of solar PV had fallen dramatically that the government came in and established the support policies behind. So this is not to denigrate the good efforts that have been made in terms of government R&D, but I just think it's really important to realize that it's not always a government-led strategy. And the solar PV case is I think an excellent example of where the government really had very little to do with China's emerging success in that technology. But I should contrast that with the coal gasification case, where the government study, consistent determination and support did lead to the Chinese acquiring those capabilities over the years. And I think that's exactly what the Chinese are trying to do in gas turbines and advanced batteries for vehicles now. I don't have time to go into detail on the barriers and incentives, but just suffice it to say I broke them into four categories. So the first is policy factors, costs and finance, IP, and business practice factors. And let me just kind of summarize the big picture here. The most important barriers were certainly cost. Lack of policy. And insufficient access to finance. And the most important incentives are market formation policies, and provision of affordable finance. It was interesting to differentiate between the Chinese perception of these barriers and incentives and foreign perception. I did a lot of interviews in Germany and the United States, and on the barriers there was very little agreement between the Chinese and the foreign firms about what were the most important barriers. But there was a high degree of agreement on the incentive side. So we can talk about that more in the Q&A, if you're interested. I wanted to quickly talk about the three categories. The intellectual property and policy -- actually, I think I'm just going to do those two categories out of those four. So in terms of intellectual property, I had a very surprising finding. And I want to preface this by saying that these findings I think are surely not true for other sectors, but I think that they are -- they are correct for clean energy. But there are certainly other sectors that have experienced widespread infringement. In clean energy there's one notorious case where there was significant infringement of clean energy IP. But in general, and especially in my four case studies, no significant infringement. Now, this is not to say that there were no issues. There were some issues that, you know, I was told about in my interviews. But most of them were manageable, were not life- threatening to the firm, most issues were caught, in some cases the firms were able to actually take firms to court and achieve remedy. And so it's

an interesting finding. There was also some evidence of withholding. The two cases where that emerged was in gas turbines, where some firms have refused to license very efficient gas turbines, more advanced gas turbines. And also in hybrid electric vehicles, Toyota has refused to license some of the electric control technology related to hybrid electric vehicles. And that's one of the reasons why the Chinese have abandoned hybrids and are pursuing a battery electric strategy now. I won't go through this now, because I think I'm running out of time, but let me just say I have some hypotheses for why I arrived at this, you know, surprising finding. And the first is that Chinese -- or foreign firms are reluctant to pursue court cases because they might not win in a Chinese court, or it's not worth the trouble. But the fact is that there have been no court cases related to these case studies involving foreign firms. I found seven, and they were all Chinese-to-Chinese litigation. Hypothesis two is that for some reason clean energy technologies aren't sufficiently mature to warrant significant litigation. Three is that maybe these problems exist but they're mediated or arbitrated in Chinese courts, which is very common. Four, that the technology systems are so complex they're very hard to copy. And I think there's something to be said for that. And the fifth hypotheses is that Chinese capabilities are in fact pretty strong and they want to protect their own IP in this sector and are taking action to make sure they do that. Okay let me just make a couple comments about costs and then policy. Shi Zhengrong who is the CEO of Suntech gave a great interview to me, and he asserted in the interview that the number one barrier is policy. Well, it is cost. And therefore you need to have policy to create the market. So this is one area where there was universal agreement about the need for market formation policy, and whether that's in China or around the world. One important kind of surprising finding for me was that access to finance, access to capital, was not a barrier at all for any of the Chinese. They had no problems getting access to capital, but in the United states and Germany this was routinely raised as one of the most important barriers they faced. But I would assert that the incremental costs of cleaner technologies are already being overcome with market formation policies around the world. Here's three quotes from major firms about the importance of this market formation policy, which is one of my big conclusions, is that where that policy exists we are able to overcome cost barriers. And I think that's sort of surprising, and it helps us realize that in fact there aren't so many barriers to the cross border movement of technology where incentives exist. The four types of policies that I distinguished were domestic manufacturing or industrial policy. Dr. Jackson, one of the quotes from my book is that you can't export what you don't manufacture. So how can you have cross border movement of technology if you're not manufacturing it in the first place. Second, technology innovation policy was clearly important in some of the cases. Export promotion policy. And then of course, market formation policy. I just wanted to show this slide which I realize is impossible for you to read, to make two points. This is from a separate set of research that I did with some colleagues, just trying to estimate for the first time public energy R&D investments on the part of the rapidly emerging economies. And here what you probably can't see clearly is that Chinese public investments, with a lot of data gaps, so this is clearly an underestimate, appear to be outspending U.S. energy R&D investments by a factor of 3. So it just is an indicator of the level of effort that the Chinese are putting in to energy R&D. So I'm going to just wrap up with two last slides. The first is that the clean energy industry globalized around the year 2,000. Why and how. These were the underlying factors that I found in these cases. The internationalization of university education. Many of the leaders of these firms were educated overseas and came back to China. And I think that gave them a global perspective on markets, and also gave them a global perspective on where they could go get the technology that they needed. Very important. International collaboration was

evident in all these cases. The easy and normalcy of migration. Foreigners are now working in these Chinese firms, that's something you would never have seen 10 years ago, or extremely rare. The globalization of energy RD&D. The aggregated national market formation policies are clearly creating global markets that can be leveraged now in clean energy. Trade liberalization was clearly important, China's entry into the WTO clearly allowed China to be able to access these foreign markets and help bring the cost of these technologies down. And then I think we need to acknowledge that China's willingness to finance the transition made a big difference, and I think that's most clearly exemplified in the solar PV market. So let me just conclude with three implications for policies since we are here in Washington. The first is that market formation policy is essential. It's correcting the market failures, it creates investment certainty for the firms, and it facilitates learning by doing, and we've seen that it usually leads to cost reductions. One question is should we be pushing for harmonization so that there's a little more standardization that firms can respond to. Second, I think we need to, especially here in the United States, think about how to improve access to and availability of favorable finance. And here, I think it was quite clear that the United States -- U.S. firms were at a competitive disadvantage in this regard. And third, we all need to take a global perspective on technology acquisition and sales. Innovation and clean energy is clearly no longer a national process, it's a globalized process. Let me stop there and take questions.

>> John Holdren: Well, thank you very much, Kelly, and thanks to Denis as well. We are a little constrained for time, but we only have one public comment to deal with today, so we have close to 15 minutes for discussion. The fastest flag up was Dan Schrag. Well, I didn't see Eric , so go ahead, Dan.

>> Daniel Schrag: Thanks to both of you. Kelly, I want to ask you more about the -- as you said, surprising finding that there was really no IP infringement in the energy space. A few years ago Anne Lauvergeon the CEO of Areva said very clearly when she was visiting that the Chinese had wanted to purchase a nuclear power plant from them, but only on the condition that they make available their plans, and she said that was out of the question. All the technical details that they wanted. And she was shocked that Toshiba, who acquired Westinghouse was willing to make that deal. So it seems like aggressive -- you know, collection of technology and IP was very much at the core of their strategy, at least in the nuclear sector. Have you looked at that sort of a case, or have you just focused on those four sectors that you talked about?

>> Kelly Gallagher: I didn't do a full case study on nuclear, and one of the reasons why I steered clear of it was that there are so many dual use concerns, and so I think clearly there are export controls on a lot of the nuclear technology. But let me make a couple of comments, to sort of get to the business practice piece that I didn't talk about. I think firms that have gone to China with an attitude that there's a big market here and that's clearly true, in her case, for nuclear. And that I'm going to create a partnership with the Chinese firm that is going to be mutually beneficial somehow or another, have done pretty well so long as they have taken careful measures to protect their intellectual property. You know, my first book was on the development of China's auto industry, and I'll never forget interviewing Phil Murtaugh who was the CEO of GM China at the time, and I said to him why do you have such a good partnership, why does SAIC Shanghai Automotive like you so much because usually there's a very contentious relationship. And he said, well, we did everything we promised to do, and we're clearly making a lot of money here. They planned for some technology leakage, as they called it, and it hadn't been as much as they planned

for, and he thought that was because they had aligned the kind of business incentives really well in that partnership. So one of the messages I'm trying to send here today is that I think perhaps our firms are overly fearful about the Chinese market. And in the clean energy space, just as the kind of comparative example, Siemens is everywhere. And GE is not everywhere, you know, as I was going through factories and looking at technology that's on the ground, you know, it made me wonder where is GE, why aren't they here, why isn't this turbine being used, why is it the Siemens turbine. And I think part of that is because they're a little more risk taking. Siemens is a little more risk taking than GE.

>>John Holdren: I know folks would be interested in follow up, but because of the time I'm just going to run quickly through. Eric?

>> Eric Lander: First, wow, those are two great presentations and so much food for thought. I want to pick up on a possible tension between the things you said. China being concerned that it's not inventive enough, there's not enough real invention going on there. And then maybe the possibility that, oh well, maybe that's not so important because if you have large amounts of capital, and you're -- you know, world's biggest economy, you can in fact, through partnership, acquire, let's say even in a fully valid way, through acquisition of firms or licensing, to key technology and expertise to propel yourself in lots of key markets. If you guys were running China, how do you -- which is probably not in the cards, but nonetheless. How would you balance, or more to the point, how do you think they balance those two things? They might be able to get very far, based on what you're talking about, Kelly. But of course we like to think in the long run that you really have to build up this solid innovative base and train people and invent a lot of stuff yourself. But we've not seen this experiment run before, where someone enters upon the science and technology revolution from such an unusual position.

>> Denis Simon: I think that's exactly the point. So when we think about China, is China developed country, is it a developing country? If we look at the military side we can see some very, very advanced weaponry in place and I can take you to facilities that are just the state of the art is what you would find anywhere in MIT or RPI or wherever else we might go. But at the same time I think there is this issue of control. And it's a political issue, and that is that in the international system, the way that innovation is driving the global economy, those who are in the forefront of having the influence are the ones that bring them -- with them, technological capability. So while in the short term I think the Chinese are becoming what some recent report called an absorptive state they are like a sponge they will suck in whatever they can to help foment a technological advanced, the reality they must complement that with some indigenous development. And I think if you look at the world of technology transfer today and technology collaboration we've moved from what I would call the unilateral pardon to bilateral patterns. To get technology you have to have technology. So it may be complementary technologies, but you have to have those other technologies so that you can marry them together. And I think you know GE, I don't work for GE, I don't even have stock, but I will say that GE actually is a risk taker. GE is involved in the C 919 airplane project, GE is also a company that has decided to partner with Chinese construction firms throughout Africa and other third world countries, because it says 50 cents on the dollar is better than nothing on the dollar. So you use my turbine or my power plant and you build the concrete structure, which is your best bet and together we can get the market and we can win. So Jeff Immelt obviously has made a strategic decision that collaboration and partnering with the Chinese is better than to be left out. So I think that

does happen, and that's what a lot of U.S. firms are starting to look at. And I think that there is an implication on the government side, that is, do we collaborate with the Chinese or do we compete. So for example, the advanced manufacturing initiative. So when Dr. Jackson gave her presentation I was struck by the fact that the word international did not appear. So I would think that the Chinese are sitting there drooling at what we're going to be doing in advanced manufacturing. I get asked about this every time I go and give a talk about U.S. science policy in China, and I would think that there's a huge opportunity out there to leverage what we're doing there, because the Chinese, they're just waiting with bated breath to see if something dramatic is going to happen. So we need to think differently about what's going on, because the Chinese are thinking differently, although it's not zero one, either or.

>> John Holdren: Mark Gorenberg.

>> Mark Gorenberg : John, thank you. Eric's question set my question up very well, which is to follow on your presentations about the idea of one of the great strengths in the United States is immigration, and particularly the immigration of entrepreneurs who come here and start great companies. And in fact, in the last ten years a third of the successful IPO venture backed companies in the United States have been started by immigrants, companies significantly like Google and Tesla, in fact. So how do we compete with the Chinese that way, are they thinking yet about -- you talked about foreign companies coming over, you talked about outsourcing technologies to foreigners coming over. But are they thinking yet in terms of how do we attract people from around the world to come to our universities, start companies, and will we be faced with that competition with China anytime in the next couple decades?

>> Denis Simon: So I'm in that business, actually. So I talked about a 15 year talent plan. That talent plan, the underpinning of it is something called the thousand talent program in which the Chinese are trying to recruit back, trying to use Americans for example, Chinese Europeans who have stayed abroad, and they want them to come back to become the new vanguard of a whole class of technological entrepreneurs that hopefully will transform the Chinese economy and the Chinese research system. But now they've expanded that thousand talent program to the foreign talent program so people like you and I, we can go, if we're interested, and be recruited for five years 10 year stints to stay in China, and they're particularly looking at young Ph.D.s who have not yet gotten traction in their career, might want to work in a state of the art laboratory, and bring them to China. So there's an immigration policy change that's going on in China. At the low end it's becoming much tighter to get the visas and things, but at the high end they now have multi- year, multi-entry visas that make it easy for people now to come. Every city, major city, every major province has a talent plan that is a subset of the national talent plan. A big bulk of it is design. They send delegations to New York, Washington, San Fran, LA, they hold meetings within the Chinese community, and they basically say to people, if you're interested to come back, here's what we'll give you. A, B, C, D. So that's why the piece of our immigration legislation that we were discussing about giving people a Ph.D. in the left hand and a green card in the right hand is so important. Because in some ways we are on the verge of what you might call a talent war with China, for the same minds and the same brains, it's just as important if not more important for the Chinese to get these people to come back. And you could imagine if this would happen to some great degree in the United States, we would have whole departments that would disappear out of our universities. So these are not small issues. These are potentially large issues, if this kind of battle for the brains actually does go on.

>> John Holdren: Chad Mirkin.

>> Chad Mirkin: These were spectacular presentations and really mirrored my own experience, I spent a lot of time in China as well. And I'm glad you touched on the talents program, I've been talking about that to PCAST for quite some time. My impression is it's not only incrementally happening, but we're on the verge of potentially losing. And not just losing Chinese Americans -- or Chinese that are trained in America, going back, but actually losing a lot of our own talent here. Because they're offering tremendous resources to pursue big ideas over in China. Do you see that, as well, or not? Or is that just an anecdotal observation of mine?

>> Denis Simon: So there are big dollars at stake. So you can go back and you can get paid more than your U.S. salary, and you can describe a laboratory that you would like built for you, and that laboratory will be built for you. With -- with state of the art equipment. And again if you look at the impact of the stimulus, in 2010, 2011, those big spikes in the spending, they went into modernizing an entire S&T infrastructure. Not every place, of course, but there are many, many state of the art labs now that exist in China that people in the west would like to go to those labs to work on that equipment because they're simply not available, particularly if they're in the public university sector, where they can't get those. So I think that the money is not the issue. The issue is -- two things. One, will China have -- does China have a culture of creativity, where it allows independent thought to prosper and allows you to engage in out of the box thinking without penalty. And so will they allow you to take the risks that we accept in our society, and allow people to engage in this kind of entrepreneurial thinking. Second of all, is the political culture going to change. And, under Xi Jinping I think there were expectations that he might be an agent of political reform that has not happened yet. He has tightened up, he has gone after corruption with a great deal of ferociousness, but he has not indicated where he will go with his political reform agenda. If there is indeed one. I think I speak to a lot of these Chinese Americans because they know I work on S&T issues in China, and they ask me to a person, should I go back. This is a very interesting question to ask somebody. And I know that the thing that makes them most nervous is that they will give up those degrees of freedom that they have here in the United States. Family issues are something else also for kids, you know, going into the Chinese education system. But the big issue are the degrees of political freedom and intellectual freedom that they would have if they returned to China.

>> John Holdren: We need to bring this to a close because we need to be done at noon. Kelly, do you have any closing thoughts on these last couple of questions?

>> Kelly Gallagher: Yes, thanks, I just wanted to get in a couple of points. I think so far to your question about immigration, so far the main strategy is sending students abroad and trying to get them to come back. And the number of internationally mobile students from China has gone from 7 percent of the total in the 90s, to 17 percent of the total in the last decade. And many of the people I saw in these firms were students who had gone abroad and come back. On the Chinese strategy that Dr. Landers questioned, I want to make two points. Shi Zhengrong who was the CEO of Suntech said to me spying is a great strategy for technology acquisition. He just thought it was great. He has a Ph.D., he knows what he's talking about. He felt like he could bargain hard, he could go bargain people off of each other, and he had the resources to buy. And I think that's increase -- I mean, that seems very modern to me in the Chinese realm, and I

think everybody is learning from that strategy. On the other hand, when the Chinese perceive monopolistic or oligopolistic structures, that really forces them into indigenous innovation situations. And I think the gas turbines case I described is one, where they feel like they're getting charged very high prices from a very limited number of firms. And the hybrid electric vehicle case that I explained is another, where they feel like okay, we can't do hybrids because we can't legally license this technology, and we can't figure out a way through this patent thicket. So therefore, we need to have a different strategy altogether and go with a battery electric vehicle.

>> John Holdren: Good. Thank you very much, both of you, that was spectacular. And let's briefly acknowledge. (Applause.)

Public Comment

John Holdren: We now turn to the public comment section, I believe there's only one. Bill Press, one of our Vice Chairs, will preside in the public comment session.

>> William Press: Thanks, John. Is Che Smith here? Yes. If you could go up to the front. Che is Chief Innovation Officer and senior consultant for DARE Global Innovations, and the topics of her remarks is on messaging around the innovation and open data era. Shea, you'll have two minutes, and I'll give you a 30 second warning at the end. I think the lights will also give you some.

>> Che Smith: Okay, thank you. Dare Global Innovations is a consulting firm focused on delivering data differently. And fundamentally we are epidemiologists and statisticians who understand the value of data and analytics, especially when it's transformed into a consumable package that aids clients that we serve to make timely and informed decisions. In our former positions at a local health department, our team felt very constrained by inflexible governmental bureaucracies which by design stifle innovation, especially at this local level. In attending events like tech med and the health data palooza we've observed at this exciting intersection of science, technology and policy for health at the federal level, this focus on health care and health IT has largely left out many public health professionals at the kiddy table in terms of innovation. The open data movement has been targeted towards startups, as the primary end user, and not local governments nor the larger public. Those working at the ground level who may benefit most from data that can be used for decision support, not just those with STEM backgrounds, but all consumers of data and information. So some questions for you today are: Is the phrase open data appropriate, and is it enough? Who will lead the next step of transforming data into actionable information and knowledge? Who will equip under-resourced organizations with tools, both technical and nontechnical, to effectively use data? Must innovation require a technical solution? The assumption around this movement is that a technical solution is preferred over innovation and other aspects of the way the government functions and how data are used and disseminated.

>> 30 seconds, please.

>> Thank you. I propose that now we're giving away the ingredients, which are the open data, that's the eggs, milk, butter, sugar, flour. And as we equipped many end users as possible with the tools to transform the data into consumable and actionable information, and that would be the frosted delicious cake. So how do we move from the ingredients to the cake? To do so we might consider rebranding some of the buzz words and phrases that have thus far defined this open data movement. And in doing so, we'll increase the diversity among this burgeoning community of innovators, welcoming those with varied subject matter expertise and knowledge of how government really works at all levels, and who have the passion to increase our collective knowledge toward better health and better lives. So this is a conversation that we're starting, and we look forward to continuing this with all of you. Thank you.

>> William Press: Thank you very much.

>> Thank you.

>> John Holdren: Thank you. Well, that brings this PCAST public meeting to a close. Again as always, our thanks to the PCAST members, to the OSTP staff, to the wider science and technology community members who have been with us and who have been watching on the web. We, PCAST, will be having lunch in this room. Ordinarily we have lunch in a different room. So we have to ask the members of the public to exit expeditiously so we can set up lunch in here. But again, thanks to all for their participation. (Applause)