

PCAST Meeting - July 11, 2014

Welcome from PCAST Co-Chairs

>> John Holdren: Can I ask everybody to take their places, please. It is my great pleasure to welcome you all to the 30th official meeting of President Obama's Council of Advisors on Science and Technology, that's 30th, three-zero. And of course, a particular welcome to the members of PCAST who in many cases have traveled far to be here. Welcome, as well, to the staff of OSTP and the Science and Technology Policy Institute, who together work very closely with PCAST. Welcome to the members of the wider science, technology, and innovation community who have joined us in the room, and of course welcome to all those who are watching us on the webcast. And let me while mentioning the webcast, take this opportunity to remind those who will be speaking to please turn on your microphones before you start to speak, because in this case, while the people in the room may be able to hear you without the microphone, the people on the webcast certainly will not. And I'm sure in terms of sheer numbers they represent the largest part of the audience. Before I go any further, I want to note two particularly important personnel changes related to the work of PCAST. First of all, almost exactly two weeks ago the United States Senate confirmed Dr. Jo Handelsman as OSTP Associate Director for Science, and Jo is here. Congratulations, Jo. (Applause). And on a different note, I have to record with regret that our longstanding OSTP/ PCAST triple AS fellow Dr. Knatokie Ford, is experiencing her last PCAST meeting before she moves on to new challenges. So let us thank Dr. Knatokie Ford for her incredible service. (Applause). Since this is the 30th official meeting of PCAST in the Obama administration, I thought it worth reflecting, at least very briefly, on the extraordinary record of this group in terms of its level of activity, and in terms of the fraction of its recommendations for the President that he has embraced and that have become part of administration policy. We have done an enormous number of studies, almost as many studies at this point as we have had official meetings, over 25, and more to come. And if one looks at those studies from the very beginning up to the most recent ones, one finds a remarkable degree of resonance with administration priorities and with executive orders, presidential memoranda, and other instructions the President has given going forward to embrace and embody the recommendations of this group in his policy. One could start with health information technology near the beginning of our record and the study of systems engineering of the health care system to get better outcomes for more Americans at lower cost in our very recently released reports. The recommendations of these reports, both the early one and the most recent one, are being embraced and embodied in the policies and actions of the Department of Health and Human Services, the CDC, the FDA, and others. Our work on the allocation of federal spectrum continues to be acted upon by the administration, and that

policy is moving forward expeditiously. Our recommendations in 2010 on accelerating energy technology innovation; in that report in November of 2010 we recommended a quadrennial technology review by the DOE, which was carried out in the next year, and a new one is now underway. And we recommend a quadrennial energy interview, an interagency look at energy technology innovation in the context of energy policy as a whole, and the quadrennial energy review is now well underway as an interagency effort led from the White House with a strong secretariat in the Department of Energy. The recommendations of this group on climate change in early 2013 can be seen reflected in substantial measure in the climate action plan that the President rolled out in June of 2013. And again, that climate action plan is being implemented with really enormous focus, commitment, and coherence, led in the White House by the President's Counselor John Podesta. The report relatively recent on big data and privacy, the technological issues at the intersection of big data and privacy, a companion report to the interagency study led by Counselor Podesta, is also in the process of affecting United States policy in this domain. Similarly our report on cyber security of more than a year ago is being implemented under the direction of the National Security Council in many of its recommendations. Our report on agriculture R&D has been embraced by the USDA and with enthusiasm, and again, a large fraction of its recommendations are in the process of being acted upon. Our report on accelerating drug development and approval, obviously a very important issue in the larger context of public health and the health care system, again, being embraced by NIH and the FDA. Advanced manufacturing, a major theme of an early study by PCAST, has led to two rounds of advanced manufacturing partnership engaging many of the leaders of the high tech industry and our major research universities around the country, with a whole series of specific results, including initial installments in developing a national network of institutes on manufacturing innovation. Again, I think already having substantial effects on the whole process of increasing U.S. competitiveness, bringing back jobs in manufacturing, giving the United States an important economic edge in a variety of important manufacturing industries. STEM education. This group has made so far three reports on STEM education, going on four, and the results of the reports that have been completed so far are abundantly reflected in the administration's strategic plan for STEM education which is being carried out under the oversight of one of the standing committees of the National Science and Technology Council, which OSTP co-chairs. So I think we have a lot to be proud of in this group. It has been an incredibly hard-working PCAST, with folks who of course are uncompensated, except for me, I'm the one full-time government employee on PCAST. My co-chair, my vice-chairs and all of the members otherwise serve without compensation. Quite the opposite; they get to take out of their pockets some considerable part of the expense of doing this, because the government reimbursement rules don't quite stretch to reach the full costs of doing this. And I have to say that as you know, and you'll hear it again from the President himself later today, the President is enormously appreciative of the work of this group, and the role it has played in his

formulation of policies around science, technology, and innovation. With that, I'm going to ask my co-chair, Dr. Eric Lander, the head of the Broad Institute of Genomics at MIT and Harvard, if he has any opening remarks.

>> Eric Lander: No, other than to admit that I hadn't realized it was our 30th meeting. It is remarkable across 25 reports, and we'll have another one that we bring to the council today for approval, and another one that I think we're going to have ready to bring in September, and maybe two by then, that the energy of this group has not flagged. I just think it's fantastic. We'll dive into the meat of the reports there, but I'm also grateful that so many people keep showing up to our meetings here in person and on the web. So both the interest in the White House, the energy of the group, and the energy of the broader community I think really sustains us, and so thank you.

>>John Holdren: And let me just add there are two and a half years left in this administration, and we are not finished. There is a lot of work yet to do. Interesting and important challenges that remain to be addressed in the science, technology and innovation space, and we will hear about some of those in the course of this morning's meeting and we'll be again discussing them with the President later today.

National Nanotechnology Review Discussion

>> John Holdren: I want to turn to the discussion of the national nanotechnology review. And there I believe that Mark Gorenberg will be leading off the discussion. So Mark, the floor is yours.

>> Mark Gorenberg: John, thank you very much. The 21st century Nanotechnology Research and Development Act of 2003 calls for a National Nanotechnology Advisory Panel to periodically review the National Nanotechnology Initiative, the NNI. It was designated in 2004 that PCAST be that NNAP, so this is now our fifth review of the NNI, and the third one under this particular PCAST.

>> Mark Gorenberg: What we're going to talk about today is actually a work in progress, to give you an idea of where we are in progression of that review. Okay.

>> Mark Gorenberg: So we started earlier this year, this is co- chaired by Michael McQuade, a member of PCAST, and also with great oversight and a lot of great input from Maxine Savitz and Bill Press. Tireless, tireless work by Ashley Predith, who is the Assistant Executive Director of PCAST, and of course oversight and great inputs and direction from Marjory Blumenthal the

Executive Director of PCAST. We've consulted and put together a group of 11 industry experts from academia, from industry, and also from areas like the venture capital community, to look at the field, not just from a nanotech expert view, but also from a generalist view with the idea of nanotechnology as part of what they do. We've also had two in-person meetings and we've hosted many conversations with folks around government agencies, industry, universities, et cetera, to understand their views.

>> Mark Gorenberg: I also did want to say before we move forward that we're honored to have two folks here in the room with us, one is Lloyd Whitman, who is the Director of the National Nanotechnology Coordination Office, which is important in sort of the common -- the connection between the NNI and the outside world, as well as work within the agencies. And also Altaf Carim, who is the Assistant Director of OSTP responsible for nanotechnology, and one of the co- chairs of the subcommittee on nano-scale science engineering and technology core part of this organization, which reports under the National Science and Technology Council.

>> Mark Gorenberg: The National Nanotechnology Initiative is a cross-cutting national vision for nanotechnology development in the United States. It sort of combines the federal effort in -- across different agencies in nanoscale science, engineering, technology, and related issues. In 2014, however, five of those agencies garnered 93 percent of the budget, but the NNI is inclusive of 27 active agency units that are involved in this effort.

>> Mark Gorenberg: The definition, by the way, that the NNI put on nanotechnology, was a size one, a dimension of 1 to 100 nanometers. So it's actually material that -- or that has quantum mechanical effects that could have very different properties than similar types of components at different scales. And that size threshold was used rather than sort of a particular discipline in terms of its definition.

>> Mark Gorenberg: And you can go to the site, nano.gov, to obviously get far more information on this. The FY15 budget right now that under proposed is \$1.537 billion, relatively the same as FY 2014. The innovation calls for healthy research effort to continue.

>> Mark Gorenberg: But international competition in this area says that, while the U.S. -- the GAO report of 2014 says while U.S. is still in the lead in research, which, although there are some barometers like research papers being submitted now more from China and the EU than from the United States, the one thing the GAO report did say is that we've fallen behind other countries in some of the infrastructure around nanotechnology like nano-manufacturing of products. And that did influence some of the thinking that has already gone on in this committee.

>> Mark Gorenberg: This gives you a context of spending in nanotechnology field. Overall, worldwide about \$18.5 billion. The U.S. Government and state governments as well which have been involved, about 2.1 billion, Europe about the same. Corporate spending is actually up, now it's 4.1 billion, and Japan is a large player corporately. But what's really been moving forward well is the idea worldwide nano-enabled product revenue, \$731 billion in 2012.

>> Mark Gorenberg: We looked at this as a transition point. So while we believe that a healthy research environment must continue, the primary conclusion of the 2014 PCAST review of the NNI will be that the United States will only be able to claim the rewards that it's made from investing in nanotechnology research by bringing together this federal initiative, federal agencies, the Office of Science and Technology policy, and all these different efforts with the community to apply this research towards having leadership for translating technologies into commercial products. We are actually framing this under the concept of NNI 2.0 which is the idea of moving from nano scale components to moving to interdisciplinary nanosystems. And we're seeing increasing applications in nanobiotechnology, energy resources, food agriculture, simulation, cognitive technologies, and the number of different disciplines where this is involved is actually fairly staggering to think about.

>> Mark Gorenberg: The added value of the NNI over the last 13 years has been very significant. I mean- Think about things like collaborations between the agencies. There are only recorded 35 collaborations between the agencies in this work in 2005. 159 last year. And that's been very prolific in their work through the agencies and great camaraderie effort.

>> Mark Gorenberg: But the international competition that we're seeing and the maturation of the field says that we have to do more. And the nano ecosystem has to go beyond the government to this full ecosystem of community, industrial, government, public, philanthropic partners all working together. And we've also looked at this going beyond the current concepts by the NNI.

>> Mark Gorenberg: And we believe the primary driver of what we'll say in our report, is that the primary driver for the next wave of the NNI should be this concept of grand challenges. That it should be centered around the idea of audacious, achievable, inspirational goals that have clear endpoints. The cross-sector involvement in the selection refinement and pursuit of these goals. And this has been a staple we're starting to see in this administration through the OSTP. We're already seeing grand challenge in areas like the Brain Initiative, or the DOE sun shot, the NASA asteroid grand challenge, the USAID grand challenge for development. The administration has moved forward on grand challenges because they can help solve important societal and economic problems, they can serve as a North Star for high impact, multidisciplinary collaborations. They create a foundation for jobs of the future, capture the public imagination, and also inspire a next generation of scientists and engineers.

>> Mark Gorenberg: We will have some illustration of some grand challenges in the report. And actually would love to hear, since we're here in a public forum, would love to hear some over the next month or two from people in the community that they think actually would make some great grand challenges for the NNI initiative to be illustrative in the report.

>> Mark Gorenberg: But to give you some examples of some that we have looked at, one of them is the nano-enabled desalination of sea water to solve the emerging water crisis. This is one where a nanostructured membrane can be used to control pore shapes, and they can have very high selectivity separating out the salt from sea water. Another nanobased antibacterials that eradicate un-treatable infections. In the tradition of grand challenge we're looking at putting a year on that of 2025. The idea of using nanomaterials to disrupt the cell walls of bacteria, overcoming their ability to genetically evolve in response to drugs.

>> Mark Gorenberg: Another one, the idea of reducing global greenhouse emissions with nano-enabled solid state refrigeration. The idea of power production for building HVAC systems that contributes to large amounts of greenhouse gasses. The nanostructured thermoelectric material could enable that to be far more efficient for heating and cooling.

>> Mark Gorenberg: Those are just some examples, we'll also talk about things such as 3D printing, we also -- and some involved with cancers. But we also believe there could be a huge impact in nanomanufacturing and we believe one of the grand challenges should be around nanomanufacturing.

>> Mark Gorenberg: The report will talk about some of the efforts involved with commercialization in nanomanufacturing, today we see that a big thrust going forward. There'll be -- well, There's different organizations such as the National Nanomanufacturing Network, the Nano Business Commercialization Association that, has been prolific in tying together the government with the outside community, setting up centers that people can use, as well.

>> Mark Gorenberg: One that we do want to highlight, though, that the government has put forward is the National Network for Manufacturing Innovation. So- in the- That was put forward in 2013, for federal investment. It links institutes for manufacturing with common goals, but with unique concentrations.

>> Mark Gorenberg: In the budget of 2014 the President proposed creating a network of 15 regional institutes for manufacturing innovation, that has now been expanded to trying to put together 45, to solve the aging structure of manufacturing. It's a great thrust and has some great immediate success in the administration. We think the NNMI should be a natural partner to the NNI in bringing forward nanomanufacturing.

>> Mark Gorenberg: One of the great areas we should commend the NFCT is its successful coordination of nanotechnology R&D with environmental health and safety issues, essentially set up a subgroup called the National Nanotechnology Environmental and Health Impacts group, NEHI working group. They put out this report in 2014 that was -- talked about the collaborations amongst the agencies on the EHS, and it's entitled progress review on the coordinated implementation of NNI 2011 EHS research strategy. About- We've been told that about 40 percent of the effort of the NFCT centers around EHS today. So a small amount of dollars but a large amount of work, very important work, essentially in the government.

>> Mark Gorenberg: Some of the implementation of this 2011 study included development of comprehensive measurement tools, collection of exposure assessment data, enhanced understanding of modes of interaction, improved assessment of transport and transformations of E&Ms, development of principles for establishing robust risk assessment. And coordination of the efforts to enhance data quality, modeling and simulation, in order to work in this field of collaborating nanoinformatics infrastructure.

>> Mark Gorenberg: A lot of this has been tied together, as Lloyd will tell you, with the NNCO. So Lloyd will be -- is planning to go back to -- he's sort of been on loan in the interim. And he's actually working with OSTP to find his replacement. But the NNCO director is a very important position in this, and we're hopeful that the NNCO director will tie together with these new ideas around grand challenges and really be an instrumental force in helping to bring them forward.

>> Mark Gorenberg: The NNCO acts as the primary point of contact for information on the NNI as we talked about, provides technical administration support, develops the updates for the NNI website and does the public outreach for the NNI.

>> Mark Gorenberg: So with that, I guess we can open up to questions. Maybe I can conclude by just saying that again, NNI has been a truly successful venture for the last 13 years particularly good for setting up collaborations between the agencies. We think this is a great opportunity and we think actually that the international landscape requires us to take this up a notch and really bring all this together, not just for research but also far more for commercialization.

>> Mark Gorenberg: And we're starting to see some great centers come together, I mean many universities had this for years. But particularly there's been a lot of publicity recently, this is now the highest priority at MIT going forward, a central facility of 2,000- - 200,000 square feet, 2,000 MIT researchers to bring the whole campus together, so we think this will be sort of a future shining area for the next decade as we pursue NNI 2.0. John, Thank you.

>> John Holdren: Thanks very much, Mark. The floor is now open for discussion from the PCAST members. Maxine Savitz, please.

>> Maxine Savitz: Yeah, Mark, I want to thank you, Michael, Ashley, and the whole committee. Two questions. Two questions, One, sort of alluded to your last comments at MIT, but moving to the grand challenges is, you know, right thing to do, but what about the fundamental research aspects of the government program? I mean, that's been key through the 13 years, you see -- you know, what, where that still fits in as an important part.

>> Maxine Savitz: And the other one, are you- are you starting to think more about what might -- we asked in the other metric, how do you measure the outputs of this.

>> Mark Gorenberg: Yeah, those are really good questions. We're very adamant that the research has to continue. We're not looking at commercialization at the expense of research, but we're just saying that now we're in the next phase of international development around commercialization, we're seeing far more products come to market.

>> Mark Gorenberg: So the government has to continue that research to go on, but commercialization becomes a sort of necessary component side-by-side.

>> Mark Gorenberg: The second question -- oh, about metrics. Yeah. So there's two recommendations that came forward in the 2012 report that we will certainly continue in the 2014 report and even put more emphasis on. One of them is the idea of creating an advisory committee that involves industry and academia to work in almost a continuous basis with the NNI and NSET to bring forward these concepts. The other one that was brought forward in the 2012 report that will also be a key part of the 2014 is the idea of metrics, and measuring. And we're started to look at some more concrete concepts of that, like the star metric systems that we'll be highlighting in the report.

>> Maxine Savitz: Thank you.

>> John Holdren: Jim Gates, please.

>> Jim Gates: Thank you John, and thank you Mark, and the entire leadership group for putting together this report. My question is related to that of Maxine's, you responded that a continuation of research is going to be a high priority- a high priority in the future. And related to that of course is the ability to retain talent to actually carry that research out. Can you say something specifically about that, in the face of this fierce international competition that we keep hearing about?

>> Mark Gorenberg: Yeah, we're starting -- Jim, it's a really good question. We're starting to see for the first time the -- and particularly in the nanotechnology area the brain drain of some of

the experts here in this country to go overseas, of being enticed. The international budgets now to rally around nanotechnology are such that they're starting to attract some of our best and brightest and some of our longstanding, you know, not just young professors but well tenured professors to go overseas to do these efforts.

>> Mark Gorenberg: So we're looking at the idea of calling for -- and we haven't formulated the exact recommendations yet -- but we are looking into the area of calling for specific grants to be granted to well-known single investigators to make sure that their research continues on here and that they're enticed to stay here in the United States to move that forward.

>> John Holdren: Good. Bill Press.

>> William Press: Yes, thanks, Mark, for such a clear presentation. I wonder if you could elaborate a little bit more on what makes a grand challenge a grand challenge. How is that different, say, you know, from other kinds of initiatives. And what are the differences that give your workshop this confidence that grand challenges are really the way to push this forward?

>> Mark Gorenberg: That's a great question, Bill. Most of the work that has gone on to date has been more around coordination, and in fact in the 2010 report they put together ideas that they call nanotechnology signature initiatives, which coordinated agencies together on the work that they're doing. And that has -- again, in the context of coordinating research, that has been a good thing, to do. And five of them have been created.

>> Mark Gorenberg: But we see that if we brought this up a notch in terms of grand challenges what are the characteristics of grand challenges. And actually this is something that OSTP has been talked about very well in sort of other areas. So first of all, they have a measurable end point. Second of all, they require advances in fundamental scientific knowledge, tools and infrastructure to be completed. Third is they have clear milestones along the way that can be looked and can be measured. And fourth is that they're integrating. So they're interdisciplinary amongst different organizations.

>> Mark Gorenberg: And the fifth, hand in hand with that is they're too big to be undertaken by a single or even a few institutions. And even in fact just by the government. So this is one where the government becomes sort of the bully pulpit to also bring in a lot of other organizations with the agencies to work on these grand challenges.

>> Mark Gorenberg: We will in the report talk about ideas for identifying and implementing grand challenges, so those are the basic tenets but we'll have a lot more to say on that.

>> John Holdren: I see no more flags, and we are right on schedule to transition to the next topic, so let me thank Mark and all your coconspirators in this effort for the great work that you summarized here this morning.

Antibiotic Resistance Report Discussion

>>John Holdren: We will turn now to a discussion of the report on antibiotic resistance, and that discussion will be led by my Co-Chair, Dr. Eric Lander. Eric.

>> Eric Lander: Thanks very much, John, and I want to thank Chris Chyba, PCAST member and Co-chair with me on this study that we've been working on for awhile now. We are bringing today to PCAST for approval, if you're up for approving, that is, this report on antibiotic resistance. We've been covering this topic now for more than six months and had the opportunity to benefit from discussions with experts in a wide range of fields, members of a working group that we put together covering topics from public health, to the development of drugs, to basic research to agriculture, and many, many other fields, as well. As well as having heard, I must say, and very helpfully so from many different members of the public and from organizations. I don't remember a topic on which we've gotten quite as many different inputs, people sent in, read this scientific paper, read that scientific paper. Wait a second, I don't believe this scientific paper. It was a really rich engagement and there may be people here on the web or here in the room who helped out in that discussion. And we're really, really grateful for that. We also had the opportunity to talk extensively across the federal government with the many different agencies that have expertise in this area. The USDA and the National Institutes of Health, the CDC, and the FDA, CMS, OMB, almost every three letter acronym you can think of was involved in this discussion. And we learned a lot. It's a big and complicated problem. All that said, it's sort of simple at some level. There are really three things that have to be done. Well, we know that there is no permanent victory against microbes. Microbes continue to evolve in response to selective pressure. If you use antibiotics, whether in human health care or in agriculture, you will over time see resistance. This was pointed out by Alexander Fleming in his Nobel address, this is not a surprise that there are lots of mutations that occur in bacteria and lots of exchangeable pieces of DNA that transfer between bacteria that create ways to spread and create new resistance. It is a cat and mouse game played at this microscopic level between our agents, our therapeutics, and these microbes. There is no permanent victory in that sense. Nonetheless, we can stay ahead of it. And the simple triad of strategy is surveillance, stewardship, and continued development of antibiotics or other treatments. It's a rate question. If we can surveil and see what's going on and we can slow down the rate at which we lose antibiotics, through stewardship, and speed up the rate at which we create new antibiotics or equivalent therapies through science and other such

measures, science both in academia and industrial scientific development, we stay ahead; we win. We have a pharmacopoeia of agents and collection of treatments that let us to largely stay ahead. If we fail, if we fall behind in our stewardship, in our creation, or if we fail to surveil to understand what's going on, it's a very real risk to see a resurgence of what life looked like a century ago when we had bugs we could not treat. It is a terrifying prospect. Now, I don't -- it doesn't help to do scare tactics around these things, but it's just plain scary. Members of PCAST has commented to me I now worry when I go into a hospital whether I might get an antibiotic resistant infection. And that is not a crazy prospect anymore. We were doing okay I think two decades ago, but it was really becoming clear we were in trouble on the point. A decade ago it was clear to wise observers and many folks, the infectious disease society of America and others were raising alarms that we were going to be in trouble. Today we see something like 17 really serious threats that emerged. And give rise to something like 23,000 deaths, much, much larger numbers of people who are sick, and a total economic cost, including the health care costs, and the associated loss of productivity costs, that are somewhere between \$50 billion and \$70 billion a year. Given that it costs this much in lives and in money, if we could reduce it, it's certainly worth putting money behind that problem. If we could reduce that 50 to \$70 billion by 10 percent that's a savings of 5 to \$7 billion, in the crassest economic terms. But it's more than that, because this is a curve that's getting away from us. So one shouldn't be trying to do arithmetic based on today's numbers, one should be doing the arithmetic based on what it looks like five years from now and 10 years from now, which is a much more serious thing. It's something that has been of interest to all of PCAST. Now, we have a report, and I'm going to say in advance our usual practice at PCAST is, because when we're done and we vote on a report, it still has to get cleaned up and edited, various people have editorial comments, and so my expectation is that we certainly will not be able to publicly release the report today, my expectation is, as we always do with PCAST reports, within the next several weeks as soon as the editorial work is done and it gets properly set by White House graphics we'll be able to release this report in the next several weeks, but I'd like to sort of sketch today for people who are listening roughly where we're going with this. And I'm hoping when the actual report is publicly released there will be an opportunity for much deeper discussion of all of these points. So the first thing to say is -- it's going to take federal coordination and leadership. And so PCAST has looked at the coordination that's been in place for the last 15 years or so, there has been an interagency task force working with this, and it was probably the appropriate thing for the time. But I think it's clear to us right now that given the new focus and new investment that we're going to call for, it's very important that that investment be coordinated and managed in the most serious and I think strengthened way. With an appropriate interagency task force at high enough level, involving the leadership of the secretary of those agencies, and also with White House coordination, with appropriate office in the White House being tasked with -- that is with an existing office in the White House, being tasked with responsibility for ensuring that the

interagency coordination goes on. And we also suggest that there be a Standing Advisory Council. So this is a pretty serious suggestion of coordination, interagency coordination, making sure that the White House itself stays on top of a national plan here, and is accountable annually for how we are doing against that plan. Someone tasked within one of the existing offices needs to be accountable for the progress annually on such a plan, and as I say, an existing group -- a new federal advisory group, that will be able to involve the external community. This we hope will keep the spotlight on progress. And this is a measurable goal. We can ask what is the incidence of each of these antibiotic resistance organisms, what are the new ones that are popping up, is it going down, there are many things it's hard to know if you're making progress. We can tell if we're making progress. Do we have more antibiotics in the pipeline, are more getting approved. We should have in the next several years a scorecard. And we ought to know each year how we're doing against our scorecard. I wish many things could be as crunchy as this, but this one is crunchy and we ought to make sure we stay on top of it. So we're going to make -- we have some recommendations about concrete actions like that. Now, the second area that the report will touch on is surveillance. Being able to systematically surveil the problem and respond to the problem is very important, and there are two directions in which we make recommendations. One has to do with strengthening state and local public health infrastructure for surveillance and response. The CDC does provide some funding for states and localities to do this kind of surveillance. It's a small amount of funding, and it is a crucial life blood to those agencies that do -- that are on the ground in states and municipalities, and do the actual traditional surveillance using existing microbiological methods and connect with the clinic, they don't have funding in many of the states the CDC funding is essential, and this is a case where additional federal funding would make a huge difference. And we call for that. But there's something more that's needed. We need to have new high-end technological surveillance of a sort we could never have before. When you see that somebody has a particular antibiotic resistant infection, carbapenem resistant bacteria, it's really hard to know whether three patients in the same facility got it from each other, each brought it from the same location, or whether they arose independently. Because when you play it out on a petri plate you can't see the difference. But the DNA contains a record. If these things came from the same recent source, like spread from one patient to another within a facility, the DNA sequence will be almost identical. If they had totally different origins, there are tell-tale genetic differences sprinkled all over the genome. And you know what, one is also going to be able to tell whether this came from another country, or whether this came from agriculture. There remain great debates over how much is the exchange between humans and animals. Well, with DNA sequence, deep DNA sequence, you can establish the provenance, you can reconstruct the evolutionary tree and the exchange tree of genetic material. We could not have made a recommendation like these five years ago because the technology wasn't up to it. It would be a ludicrously expensive thing to do. But technology is advancing dramatically here. By next year

we expect sequencing an entire human genome will cause \$1,000, and a microbe is typically about a thousand times smaller than a human genome. Now don't get me wrong, we're not going to get the one dollar microbe, because the sample prep costs, things like that, but in a world where that's the direction where we're moving, we ought to be getting as much information out of this, because with awareness, awareness of what's the rate, what are the numbers of different types of mutations, where they coming from, we can take informed action. There's a need to create a national capability for this kind of surveillance, and we think there are probably two directions that you ought to proceed. Regional laboratories that can do this for many facilities, and then also for some major hospitals, being able to do this on-site in the hospital makes sense. It certainly isn't going to be possible I think for every single doctor's office to do this themselves, in many small hospitals, but some large facilities ought to be doing this, and we ought to have regional capabilities for this kind of surveillance across -- serving the rest of the national health care system. And many things go along with this. You're going to need to have reference databases of sequences of all these bugs. And the CDC has huge collections, and the USDA has huge collections, we ought to get them sequenced and the database freely available. And we ought to have the software easy to analyze this in different places so we're really saying let's apply the genomic revolution to the surveillance here. But also let's not forget that the basic state and local public health infrastructure is critical. Those are not in competition with each other; we need both. Now, the next area to speak of is fundamental, is the creation of new antibiotics. There are multiple components to that. Why is it hard to create new antibiotics? One gap. Scientific knowledge. Bugs are smart, they're really smart, and they've got a lot of tricks. Take gram negative bacteria, they have this funky cell wall and it's really hard to get molecules into a gram negative bacteria. And if you get them in, they have a lot of ways to pump them out. Some of them have dozens of different pump mechanisms to pump these things out. It's really important to take on the whole range of scientific problems associated with beating back the tricks of bacteria. In the report we'll lay out, I think we've picked out 8 or 9 examples of the many that are bubbling up in the ferment of scientific community, of things we could learn that could accelerate this. Like how you get things into gram negatives. How you can take a bacteria that's become resistant and resensitize it by hitting the resistance mechanism and leaving it vulnerable back to the initial antibiotic. By understanding how it is that a tiny percentage of bacteria can hunker down in a kind of persistent state and be tolerant to, not genetically resistant but just tolerant to because of their physiologic state, the antibiotic. There are rich and important scientific questions that won't simply yield to brute force. They will take the cleverest investigators of this generation to work on those problems and provide a scientific foundation. And we call for increased funding there. That's clearly the NIH, but I think other agencies as well have roles. The FDA has roles here, DARPA, DITRA I think have contributions to make here. That's larger with regard to human health. There's also a basic research question with regard to agriculture. Ideally, we would like

to have ways to be able to provide the benefits to agriculture that are currently associated with antibiotic use through other means. So finding alternative approaches to either do growth promotion, disease prevention for agriculture, and decrease the need for any antibiotics there or any human relevant antibiotics. I don't just mean medically useful, I mean human relevant. The ones that if you got resistance to, the animal, that resistance would cross-transfer to resistance in humans. Even if it's not the same antibiotic, it's in the same class or could be transferred. So I think there's a lot of work in agriculture that says let's find scientific ways, maybe probiotic combinations that you can feed animals that will be effective at driving out a particular bacteria. So tremendous creativity is needed there. All that said, there are other things that are needed to create new antibiotics, so in addition to calling for more research in those areas, and serious funding in those areas, we've got to think about the clinical development path for new therapeutics. One place where you run into trouble is clinical trials. It's not so easy to do a clinical trial. If I have a cancer patient and I try to run a clinical trial, I discover the cancer patient and I could enroll them in the clinical trial for that patient, might start three weeks later or a month later or whatever. If I have a patient with a serious antibiotic resistant infection I've got to enroll them instantly. I don't know when I'm going to see that patient, I've got to enroll them instantly, I'm not going to have that many patients in any one facility. So we need to have the most streamlined, efficient clinical trials infrastructures to decrease the cost to the developer of a new antibiotic, of testing that antibiotic, as safely and effectively as possible. So we call for the federal government to help stand up a national infrastructure for clinical trials of new antibiotics. I think there are pieces already in place that will provide some of that infrastructure, but it needs to be knitted together. And obviously the sponsor of any particular drug should pay for the cost of that clinical trial. This is not to substitute for the fact that developers should pay for the cost, but it's to put in place the ongoing, continuous, as they sometimes say, warm infrastructure, that somebody can drop into, rather than having the huge cost of assembling a clinical trials network for this one antibiotic you want to test. In addition, there are things that the FDA can do with regard to the regulatory pathway for new antibiotics. If you have an antibiotic that treats individuals with a serious life-threatening antibiotic-resistant infection, you could test it in such patients and show that it was efficacious and had acceptable risk profile. That's not that hard to do. If, in addition, you have to test that agent in many patients with other kinds of conditions, where the risk-benefit profile would be very different, that's a much larger and more complicated study. So if there was a way to approve an antibiotic for a limited special use, and with a screamingly clear label that said this is only intended to be used in the cases of, the FDA could proceed with an approval in that case based on a focused clinical trial. But then we have to make sure in protecting patients that the system is there, that everyone understands that. And I think the FDA is, and has been for awhile -- this came up in an earlier PCAST report -- thinking hard about does it have the authority, is it clear that it has the authority, would it be a good idea for

Congress to give it the authority. I think there are many who believe that it has the authority but it's a close call, and therefore might be better for the Congress to signal that. In any case, it's sitting there. We think the FDA should be doing this, and we think that should be resolved. Because we think it is in the benefit of patients that a clear system be set up where people who desperately need these drugs can get it, and where we do everything possible to make sure that it's just those patients who are getting it. Subject to the fact that physicians do have a right in this country to prescribe as they see fit. So you've got to strike those balances. But we think that's worth putting in place. Now, even with a clinical trial system, even with basic research, it is a very complicated economic proposition to develop an antibiotic. We attend to the question of commercial development. We tried to analyze what does the economics of antibiotic development look like. And it's not pretty. It's not an accident that there's hundreds and hundreds, perhaps a thousand agents for cancer in development today in pipelines. Cancer, while it's a very hard disease to treat, there has been a lot of progress, but cancer is something where it's a chronic condition, and it's a condition where for a variety of reasons the reimbursements have gotten to levels of sometimes \$100,000 for a course of treatment. An effective antibiotic should clear an infection in two weeks. It's really not intended to be a chronic treatment. And the idea of paying \$100,000 for that is just wrong -- but when you think about an investor either at a large pharmaceutical company or venture capitalist, scratching their head saying which one of these should I invest in, and they say well, there are a lot of risks around developing this antibiotic, and if I succeed it's not such an attractive proposition economically, maybe I should allocate my capital elsewhere. We do rely on a market, and in order to rely on a market things have to be attractive economic propositions. So we spend a bunch of time trying to think about what are the ways around that. Well, you've either got to decrease the cost or decrease the risk to incent people to come into this market. And you can decrease the cost in a number of ways. You can do it by push mechanisms and pull mechanisms. Push mechanisms would be provide co-funding for good projects that address critical needs. BARTA, the agency BARTA, for example, has done this with regard to agents to deal with bioterrorist effects, it's authority would allow it to take on similar co-funding of projects for situations involving serious antibiotic resistance, and we think it should. This will cost money, of course. It could also alternatively dangle advance market commitments. Saying if you develop this, we'll guarantee that there will be a market for it, so you don't have to worry about that. That's another approach. There are still other approaches you could take. CMS could, in theory, although it would require probably legislation, say we're going to pay a lot more for antibiotics that do X and Y. It's another way. There are de-linkage mechanisms involving lump sum payments. And if you want a totally market based solution, you could simply have tradable vouchers. Anybody who produces an antibiotic that meets this critical public need defined in some way, gets a voucher that they could trade to some other company, that will allow that other company to extend the patent life by three months on some other

drug. That could be worth a lot of money. Now, we're mindful that somebody is going to pay for that. Actually, anything we've said somebody is going to pay for. Whether it's going to come directly out of the federal budget, whether it's going to come indirectly through tradable vouchers, whether it's going to come from insurers. I think we're reasonably convinced as a fundamental theorem that one is not going to be able to incent new commercial development without putting some money on the table. I think that's a basic law of economics, here. This is a partially public good we're talking about, and as a public, we must partially pay for it. Now, there will be economic benefits to the makers of these drugs, and they should be co-investing with it, and we've got to strike that balance. We've laid out a number of options, we've suggested what these things might cost. And I think PCAST has not said that we have done a deep enough analysis to say what's the right choice economically, what's the right choice commercially, what's the right choice politically. Because what would be politically feasible is an important part of this equation, too. We tried to scope out the problem here, and there's just no doubt that without an attention to the economic incentives we're not going to see major investments in new antibiotics, enough to produce the numbers that we want to replace the loss. Finally, stewardship. And I realize -- tell me when we're going here -- we're doing okay. Doing fine. Stewardship. Two areas of stewardship, health care. Well, there are best practices for stewardship of antibiotics, making sure that they're used in the right cases, that they just don't get prescribed willy-nilly, somebody comes in, and they might have a bacterial infection, they might not, and why don't we give them antibiotics because they're cheap; it's not a good solution anymore. We really need to know who should be getting these antibiotics, and when they get them, they should be used for the right amount of time so as not to produce antibiotic resistance. There's a whole set of guidelines that are implemented in a number of institutions are for high quality antibiotic stewardship. It is time to use the levers that the federal government has to promote complete adoption of those stewardship principles. Some of the best levers we have are at CMS, the Centers for Medicare and Medicaid. They have an ability to set requirements for reimbursements or for more or less reimbursement, and that's used in certain cases. And we believe that having an antibiotic stewardship program is a reasonable expectation. Having certain reporting, the physicians quality report system, is a reasonable expectation. And we lay out a set of expectations that can be, yeah, I'm going to say imposed. But the truth is everybody knows this is the right thing to do, and they're not that hard to do. This isn't that hard. This is a question of rationing is all up to what are the best practices for antibiotic stewardship. And we know this works, and we know this promotes the health of the individual patient. This isn't just, quote, just for the benefit of the population, although that's a pretty big benefit, it is shown through many studies that these antibiotics stewardship measures on the whole benefit the individual patient. So there are tradeoffs here. There's just no reason not to be doing good antibiotic stewardship. The federal government itself should practice what it preaches and lead by example, by applying this in its own health care facilities.

And also, where the federal government gives grants, the federal government should be attaching conditions around this for grants related to health care, for example, in various communities settings there should be an expectation. It ought to be universal expectations we are practicing, High quality stewardship. All this stewardship will be aided by better and better diagnostics. If the doc in her office is able to know rapidly whether this is a bacterial infection and whether it's resistant infection, she's going to be able to prescribe correctly. But that means we need really rapid, really cheap diagnostics being broadly available. Now there's been great progress, in hospitals, now there are some pretty impressive technologies that can turn around answers in a couple of hours for a number of things, and we're very encouraged by that. But we think this is a great place where the federal government including the NIH ought to be hanging prizes out there. Prizes to reward people, for companies, inventors and innovators to be able to develop rapid diagnostic technologies that will actually shift clinical behavior, shift clinical treatment. Totally by accident, we found after we wrote this in this report, and socialized this, to find that the United Kingdom has reached the same conclusion and decided for its famous longitude prize it has just announced they're picking the same topic. I think it's not an accident that the US and UK see that better diagnostics here would have a big impact. Then Finally there's animal agriculture. I'll admit up front this is a very controversial subject, and we've heard a lot about it. I'm going to make some statements about it and there will probably be people who disagree with me about these statements, but I'm going to tell you what we've done is tried to read the literature closely and understand the literature as best we can. We -- you know, we don't always sit down and read primary papers, but we did sit down and read primary papers. So, unobjectionable things. You use a lot of antibiotics anywhere, whether it's in human health care or agriculture, you promote the development of antibiotic resistant bacteria. If you use them in agriculture you promote the development of antibiotic resistant bacteria in animals. I don't think that's an objectionable statement at all. Can those antibiotic resistance bacteria transfer to humans? Yes, they can, they do sometimes transfer. There's clear documentation that there is such exchange. Where we are truly unclear is how much of the problem can be attributed to agriculture. I think there's very serious concerns, we share very serious concerns, that it can be a very important reservoir. But if you ask can we pin down all of that transfer, most of the scientific literature until recently has been indirect and correlational. In the last several years with the ability to sequence genomes you can actually see because of all the little genetic breadcrumbs scattered up and down the genomes that things are going back and forth but it's still a limited number of such papers. So I think it's fair to say that over the next several years we're expecting to see an awful lot more data like that. But it's clear it does happen in agriculture, it can transfer, and I don't think we're in a position ourselves to take a position on how much of the total problem it accounts for, even how to think about that question. It still means we have to act. The things I've stated alone are enough of a reason to be acting. And I think everybody -- and I'm impressed with the people we've

talked to in agriculture feel strongly that they have to be highly responsible. That judicious use in agriculture right now is absolutely essential. There may come a point where one will say it's justified to say no use. But a very important step the FDA has taken is a set of guidance it has issued where the FDA has done something very interesting. There's a voluntary part and a mandatory part. The voluntary part is companies that make antibiotics for agriculture are asked voluntarily, would they please withdraw from the label the claim that those antibiotics can be used for growth promotion in animals. You could worry that because that was just voluntary it wouldn't happen. But as of today 26 out of 26 companies said they would withdraw those claims. Once those claims are withdrawn, it is now no longer voluntary. It is then illegal to use those antibiotics for growth promotion. We ought to see a decrease as a consequence of that. It must come under the care of a veterinarian and be used for either disease prevention or disease treatment. Now, we are very aware of there are people who are concerned that disease prevention could be a big loophole. You might say we're going to suddenly want to use the same antibiotics and just say we're using them for disease prevention. I don't want to cast aspersions because I think veterinarians will be responsible -- are responsible people here, and I don't think they will do that. But that's something we're going to have to monitor. If we don't see a decrease in use of antibiotics when one of these major uses, growth promotion, has been now -- will be withdrawn, then that's a pretty serious signal. And we support the FDA's path, and we support monitoring of this, careful monitoring of this. And if in fact, you know, one does not see a response, one will need to take further actions on it. But I'm being straightforward and I'm expecting that what we'll say -- you know, there are folks who probably will be unhappy because they would like to go further and folks unhappy because they'd like to go less far. And I'm telling you this is at least -- I'm trying to read carefully -- I've got to thank all the people who wrote to us, this is about where we're coming out, that we think it's important to move down the path here. Again, the details are in the report. Finally, international cooperation. We run toward the end of our time, I'm going to say simply this is a topic of enormous interest across the world, and we can't do this alone, and we call for international cooperation on these topics. We can't do this without the World Health Organization. And the U.S. has been playing a leadership role here, and the World Health Organization has recently announced an international agenda, and we should be coordinating with it. I've gone on long because it's an important topic. I realize I haven't gone into enough details really to say specific things, I'll ask folks to await the report's actual release because I just didn't have time to go into more details, but I'm going to stop and ask my Co-chair Chris Chyba if he would like to add anything, and then ask if PCAST has questions.

>> Christopher Chyba: I think there's really very little I want to add to Eric's comprehensive remarks. As he said, this is an issue that has been brewing for a very long time, and yet there's a feeling I think in the infectious disease community that it's approaching a crisis. And that means that -- that in part, our report has to focus on immediate steps, that in the short term can help

mitigate the challenge that we face. But as Joshua Letterberg pointed out 15 years ago, and Eric has done a very nice job reiterating, this isn't some kind of conflict that can be won. Our relationship with microbes is a relationship that has to be managed forever. And therefore -- and this is I think the strength of the report -- we also need to be thinking about steps we take in the medium and long-term, that will manage that relationship in a more effective way than we have done to present. And I believe you will find, I believe you have found, that in many of the sections of the report you'll see immediate steps that need to be taken, and then you'll see ground work being laid, whether it's in fundamental research, whether it's in calls for certain type of development, that for managing that relationship in the long term. And in particular, I think in terms of the managing the relationship situational awareness is especially important, and that has to do with surveillance, traditional public health surveillance, and also the opportunity that we have now to establish DNA -- rigorous DNA based surveillance on a national scale. And also, data collection. So we can understand better than we do currently, the effect of steps we are taking and steps that we will take in the future. And finally, I'll reiterate Eric's comments about how this is an a fundamentally international problem, this entire problem exists in an international context. Diseases cross borders with ease. The good news there is that the World Health Organization has recently -- is recently putting in place a global action plan. And the United States has a global health security agenda which should help find the financial resources to make international steps possible. It is very much to our advantage, and this is true not only for fundamental moral reasons but also for national self-interest reasons, to address as much of this problem overseas as we can, in addition to addressing it within our own country. That's all I think I have to say.

>> Eric Lander: Let's throw it open to questions from PCAST. Susan.

>> Susan Graham: I want to check my understanding of some of the things that you just said. When you introduce a new antibiotic, the role of surveillance is to detect the resistance. And presumably, as those techniques improve, we're discovering resistance -- or more broadly, knowing that there's resistance, faster than we did in the past.

>> Eric Lander: We're knowing about its spread particularly. I think that's often -- our surprise some resistance problem has been brewing and then exploding on us, and we could know that a lot faster. But we could also know where it's coming from. Hospitals want to do the right thing. They could know that they're spread within their own institution, for example. That's very powerful knowledge.

>> Susan Graham: So countering that is stewardship which extends the --

>> Eric Lander: Life.

>> Susan Graham: The lifetime of an antibiotic.

>> Eric Lander: Useful lifetime of an antibiotic, exactly.

>> Susan Graham: And what I'm trying to understand is the balance there, and if we were to attempt to project into the future, which side is going to dominate.

>> Eric Lander: Oh, look, stewardship is critical because once you put all this work into getting an antibiotic, if you could get four decades out of it rather than two decades out of it, that would be great. Sometimes we're seeing antibiotic resistance skyrocket much earlier. So the stewardship is critical. But how would you know it's working well, how do you know what to be prepared for in the future without surveillance. So they're both components. Surveillance will help your practice in many ways. So I think they're really two parts of the same equation there, of good management of the antibiotics we have, while on the other hand we make sure we develop new ones. Chris Cassel.

>> Christine Cassel: Thanks, Eric, my congratulations to both you and Chris on a masterful and really thorough look at the original literature about this. I just wanted to -- this is not really I think in the report yet, but to add to the definition of stewardship in two ways. One is we think of stewardship as not prescribing antibiotics unnecessarily. But there's another kind of stewardship, which is reducing the risk of infection so the person doesn't need the antibiotic. And there's a kind of a mass effect that can occur if you think about American hospitals -- I'm putting a connection here with systems engineering.

>> Yes.

>> Christine Cassel: Medicare and Medicaid, particularly the innovation center programs, have incentives in place now under the partnership for patients and other kinds of things, to reduce hospital acquired infections, which is where some of the more dangerous ones are. And we learned that just in the last year that's down 10 percent. You may say 10 percent isn't a lot, 10 percent is half a million adverse events, and 15,000 lives. Not to mention lots of dollars, but also lots of avoided need for antibiotics in the first place. And for exposing those bacteria to more antibiotics. So I think there's a way in which looking at the prevention of infection is an important thing. And then the other thing I wanted to say, which particularly on behalf of my physician colleagues, is that particularly in the ambulatory setting if there is a -- there has to be a partnership with the consumer and the patient.

>> Eric Lander: Yeah.

>> Christine Cassel: Because patients sometimes innocently and mistakenly think I'm not getting good care if I don't get an antibiotic when I go to the doctor. So there needs to be a

whole community effort about educating people about actually that's not the case, and sometimes your doctor is exactly right when they're telling you that you don't really need an antibiotic, and call me, you know, in three days if this doesn't get better kind of thing.

>> Eric Lander: Yeah.

>> Chris Cassel: We just need more understanding of that.

>> Eric Lander: We do. There are risks in prescribing antibiotics, and your point about infection control inspired us. There is a condition of participation in CMS for infection control. You have to have an infection control program. So we're think antibiotic stewardship should follow behind it. I've got Bill, Jo, and Jim, and we'll come to the end of our time, I think.

>> William Press: Thanks, Eric. I think this is a terrific report, and I particularly liked the rational and dispassionate way that it looked at the agriculture question, because that's a question that attracts a lot of heat. I think sometimes the heat is just from communities that aren't really talking to each other, or aren't communicating well enough. I wonder if you could just say a little bit procedurally about how you made contact with those communities, were you able to bring them together around the same table, how did you reach the conclusions that you reached?

>> Eric Lander: Well, I must say within the working group we assembled, we had people from agriculture, people who work for big agriculture companies, and people who are passionate from the public health community, and there is quite a diversity of use. This is a PCAST report, but it's informed by the whole working group. So as we sought people's views, as we asked people to point us to literature we then asked everyone to critique the literature that was being cited in all directions. And then as it became known through the mechanism of our having PCAST meetings and reporting on it, we received a very large number of emails from people. And the scientific public at large wrote with many, many different suggestions and studies, and we put those in front of the working group we had and said what do you make of these. And then after we collected all of that input that had been received, we sat down ourselves and read all the papers. And so I fully understand the passions on all sides of the question. And I think we feel passionate about it, we'd like more data on some things, but we also recognize that there are actions that have to be taken, given the data we have. So it was a really great learning experience for us. And at least in that conversation, it was very respectful conversation because it was about the science. I think there are many people within agriculture who want to use antibiotics judiciously, who would be thrilled if they didn't have to use antibiotics. I think there are many people who feel like there is too much use of it, and not justified given the potential risks. And I think we're on a path right now, but it's a path that I hope gets us to the

right place. And I think this is a good place where having the discussion focused on the science was the right thing to do.

>> John Holdren: Jo.

>> Jo Handelsman: I have a question.

>> John Holdren: The Honorable Dr. Jo Handelsman.

>> Jo Handelsman: I have a question that's for you and Dan Schrag, because you might have come across it in your studies. The last thing Dan said to me as we were coming into the room, was market economics works. If people eat more broccoli, there will more broccoli produced. It seems like that principle failed with antibiotics. Why didn't the price go up because people are dying? It's very immediate, it's like cancer except quicker. They need drugs, their families want them to have drugs. Why haven't the prices gone up and just made it more of an incentive? And is it different from broccoli, Dan?

>> Eric Lander: Well, we take refuge in the fact the report is we're the President's Council Advisers on science and technology, and the folks who should really answer those questions are the council of economic advisers. But when you think about the alternative investments people can make, uncertainty plays a very big role here. Knowing that you're going to really have a market, you need a very big risk premium. Not having as many precedent cases. You can say I'm going to try to get \$100,000 for an antibiotic, but there is a period when nobody was sure they would see those reimbursements in cancer. When you saw a precedent in cancer -- I'm not saying that's a good or bad thing that these treatments are so expensive, but I do know it has produced a tremendous amount of interest in producing treatments. There's not a precedent path right now that says that's going to solve that. Moreover, there's a bit of a Catch 22 here. If you've got a lot of money for it, you probably want to promote the broad use of those antibiotics so you'd get more money. We actually don't want those antibiotics to be used broadly. In a certain sense the optimal world is to have those antibiotics and have them be used judiciously. That's a very perverse incentive for the manufacturer. So for a lot of reasons I don't think we have a perfectly functioning market, because here we have an externality your use of an antibiotic screws up Mario's use later, because you're contributing to -- through your use you're creating an externality of resistance. So in situations like that, markets can fail.

>> Jo Handelsman: I beg to differ with that, remember I'm honorable.

>> Eric Lander: Oh, yes, sorry. Not Jo's use of the antibiotic, but someone injudicious and less honorable might be doing that. In any case, it's a complicated thing. I think we understand a little bit of the economics of why people do it. And we talked at length to people in the industry as well about this, we involved some of them in the working group. And they walked us

through, and we compared to other people's analyses of the economics. You know, there's just a big premium to pay to come into it. And some of what government co- sponsorship can do is erase that premium and set it back to the right level. Finally, Jim Gates I see the last flag up.

>> Jim Gates: Thank you. First of all, congratulations to you and Chris and all the group. This is a fabulous report, and I'm confident that it's going to meet with the full approval of this group. As I was reading the report, and perhaps I missed this, I need the answer to a question. In an article I guess let's see in March one of our colleagues said that physics isn't sexy, but everybody looks up. Meaning that one of the reason that astronomy gets so well supported is because everybody can relate to it. So when we sort of bring this issue over to AMR, is there some -- and in particular, the philanthropic community has in recent times become a remarkable source of funding for science. So the thing that I didn't see in the report was our kind of reaching out in that direction, saying there are other resources that could perhaps be brought to this problem. And as I said if it's there I missed it and I apologize. But my question is can we make AMR sexy in the way that some of these other diseases are and generate a community interest

>> Eric Lander: I do want to acknowledge that foundations like the Gates Foundation takes these questions very seriously and has put significant funding behind it. And I think there are other foundations as well that take the antibiotic resistance question pretty seriously. But is it sexy? I think it isn't yet, because the way it arises is a patient comes into the hospital, gets something, it's not a sexy thing, and I think -- I don't know which presidential council has expertise on sexiness, it's probably not us. But in any case. (Laughter) It is a worthy question to ask about how to get more public attention on this question. So I realize we're at the end of our time. And I want to first thank the people who are involved in the report, and then I'm going to turn to John, who I think will ask for a vote on this. The members of PCAST who were involved in this, and providing input. The members of our working group, I particularly also want to thank two people who played a critical role in the staffing of this report, Ashley Predith, and my own assistant Kristen Zarelli who is down from Boston here today to attend this public session, to thank them for putting up with us through innumerable drafts of this thing. I'm going to turn it to John.

>> John Holdren: Thank you, Eric and thanks to you and Chris Chyba for Co-chairing this effort. Let me now ask for a show of hands from PCAST members. All of those in favor of approving this report contingent on the usual final edits, please raise your hand. All those opposed? Abstentions? Seeing none, the report is approved with the usual condition of further edits.

>> Eric Lander: Great. And I will say I am sure there will be people from the press here who will say, can I get a copy of the report in advance of the usual edits, and can we talk about details of that. And I'm going to apologize in advance, we have to actually get the thing properly edited. But we will arrange that at the point of public release we'll have an availability by phone to be able to talk to people about details. Thank you.

>> John Holdren: Good. With that, we are going to take a 10 minute coffee break, or maybe 12. Be back here five minutes later than scheduled, 10 minutes to 11:00 promptly, please, and in the meantime happy coffee.

Oceans Science and Policy Panel

>> John Holdren: So let me welcome everybody back to the continuation of this 30th meeting of President Obama's Council of Advisors on Science and Technology. We're very pleased indeed to have a distinguished panel to discuss with us the very timely and important topic of ocean science and policy. I'm going to introduce the panelists very briefly, because the members of PCAST have their bios in the briefing book. But we'll be hearing from Beth Kerttula, who is the relatively new director of the National Ocean Council charged with implementing President Obama's national ocean policy. Beth was previously a member of the Alaska state legislature, and for many years its minority leader. Bob Gagosian is the president and chief executive officer of the Consortium for Ocean Leadership. And I first really got to know Bob when he was director of the Woodsall Oceanographic Institution. Anthony Knap is the director of geochemical and environmental research group, professor of oceanography and the James Whatley endowed chair of geosciences at Texas A&M University, a leading expert in ocean science. So we are really delighted to have the three of you with us, we thank you for being here. And I'm going to turn it over to you for your initial presentations, after which we will open it up, and Eric Lander will moderate the discussion with the PCAST members. So Beth are you going first?

>> Beth Kerttula: I am.

>> John Holdren: Good.

>> Beth Kerttula: I get to sit with the mic, thank you, sir. All right. Thank you very much. And very pleased to be here today. I'm Beth Kerttula, I'm the new director of the National Ocean Council. My honor to be presenting to you today along with Dr. Gagosian and Dr. Knap. Their tremendous knowledge and experience about science, the ocean, climate change and the observations, are going to make their presentations very informative. As Dr. Holdren said, my background is in law and public policy. I was in the Alaska legislature 15 years. I represented a

coastal fishing district in Southeast Alaska, and ocean issues have been paramount to my community and to me my entire life. Before I begin, I'd like to thank Drs. Holdren and Lander and members of the PCAST. I'd like to thank Marjory Blumenthal and her staff. I'd like to thank Dr. Bradley Moran without whom I wouldn't have this presentation. Tammy Dickenson and Hanna Stafford from OSTP for helping me prepare, and our wonderful National Ocean Council intern Ph.D. student Crystal Pree. My presentation is about the national ocean policy. Next slide. Many of the photos I've used are from Alaska. This is Kachemak Bay looking west from Hesketh Island at sunset. This was taken by my cousin, and the quote, of course, is from President Kennedy. Just as he said, many of us are tied to the ocean. And indeed, according to NOAA information, 39 percent of Americans live in coastal shoreline counties representing less than 10 percent of the U.S. land area. Now, that excludes Alaska, and we would skew that result, but it's still impressive. Slide 3. As you can see from the timeline, President Obama and his administration have taken national ocean policy very seriously. From the beginning of the interagency policy task force five years ago, through the executive order, up to the national ocean policy implementation plan, and the marine planning handbook just one year ago, the administration has shown a commitment to working with states, tribes, regions, local communities, industries, stakeholders, and academia, to have scientifically informed, common sense solutions to ocean issues. Next slide. Overseeing the national ocean plan and its implementation is the national ocean council. 27 federal agencies and offices are on the council, co-chaired by the directors of the office of science technology policy and the council on environmental quality. Next slide. But what does the national ocean policy really do? Why do we need a national ocean policy? I think it's back one. Efficient federal permitting, coordination of federal resources. I think it's the other slide. There we go. The benefits. Efficient federal permitting. Coordination of federal resources, and developing sound scientific information are some of the critical points of the policy. I've already mentioned that a lot of us live on the coast. Economically many of us depend on the ocean for jobs, food, transportation and shipped goods. We love to be at the beach. We fish, we surf, kayak and cruise. As Drs. Gagosian and Knap will be explaining, the ocean profoundly affects our planet. Federal agencies spend a lot of time and effort and have a lot of knowledge about the ocean. States, tribes, local communities, industry and stakeholders depend on the ocean and interact with the federal government about the ocean. All in all, it just makes sense to have a plan on how we all interact concerning the ocean. The national ocean policy and its implementation plan organizes federal agencies to work more effectively together and to collaborate with everyone else. The photo is of subsistence users at fish camp on the Yukon River in Alaska. Slide 6. More specifically, the next five slides outline the five major users in the national ocean policy's implementation plan along with some major highlights of accomplishments from 2013. And before I begin with the slides, I just want to commend that yesterday -- two days ago I got to sit in on one of the working group meetings of the federal agencies. In fact it was the two major ones getting together for a

biannual meeting. And these highlights are just the tip of the iceberg. The federal agencies are coordinating and sharing information in a productive way, and it's very exciting and energizing to see that. I've worked with state resource agencies for a long time and I can tell you that a lot of my frustration working with them came from the fact that you get into turf battles, you get siloed, you don't share information. And that's just a very difficult thing to work with. I've been trying to think of an analogy, and the analogy for me is my mother recently had a stroke, and in health care we see this intense specialization at times where the doctors don't talk to one another. And that's what happened to her. One specialist didn't talk to another, medicine went ungiven, and she had a stroke. Thankfully she's going to survive, but it's very similar to what we see sometimes with resource agencies in the states. And getting to watch the federal agencies working together collaboratively, sharing information, sharing resources, is just a great way forward, and it can lead to many healthy interactions for the ocean. Back to the implementation plan itself. The first main point in the national ocean policy implementation is the economy. Not only do many of us live next to it as I've talked about, but in 2010, 41 percent of our gross domestic product was generated from shoreline counties of the U.S. and territories including the Great Lakes. Employment, commercial fisheries, Marine recreational fisheries, offshore energy, mineral production, the cruise industry, shipping, and not even accounting for subsistence use, it all is a tremendous benefit to us economically in America. Given the huge economic impact our ocean has, coordination among federal agencies to support healthy economics seems paramount. One of the highlights has been the national fishing initiative from NOAA, and the national fishing initiative promotes these kinds of healthy interactions. Launched in 2011, the initiative aims to increase populations of oysters, clams and mussels, and to create jobs, produce more American seafood, and create habitat for endangered species. This will also support cleaner water, protect shorelines from erosion and weather events. But the national effort has spun off into the states, and I've seen some of this. Washington, California, even Alaska, has begun to really take a hard look at their shellfish work with the federal agencies, have private, public partnerships, and a huge issue you're going to hear more about soon, work on ocean acidification. The partnership is encouraged by the national ocean plan and the implementation plan are showing gain. Second area in the implementation plan, safety and security, don't have to tell you how important our waterways and our oceans are to the nation's safety, and of course the warming of the arctic is posing a tremendous threat to our national security. The good interagency work being done by the Department of Defense, U.S. Coast Guard and NOAA, to ensure consistent data formats allowed for the use of best information last year. Also, NASA is working to accelerate the release of sea ice and snow thickness data in an ever-changing arctic environment with increased shipping routes, this information is going to be vital. And it is astonishing how fast this change is coming, and how fast the shipping is happening. The transit routes, I don't have that on the slide, I wish I did, are just increasing, and it's an increasing risk to the arctic. And NOAA, NASA and the Coast Guard

are doing a great job of coordinating, working with the states to be able to get information quickly out. And this of course also, under the next highlight, helps navigational safety. The Coast Guard and NOAA have coordinated together to set buoys, and that saves time, money. And a place like the Bering where they started, it saves lives. Next slide. Coastal and ocean resilience is an incredibly broad topic. When I think about it, I think about the villages of Kivalina and Shishmaref in Alaska that are literally going into the sea. But the same issues arise in southern Florida and here on the east coast. You'll see more about this on Dr. Gagosian's slides, but how to reduce adverse conditions and prepare for change is part of the new normal encompassed by the national ocean policies implementation plan. To highlight, now there are web based scenarios, so you can actually go online and see sea rise scenarios to help you understand possible impacts. And also through great cooperation among the agencies -- and I've seen this again mostly on the west coast from my experience, a lot of work to save coastal wetlands. Which not only protect us, and our communities, they create habitat for fish and wildlife and critical for the oceans. Fourth in the implementation plan is acknowledging local choice. At the heart of the work of the national ocean policy and the implementation plan is working cooperatively with communities, tribes, industry academia, and recognizing local and traditional knowledge. That is a huge step forward, and it is important in and of itself. If the plan did nothing but work on coordinating, permitting and recognizing local and traditional knowledge, it would be a tremendous document. You know, we have a great source of information in local and traditional knowledge, and we ignore it at our own peril. Local and traditional knowledge can give us information about natural history, cultural geography, weather, ice conditions, harvest patterns, and oral traditions. Very quick story many of you will have others about local and traditional knowledge. My father served in the state legislature as well. One day one of the agency representatives came in to make a presentation to the senate finance committee which he was on, and I watched this person come in and say, "You know, we've spent a couple hundred thousand dollars, but by golly, we've discovered the place where the dog salmon spawn, and it's on the Nulato River." So he was going on and on, and the Co-chair, Senator John Sackett and himself from that region, looked at the state agency representative and he nodded and he thought about it a minute and he was pondering, and then he said to the state representative, "That is very interesting. And do you know what Nulato means? And the man said no. And Senator Sackett replied, "It means place where the dog salmon spawn." (Laughter) Now, that's a funny example but, you know. And everybody in Alaska remembers that example. But there have been really important economic endeavors that have been stopped or haven't been able to progress in a healthy way, because of the failure to work with the communities. The failure to work with the local people, the indigenous people in particular in Alaska, that have that kind of local and traditional knowledge. The implementation plan uses it, helps utilize that critical information, in a respectful and collaborative way to the benefit of us all and the ocean. A highlight of local choices is the

creation of the regional planning areas and the regional planning bodies. There are nine regional planning areas that cover the coast line of the country, and, next slide, four regions have chosen to voluntarily establish regional planning bodies. The northeast, Mid-Atlantic Caribbean and Pacific islands, and two of these regions are very close to having their final plans. It's a very exciting way to have local input on how we cooperatively use our ocean. To doing this common sense solutions for shipping routes, avoiding whales, avoiding rigs, avoiding fishing boats, how we just make it all work together in one plan. Next slide. So maybe more to point for you all, final point, not necessarily in, you know, order of importance, science and information. As in my previous slides, as a legislator, I can tell you that all too often we had votes where I can tell you very few of us on the floor understood the ramifications of our actions. I sat next to a Ph.D. geologist and I can tell that you he spent his days holding his head because of some of those folks. But science and information has to inform decision- making, and we have to get the information to decision-makers. It's too important. So one of the highlights is the federal oceanographic fleet report in 2013. 47 ships from differing agencies coordinating to measure and project climate change. Again, ocean acidification, to protect lives and properties to do the warnings for tsunamis and hurricanes and navigational mapping. Hopefully we'll have even more highly advanced ships introduced and continue the good work of this fleet Brad Moran kidded me that this isn't the Arctic, but I couldn't help but put in at least one Hawaiian ship. Slide 11. what comes next. This is a shot from the devil's thumb out of Petersburg, and I don't know, that may sound a little ominous, but really the future is really very exciting. One of the most exciting things to happen right after I came on June 17th, the President established a task force to combat illegal, unreported and unregulated fishing and seafood fraud. Being from Alaska, where commercial fishing provides the most jobs of any industry, and where we take our fishing seriously, I can't tell you how good a step this is. It not only helps the consumers, it helps the fisheries, it helps stop unsustainable fishing practices, and of course, it combats the fraud. Understanding where our fish comes from is a very good step in traceability. The task force is now to report to the national ocean council within six months and they're already working very hard. The second point is the governance committee. The governance coordinating committing under the national ocean council is formed of state, local and tribal representatives. These people report directly to the national ocean council, and we're working for new nominations for the next governance coordinating committee to be able to work hand in glove with the national ocean council. And we should have that first meeting of the next committee this fall. Finally, the work will continue with the regional planning bodies. To come up with common sense solutions for tribes, stakeholders, and to find solutions to ocean issues. Next slide. There's my contact information. Next slide. Right This is a Beluga. We have a lot of them in cook inlet and on the coast of Alaska they're important for subsistence hunters, and he's saying hello to you, I hate to admit, from the Georgia aquarium, but it was so delightful that I had to include him. And finally, thank you very much. This is my cousin Alden

this summer holding her first commercial fishing cast in Lynn canal near Juneau, Alaska. We've had some internal family arguments about whether those are both red salmon, but my cousin ensured one is a chum and one is a red. So there you are. Thank you very much for this opportunity, I look forward to hearing the next people.

>> John Holdren: Bob, are you next? We'll hold the discussion until all three speakers have been heard from.

>> Robert Gagosian: I very much appreciate the opportunity to talk to you about the effects of climate change on the ocean. I'd like to briefly outline for you some of those effects and then talk in more detail about one of them, sea level rise, because it encompasses the majority of these effects. The IPCC pretty clearly has shown climate change is real, it's here to stay for some time into the future. You all know this. The latest report in the national climate assessment report strengthened this conclusion even further. An increase in atmospheric carbon dioxide emissions have driven temperatures up .8 degrees centigrade in the last 100 years. Second part of the IPCC report concluded that even the best case scenario would result in an increase in global average global temperatures of 1.6 degrees centigrade, or the worst case scenario of 3.7. Now, what does this mean for the ocean? The predominant physical feature of our planet that covers 71 percent of it, with an average depth, I want to remind you, of two and a half miles. The ocean is a critical part of a complex climate system of atmosphere, land, ice, and humanity, as it absorbs, stores and transports vast amounts of the earth's heat, water and carbon dioxide around the globe. The surface has warmed six tenths of a degree centigrade since the mid-70s since mid-1970s and the predictions are that it continues to increase. In fact just the top 10 feet of the ocean holds as much heat as the entire atmosphere. Now, over a third of the carbon dioxide that enters the atmosphere ends up in the ocean. So does this temperature increase and CO2 increase in the ocean make a difference? If so, how, where, and when. The transport of heat, carbon dioxide and water across the ocean-atmosphere boundary vertically into the deep sea and horizontally through ocean currents is critical in controlling the climate system. Now, beyond driving the climate system, to me anyway, it's sort of climate's flywheel, the ocean itself is being affected in a number of ways. First, increasing CO2 reacting with the ocean is making it more acidic. How will variations in ocean acidity affect oceanic biology. Second, the circulation. The melting of Arctic, Greenland and Antarctic ice is increasing the freshwater input, thus disrupting the temperature-salt balance circulation of the ocean. How will the opening of the Arctic ocean with sea ice loss change ocean circulation and climate variations from influx of less dense freshwater? Thirdly, warming also changes ocean currents and circulation, thereby impacting and influencing the transport of heat, oxygen, and nutrients into the deep sea, which affects the productivity of not just fisheries but the whole food chain. Its biodiversity, species distribution, and migration. This change in ocean heat content and structure will have profound impacts on ecosystem structure and function. Thus, understanding

ocean mixing vertically and horizontally is really key here. And fourth, the impact of sea level rise driven by rising ocean temperatures and melting ice has exacerbated -- is exacerbated by the predicted increase in high precipitation weather events and associated storm surge. So it's this nexus of extreme weather events and sea level rise. For instance, the 20 to 25 foot storm surge in superstorm Sandy is equivalent to the wave height in several areas of Japan that were impacted by the tsunami of 2011. A tsunami as you all know is a relatively short term wave action, whereas a superstorm, or hurricane, is a surge that just keeps on coming until the wind dies down. Of this group of impacts I want to focus on the issue of sea level rise. I feel that if we can't improve our capacity to forecast the rate of sea level rise and we don't learn how to adapt and start making long-term plans now, sea level rise will have a huge economic and national security implications for the future of this country and for the world. Why do I feel this way. Global average sea level rose by 6 and a half inches during the 20th century. But by the end of that century, the rate at which global sea level was rising doubled. Everything revolves around the rate of change. Locally of course the level of the sea relative to the land or relative sea level varied by greater or lesser amounts depending on the vertical movements of continental land masses. Also sea level does not rise uniformly throughout the oceans as a result of differential warming and redistribution of ocean waters. Further complicating the ability to forecast future sea level for any given coastal region of the world. You definitely have to take changing ocean currents into consideration. So why is global average sea level rising? Why isn't this working? Thank you. I'll go to you, okay, from now on. Thanks. It's the result of several factors. First, the melting of glaciers and ice caps such as the polar ice sheets on Greenland and Antarctica. Second, the thermal expansion of warming ocean waters. And third, changes in water storage on land. Either through droughts and evaporation or human demands for extracting water. The contribution to sea level rise of the melting of polar ice sheets dramatically increased the last decade. In the next slide, as a matter of fact, Arctic sea ice has shrunk 40 percent since the early 1980s that's an area the size of Europe. Current estimates suggest that a global sea level rise of three to five feet during this century is not only possible, but likely. Furthermore, sea level will continue to rise for centuries as an irreversible consequence of climate change, even if greenhouse gas concentrations are stabilized. So mitigating the increase in greenhouse gases will only limit the height of sea level rise. Adapting to what is already occurring, and what will continue to occur is essential. Although global estimates are several feet, locally sea level rise may rise as little as half a foot or as much as five feet by end of the century. This differential is driven by a number of processes a major one being areas where the land is also sinking. In the next slide, an excellent example of the effect of this process is Venice, Italy, where the pumping of freshwater has lowered the mean sea level significantly. Venice subsided about six inches in the 20th century due to natural hydrological processes and ground water extraction for freshwater. Plus it saw a sea level rise of about another five inches at the same time. Now, in the next slide this uncertainty regarding

the rate of sea level rise has major consequences with regard to its impact on coastal environments, communities, and infrastructure. Sea level rise will not only affect shoreline erosion and inundate low lying land but it will also exacerbate the risk of storm surges a 100 year flooding event would occur annually with just a one and a half foot rise in mean sea level in many regions of this country. Keep in mind that sea level rise that is already occurred and will be experienced in the future is unprecedented during modern civilization. For the several hundred years prior to the industrial revolution, global sea level rose only slightly. During this period, and into the mid-20th century, present shorelines and wetlands were formed, communities were established, and infrastructure was built. Next slide, please. Coastal infrastructure such as roads, bridges, train tracks, ports, wastewater and drinking water facilities, oil refineries, and nuclear power plants are vulnerable. Just drive from Miami to Providence on interstate 95 or drive on interstate 10 from New Orleans to Pascagoula, Mississippi. Many of our major coastal cities are really exposed to the threats of sea level rise. The devastation from superstorm Sandy would have been very different in a one foot sea level rise scenario. Miami is a city that is experiencing the effects of sea level rise right now. They spend millions of dollars a year on electricity to operate the pumps 24/7 to keep the Atlantic ocean out of downtown Miami. Sea level rise also cost governments and private landowners hundreds of millions of dollars as they pump sand onto eroding beaches and repair the damage from storm surges. Rising sea level will also increase the penetration of salinity into estuaries and saltwater infiltration of coastal aquifers. This is really becoming a significant problem in the San Francisco bay delta, Sacramento river basin, an area affecting ecosystem structure and availability of fresh drinking water. But you know, there are also significant national security issues associated with sea level rise, because Naval bases are located at sea level, and Navy infrastructure planners work on 25 to 50 year time scales. Currently, the Navy is spending many tens of millions of dollars on their major base in Hampton Roads, Virginia, which, by the way, is one of the biggest naval bases in the world. And this money is not going towards just raising docks, it's going to completely rethinking the city's transportation infrastructure on how to get people to Hampton Roads through the highway system in order to ensure the operability of civilian and military infrastructure. About 7 to 8 million Americans live within six feet of local high tide and risk being hit by more frequent coastal flooding in coming decades because of sea level rise. Globally over 150 million people live in coastal areas within three feet of present day sea level. If the rate of sea level rise accelerates as much as expected, coastal flooding at levels that were once rare could become a very -- an every few year occurrence by the middle of this century. By far, the most vulnerable, and so in the next slide, is the state of Florida. With roughly half of the nation's at risk population living near the coast on the porous low lying limestone shelf that constitutes much of the state. But much of the east coast is also vulnerable because of the shallow wide continental shelf, its barrier islands, and its location relative to ocean currents So sea level rise requires a long time scale decision-making process which huge

demographic, cultural, societal and financial ramifications for cities, their surroundings, and their inhabitants. There are some extreme solutions, by the way, that society has dealt with, with respect to sea level rise. The leaders of Kiribati, a group of 32 islands located in the central tropical Pacific Ocean, have come up with a unusual plan to deal with fears that rising sea levels could wipe out their entire Pacific archipelago. If sea level continues to rise at projected levels, it's estimated that by 2100 the entire nation might be submerged. So the Kiribani cabinet endorsed a plan to buy 6,000 acres in Fiji's main island, an area that could accommodate Kiribani's entire population of 103,000 people. Kiribani's president stated his people need to find employment, not as refugees, but as immigrant people with skills to offer. People who have a place in the community. And people who will not be seen as second class citizens. So ladies and gentlemen, there is a serious geopolitical issue here, and there are serious other geopolitical issues facing our human species and our way of life and culture. Next slide please. In order to adapt to a rapidly changing environment, we need the capacity to predict and reduce the risks of vulnerabilities of future ocean scenarios, and that requires models based on the best science, which requires physical, biological, and chemical data, which are obtained from observations. Remotely by satellites and radar, and in situ with buoys, autonomous vehicles, vessels, stream and tide gauges, et cetera. It's plain and simple, there's a lack of observations. There's a thousand times more heat in the top meters of the ocean than there is in the entire atmosphere. Yet, the National Climate Prediction Center collects roughly a thousand times more atmospheric data than subsurface ocean measurements for their storm models. Hurricane forecast have improved with regards to track, but not with regards intensity. There's a lack of subsurface water temperature data. Fluctuations and predictability in decadal variability in the Atlantic and Pacific are also poorly understood. And as you all well know, El Nino issues are decadal. The southern ocean takes up half of the excess CO2 and heat, yet it's the least sampled and most underrepresented in climate models. We need to be sampling the ocean 24/7, 365 days a year. We need the development and deployment of multipurpose ocean observing systems, particularly in the deep ocean, the high latitudes, and the southern ocean. This data is essential before we can accurately predict the effect of climate change on ocean processes and the effect of the ocean on our climate. Thank you for listening. Last slide, please.

>> Thank you. And let me now call on Dr. Knap.

>> Anthony Knap: Well, thank you. It's a pleasure to be here and I appreciate you asking me to present to you. Second, I'd like to really start with an apology. I've been in Texas, I admit, for only 15 months, so I don't have a Texas accent. And I've had 32 years in Bermuda, so this accent -- anyway, this is the way it's going to be. And I speak in terms of metrics rather than my colleague here who is still in the old ages. But that's okay. So -- so I think both presenters have proved I think that the ocean is important. And we should really have an organized and

sustained approach to measuring it, understanding it, and conveying information about its health and its state. Next slide. So I'm just going to give a summary which is I believe you can only manage what you can measure. The commitment to a sustained globalization observing system is essential, this commitment will require new technologies, especially good sensors for biology and chemistry as well as physics. And sufficiently globally distributed platforms. The government and private sector need to work together more, especially in these times of short notice. Next slide. So the world observing system was proposed by Henry Stommel from the Woodsall oceanographic institution, a long time ago, and John woods who was chairman of the panel of the intergovernmental oceanographic commission wanted to create a wet office, which was the ocean analog to the met office, the meteorological office So the program started in 1990, it was a blue ribbon panel, people like Carl Wunsch from MIT and Walter Munt from Scripps, people who know a lot about the ocean, were part of that. The system was supposed to be built out by 2007; it's not. Just as an aside which I'll come back to, Stommel wrote an imaginative story about gliders roaming the ocean remotely measuring the ocean from a land based mission control. You'll see by the end that we're close to that. Next slide. So where are the gaps. Well, the system the not fully built out, there are funding issues. The sustainability of the system, they're not at full operational capacity even though they're in the water. Many are funded through research programs rather than operational systems, and they compete with peer reviewed science, which is as I believe a big issue. The deep ocean, under 2,000 meters, as Bob said it was -- I can't remember how many miles, but it's 4,000 meters average, is very undersampled, and it's an issue of technology and cost. And physics is far more developed than biology and chemistry. There are some winners. Satellites giving us sea surface heights and surface temperature, ocean color for productivity. The Argo system, which I'll explain in a minute. And also marine microbiology and genomics have expanded thanks to efforts of the National Science Foundation and in a public private partnership with groups like the Moore foundation who have made a huge difference. Now, emerging nations are starting to play an important role. South Korea, China, Taiwan, India, Brazil see value in ocean research because they eat a lot of what's in the ocean. And thanks to the partnership and observations of the global ocean, of which Bob Gagosian is one of the founders, they work very hard in helping the emerging world sort of develop. However, we're a long way from having an integrated system. Next. So we go from ships to floats to gliders to organisms. So top left slide is a float that was developed in the 1990s, the bottom left slide is the five years later, some sensors were added and the Argo program was started. 3,000 floats were proposed, each returning a profile of zero to 2,000 meters every 10 days. That led to gliders which have positioning which I'll talk about in a minute. And top panel on the right are the animal oceanographers, mainly used in the southern ocean. These are pinnipeds with devices attached to them. They go about their life feeding and doing things and collecting profiles. I'll show you how useful those are in a minute. Next. This is how the Argo floats work. They spend a short time on the ocean surface, deflate a

bladder, go to 1,000 meters, drift for 9 days, go down to 2,000 meters, take a profile coming up. So every 10 days these gliders give a full oceanographic profile of temperature, salinity and depth. They last roughly about five years, they cost about \$18,000 each. Next. This is the slide from February 2014 that announced 30 nations involved, 3,600 floats. You have to pardon this slide because it looks like the ocean is very well measured. Each one of these floats is about 5 times bigger -- the dots about 5 times bigger than Bermuda. So it artificially looks like we really have got the ocean completely covered, but we don't. The green dots are the U.S. 1800 floats. Next. This is the IPCC assessment chapter 3, the importance of the ocean to global heat. In blue is the upper ocean, light blue. Dark blue is below 700 meters, and the other little things below that are the ice, land and atmosphere. Because of the density of the ocean this was an obvious thing that would happen, a lot of the heat is moving into the ocean. Next. And so one of the things we're learning is that we really need to understand the deep ocean. If the deep ocean is warming, that's going to -- Bob was explaining the expansion of the ocean, and sea level is going to be a lot different than what we expect from 700 meters. So new floats up to 6,000 meters are being tested. And because the temperature and salinity don't change much, this has to be done at the same time as developing new methods and very good methods for measuring temperature and salinity accurately. Next. This is the ocean sites network, these are the fixed platforms, these are mainly for physical parameters. The green dots again, these are now bigger islands than before, you know, probably Rhode Island, the big ones in the center. So the Toga Tower array in the Atlantic is the parata array, then there's the Indian Ocean array. The Indian Ocean array is interesting because China used the data -- China has data buoys in there, and they use that data to decide where they're going to plant crops depending on the rainfall that they develop through models. So they're very useful. Next. Now this is the only biology you're going to see, but marine ecosystem changes are in the sample. In 1986 David Carl of Hawaii and I got together, we produced two proposals that went to the National Science Foundation to create HOTS, the Hawaiian Ocean Time Series, and BATS, the Bermuda Atlantic Time Series. And these through really the community of reviewers have continued throughout. The research programs that are funded as almost observational programs. The phytoplankton have changed, the little organisms that live at the top that take the sunlight and convert it to energy. There are fewer diatoms, fewer coccolithophores, you don't have to remember this, there are a lot more small phytoplankton. So we've changed the whole structure. The problem is that we're the only people that have ever taken those measurements. So we don't know whether this is happening in the Sargasso Sea or whether this is happening in the rest of world. We believe it's a physical biological problem where because the ocean is warming, there's less mixing, less silica is coming up to the surface of the ocean and diatoms and coccolithophores need silica. Next. This is an important slide, although a busy one. These are a number of time series that have been going on, these are sustained observations from the north all the way down to New Zealand, and they show CO₂. And this data is remarkable, it's the longest, I have to say, the longest

continuous record is at Bermuda, it started in 1982. So without these records we wouldn't know really what was going on over the long term. So sustained long-term observations are important. Next. This is the world ocean database by instrument type. Now, I want you to look at 1965, roughly, and go straight along the top. In brown there were some moorings put in in the mid-2000s but they didn't last very long. The green are the pinnipeds, so they gave some data. But if you look at the purple, that is the data rate coming from Argo. Without Argo, with the decline in ships, et cetera, we would have gone backwards. As it is, we've basically stayed the same with ocean data since 1965. I think we can argue whether that's good or bad, I tend to think the latter. Next. I'd like to switch gears. We're -- this is near my Texas home, this is the Gulf of Mexico this is a measuring system that measures sea level height, and in the red there is an eddy that spun off the gulf room current and that eddy has got warm water in it, about 60 centimeters high -- what's that in feet, Bob? Anyway. Sorry. The blue is cooler water, which is about 30 degrees centigrade. This gives us a proxy for ocean heat. The problem is these satellites go over -- one goes over every 10 days a part of the gulf and one goes over every 17 days and we get a composite. We don't know exactly where the heat is, if it's concentrated in the top, or whether it's concentrated over the whole water column. Next slide. So this is why it's important. So this is the Gulf of Mexico temperature on the left panel is the Gulf of Mexico prior to Rita in 2005 and at 75 meters depth you can see the loop current is full of very warm water. Next slide. So hurricane Rita intensified and so did Katrina, and there was enough heat in those areas that they got up to category 5's. Which is quite unprecedented for the Gulf of Mexico. Next slide. If you can see on the left side hurricane Rita, which was supposed to go to Galveston, started off very cold water that was under it and you can see the wake you can see it's pulling up very cold water and that water cooled the right side of the storm by 5 degrees centigrade and the same with 75 meters depth, it was still drawing energy out. So there's a whole connection between the ocean and intense storms, it's very important. And as we are warming and shallowing the mixed layer there's going to be more storms that are available -- or more heat that's going to be available to provide energy for new storms. Next slide. This is the glider. These are two gliders from 2012 and 2013. Left is 2012, you can see the glider path at the top and you can see it found a very deep pool of high temperature water. This would have caused a very intense hurricane. And then on the other side in 2013 they didn't sample the same space, but you can see less of a shallow amount of heat. And so you'd have probably a less chance of a major storm at that time. I should say I was on the board of a reinsurance company at that time, and insurance companies and businesses are making quite a lot of -- either winning or losing depending on how they get the ocean heat content right. Could I have the next slide, please. So this is one -- a picture that came out I think Beth mentioned 47 ships. This is -- came out of science magazine, and I couldn't change the slide because they say you're not allowed to change it. But this on the left bottom panel 2001 there were 28 ships in the U.S. fleet, there are now 19. By 2025 this is forecast to be 13. I think this is a huge problem. Unless

of course the other agencies that are doing operational work update their game, and add more ships. Can I have the next slide. So these are some gliders. So these are some emerging technologies. Everyone is working on trying to make measurements cheaper. Top right panel are the Slocum gliders, I mentioned Henry Stommel in the beginning, his view, these are produced by a company called Teledyne, and there are 420 have been delivered so far. They dive along at 27 degree glide path, can stay out for three to six months depending on their battery -- type of batteries they use. Bottom panel on the right is a wave pad vehicle, this is built by Liquid Robotics, it uses wave energy to power itself. This one is called honey badger, and it's going from Hawaii to the west coast of the United States and it's towing a holographic camera we put on, we were afraid it was going through the white shark cafe, I don't know if you know that part of the Pacific, but it looks a bit like a lure. So we'll see what happens. Top left is a new vehicle called an autonaut, it is like a dolphin tail, we'll try to put It has a fuel cell in it, as well. And the bottom is just another surface glider. There a winch in it that will allow us to do 150 meter profiles for 90 days every two hours. are many types of gliders, and in this short presentation I don't have much time to tell you any more about them. Next slide, please. So this is the Challenger expedition, it's a ship the Challenger that went around the world mainly visiting, if you remember what the world was like, British colonies. So hence my accent. And it visited various places around the world, 40 volumes of incredible scientific work was done from 1872 to 1876. Last slide please. This is the return of the Challenger. This started in March this year, it's going to go for two years, 16 gliders going around the world measuring all aspects of the ocean following the Challenger route, and on the 140th year of the Challenger expedition, we'll have a new view of that part of the ocean and what the Challenger saw. This is being run by Rutgers who do a great job in their glider program, so do many of the other U.S. institutions. Anyway, I'd like to end there. Thank you for your attention. But remember one thing, these observations need to be sustained. Thank you.

>> Eric Lander: Wow That was very cool. We follow a practice at PCAST of turning our flags up to indicate who is interested. I see Dan Schrag has his flag in his hand and is debating whether to turn it -- and he has turned it vertically. So Dan Schrag gets the first question.

>> Daniel Schrag: Thanks to all of you, I really appreciate all of your comments. And there's so much to dig in on it that we can barely scratch the surface with the time we have available. I want to touch on what Bob and Tony both talked about in terms of the role of new technology. But also, draw on your experience running oceanographic institutions. And thinking about how our changing scientific community reacts to these new sorts of technologies. You noted the decline projected in ships. On the other hand, a lot of the things we used to do with ships are now being done by remotely operated vehicles. You know, argo floats, you know, Carl Winch used to talk about how we would go out a couple times a year to make temperature and salinity measurements on a ship, which is really a very expensive way to take temperature and

salinity measurements. And at the same time we're seeing block grants to Woods -- Institution from the Naval research, for example, go away. We're seeing big funding issues in terms of our intellectual capacity in the oceanographic space. So can you talk a little bit about some of those challenges, and how these new technologies, as exciting as they are, are also putting incredible challenges in the path of our community?

>>Robert Gagosian: That's a good question, Dan, one that I've wrestled with, as you might imagine, with my colleagues at other institutions, and certainly at the Consortium for Ocean Leadership, since we're a membership organization. Traditionally it's taken about 10 years for the community to accept a new technology. It took about that length of time for the community to accept Alvin, the submarine, and it took another 10 years for them to accept robotic remote vehicles and autonomous vehicles. But right now because of the squeeze on the funding budget, people are actually accepting I believe new technologies faster. It's very expensive to go to sea and so being able to do it remotely is having a big effect. A good example is -- and Tony mentioned this -- the whole issue of doing genomics under the water, microgenomics under the water has just completely changed our thinking of what's there. And that's the obvious thing now, all being done remotely to a large extent. And people have embraced that. So it's like every other field. It's going to be the leaders that embrace it, and the other people will gather it. I think a bigger issue that we can talk about later is the issue of the business model. The business model of the federal government, of providing three or 10 percent increases for federal research forever, that was predicated on World War I and World War II, certainly in oceanography. It was how to find submarines and how to hide them, it was as simple as that. And that's gone now, and so we need to rethink that model. And I think the private sector is playing a big role in that, but what will the long-term role, the sustained role be for the private sector? So that plays into it, as well.

>> Anthony Knap: I agree with Bob. The other thing is, though, these technologies aren't cheap either. A glider costs around \$30,000 a month and you need pilots that are up, watching them all the time. But regarding institutions I think there's a big issue because the funding model has changed so dramatically. Years ago when my place was started in 1903, Woodsall came along in 1928 or -- and the model's role, similar to the MBL where you get a couple really good scientists, give them two years of money, they start writing research grants, the overhead would come in and things would work. That's all changed now. So the stained -- oh gosh, never mind. So the long term future of these sort of organizations is -- is tough. They're very tough to manage. And so you know, these models have to change, because the funding is not going to go back to the way it was. So that's about what I'd add to what Bob had to say.

>> Eric Lander: Next up we have Barbara Schaal.

>>Barbara Schaal: This is for Beth. First thank you all for a real wonderful and informative presentation. Beth, you made a strong and compelling case for the importance and the value of local and indigenous knowledge. And I was curious, what are the efforts that are currently underway to gather, to record, and to analyze that knowledge so that they can be of use?

>> Beth Kerttula: Thank you. In the national ocean policy and in the implementation plan, it's distinct recognition first of all, which is unusual, in a lot of documents like this and a lot of planning efforts. And the actual on the ground experience is bringing in the tribes or indigenous groups to work with the communities in any of the regional planning bodies. They're absolutely part of that effort. And again, that's unusual. It's a great step forward. Also, the agencies themselves have that overt recognition of the benefits of that information, and as part of the national ocean policy and the national implementation plan, they are to recognize and work with that information. So it's a really terrific step forward. Many agencies that are part of the effort, National Science Foundation for one, have been working with that information for a long time, and recognize its usefulness. But for some, and for the states, when you're working in the regional planning bodies, for some that's a pretty big step forward. So it's not going to be, you know, without its bumps, but that's -- that's what's happening. And it's an experience of involving rather than avoiding or -- you know, altogether ignoring. Thanks.

>> Eric Lander: Great. Rosina.

>> Rosina Bierbaum: I want to thank you all for both an exciting and depressing set of presentations. Exciting because all that the technology offers, depressing because of how fast we need to make progress given climate change. So in a previous life I was a marine ecologist, so I guess I found Anthony's one slide on biology insufficient. And I think it has been very interesting to see how NSF and the Moore foundation have really jump-started the whole field of microbiology. But I wanted to talk about bigger stuff. And so Beth, you talked about ocean acidification and the implementation plan will have and a focus on that, and of course ocean acidification has the potential to just wreak havoc with the food chain since a lot of the base of the food chain depends on the calcium chemistry. Some of the new reports that have just come out, the newest intergovernmental panel on climate change terrified me, because we have talked about for a long time that terrestrial species might need to move on the order of six kilometers per decade to keep up with climate change. But in there they had something like 350 species are moving 350 kilometers per decade. So this is really changing the entire marine ecosystem in ways that I don't think we understand, and some species may actually be pushed off the top or the bottom of the planet. So I wondered, you know, what the research needs in this realm are, and what's being done to try to tackle the species shifts we're seeing now and the implications for economy, ecology and et cetera.

>> Beth Kerttula: So I can just quickly tell you from my first couple weeks here in Washington, D.C. and in OSTP, I have seen a tremendous recognition of and focus on this issue. I know Dr. Moran and Dr. Holdren, Tammy Dickenson have all worked on this issue, and I see that as sort of the beginning push to getting the agencies aligned so that the information can be gotten and worked on. In the states, Washington state and California have both been working on the issue, gathering data, Washington I think it was Puget Sound area really did take a lead. I can tell you really quickly as an aside, in Alaska three years ago one of the reasons why I started realizing why I needed to change my life was because we had a resolution on ocean acidification, I got one hearing on it. One. Could not move a resolution without any force of law, because people didn't want to talk about it. So it is frightening because the change is coming so fast. But there are those who will not listen to it. So we have a big job ahead of us, and I'm really proud to say that at the White House people are really focused on it, working hard to get the information out. But there's a lot more to do. It's a -- the national science bowl winners, the children, the students who participate in high schools were online the other day in webcast and the question -- they asked them, what's the most important issue that you see with the ocean, and their answer was ocean acidification.

>> Eric Lander: Wow. Well look, there are no more flags up, but I just want to say this was a great presentation. I'm sure that there will be a bunch of questions people want to have after we end the formal session. But I'd like to express my thanks and the whole council, thanks to the panel, and we'll have to move on to our next component. (Applause).

Public Comments

>>Eric Lander: So our next step in this meeting, I think the last formal part of the agenda will be public comments. And we have four speakers who are both registered and here. And our pattern is that they'll get a two minute opportunity to speak, and that 30 seconds before the end of that two minutes they'll get the 30 second warning. And Maxine, my Co-chair here, will take over this part of it.

>> Maxine Savitz: Thank you, Eric. And as you mentioned in your introductory comments on antibiotics resistance, you had received a lot of comments from various parts, and today all four of our commenters are speaking on antibiotic resistance. So the first one is Allan Coukell, please excuse if I mispronounce your name, if you would come to the table. And he's from the Pew Charitable Trust, so your two minutes are beginning.

>> Allan Coukell : Good morning, and thank you for the opportunity to present comments. My name is Allan Coukell, I direct drug and medical device programs at the Pew Charitable Trust, including our work to address the growing threat of antibiotic resistance. We're a nonprofit

public interest research and policy organization. I commend you for taking on this issue. Protecting the public from drug resistant pathogens is an immediate and pressing need. Your leadership is essential, and as you've said, we also need cooperation between federal agencies, health professionals, the private sector, and members of the public. The three pillars you identified, improved surveillance, appropriate use of antibiotics in people, animals, and development of new drugs and diagnostics are essential. As is preventing infections. Pew's efforts to date have focused on the urgent need for new antibiotics and the widespread overuse in animal settings. Two years ago congress passed the Gain act to address some of the economic challenges, and is now considering legislation to create a new approval pathway for antibiotics in limited populations of patients with serious or life-threatening infections who have few treatment options, or none. Congress should move quickly to give FDA this important authority. And in parallel the administration should facilitate discovery by addressing major scientific barriers. There's growing recognition nationally and internationally that we need better coordination between industry and publicly funded science towards priorities and solutions. As a nation we also have to do a better job of managing the drugs we have. We need to collect better data on use both in humans and in agriculture. We need to invest in science on best practices and we need to reduce use. The current administration has made progress towards phasing out the use of antibiotics for growth promotion on industrial farms, and we urge you to recommend additional steps to curb other inappropriate non-therapeutic uses and assure appropriate oversight by veterinarians. Similarly we address overuse of antibiotics in human health care. We should set a national target and hold ourselves to it. I thank you again for your leadership, and Pew looks forward to working with you and the administration to ensure implementation of your recommendations are as strong as they can be to protect public health.

>> Maxine Savitz: Thank you very much. The next speaker will be Michael Russo, federal program director, U.S. Public Interest Research Group.

>> Michael Russo: Hello Thanks very much. My name is Mike Russo, federal program director with U.S. PIRG, the United States Public Interest Research Group. We're a nonprofit, nonpartisan consumer advocacy and public interest organization. And I wanted to talk to you today about the important issue of antibiotic overuse in agriculture, echo many of the things Allan just said, and thank you for your leadership in taking on this really critical public health issue, and elevating what's going on and setting out a framework for understanding what's happening and how to move forward on it. And I just wanted to underline in my testimony that, you know, we really see that this is a problem that doesn't just stay on the feed lot. There's well understood ways this can impact human health, including to the antibiotic resistant chicken

outbreak and recall that was seen over the past year or so, as well as some of those other more dynamic ways that we seeing developing and getting more understanding of now, which really makes the case for strong action pretty clear. I would just say we're looking forward to digging into the report and seeing what recommendations are there especially around monitoring and auditing what the FDA approach does. Since we are worried there are some limitations in what that proposed. From seeing some of the statements that have come out about, Zoetis which is one of the biggest companies here told the New York Times that they didn't think it would have much impact on their revenues because their drugs are approved for both disease prevention as well as growth promotion. The Animal Health Institute similarly said they didn't think it would have-

>> Maxine Savitz: 30 seconds.

>>Mike Russo: much of an impact on overall use. And similarly alanco another one of the big industry players here said the FDA process was not a material event. So we think that we really think there needs to be strong monitoring to make sure this is having the impact we need is going to be very important, so we don't just wind up three years from now with the same exact things happening but a different word on the label. So look forward to the report, thank you so much for your leadership, and look forward to continuing to work with you. Thank you.

>> Maxine Savitz: Thank you very much. Our next speaker is Susan Vaughn Grooters, policy analyst, Keep Antibiotics Working Coalition.

>> Susan Vaughn Grooters: Good morning, and thank you PCAST for having me speak with you this morning. I'm Susan Vaughn Grooters with Keep Antibiotics Working. As you complete your report on antibiotic resistance for President Obama, I would like to note recent developments for your consideration. On July 1st the CDC released a report on resistant food-borne bacteria as part of NANS. It stated that antibiotic resistance in food-borne germs is an ongoing threat. Adding that such resistant food-borne pathogens sicken at least 430,000 people every year. This resistance can be medicated. Second, on June 30th FDA issued its first report on the progress of guidance for industry 213. While all the pharmaceutical companies that sell antibiotics for growth promotion ensured FDA they will stop doing so within three years, several of the largest companies will continue to sell antibiotics for the, quote, maintenance of weight gain, end quote, so sub-therapeutic use will not change. The marketing materials of these companies and their sales practices must change for the how, in theory, drug companies and producers could exploit loopholes in 213 to continue using voluntary guidances to be impactful. Earlier this year the council heard testimony as to antibiotics to boost production. We have several real life, real-time examples that demonstrate just how they will carry this out. The public health goal of the FDA policy to reduce antibiotic resistance, while laudable, can only be achieved through significant reductions in the use of the antibiotics in animals. I was grateful

to hear Dr. Lander note that for the USDA's guidance to work, use must come down. FDA relies on veterinarians to ensure appropriate use, and they use the onus of responsibility to justify why the agency doesn't do more to curb disease prevention. Yet in FDA's attempt to put veterinarians in the driver's seat, FDA has taken one step forward and two steps back. Requiring veterinarians to prescribe or order antibiotics for use in animals is an important step, but in the draft the FDA agency proposes to roll back federal standards for veterinary oversight. Of greatest public health concern, FDA would eliminate the current federal definition of a veterinarian client patient relationship with respect to animal antibiotics, and instead would defer to a patchwork of state policies. However, there are four states that have no such definitions, and in the 34 states that do, their definitions do not apply to the addition of drugs to animal feed. FDA envisions state policies as a safety net, but that is only accurate in the sense that nets are full of holes...

>> Maxine Savitz: Thank you-

>> Susan Vaughn Grooters: I respectfully urge this council to consider the scientific weight of evidence that antibiotic overuse in livestock threatens human health as well as the equally practical evidence that drug companies and industrial livestock producers will continue to protect their bottom line and misuse antibiotics unless FDA takes steps to close the disease prevention loopholes in 213 and require meaningful veterinary oversight.

>> Maxine Savitz: Thank you very much. Then Nicole Mahoney, Director of Government Affairs Regulatory Policy, Cubist Pharmaceuticals.

>> Nicole Mahoney: It was pressed, maybe I'm not close enough to it. So I am Nicole Mahoney, thank you for this opportunity to comment on the PCAST important work to address the growing threat of antibiotic resistance. Cubist is a global company with a growing commitment to public health through our leadership in the discovery, development and commercialization of novel antibiotics to treat serious and life-threatening bacterial infections. The company hopes to deliver at least four new antibiotics in support of the IDSA's goal of 10 new antibiotics by 2020. Approximately 75 percent of the Cubist employee base is focused on the research, development, commercialization, and support of antibiotics, and the company plans to -- expects to invest approximately \$400 million on anti-bacterial R&D in 2014. As you already know over the last decade the emergence of multidrug resistant pathogens has increased but the number of new antibiotics developed and approved has declined. Leaving patients and providers with fewer treatment options. While there's a pressing need for new antibiotics, economic regulatory and scientific circumstances make their development challenging for companies. Congress took action to address some of these challenges through the gain act which was passed in 2012. Gain was an important first step in revitalizing the antibiotic pipeline but as was mentioned today more needs to be done to encourage investment and innovation in

the field. it's clear that a combination of incentives and reforms are needed to spur the development of -- to spur development and fix the broken market of antibiotics. And we commend your efforts to identify meaningful solutions. We thank you for considering additional market based incentives, reimbursement reform, and greater investment and fundamental research in order to replenish the antibiotic pipeline. We extend an offer to work with PCAST if we can be of assistance, and we look forward to this important report. Thank you.

>> Maxine Savitz: I'm going to thank you, I'm going to thank all four speakers, and we do have copies of your remarks. And as always, we do encourage the public to come and speak to us at each of our meetings. And I turn it over to Eric.

>> Eric Lander: Let me specifically thank the speakers we had on the topic of antibiotic resistance, it's part of the pattern of people having been deeply engaged with us on it. This is a partnership with the whole community, so thank you for turning out today. And we're going to be counting on all of you after the report comes out to really continue your active role in ensuring that all of the various steps that have to be taken get taken. I'm going to turn it back over to my Co-chair John Holdren, who will close the meeting.

>> John Holdren: Well, that does complete our agenda for this 30th meeting of PCAST under President Obama. Thanks to all the presenters. Terrific set of presentations this morning. Thanks to the PCAST members, to the OSTP and STPI staffs, to the wider community both here and on the web. It has been a pleasure, and we look forward to seeing you all next time.

>> John Holdren: We are adjourned.