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PCAST

>> Moderator: Good morning, everybody. Welcome to this public session of the President's Council of the Advisors on Science and Technology. I thank the PCAST members assembled. The OSTP senior staff and PCAST supporting staff who are also here, welcome the folks who have come to join this meeting as the audience and welcome to the folks who are watching this on the webcast. We have an exciting agenda before us in the Obama administration in the second term. We're working hard on a variety of fronts, including jobs and the economy, implementing healthcare that will bring better outcomes to more Americans at affordable cost, working on gun violence, integration, energy and climate change, variety of issues in national and government security and it is a full agenda. And I'm delighted that we're going to be addressing in today's public session two very important parts of it, one the jobs and the economy issue, and the other the BRAIN initiative. And without further adieu, I want to turn the microphone over to my co-chair Dr. Eric Lander, who will also moderate the first session. Eric.

>> Eric Lander: Great. Add my welcome to John's. Thank you members of PCAST for being here for today's session and thank the people we have attending in person and many people attending on the web, as well. Let me take on in this first session a somewhat unusual topic. Technology and economics, it's a topic that tremendous importance to the nation and tremendous importance to the President in particular, which is jobs and how it is that employment grows with the productivity of our industries. A number of people have noted in the past couple years with information technology the number of jobs that are created for given amount of economic activity would be less than you think because it is so efficient.

Well, is that a sign that we're going to see a tremendous revival in the economy, but not revival in jobs in the long run? That is a very important question or a way to think about the question. (Inaudible) the economy over the course of the coming decade and growth in employment at the same time. Well, there is obviously important question, hard questions and to address them, educate us and those who are listening in, we have three unusual people to start these conversations, possible they have with them today the complete answer to the question of the coupling of economic growth and job growth or possible they'll give us really interesting direction in which to be thinking over the course of the next year or so and this may be a topic to dive into

deeply. To guide us and to start off this discussion, we've got Erik Brynjolfsson, from MIT, and he is in fact writing about this very subject and got a slide up there about (inaudible) machine, which gets to this very point. He is professor at the Sloan school of Management at MIT, we have Tim O'Reilly, CEO of O'Reilly Media and many of us have O'Reilly Media books that have animals on the books and such in the IT industry and we have Dan Swinney, executive director for Center of Labor and Community Research, and Dan has been involved in manufacturing renaissance council in Chicago and the creation of the Austin Polytechnical Academy Public High school that prepares students for manufacturing. So each of our three panelists brings experiences from academia, from industry, from manufacturing in particular, from labor and we're very much interested to hear what they are going to tell us and we'll reserve about half the time for this session for discussion with PCAST panel. Each of our speakers has agreed to take about 10 minutes, I think what we need to do listen to them in order with no interruption, although you never know and then we'll have it open for free for all discussion for panelists and I understand Eric, Tim and Dan is the order. Thank you for being here, over to Erik Brynjolfsson.

>> Erik Brynjolfsson: Thank you. (Inaudible) --

>> Push your button. Great.

>> Erik Brynjolfsson: Thank, Dr. Lander and upon can Dr. Holdren, and the rest of the PCAST panel, esteemed group of people here. I'm honored to have a chance to share the research in this area. It is a great challenge of our area, great technological and economic challenge of our era, I hope we can take it seriously and make some progress on it.

Let me start with a paradox which is innovation has never been faster, yet people are more pessimistic about the future. The data show many statistics are at record highs, never been more productive at record productivity, GDP fully recovered, corporate investment and profit at record highs and so by some metric, we are doing great. I'm sure you know, even with today's job report this morning, unemployment is doing terribly, to the point where 165,000 jobs is considered good news a few minutes ago, but in fact as you can see by the chart here, the employment population ratio has fallen precipitously, and it was falling even before the Great Recession and a number of other metrics like median income, which is struggling. The income of the family in the middle of

the income distribution is lower now than in the late 1990s. So how can it be we're having such a divergence through the economic statistics and others?

The basic story I think is behind this is frankly technology. It's not that we have an innovation stagnation on the contrary, technology is doing great, technologies are changing rapidly, particularly digital technology. However, for an effective economy, you need to combine technology with people skills, with new organizations and business processes and those are not keeping pace. The human side the institutional side is not keeping up with technological change and so we're getting growing gap in divergence and this is leading to millions of people being left behind. Great wealth is being created, but not shared prosperity.

So the first you know pretty well, (inaudible) of the economy, more law, technology racing ahead at exponentially improving speeds, there are something like 300 terabytes of information crossing the internet every second, more than the Library of Congress.
That side of thing system phenomenal and because each exponential improvement builds on larger base tis happening faster and faster. However, that economic digitization has consequences. In particular, one thing that doesn't seem to be widely understood is that while progress does make the pie bigger, no economic law, nothing in any textbook that says everyone has to benefit evenly or everyone has to benefit period.
It is entirely possible that technological progress can lead to improvements in the economy, but could go to less than half the population or even 10 or 1% of the population. Historically, that is not what happened, but in recent years, past 10 or 15 years that is what happened. You can see that with this chart, this epitomizes how things have changed. The green line is productivity growth. You can see that has been growing, if anything may have accelerated since the 1990s. So productivity, the output per person, output as function of the inputs is growing faster than it has before and that record highs. Historically employment grew alongside it. Those two lines kind of paralleled each other. You can see in the late 1990s, they started diverging and we had a difference there. Again, no economic law they have to go together, it's been nice empire cal fact they happen to go together. A lot of the economist took for granted they would keep doing that. It started happening even before the great recession kicked in.

And the reason for this is that we have at least three sets of winners and losers created by the advances in technology. Let me briefly illustrate the

sets of winners and losers. The pie is getting bigger, but helping groups relative to other groups. The first set of winners and losers is well understood and well known, it is called skill bias technical change, hundreds of papers, including some written by me in journals about this, basically the idea that high skilled workers benefited disproportionately relative to low and mid-skilled workers. You can see this is in the wages of people. If you control the demography and other factors, you get a clear picture that although wages went up in the beginning of the chart, before the 60s and 70s, for everybody together, after the oil shock, everyone suffered a bit and then the story is that therefore you see resumption of wage growth and income growth for people with more education, graduate school and some extent college. But people with less education have actually fallen in real terms in terms of the income they make and recently it has been found that especially hard hit people in middle of the income distribution. The chart on the left shows demand for employment, the number of jobs as a function of skilled percentile and this chart is not based on education, but based on wages and work David Otter and David Doran did. It is a u-shaped curve,
What is going on there, people in the middle tend to have more routine information processing tasks they are doing, things like accounting, bookkeeping, travel agents, bank tellers, can easily be automated. The high end, a lot of people doing creative work, entrepreneurial work, not a subject to automation, interesting the low end of the wage distribution people have held up a little bit better, those are things that require physical work, often not very routine, think of whether it is janitors or gardeners or hair dressers, that have not at least yet been easy to automate, truck drivers, some are changing.

The second set of winners and loser system capital versus labor, distinct from high versus -- skill level, but basically people who own capital say people who buy the robots in factories have done better. The people who work in the factories are now being replaced by robots and are not doing as well.
This shows up in the data quite clearly. The blue line is what happen to profit, return to capital in a sense the red line is share of GDP going to labor and that sort of bounced around for most of the previous half century, but then starting in the late '90s and around 2000, that started falling quite precipitously and the share of all income in the economy going to workers has gone down. This includes high skilled workers, as well as low skilled workers, including CEOs for that matter. It shows (inaudible) distribution. The third set of winners and losers, more focus, not what happen to the top 20%, top 10%, it is the top 1-tenth or 100th of 1% of the population, and these are super

star, whether in media or software or CEOs, each of these areas, people with talent or luck have been able to replicate their skills across millions of potential users. Take Scott Cook there, brilliant guy, helped develop Turbo Tax, many people can do taxes for $49, it's basically set of processes that can be codified. But same time, hundreds of thousands of tax preparers are not needed anymore. The number of tax preparers fallen by 17% in recent years, not because taxes are easier, but because you can now do it with software and algorithms, redistribution, it is a gauge of the consumers, that is one example and the other cases, as well, but the benefits are very uneven and tend to be concentrated in very small group of people.

In this case, this is not the top 1% of the income distribution, the top 100th of 1%, that is at record high now. As super stars in many different industries of many different types are able to address markets of millions or hundreds of millions or billions of potential consumers and use talent that way.

So that is what happened so far. One reason I think it is such an important challenge is that my meeting of the technology and the economy is that this is only going to accelerate, we are still in the early stages of a big revolution and it is fairly predictable what is going to happen to technology. We know that Moore's law baked in several doubling, maybe more, and events happening in other fronts in mobility and other areas. We are seeing technology that up until recently I didn't think would be feasible. A few years ago, giving example of something humans could do well and machines couldn't, driving a car, too much unstructured information. We all know that Google has driverless cars, I got to ride around with my co-driver, Andy, frankly it drove better than most people in Boston drive. That was important mile stone and I have to adjust what I tell my students, machine consist do well and can't. We also visited robot factory like Robotics, where machines like Baxter robot are doing simple manual task, no programming, take down the box and in an hour or so, by moving its arm around and showing it what needs to be done, it can learn a simple task and then most importantly, what is happening in information processing work, 65% of Americans do information processing work and intriguing to know Watson was able to beat the world chess champion answering questions in Jeopardy, but the same basic technology is being used in law, in medicine, on Wall Street and call centers and it's getting jobs in all areas and easy to envision that rapidly proliferating as well. Those are in early stages, but will be advancing quite quickly. I think we reached a point here where the exponential trends are beginning to catch us off guard and beginning to have

more profound effect as each doubling builds on larger and larger base over time.

So what is to be done? I think we need to work on rethinking the way technology and the economy work together. It's clear digital technology will continue to accelerate. It is also clear that our skills, organizations and institutions are all currently lagging. That gap is going to grow bigger and business as usual is not going to solve that kind of problem. There are two broad categories of advice that I have to work on this. Basically have to work on both tabs of that mismatch, one hand, we need to improve the skill level, the education level to people to be more suited for this new economy. Secondly, we need to speed up the creative part of the creative destruction that happens in the economy. Manager and entrepreneurs have been effective at automating existing job, but another part inventing and creating new jobs and the art society, people in charge of that be entrepreneurs and need to facilitate that. A set of suggestions I have to what we can do in that area, first off for education, it should be clear this should be done at all different levels, this is not just boosting college attainment, we can do more of that, but a lot of people are better off with other kinds of education, vocational and realize with rapid change in the economy, this is on the job, lifelong process, as well. Some of the good news, I was saying to Craig beforehand, education is actually a huge lag art and I see that as good news because it has upside in terms of industry. My industry, the main technology is do like a piece of chalk you scrape across a board that a cave person would be comfortable with. In other industries, whether it is in media or retailing or finance, you see phenomenal changes in technology of production and distribution. We could start doing that and of course I know you are doing a project on Mukes that would be an example of the kind of thing to be done. Nukes can replicate the best talent and the best methods, but I think more importantly and profoundly could allow it to have data on what is working and what is not working, finer level of detail. Raise the level of performance, but a faster pace. There are a number of other things in education, we can talk about those a little later. Let me mention a slew of suggestions we have in the area of entrepreneurship. The idea here is not that we'll make everybody in entrepreneur, 100 million people are unemployed, that is not the main point. The main point, those are people who are inventing the new jobs and industries that need to be created just to say Henry Ford invented new industry for the hundreds of millions of people in agriculture. We now need to find the ones going forward and that can be done in a whole set of things. A lot of policies we can do to support that going forward. So let me just sum up

there, we are doing work at MIT, initiative on the digital economy to address both parts of this and research precisely the types of changes and institutions that are going to be needed and I'd be happy to discuss them further when it comes time for the general discussion.

>> Moderator: That's great. Tim O'Reilly. O'Reilly Media hi, thanks. While I agree with --

>> Turn on the microphone.

>> Tim O'Reilly: While I agree with Eric rather, Andy and Eric on many points, I want to bring up one other issue, which is not just a question of technology, it is a question of values and I would suggest that everybody on this committee read a book called the Shareholder Value Myth, which came out last year by law professor Lynn Stout. It is corporate value, part of what is driving the trend. I want to give more optimistic perspective on what is happening right now with technology.

Based not on any experience as economist, but on the frontier of technology. I have venture capital firm, and a publishing company, O'Reilly Media, and our thesis has been innovation actually starts with enthusiasm. Before Steve Jobs and Steve started AOL, they were members of the club, first Apple 1, which Steve made in a wood shop. You know, this is the first commercial website which my company put out in 1993, at the time we did it, directly of websites, there were no commercial websites, we were the first, it was enthusiasm. The sites started a year or two later, venture capitalists later. Leonard, creator of Linux, wrote Just for Fun. And the Maker Faire last year; they started in 2006, venture capitalists didn't show up until 2009, 2010, they are now hundreds of companies funded in what we call the matrix space.

So that is the first point I want to make. The second one, the economic markets where people are having fun are often sharing economies, open source software is a great example, Larry Wall, the creator of the programming language once said to me, I gave myself away for free because I had gotten so much else for free. But businesses do arrive. They come over time and recently I met with Hari Ravichandran from Endurance, International Group, he had just sold the company for billion dollars, aggregator of web hosting firm. He built on open source software and I want to give something back. I started talking with Hari, how did you build your business on open source software? Of course. Web hosting firm, but providing access to Word Press, to DNF,

domain name system, to e-mail, to the AP ache web server as subscription. And in the course of our conversation I remember an article I read in Stewart Brand's (inaudible) back in 1975, called Clothesline Paradox, which made the point, if approximate you put your clothes in the dryer, the energy is measured and counted. Put them on the line, it seems to disappear from the economy. It doesn't really disappear, it becomes consumer surplus. So in the early days of open source, there was huge focus on my God, this is value destruction for the software economy. We had people like Jim, at Microsoft, saying this was a cancer eating away at software industry. You know, I think now Craig would acknowledge that Microsoft is one of the big supporters of open source in the industry.

What happened actually? We saw first Pure Play open source companies, Red Hat, My Sequel and so on. We did in fact shrink the size of the software industry. Bob Young of Red Hat said, my goal is to shrink the size of the operating system market. Martin Maker My Sequel, said much the same thing about databases. Open source was used as basis to build entire new kinds of businesses with very different business model, Facebook, (Inaudible) so on and then these other areas that are still not seen today. You know, the ISP service market, 79 billion dollar market and Clothesline Paradox at play here. Because the pure production of web content powers that ISP economy. You know, we have this idea somehow that internet users want a free ride. If you really start thinking about it, who is getting the free ride? Comcast and people like that. When Comcast shared television, they paid content providers, but when people watch YouTube or spend time on Facebook or Twitter, Comcast gets it for free.
It is a sharing economy.

So this is a great example, a video that my four-year-old grandson loved, it's basically Thomas the Tank Engine train crash, whole genre of videos made by kids, mind craft videos. Made by kids for kids, this has 24 million views made by a six year old. That is the peer economy at work. But what is interesting is that youTube is starting to monetize in new ways. I went to a conference called Vid-Con this last year and it was like seeing the Beatles in 1964, the YouTube stars each coming out on stage for five minutes, greeted by thousands of screaming girls, a line of people waiting to get autographs from one of the YouTube stars called Charlie McDonald. What is also interesting is how what you learn when you go there. Google figured out how to monetize fan content, What people don't realize is that they order the tech music. Here is viral video, it has 80 million views, it actually plays a song. The (inaudible)

doesn't go to the person who made the video, but to the person who made the song and they sell the music. I heard account of one popular star, I can't name, who gets more than half of her -- more revenue from YouTube than from iTunes and more than half of that comes not from her official videos, but from this kind of fan uploaded video.

But coming back to this, we actually job creation aspect of this and how these things monetize, you know, look here at the one aspect. This is the web design and so on. You have database of all online job postings going back to 2005 and methodology is to look at the rate of change. Normalize it starting year, so for example, here we are looking at starting in 2009, looking at jobs that involve any kind of web development technology. The green back drop is overall rate of job creation. The red bar show relative rate of job creation for jobs requiring HTML, CFS, various kind of web design skill. Outpacing the economy as a whole. The absolute value, but just for give you sense of quantity, 182,000 job postings requiring web skills and March 2013, about 3.2% of all the online jobs we had posted that we found posted that year.

So the results also point that Hari made I thought was worthwhile, pointed me to McKenzie report, having website increases business for small business by 10%.
That is where value gets captured by, give stuff away for free, captured by everybody. We did a study which I've handed out to you. We did calculations on what the actual uplift potential uplift of to small business from having a website, which they can literally pay $5 a month for. Came out to $124 billion for customers alone. The AIG companies. Given the total size of that market, about 1.3 billion in potential revenue is affected. You know, 10% uplift in that. The point is sharing economies look like loss of jobs, but it is in fact creates economic surplus that gets picked up elsewhere in the economy. I would trust some of that won't happen.

The last point I want to make, look at all these technologies I've been involved in, what do they have in common? They are all platforms, there is platform that kicks over this shift from the sharing economy to the paid economy. And government can act as platform. Look at GPS, the decision to open that up as a public good and not just for approximate the military led us ultimately to things like the Google self-driving car, maps and navigation on our phones and application like Four Square.

There are tech policies you can make, national Weather Service, big current data initiative, unlicensed broadband, things that came because of Wi-fi. We need more licensed broadband. Open access to Federally funded research. This actually creates a lot of clothesline paradox value. Meaningful use, electronic medical records, again, using jobs methodology, I've given you a paper that is forthcoming, we worked on with Aneesh Chopra, showing rate of job creation as result of the high-tech Act. You can see starting on the date the meaningful use legislation passed, that rapid increase in number of jobs looking for skills related to EMRs. So for me, the unanswered questions regarding the rate of the machine were enthusiasts doing with robots and we can talk about that during the Q&A. What is the crucial platform that will take this to a new level of economics?

And I'd also suggest just in terms of economic policy, a lot of talk about the importance of start-ups and I just urge you to look earlier at the preconditions for new industry which are often show by (inaudible) disruptive innovation that doesn't have a business model, it almost always, you have to think about the way these things develop. And often the monetization comes later in unexpected ways. If we had protected, you know, the software industry against Linux, we might never have had Google. Thank you.

>> Eric Lander: Thank you. (Inaudible) to the discussion to hear you guys actually disagree about anything because I hear Tim saying there is lots of consumer surplus being created through disruption and innovation and I hear Eric saying, that is right, but not creating a lot of jobs, I didn't hear you disagree, but I'm curious how we're going to address that question of how this consumer surplus is distributed across the society and are there things we can do to make sure people can share in the surplus as possible. And perhaps you can give us your perspective, you have unusual background coming from many years in labor and creating this manufacturing renaissance council and what school of manufacturing, what is your perspective on all this?

>> Thanks, real honor to be here, what I thought I would do, tell you broad assumption about innovation, the Chicago story and tell you what I would tell the President if I had his undivided attention for two minutes. Explain the name change, going forward, it is now called Manufacturing Renaissance, that is in the materials. Best way to start the discussion is introduce you to Kenny (inaudible) program and CNC machine and will attend national championship in Kansas city in June. Only student to win the title in the last 20 years. He was a student tour leader for what Randy (inaudible) to Kenny and said, what is

this technology mean to you? His answer was it is a playground for my mind. He later explained he can make any object he can visualize. He wants an engineering degree and start a manufacturing company. Our job is to find and nurture hundreds of thousand of Kenny's to join us and that is the challenge I want to discuss this morning.

To me, the most important policy issue of this decade is role of advanced manufacturing in our society. Too many peep and he will too many leaders believe we couldn't or can't compete in the global economy in manufacturing. We have a competitive advantage in advanced manufacturing, must expand global leadership in the sector. One of the President's key priority to have a sustaining broad-based employment for all groups of society. Advance manufacturing is the only sector that can build and sustain broad-based middle class and (inaudible) poverty. It is about the math, average wage and manufacturing is 75,000 a year, for service, 50,00 z, for retail, 30,000. Multiplier, each (inaudible) job in the economy. Each service job creates one. Each retail job creates a quarter of a job. As manufacturing as percentage of overall employment declines because of productivity, it is engine for job creation in the economy, only way to have a broad-based middle class. Only advanced manufacturing that can solve the environmental crisis. These problems can't be solved by lawyers suing company, challenge and production, new process and new product will be the solution.

Advanced manufacturing work is interesting work. Requiring critical thinking, use of technology, creates enormous opportunity to create social capital. People having interesting transforming work while having good standard of living after work. Challenge of innovation to look at intrinsic value of new philosophy of change and look at level of impact these technologies and related products have in building a broad-based middle class in the United States in sustainable society.
That is fundamental criteria for successful public policy on on innovation.

Becoming the global leader in advanced manufacturing, requires unrelating base of innovation and production in use of advance technology. New program like national network are powerful step in the right direction and congratulate the council on hard work in that area. Machines are allies, as he argues millions being left behind, millions of people. There must be institutional innovation and technological innovation.
This innovation in general must be led by private, public partnership, not just the private sector alone. One obstacle in the whole discussion, talking about

manufacturing, talking about it from perspective of private agenda on manufacturing, the companies that are engaged in manufacturing, people that work for them. A discussion about the pipeline or workforce development and shifts to tax rates and regulation. Those are all complex and important issues, but if we're going to develop consensus, we have to also equally address public agenda on manufacturing. One that can win over the majority of American people, involved in manufacturing or not to see their future depends on manufacturing and resources need to be allocated in this way. For example, innovation agenda must include communities devastated by ways of deindustrialization over the last four years, frequently communities of color. These communities benefited from post-World War II growth of the manufacturing sector, but the picture wasn't pretty. Deep history in manufacturing sector of discrimination in hiring and access to skilled work and mobility and condition of work and representation and in ownership. Today 95% of manufacturing companies are white owned. Black and Latino communities can be skeptical with manufacturing and innovation if past tradition of (inaudible) candidly confronted in policy and practice. Not just the right thing to do, the essential thing to do if we're going to build unity of will into enormous talent bring in talent of communities we've ignored in the past. That is what we're doing in Chicago.

In 2005, we were the Chicago federation of labor, the city of Chicago, Illinois manufacture association created renaissance council. The council's first project was creation of Austin PolyTech, a high school African American community with high rate of poverty, catch up with my slides, and unemployment. For this one small school, we have 60 manufacturing companies that are partners in invest in school in a number of different ways. We make clear Austin Polytech is not vocational school or trade school. The school's mission to provide education for the next generation of leaders in all aspects of manufacturing, including skill production, management, ownership and careers related to manufacturing outside the firm.

Every student in this included Kennedy takes three to four years of pre-engineering and advance machining class to learn skills credentials and last two years 137 students have earned over 193 NIMs credentials in the country. We see a career as a machine operator as a career in manufacturing.

We also have a course, had a course provided by John Marshall Law School and our students earned 150,000 dollars in scholarships to go to Law School for their success in mock trials and upon can IP law. We see an attorney doing IP

work as manufacturing career. Austin PolyTech, a group of students are starting a manufacturing company they will own and operate out of the school. The company will produce a Trumpet mouth pieces and we have a new patented mouth piece, our machine instructor is a jazz musician, we will produce those students are going to own and part that company. We see a career in manufacturing as owning a manufacturing company.

Austin PolyTech's purpose is to rebuild the Austin community, not just college enrollment or in fact media jobs for students, we've opened machine shop in the evening for adults, they are getting same credentials and same kinds of jobs. We are deeply involved in development of Austin Innovation Park that links research and production to future oriented structures to attract new companies to the region. Last week signed second MOU to consider locating in our park.

This is first indication in the last 25 years of rebuilding of manufacturing sector in the Austin community and based on innovation and forward thinking. And (inaudible) familiar to many of you has joined our board of directors and helping guide this project.

Most significant is that the renaissance Council and co-chair from the labor movement, Jorge, was mayor to state that Chicago should be leading hub in advanced manufacturing and that is number one strategy of the city of Chicago at this point.

So in con -- going toward conclusion manufacturing renaissance council model we started in 2005 is a true bipartisan private-public partnership that is scaleable. We have similar efforts in San Francisco, Detroit and New York City. Austin PolyTech is a public school, it is scaleable, we are working with school system in Baltimore, mobile, Alabama, to replicate the model. If I had two minutes with President Obama here is what I would say we need to do. Mr. President, advance manufacturing is central to the future of the country. You must remove any agnosticism at the top level of leadership in administration. The advanced manufacturing and technological manufacturing is foundation for society. As you know the world doesn't stand still, to fail innovating technology and in our institutions particularly education, will leave the next generation live nothing unsustainable and polarized society. Mr. President, equity has become the code word for involvement in low economic communities. Equity must be in policy, RFPs and innovation to ensure race to the top is driven from the bottom. Private public partnerships like manufacturing renaissance council drive innovation, these are independent bipartisan

partnership essential for true change and innovation at the ground level. We have three or four, we need 100. Of course we must have profound reform in all aspects of public education. That restores integrity to education and link to designing and making things. We need to add M to manufacturing and stem setting stage for existing funds in more strategic way and focus on secondary education linked to manufacturing to compliment your new investment in post-secondary education.

When you are President Obama you recognize the potential of Austin Polytech and speech in September 2008 you said "I'm calming for creation of innovative school funds, this fund to invest in schools like Austin PolyTech," thanks to a partnership with a number of companies, preparing students for engineering and requirement students create with two industry certification, Austin PolyTech is bringing hope to the community. That is the kind of model we will replicate across the country when I'm President of the United States. Mr. President, we said what we said we would do, take this model to scale, we need a thousand programs around the country to send the signal initiative in technical innovation will be matched in institutional innovation. Finally, our job as nation is to find and nurture hundreds of thousands of Kennedys to join with us in building truly innovative and sustainable society that compete in the global economy. We need institutional innovation to become the norm for the nation in Chicago. Thanks.

>> Eric Lander: Great. Well, the question is on the table. Thank you, those were all really thoughtful presentation, they came from distinct perspectives but all intersect. Our pattern in PCAST is people raise their flags to be recognized and Mark Abbott raised his flag first, I see Jim Gates. Mark.

>> Mark Gorenberg okay.

>> Eric Lander: Your mic.

>> Mark Gorenberg: Ah, okay, great. Oh, okay, great. Eric, thank you and thank all of you for your talks. I'm curious, you talk about going into this new age where we have great productivity, but huge challenge creating unemployment. We have this great asset we're creating today called beta, that we've never created in this mass before and we have the opportunity to use analytics and predictive analytics to try to solve a number of problems in society. And yet it seems like we haven't totally turn today on on with the Idea of how do you better create employment. Do you have thoughts on how we

can use all this data, mine all this data, use analytics to help with the unemployment situation? Please. All of you, I suppose.

>> I'm sure Tim will have more to say on this, but I think huge potential there, in fact, Tim mentioned the database he's put together and others working on similar databases. One big problem right now is that it is very difficult for people to see the kinds of career opportunities that are going to be best for them, match best with them, my students at MIT, have done amazing things figuring out how to get people to click on ads more effectively. Click streams. Similar data available from Mukes and from what happens with employment, many of them would be delighted to work in that same kind of area. Few start-ups I'm helping that are beginning to do this type of thing where they have students and perspective employees take cognitive tests to play games, feed in their previous records and then it helps identify the kinds of things they might be most effective at working at and also provide realtime data on where job opportunities are, which are emerging and which ones are fading. It is not just trying to make blind prediction into the future, but more sense and respond method where you more quickly realize what the demands are in the immediate period.

>> You know, I would say that one big shift that we need to make is to stop thinking about jobs. (Tim O'Reilly) -- I know that is a really hard shift, but I think a lot of the income of the future will not come from jobs, you know, I see more and more people who are self starting businesses of all kinds, those businesses aren't even a sole proprietorship, I'm getting income from here, getting income from there, getting income from a variety of places. Right now look at sight like Etsy, which is heading for billion dollars in revenue, going to somebody and their average income is below the national average, that is a lousy job compared to a manufacturing job, but it's still early. There are people who are making multiple streams of income from a lot of different types of activities which are internet enabled and I think that may become a bigger part of the economic picture, people with streams of income that are not actually jobs. We need to think about that at least as a potential future. You know, scenario planning you think about divergent futures and one in which people are making a living, but do not have a job, what do we need in way of social safety net for the future is very different than one provided by employer. The second thing that I would say in terms, so how would you use data to track income and not jobs, I think is probably an important area. The other thing I would say is to this notion of self-starting, you know the notion of venture capital and the venture capital back start-up is so high in the

mindset because Silicon Valley, but small businesses that do not start with venture capital, that start with somebody just doing something and finding customers are I think far more important to the economy and we need policies that support those kinds of activities and to the point of advance manufacturing, one places I would go study is maker space in Summerville, Massachusetts, artisan asylum, it's basically home grown, people doing advanced manufacturing, 70% of the people who are working there, little booth sharing major machine tools, but they are all small businesses or artists or -- I look at that bottom up innovation.

>> I want to make sure I get the facts right here and move on to the next question. But are you saying that you think the deficit in jobs that Eric writes about (Eric Lander) will be made up for in quantitative numbers by people assembling income out of self-starting activities? Of course the issue is there are wonderful stories and are they anecdotes or harbinger of different future. Eric shows big divergence through economic growth and jobs, if you did income rather than jobs to Tim's point, would you still see that same divergence and you know to Tim, are you imagining that it is really going to be a future where the vast majority of Americans who are perhaps out of a job because of technological changes are getting that same income they would have gotten by assembling in the fashion they are talking about?

>> Tim O'Reilly: First off, I would say I don't know it will make up at the income level, I think we will still see divergence, but I think that is driven much more by corporate values than it is and the fact that we are looking if for the lowest possible price, optimize for corporate profit rather than overall wealth of society. I think that is a serious social and morale problem.

But I do think that there are new forms of organization on the internet that we do need to take seriously. The fact is if you look at a start-up like Uber, which basically, if you don't know Uber, so-called everybody's private driver, you can imagine the increased convenience of coordination which allows you to get a car to pick you up and bring you somewhere using a phone, will actually change transportation patterns, change ownership. May take away high priced manufacturing jobs, we need fewer cars, increase the number of effective taxi drivers the overall economy looks very different and yes, the income may be lower.

>> Eric Lander: And the Uber car might not have a driver, too.

>> Tim O'Reilly: That's right.

>> Eric Lander: Dan, did you want to jump in and say something here?

>> Dan Swinney: I do. I disagree with what Tim said, massive infusion of new data in the '70s, I gave basis that (inaudible) cannibalize the same products they created that we benefited from as a society. That is exactly what happened. David Rod Rick said I'm in this business to make money, not steel. He now has capacity with the information technology to go into shift capital, go into all kind of investment to assemble bits of data for narrow purpose. I think that first of all, how we use data, agree with Tim, it is all about values. The question, values have to be to have a sustainable society or we won't have a sustainable society. We see beginning of polarization, after the financial crisis of 2008, people can see fundamentally darker side to what America can become in relatively near future F. We don't profoundly tie technological innovation, which I'm in favor of all the data we can use, all the experimentation we can do with business development. The fundamental question, does it build sustainable society? The public side of the coalition around innovation has to be profoundly developed in advance and not now. My belief is we're entering new industrial age. The people who develop manufacturing are doing it because it is essential means to an end, not just means for private accumulation of wealth that has to derive public policy at this point.

>> Eric Lander: Good, Jim Gates.

>> Jim Gates: Thank you, Eric, thank you briefers for terrific presentations. I have three questions and they are actually directed toward Eric.

So the first thing, one of the early slides, you were talking about the historical tie-in of productivity to essentially income levels in the country. So the question is when you say historical, when does history begin? As you do your -- as you make your presentation, when do you start history?

>> Erik Brynjolfsson: So that data, from the post-war period, less accurate data from the 1800s, but historically productivity and employment have grown hand in hand. People were worried in 1820, Leadites that machines would take away jobs and repeatedly for a couple centuries people raised that flag over and over and it hadn't happened until recently there has been a divergence as I

showed you. But for the previous century, at least, those two grew hand in hand.

>> Jim Gates: The presentation itself, is available, can someone like me have access to it?

>> Erik Brynjolfsson: Absolutely, I continuing is being posted. There is more detail, happy to send that to you, too.

>> Jim Gates: What you tell students about self-driving vehicles, are you talking about self-driving longhaul trucks now?

>> Erik Brynjolfsson: I think there will be, that was meant to be illustration, I try to be techno optimist and be very aware of the latest technology and I think even I was caught off guard by how rapidly some of the changes, I try to point to things that are going to be difficult to automate and getting harder and harder to identify those. My ride in the self-driving car made me convinced that it is not going it be quantum shift all at once, better gradually better and better super cruise control and other features will creep in over the next decade and over the next two decades to the point where there will be self-driving cars and trucks.

>> I will say one thing that I see from the various sharing economies, and that is people are driving experiences for other people. (Tim O'Reilly) You think about YouTube and kind of entertainment revolution. You look at even something like Air B&B, the top rentals are marketed as experiences. The reason why Oober works so well is that the drivers are actually competing to get a good rating. There is a really interesting connection between the internet version and reputation economy and I think an economy that is driven by that kind of how do you create a better experience for someone they are willing to pay for. I think the connection between commodities like the fact that we have labor-free devices and the inability to make money, you know, can be illustrated by bottle of water. We pay for commodity and the question really is there an experience equivalent to that, where people will actually pay more because human can add some kind of value in a very interesting way. But whether it will add up, that is the question and I keep coming back to, question of value more than a question of technology.

>> Erik Brynjolfsson: Can I just pick up on that, Tim is on to something very, very important. The nature of work is changing quite a bit. One way to think

about that is that jobs that are routine road, where a person instructs you on what to do and when to do it, the classic definition of a job, if you think about it, those are the in the bull's eye of automation, most likely to have somebody write a software program or computer or piece of machinery to do that task, so we're going to increasingly have residue, if you will, of the jobs that are more unstructured and ad hoc, and part of what Tim was describing. The big question that we haven't seen yet to answer your earlier question, so far not making up for the income, the chart I showed was income, not wages, some of them were income, not wages, we have deficit on that side. The other thing, cultural thing, Tim and I had discussion with other people like Zoe Baird, a lot of people don't feel comfortable with that kind of highly flexible lifestyle, where you don't know where your next paycheck is going to come from and the safety net that Tim mentioned is an important part of that and ability to soften some of the vagaries of that, not everyone feels comfortable in maker kind of world.

>> This is not high quality job necessarily, but one interesting sign I see of automation being seen is in the Apple Store.
This is retail environment, one of the most productive in the world that has more sales people, not fewer and they are enabled by technology every sales person is carrying a cash effectively carrying cash register in their pocket, kind of interesting model. Todd Park and I have talked about home healthcare aids, Walgreen system looking to enable pharmacists. You can imagine a world in which that additional human information retrievable interface effectively is improves employment, but not necessarily low pay jobs.

>> Eric Lander: Dan, did you want to add something?

>> Dan Swinney: Just quickly, the issue of working and what we produce, is part of global question. My view, the reason what has to drive our decision, how we will not be on on sustainable society ourselves, if we don't, we will lose the stability that we all enjoy and there is complete connection between economies, stability, sustainability, crisis, polarization and going backward. Second of all, innovation comes from being engaged in production and one challenge we have done by offshoring work, we've lost the work to make things and think of things and third of all, should be addressing and see ourselves in a global economy. My interest, how do we have massive, by being the most advanced in technology, the most advanced in everything we're talking about, not a leadite bone in my body. How do we create medical devices for the developing world. I do think the war in middle east has to do with

development. How do we reorient ourselves, but begin to produce in ways and inform that really builds global middle class that is sustainable and interesting.

>> Eric Lander: Great. Henry Kelly had the next flag up.

>> Henry Kelly: Actually answer part of my question, struck by the fact internationalization of the economy is not part of any of your talks. I had one specific question for Eric and that is you had three factors you talked about, skills gap, capital labor, winner take all, is that same phenomenon happening worldwide or unique to the U.S.?

>> Erik Brynjolfsson: Happening worldwide, although the U.S. may be on leading edge of this. You know, if I had more time I would have talked about trade and the fact that technology is enabling markets, but one thing to bear in mind, in my view and there are other economists who differ, I don't see globalization is the main big story. I think it is technology and one way to see that, manufacturing employment has fallen substantially in the United States over the past 20-30 years and many people see competition from china as being a big part of the story. It is part of the story, but look at manufacturing in china, down over 20 million since the late 1990s. So jobs are going from the United States and China to robots, not from United States to China. I would say that offshoring is a weigh station on the road to automation, jobs can be offshored are those that can be automated often.

>> Eric Lander: Hmmm, next Bill Press, I believe.

>> Bill Press: So long ago when I took economics I learned that production equals consumption and I know I've forgotten about savings and other things like that. But it seems to me, if we look at a world in which in the first instance a smaller number of people are responsible for higher productivity when in the work force and also concentrated owner of capital when they are on the capital side, then the next question is what do they consume with this income they get? I could imagine this going two ways, roughly speaking, if I am one of the halves, I might choose to buy an iPhone, which has a low labor content in it or something like that. Or my daughter is an artist, I might choose to buy art, which then immediately supports a set of people who otherwise wouldn't be haves and it it seems to me, element of social preference, whether on consumption side, people prefer to consume and I think I'm echoing a remark Tim just made, prefer to consume things that have human

touch in them whether they are the person in the Apple store or my daughter the artist, versus prefer to consume things that whose reward simply flow back to the haves because they have low labor content. My question is, do I kind of have this right and if approximate so, are there policies that we should be thinking of or social trends we should be trying to set to encourage this broader distribution of the rewards of consumption?

>> Erik Brynjolfsson: I think you are thinking exactly right. You can run an economy where 1% or 1-10th of the percent of the people create all the income and consume everything and then everyone else consumes nothing and almost like they don't exist in way the world economy is a bit like that. If you look at what China and India, before they joined the global economy, like they were not participants in the global economy and now they are. The other direction, as well, that probably is kind of economy most of us would want to be a part of and it would be one-time down shift in overall consumption. If we don't want to have that outcome, what can we do to get more people to participate? I think the first best option to try to raise the marginal product of as many people as possible so that they create more people are creating wealth in many different ways and as I suggested, two broad techniques for doing that, one is to change the skill set people have so they can create value and the other is to encourage entrepreneurs and others to be more creative about finding ways to employ people doing other types of jobs. Those two types of techniques together and whole set of policies to support them, I think are best tact for getting more shared prosperity. But the truth is, there is no economic law that will happen automatically.

>> Eric Lander: Mario. Sorry, Tim.

>> Tim O'Reilly: I would give you just a small example. I hate to see government intervention in this, but something you could consider. You take something like YouTube, which driving value for Comcast. The cable industry is extraordinarily profitable. What if we said just as we have, mandatory fees that are paid out to publishers for certain public uses. You could say there is a levy effectively that gets paid out to content creators. You know, there are different ways to start to think about the surpluses, that are not monetized or monetized heavily by and drive corporate profit. Okay, how do we create feedback loop so it goes back to the actual creators of the value. But more likely I would think the market will drive those things and subtle nudges could possibly encourage more behavior. I think Google is doing a lot to

figure out how to drive monetization, but you know, little push can sometimes help.

>> Eric Lander: Mario.

>> Mario: Thanks for your presentation, the question I have have been always discussed in the last few minutes, but let me do it any how, has to do again with the global economy. Of course you can argue that things like cheap labor of course has been exported and as you pointed out, not just that fact, but it is technology and so on. Here if I can trace a question this way, it's clear that emerging economies, china, India, so on, that GDP is growing very fast. And so in spite of that, by the way, in India, for example, yeah, poverty decreasing, but choice in equality, actually.
That is a challenge in the developing world. But the point here is that to what except it is current economic perspective based on growth because it's clear again that emerging economies need to do it, but what about developed economies like the U.S.? Still measuring things in how fast is GDP growing. Is that sustainable at all? In terms of also creating more jobs?

>> I think this is one of the biggest problems is that GDP is not a welfare metric. Tim gave many, many compelling examples of how you can increase welfare without increasing the money economy, GDP. We are focused on that, there is a footnote in every economics textbook that explains GDP is not welfare metric, but jump to measuring output. People say how much did the economy grow and use that as synonym for how much was bought and sold. But in a way it is backward. As things get cheaper, that is better for consumers. Wikipedia, is free, that is (inaudible) drunks looking under a lamp post, the light is there, that is where all our economic apparatus is geared toward measuring things, production, that aren't really create necessarily creating value. If we changed the way we gather data to emphasize more what was creating value, I think we'd be more likely to be steering in the right direction.

>> It would pose the fascinating question how to attach value to free goods. I am waiting for economists to sort that out for us.

>> Erik Brynjolfsson: I have a paper on that.

>> Eric Lander: Good, send us the paper. Dan.

>> Erik Brynjolfsson: This is something we want, please go work on this, I do think what we measure is what we are going to get.

>> Eric Lander: I didn't mean to suggest it wasn't a good thing to do, I wanted to see how you were going to do it. Dan.

>> Dan Swinney: I think we should raise productivity, but ownership and entrepreneurship, because who owns production makes the decisions on where it is produced, how it is produced, what is produced. Our model actually, which is worth people don't know approximate it, should know, most our work in the United States and Chicago based on international examples. One comes to mind, Montragon, in Spain, the manufacturing sector was started by a priest. He started polytechnical school and our school is modeled after it, taught engineering and the things we taught. Infused the children with Catholic values, on jobs, work and economy. Bought first manufacturing company organized on cooperative basis. They introduced robotics, whole focus on what they make, how they make it and what the partnerships are internationally are driven by whole different value set competitive and generates return, but also builds social return.

>> Eric Lander: Great. Craig Mundie has his flag up, I would like to defer to Craig first.

>> Craig Mundie: I was going to education.

>> Eric Lander: Then you start it, Craig.

>> Craig: Early in the deck, we really need to rejigger the education system, I am interested in closing the loop, economically on what is the country spending on education? What kind of return on investment are we getting there and how do you think these technologies like the mukes and those kind of things, how would you reapply our aggregate investment and couple the technology to change the output of the educational system?

>> Erik Brynjolfsson: It's not primarily a matter of spending, although I think that is part of it. We spend quite a bit on education, but haven't reinvented it. We are so far behind the use of technology, there is a lot of upside. Part is incentive aren't well aligned. One small example, proliferation of private vocational schools meant to teach people. In Germany, they have been effective. Here they have been much less effective. The government guarantees

the loans, but doesn't really tie it to any particular output. And we don't have good metrics of what the output are. One thing one could do is try to make the rewards more tightly linked to the performance for instance, instead of giving unconditional loans, you could have an equity kind of system, Eric Lander and I talked about this at one point, where the vocational school gets paid back if and only if the person has jobs that earn the income they were supposed to be earning. You could have almost like instead of bonds, you have equity, you have people get a share, you know, three, five, 10% of the income for certain number of years, you could have forgivable loans, if they don't get the jobs projected, then the loan gets doesn't have to be paid back. That way, the schools valid skin in the game and would have much more incentive to think, is this skill going to make them web designer or maker that is in demand or is it a skill that isn't going to lead to productivity? I think you would be impressed by how quickly they would bring to bear big data and a lot of other tools to get really, really smart about what kinds of skills are needed now and in five years and we harness that entrepreneurial energy in more way.

>> Craig: Why wouldn't you apply to all levels.

>> Erik Brynjolfsson: Absolutely. Various experiments, test third degree idea with my Dean and other and they are hesitant to do this kind of thing, I think this is some details to be worked out, but conceptually, the concept of having skin in the game, having measurement of performance, will align the incentive in the right way. Back to our earlier point, if you don't measure it, you will not be able to measure it.

>> Tim O'Reilly: I would add something I said earlier, which is as long as people think there is binary condition between having a job and not having a job, that creates a certain set of conditions. If you have the idea that yeah, sure, you may have a job, but you also can make work for yourself, we will actually encourage more entrepreneurs. I graduated with a degree in Greek and Latin classics and I made a job for myself. I've never worked for anyone else and I did make work for other people. I didn't think that way. I think a lot, we need to encourage entrepreneurship, not necessarily as you are going to go start a company, venture capital. Simply the idea that there is go find something that needs doing. And eventually you'll get paid.

>> Eric Lander: Yeah, of course some people may be in a better position to do that than others so education is incredibly important part of that and making sure that the people who in principle can do that really get the chance to do

that. That's really fascinating the conversation this morning. We're coming about to the end of the time. If you guys were to suggest to PCAST, we've taken on this topic as it lies in between the world of technology and the world of economics and I don't know exactly PCAST likes on take on topics that don't exactly fit squarely under one particular category. If you were to recommend to PCAST what else we might be learning about doing to address this big question that each of you are addressing from your very different point of views, what would you recommend as next step to PCAST if we wanted to think more about this top snick I'll give each of you a minute to tell us what you'd recommend.

>> I've been impressed by DARPA, inspire driverless cars, robots, we need new grand challenge for economists and people who are designing our organizations and institutions to reinvent the kind of economic system that matches this amazing technology. Tim has described outlines of one kind of a path. Frankly I don't think we understand it very well. But I don't think the same kind of institutions that work so well in the 1950s are the ones that will be needed in the next 10 and 30 years.

There's a lot of amorphous research out there on how this might work measuring things in different ways, incent vising people to create careers that aren't necessarily job oriented. New kinds of organizational forms that aren't forms, aren't markets, all of that is a very potent research agenda that if we specify grand challenge to go after that, I think we could make huge headway and that right now is where the bottleneck is.

>> Eric Lander: PCAST is next step, I didn't get in there, what would you have us do?

>> Erik Brynjolfsson: Support research to I'm a professor, maybe I'm being biassed.

>> Eric Lander: More research is needed?

>> Erik Brynjolfsson: Research to define that agenda, define grand challenge, kin to DARPA's grand challenge to come up with a set of organizations and institutions that could keep up with our technology.

>> Eric Lander: Got it. Tim.

>> Tim O'Reilly: My recommendation would be research agenda. It would be to identify areas where there are clearly large amounts of activity being spent, but not a large amount of monetization by the participants and that includes areas like social media, YouTube, the Maker movement starting to kick over, looking for more advanced things as DIY biothing happening out there. Try to identify those kinds of areas. And then start thinking about what kinds of interventions might actually help people to start monetizing in those areas. And to have the monetization not go disproportionately to a small number of companies. You know, the question is how would we monetize Facebook for the participants, not just for Facebook, monetize for the participants, not just for Google. So --

>> Eric Lander: And what if anything is appropriate role for government in there. That is delicate area to figure out what government should or should not be doing to help. Good. Dan, you get the last word on what we should be doing.

>> Dan Swinney: I thought Eric in his book and statement pose the question, you know, we had this huge advance in digital development in technology. The point is millions of people are being left out of it, that number is increasing. The trend is unmistakable. That leads to society that won't support research. I think Eric posed the question, talk about new technology, the question is how many people does it employ? I don't think it is debate whether you can sustain a society without middle class, contrary to the President's perspective. The question of institutional innovation, we are making huge strides, which I welcome. You know, we should continue that. But if we don't involve broader base of the population, the number of people will dwindle and dwindle in our society. I think creating that linkage, not widely understood between institutional innovation that drives discussions deeper into society in addition to the volatility and creativity of new ideas is really fundamental linkage that has to be affirmed in all aspects of technical innovation.

>> Eric Lander: Wow, we didn't know what to expect when we put together this panel, this was a little bit of flyer on our part. I'm really glad that we did. I think you've all provoked us. Each of you have done deep and original work in your respective areas and I think your perspectives are complimentary. This was an extremely interesting conversation. I think we're going to let it reverberate around the PCAST and see where we might take this next. I want to thank each of you for coming and for your work in preparing and sharing some pretty broad thoughts there. Thank you each.

(applause)

>> Thank you.

>> Eric Lander: We're going to declare a 10-minute break and resume at few minutes after 10:30 for the BRAIN.

(10-minute break) --

>> Eric Lander: Come sit down. All right. Let's settle in. So our next session is on the BRAIN. In particular, the President announced this BRAIN initiative. The BRAIN initiative stands for brain research through advancing innovative neurotechnologies and this is an initiative that stretches across the science agencies in the United States. I think it's extra ordinary to see the possibilities that can now be imagined and in many cases done for looking at the conductivity of the brain, the activity of the brain, you know, you reach some point where technologies just come together and can be used together with each other to collect massive amounts of information and begin to interpret it. So many of us have been impressed over the past couple years to see the advances in neurotechnologies and I think this is a very forward-looking effort to say that this is only going to increase and we ought to think in an organized way across the science agencies about this. We have today an amazing lineup. We have Francis Collins, from the National Institutes of Health, and Arati Prabahkar from DARPA, and John Wingfield from the National Science Foundation. We're also joined by Kathy Hudson from NIH, who will be available for discussion that we have. So to have NIH, Darpa, and NSF all with us at one table talking about the brain is quite a treat. We know that this initiative is still in the planning stages, that there are initial steps that are being taken now because you have all been working on the brain, this is not entirely new to be doing brain research. We are working together to really design, I know that there are committees organized to do this, we're interested to get update what you can tell us now about where you see this going and where you don't know exactly where it is going and are still planning, give us a sense of that, too. This is just the beginning. We haven't talked, I'm going to guess you have order you'd like to speak and it would be great if you took 10 or 12 minutes and we have enough time for real discussion afterward.

So what -- negotiating an order here. What is the -- excellent. That is so great. One, two, three. Fantastic. Francis Collins, tell us about the brain.

>> Francis Collins: Well, thank you. It's great to be able to meet with PCAST and discuss where we're going with this. As Eric nicely described this is both exciting initiative and one fair to say very much work in progress which make its particularly good time to meet with all of you and hear your thoughts about DARPA's taking us. I'll start off focusing about the NIH component and sort of set the stage a little bit about how this is in fact wonderful example of interagency (inaudible). I also thought it would be fun to show you some of the technologies that have been developed in the last couple years which provide some excitement and perhaps foundation for believing we could generate more technology to begin to understand how this most complicated biological structure in the known universe does what it does.

Let's be clear, we're talking about a very ambitious effort, really serious about understanding the circuitry in the brain, talking about 86 billion neurons, each one has thousands of connections. So the notion that we are going to figure this out any time in the near future would obviously not be realistic, but we think we are positioned at this point in 2013, to bring together the kinds of science that has been bubbling up in an organized way to set forward some specific goals and mile stones and to speedup this process of really fitting -- filling in a lot of areas that have been currently outside of our reach. So let me say a little bit about NIH's view on on this and go to my colleagues.

Again, this was a remarkable moment on April 2, when this particular initiative was put forward in the East Room (of the White House), full of scientists and the presentation of the actual plan by the President himself. Learning the language of the brain is I guess one way to describe this, we still are working on the elevator speech of exactly how to describe something as complex as this and on make it clear what is different than neuroscience which has been going on for a long time. The need is certainly great, I don't want to overstate how this project is going to have immediate consequences for medical implication, if we had a foundation for understanding basic ways circuits work, we'd be in a better position to tackle brain disorders based upon that kind of information. Brain disorders are the number one source of disability in the U.S., 100 million Americans affected with conditions like autism, Alzheimer's and obviously much attention to things like TBI, PTSD, let's mention other things like schizophrenia and epilepsy, all of which will ultimately be benefited by understanding, function of the brain we currently don't have a good grasp of. Annual cost of -- you may have seen the paper in the New England journal

suggesting Alzheimer's is costing us about that every year and that will go up and up and up because of the aging population unless we come up with strategies to intervene.

There is a need, but of course throwing money at a problem wouldn't be wise unless we thought there was scientific opportunities and here is where particularly in the last five years or so, really exciting new technologies emerging, some of which I'll show you in a minute, bringing together fields like optics and genetics and inform attics producing tools that allow us both in model organisms and humans to have insight into brain function and structure that are really quite inspiring. So here are a few of those.

Sort of take them in order. The brainbow you see there is a really clever scheme, using it is possible to identify not only the cell body, but to be able to track out axons, they have the same color and therefore to take a thicket of such connection and be able to figure out who is actually part of what. Really quite beautiful, one might say, makes nice poster, elegant scheme indeed.

The connection you saw rotating over there is a recent development which is giving us insight in the human brain in terms of the ways in which the wiring of the brain is constructed and this is based upon a particular approach of MRI, diffusion MRI, which you can see from the picture gives kind of images we haven't previously been able to get. Groups now particularly in Boston and St. Louis have generated the same kind of wiring diagrams for dozens of individuals, about 70 of these that are up on the web for people to start to work with the data, including identical twins, and it is interesting to look and see, are their connectomes more alike than you would expect for randomly chosen individuals. If they are, it is kind of subtle, quite a variation. Lots of interesting things to be determined there. At the moment, the connectomes have been on normal individuals, one wants to see what happens if you look at autism or schizophrenia, can you pick up indications of wiring differences.

Then there is clarity, just published in nature a month ago by Carl Diseroth, and his group, remarkable development they have been working on for seven years trying to come up with way to render brain tissue optically transparent, but preserve anatomy. The trick here is to take as you can see in the picture mouse brain and basically infuse it with hydro gel of acrylamide to color structure you can then stain. You can not only stain it once, stain it and wash it out and wash again so you can generate picture of brain structure with

multiple different monoclonal antibody or other means of assessing various neurotransmitters and cell surface markers are located. So here is what you might see. I will show you the mouse hippacampus, which has been in this example stained with a variety of different colored immunofluorescent, at this point you are basically slicing through it the way you would do with standard set of sections where you only get planer view. That is kind of cool. Now imagine that you can do this in 3D, because you can. There are many different things you can start to appreciate, especially when you can rotate it around, look at it from any direction you want. This is a fantastic view of the brain. This case mouse hippocampus, you can do this with human brain session, not yet the whole human brain, that will require development in terms of engineering. But this opens up an exciting new vista of understanding anatomy because previously we've had to do the reconstructions from planer views, which often make mistakes about what is connected to what. Truly an exciting development that lots of groups are picking up on.

Another thing that has been quite powerful is the ability to engineer, model organisms, I'll show you examples of fish and mice. In a way you put in a gene which allows neuron when it fires to actually emit light. So you can watch in real time, what is happening in large numbers of neurons as the animals undertaking some activity. This picture I'll show now, is done by pair of investigators at Ganelial Farms supported by (inaudible) larvae embedded to keep it from wiggling around. I don't know what it is thinking about, but a lot of activity sitting in that algorus plug.

This is pretty remarkable demonstration of the ability to record simultaneously a lot of action. So you are going to look here at about 100,000 neurons and the investigators estimate they are actually able to see 80,000 of those firing, a few missing hiding behind the eye. Let's see what happens when we start that off. This is sped up a little bit, each image is about 1.7 seconds apart. You can see those, a lot of stuff happening. Once in a while, something triggers a big flash like that, I don't know what happened right there, to get that fish excited, they don't either. There is a really big flash.

But the ability to begin to record from this, and obviously you need lots of signal processing and computational analysis to figure out what is talking to what, if you read their paper, you will see more and more coming forward. The ability to do this is really quite new and quite starting. What about the mouse? Mark Snitzer's lab at Stanford, this is small in the picture, you are

looking at a maze, there is a mouse running around in the maze with wire connection to its head, which is actually optically recording what is happening in the mouse hippocampus as mouse traverses the various arms of the maze and again this mouse has been engineered so when neuron fires you get a green light clicking on. And there is roughly 1200 neurons in the field here that are being observed. Oops.

Come on. Oh, dear, maybe that one is not going to do its thing. Thank you whoever did that. Well, do it again. What you would have seen is a lot of green flashes there. The investigators would tell you there is a pattern there. When the mouse goes to the part of the maze where the reward is, there is a specific pattern that you don't see when it goes down the less productive arm. Early days trying to figure out how to process data. Well, then this is human and this is from University of Minnesota, Camille Uberville. Functional MRI, resting individuals just where you can begin to see random activities of the brain, but not that random. The goal is to see what is connected to what. So when you see activity in one part of the brain, it's not random what is happening elsewhere in the brain, a lot of symmetry here you can see. There is more than that with the processing that goes on. You can begin to just from looking at these patterns, interpret networks that are occurring in the human brain at rest in normal individuals. So those are just a few of the really quite appealing technologies that have emerged that I guess again give us the sense we might be at propitous moment for trying to tackle brain function in an organized way.

I guess while we could say those are really cool and we're learning stuff, we are limited in understanding how the brain processes information. We are pretty good at detecting individual neurons and as you can see, perhaps suites of neuron in model organisms. We have a gap in between the very small scale assessment and the whole brain analyses and we really don't understand how circuits work. The circuit in the brain is responsible for instance for initiating voluntary motion for processing sensory input, whether visual or olfactory or auditory or more mysterious, how memories are laid down and retrieved. We really don't understand that process and probably can't get there by studying in a very reductionist way individual actions of specific neurons. The so-called emergent properties of the brain are still a mystery and obviously an enormously important one for us to sort out.

Hence, what was announced on April 2, this mystery waiting to be unlocked and the brain initiative as the president said will change that by giving

scientists the tools they need. A lot about tools to get dynamic picture of the brain in action and better understand how we think and learn and remember and that knowledge could be, will be transformative.

The announcement on April 2nd in FY 14, there will be 110 million dollars specifically put forward for this project, as you can see, 40 at NIH, 50 at DARPA, 20 at the national upon National Science Foundation, John will tell you about that. There is substantial contribution coming forward for this effort from four foundations that are listed here and others potentially may come and join. Allen Institute for Brain Science has been doing phenomenal work in this area for Mouse and for human, is very excite body this and Paul Allen and I were able to write Op-Ed about this demonstrating how wonderful a partnership this can be between government and private foundation. Howard Hughes with Ganelia Farm effort being focused on brain function, particularly in Sock institute coming forward and cowboy foundation who played significant role over the course of the last couple years in generating workshops to talk about the idea of having this kind of organized effort. So this is a good example of that kind of partnership coming forward. Not listed here are companies, quite a few of them that are also interested in taking part in this, but are waiting to find out exactly what it is. And we are, too. Let me come to that.

So for NIH, we felt that the potential here is enormous, but it is still in need of some specificity. If you mount a program of this sort, you need to be clear what your goals are and your time tables are, you can't generate trajectory without that to the genome project, need to do what was done by the Bruce Albert panel back in 1988 after discussion about genome in order to give it real specificity and make a plan.

So in order to do that, we need the kind of experts that would have the most broad view of this to help us. The goals here are certainly in a general way to accelerate the development, application of innovative technologies, because tools are going to be critical here. And to build on on this growing scientific foundation bringing together disciplines that are talking to each other, but perhaps could talk to each other even more broadly and more productively if given this kind of stimulus. We have asked an advisory council working group to assemble a plan and I'll show you the roster here in a minute. It is really quite a remarkable group of experts, a dream team, if you will. And they are charged with coming up with goals, developing a plan, including time tables, milestones and cost. This is the team, it's being co-chaired by Cori Bargman at Rockefeller. Bill Newsome at Stanford. And those familiar

with neuroscience will recognize the other names, some of them whose data I have already showed you as examples of what can already be done in terms of tool development and technology. We do have exoficio membership of (Inaudible) and Kathy Hudson at NIH, but otherwise, the group is constituted of scientists, as you can see, from a variety of different parts of the world.

This will be anchored in my advisory committee to the director, the highest group at NIH in order to provide the expertise that can guide the institutes and I should say I'm sorry that neither Tom nor Story Landis could be here this morning, they have been incredibly important in thinking and planning about how NIH's role can go forward, I'm not a neuroscientist, although I'm on a learning curve that has been a lot of fun. Tom and Story have certainly provided a lot of the details to get us to this point and will continue to be deeply engaged through the NIH neuroscience blue print.

So we will have these experts cross sectors and disciplines, blue print is a connection between all the institutes at NIH that are involved in neuroscience research, but particularly NINH and NINDS and this group will seek broad input, hold workshops, hear from the community about exactly what are the greatest opportunities they are asked to produce interim report on high priority areas by this summer so that we can use that to inform our decisions how to spend 40 million in FY 14 that NIH is to put forward here. Public will have a chance to be involved in this in lots of ways, both electronically and in workshops and the public is started to get engaged, some of them. Here is one who got engaged on April 4. Steven Colbert, wearing skull cap connected to a lot of wires and demonstrating in fact despite what you might have thought, Steven Colbert does have brain activity.

So finally just because there have been concerns raised about is this good time to do this afterall budget for biomedical research is under severe stress with sequester having removed in one fail swoop 1.7 billion from our budget. Some have said what are you thinking here, trying to start bold new program? My response is, if we are going to hunker down in the face of budgetary constraints, then perhaps that is not a very good way to make a case for the value of what we need to do, if we have an opportunity here, let's take it on at whatever scale we can manage, but it is obviously not going to be a good idea to simply delay indefinitely and when a new opportunity comes along.

Let me emphasize, what we're talking about here is a small contribution to the overall expenditure on neuroscience, as you can see, NIH spends on annual basis

about 5.5 billion dollars, minus 6%. And the brain initiative that we're talking about at 40 million is less than 1% of that. But as just as with genome project, the goal would be to develop approaches that will have benefits across the field and will provide investigators, including majority who work on RO-1s with tools to enable them to do their own research more quickly and effectively, just as genome project has enabled RO-1 investigators interested in genetics to go faster than it would have been possible without that kind of community enterprise.

So I think it's nice to be able to talk to PCAST about this interested in your thoughts, president calls this next great American project, obviously I'm excite body that, too. Many things yet to be determined, but I think this is a moment where we can take on with enthusiasm and energy and vision a challenge that ultimately could be really quite ground breaking in this perhaps greatest remaining frontier in terms of human biology, which is how does the brain work.

I will stop and turn it over --

>> Eric Lander: Thank you, Arati.

>> Arati Prabhakar: Let me take a differt tact than Francis' by starting comments by giving you context about DARPA, so you understand how we are approaching this project and share some core elements focus on brain function research and wrap up with thoughts about how all these pieces and how we work with partners across government. I think many of you know DARPA was created in 1958 as direct consequence of the surprise that we suffered when the Soviets launched Sputnik, as that time as now we understood technology is cornerstone of National Security. We want to be sure we never experience that kind of technical surprise ever again. DARPA has delivered on its mission of preventing technological surprise, usually by delivering surprises of our own, and so today in the military we are known as the place that made the pivotal early investment that led to prevision guidance and navigation and stealth technology and UAVs and communications in networks and infrared night vision, a set of capabilities that have radically transformed how we fight war today.

But of course the technology community, we are also well known as the agency that made the pivotal early investments in many areas of material science, including composites and compound semi-conductors and DLSI and CAD, and graphics and AI and most famously of the DARPA net that led to the internet. These two facets represent the two sides of what has come and what will

continue to come out of DARPA's work and they sound a little bit different, but in fact very much the same. The technologies that are in your cell phone, the MIMS technology that gives you accelerometer information and the way you connect to cell tower through power amplifier and the internet backbone that you use to communicate those technologies are actually the exact same technologies that we use for the military capabilities that I described. So that is the heritage that we're very proud of today. We're working on the next generation of revolutionary technologies for National Security. And with that, as always, we're continuing at DARPA to invest in the key enabling technology, some of that, a lot of that work is the next generation, next chapter in the information technology story or the material science story or the electronics story. Over the last 20 years at DARPA we've now started as well building some interesting new technology capabilities that have roots in biological sciences beginning with the earliest work we did in that area was understanding pathogenesis and infectious disease in context of biological war fare defense. Today we have a number of activities that have biology in their roots and the BRAIN function research is the example that I'll try to focus in on here.

Let me tell you what we are doing in our part of the BRAIN initiative. As with everything else in technology at DARPA, our story begins with National Security question, and you know, even though we have a long history of being the agency that builds gadgets and technology war fighters use, in fact, when we really look deeply at how our military service members do their jobs, what quickly becomes apparent is that these are individuals who have to learn incredibly complex tasks and missions. They are people who have to operate extremely sophisticated equipment and work with extremely complex systems to do very challenging tasks. Part of what they need to do is to interact with different types of people and organizations, be it others and their own organization or people in a country where we are trying to have some influence. And finally, these are individuals who are subject to extraordinary stress and extraordinary injury. And our focus on brain function research is in pursuit of an understanding that will allow us to help our war fighters with every aspect of these very challenging tasks they have. And here as in many other areas, we view our objective as creating a set of technology and capabilities, building on top of a really critical science foundation that is laid by our partners at NIH and NSF in this particular instance, Francis talked about what is happening in neuroscience and at the intersection of neuroscience and many other disciplines. It's a really fertile time and a very exciting time in this area and a time in which we at DARPA believe there are going to be some important technology capabilities that grow out of that. So what we are seeking to do is

to increase our understanding of brain function, to use that to open the door to new capabilities of the sort that I mentioned specifically, how human beings work with the world. But beyond that, we also are interested in whether these new -- this new level of understanding of brain function can also potentially inspire new architecture and new approaches for computing and processing and that is another branch of what we're looking at. The work we're doing at DARPA in this area is not new in 2014. We've had a handful of programs focused on brain research in the last few years, that work was largely inspired by the issues of our wounded service members coming back from Iraq and Afghanistan, PTSD and traumatic brain injury of course are sadly they are the signature injuries from these conflicts. And along with the concerns for wounded warriors dealing with those issues, coupled with that, a desire that we had at DARPA to see if there was something we could do to dramatically advance prosthetics capability for those who had lost limbs, especially arms. Those were original inspiration for the first set of program in this area. And let me just describe a couple of them to you to give you a sense for the kind of things we were doing. One was program called revolutionizing prosthetics, it had two components which have come together. One was to develop a much more sophisticated robotic prosthetic arm that had many more degrees of freedom and much more complex functionality. With that, at the same time, we also were investing in research to understand the kinds of neural signals that would control those kinds of motions in a natural way. That work culminated recently when we started doing first human trials and today a woman, Jan, who is a quadriplegic, has been for a number of years, she was one of the early volunteers to have neural implants placed through surgical procedure over a period of months, she has learned how to control and manipulate the sophisticated robotic prosthetic arm in a way that is really quite remarkable. She is able to do quite sophisticated things, just very simple but sophisticated things like picking up a stack of cookies and offering them to a visitor, something she's not been able to do for many, many years. When you watch her do that, you realize what is happening here is a very natural level of control for a function that we all do quite effortlessly, more effortless -- I can't say the word, easier for her to do it than for me to say the word. For me, this opens quite an amazing window into the kinds of possibilities that lie ahead. Obviously for restoration of function, but potentially for so many more things. Let me briefly mention the other example and I think it will also show another interesting window that is opening.

Another branch of research, another set of programs that we've had, has looked at the issues of memory loss and in particular focused on the question of

whether there is way to construct a memory prosthetic, a way to capture and transfer memory information. In that work, working with rats, we've been able to demonstrate the ability to capture the initiation sequence for complex set of motor tasks. In highly trained rat, we've been able to demonstrate transferring that to a naive rat who can then perform a complex function.
We've been able to demonstrate in a rat with a lesion, that would prevent the transfer and flow of that memory information in the normal course, we've been able to show basically jumping that gap, jumping across the lesion and restoring the ability to have that -- I want to be very clear this is not broad-based memory transfer this, is specifically about initiating a particular complex motor task. But again, very early work, but again I think it opens an amazingly interesting window into what might be possible down the road. I think this is probably a good time also to mention that in this area as in many others at DARPA, because our job is to be pushing the frontier of new technologies, we often find we are the first people to be stumbling into some very powerful capabilities, often with uncomfortable implications and I think the two examples I gave you, I don't know about you, they excite me and make me uncomfortable at the same time. Our job is twofold, one is to not back away from technology when they make us uncomfortable.
This is our job in pursuit of National Security.
It is one reason we exist. But the other half of our job is to make sure that we take a role in raising these broader societal issues, legal issues, policy issues, ethical issues, safety and security issues and again this is not unique to the brain research work that we do. I think this is a particularly good example of a place where we want to make sure we are shining a light on these kind of questions. Part one of that is to make sure we do our work in a way that meets legal and ethical and regulatory requirements, that I think is straightforward. We have mechanisms to do that and that part has worked smoothly.
It is something we continue to be strongly committed to. But we also want to take an active role in engaging broader societal discussion about how others will use what comes out of the r&D stage effort we are engaged in today and we're hope nothing this particular case to work with the President's commission on bioethics as the President asked that group to be part of working with the BRAIN initiative and we hope to make have that connection be a good way for us to raise and explore those issues. So that's where we've been, some ideas about the kind of possibilities that lie ahead, specifically our programs going forward, you should expect to see more work that demonstrates the kinds of capabilities we think are becoming possible with the new research that is emerging. We want to add to that, efforts that will try to drive forward the

tools that we have to measure and to assess and to enhance our understanding of the brain. I think one of the interesting challenges in that regard is it is easy for people who are in the measurement business or in the tools business to come up with lots of cool ideas, but the brain has so many dimensions and so many ways in which that job could be tackled. We really see this iterative process where we're demonstrating new capabilities, building models and from those insights we have clearer understanding of what kind of tools would really advance our capabilities and then as we get more data from tools we improve mod and he will do more demonstration and the cycle continues. That will be very productive and then in addition to the work that all of that is about the human brain and how we work with outside world, but again, in parallel, in some is of our microsystems work, we'll continue to look at whether there are neuromorphic architecture that can be potentially very useful for computing and processing tasks, as well. So let me just finish by saying, let's just the nuts and bolts of it. 50 million as Francis said in fiscal 14, for us this, is continuation of work we've been doing at the same level. It's not new money. The initiative is great opportunity for us to link more closely with the partners across government. And I think I'm sure it is clear from your prior interaction with our agency, but as you are listening to what you are talking about in the brain initiative, we each are going to work in different ways to make contribution to this area at DARPA our model has always been to have our program manager set the agenda and drive theory they work in, that works because we get phenomenal program managers from universities and industry and other parts of government who come to DARPA for three to five years, we bring them in for biases and strong views about areas, but when they get there, they spend a lot of time Eric and I were just talking before the meeting, my two favorite verbs for what program managers need to do is listen and synthesize and from that project vision about an area and build a program and drive it and because we're in the technology business and we're looking to create these kind of breakthrough capabilities, that is our business model, very different than the kind of science driven peer review process that is so critical in our science agencies. But you know, this brain initiative is good example of how complimentary approaches knit together, but to me it's microcosm of how the whole ecosystem works. We at DARPA are not going to exceed in anything we try to do unless we have other pieces, the funding parts, but particularly the institutional capability in our universities and our private companies in our labs because we're project agency and we are completely dependent on having that healthy community in order to go build the breakthrough capabilities that are our job. So few comments I hope will be helpful.

>> Eric Lander: Great and very exciting and you touched at the end on something I want to hear more about, how the different approaches taken by NIH and NSF and DARPA complement each other in initiative like this. I'm impressed this is vastly stronger because of the different approaches that are going to be taken. I'd love to hear more in terms of what it means, in terms of planning or not planning, both are important to sort of, I know DARPA puts responsibilities in the hands of great program managers and giving them a freehand could be a good hand, too. John Wingfield from the NSF will complete our trio of science agencies and tell us about the perspective of the brain from the NSF with respect to the BRAIN.

>> John Wingfield: On behalf of the National Science Foundation, thank you for being here and what NSF is doing in relation to the BRAIN initiative. I will start out and say, we are a small agency and great envy at Dr. Collins' budget, our entire budge set about $7.5B small fraction of that is neuroscience, about 75 million or so per year.

But I think if you look at our mission, that we are focused on basic research, fundament research, give you some idea of how we contribute to the bigger picture. So Dr. Collins and Dr. -- pointed out, (inaudible) and also educate the work force needed for the brain initiative to succeed. That is where we see our contribution. (Inaudible) geosciences because that is where biological oceanography is, computer information, science and stem education and biology. And we also must emphasize we do have collaboration with other agencies and I'll refer to again in a moment. So NSF core programs in a number of directorates, major research instrumentation and inspire program, these support research to develop molecular scale probe, sense and record network activity, develop imaging and related nanotechnology to determine the genomic and neural circuitry, emergent property of the brain. Also, establish relevant conceptual and theoretical framework which is very important. And this is particularly where social behavior and economic science come in. For example, to link brain activity patterns to cognitive and behavioral function in ecological evolutionary and development and social context. To apply social science theory to link pattern of brain activity to individual behavior that underlie what humans do. I think these -- this later point is important because it allows us in the future to be more experimental rather than just descriptive or correlational. We see contribution there. Some examples. Recall the brain at scale. Up to genetics, you have seen the pictures already, the brain bow and the connectome, and system, neuroscience, computational neuroscience and nanoproperty of neurons. Why do we have some of the same slides as

Dr. Collins? This is because these principle investigators get funding from (inaudible) DARPA, Allen Brain Institute and so forth. We all contribute in various ways to the overall goal. And NSF here is contributed in particular to the development of the tools.

So let's take the genetics as an example. And respect proteins are introduced into neuromembranes and these rhodopsins enable living tissue in real time and precise control of neuron and simultaneous measurement of effects. This again is called Diseroth, heavily funded by NSF and NIH and DARPA.

I show this slide, these rhodopsin proteins link to iron channel, were discovered in algae, microscopic plants, they control the movement of algae into the light and shade according to photo synthetic need. It was the discovery of these kinds of associations of proteins that allowed scientists such as Carl Diseroth to take advantage of this and development remarkable tools. The latest generation is clarity, brain imaging, I don't want to spend time on this, you already heard, but here neurons and molecules within in tact brain and hippocampus.

More examples from NSF, gender differences cognitive neuroscience and also from biology, epigenetics, funded in biology, again from plants, original research on purple flower and petunia that occasionally produce white flowers led to the discovery of the interaction of small RNAs that is regulate gene transcription. This is a huge area now in biological life science in general. We also do a lot of species comparison, organism and particularly in relation to evolution of nervous system and the brain. Engineers have used this to great effect to reverse engineer neural system. I can show you two examples later on. I want to give you one example from biology.
This is recent paper in nature.

From the lab, to Georgia Tech, we know that there is great variation in brain, particularly in mammals and approximate other vertebrates such as fish. The fish in particular are of great interest, their brains are diverse, neurologically, physiologically and behaviorally, but genomes almost identical. Work from Lake Maloi, one fish, the cichlid on the left is vegetarian, aggressive, has a different social system to the sand dwelling cichlid on the right side that is not so aggressive, but is a predator and has a different social system. They have been able to manipulate the protein pathways during development to opposing ones, hedgehog and wingless that establish evolutionary divergence in the dorsal ventral patterning. In the rock dwellers, extensive

early hedgehog activity and full brain stimulating expression before the dorsal wing signal result in larger subpallium of the (inaudible) sand dwellers rapid development of expression result in larger pairing. The amazing thing is that manipulation of the two path ways in cichlids fish and (inaudible) fish can mimic natural brain differences. This raises the issue of how environment, social and physical environment may have an influence on ultimate brain function.

Moving on thinking of time, modeling object recognition, neurally inspired robotics, I'll give you an example in a moment. You have see imaging issue here, neuroplasticity, brain oscillation and memory. These have allowed development to adapt interaction between human nervous system and sensory motor devices. First, a slide you have already seen, human brain, grid structure, three dimensional as Dr. Collins pointed out. I won't dwell on this, except to say NSF was a funder of the research. Two examples, from the engineering directorate microelectronic systems that show what other things will be possible in the future with this brain initiative and this one was the first FDA approved retinal pros thesis used to treat patients can pigment osa. And external video camera can be transformed into electrical data and wirelessly transmitted to the retinal pros thesis which allows patients to recognize letters, word reading, improve mobility and so forth.

Another example that I give a different example is wireless and wearable technology that converts and uses tongue motion from a chip placed on the tongue to move mouse cursor on computer or powered wheel chair. The average speed of information transfer between participant on the computer was twice the band width tested before and the subjects had full immediate control over powered wheelchair through fairly complex maze. So these are things that are coming out of the engineering directorate that working with bio, working with computer information science and information and engineering and other directorate as well such as SBE.

I'd like to end with this slide to give you an idea of we're thinking about the way forward. There will be workshop beginning on Sunday evening and going through Monday and Tuesday on physical and mathematical principle of brain structure and function. Sponsored by the mathematical directorate. There will be over 100 neuroscientist and technologist including NIH, in particular and DARPA will be represented. Also represent the meeting of the dream team, the advisory committee to the NIH. And the aim is to identify set of goals and basic neuroscience and tool development. And we are very interested in looking

at this to then partner with other agencies, perhaps to development what we call ideas labs to tackle particular problems that lie in the way of progress in the brain initiative. I can explain that in greater detail if people are interested. Thank you.

>> Eric Lander: Thank you all. At PCAST people raise flags when they want to speak and while my colleagues are putting up their flags, I might ask you each, the BRAIN initiative, what is it? We've heard an amazing array of science. Extraordinary to see connectomes and clarities and individuals who are in wheelchairs being able to navigate by picking up signal and wide range there. You know, we've heard about the ability to I thought this idea was interesting of memory prosthetic, there is a lot of things there, yet Francis, you refer to this, you made a comparison to the genome project which was a process comparison, I note, namely, when there was significant project, like genome project, there was careful period of time to work out what it was. I didn't necessarily, take that to be a comparison this was a genome project in the sense there was a specific target to be achieved rather than say a bundle of amazing tools to be created to allow research. But with that range of things as to what it is, what would you say if you had to give the one sentence description of what is it, this BRAIN initiative?

>> Collins: I think I said earlier the elevator speech hasn't quite been written, I think you are asking for a draft.

>> Eric Lander: Yeah, rough draft. I'm curious what it sounds like, I fully recognize, as you said, what is most important is directionally, it's clear there is something going on right now that is really important and what we're trying to do is distill our thoughts about how to best drive that scientific activity and that creativity. So I ask as nothing more than a rough draft and no reason why you all would have the same rough draft yet, I think the process will be the interesting thing, putting you on the spot, the elevator going up five floors, pretty fast elevator, what do you say?

>> Collins: The development and application of tools to enable the discovery of the emergent properties of circuits, not -- and in real time that conduct complex operation in the brain.

>> Eric Lander: Cool.

>> Francis Collins: Did we get to the 5th floor?

>> Eric Lander: We got to the 5th floor, other takers on this one?

>> Prabhakar: I think for our piece of it, our focus has been and will continue to be brain function, which sounds simple, but is going to take all the things Francis said and I think the development of models and tools and demonstrations and that iterative learning process to get there.

>> Eric Lander: Great. And to the NSF, what is this?

>> Wingfield: Two things, I might add here is one of our grand challenges I mentioned is understanding how the brain works and how it functions the way it does for complex thoughts. And understanding how this complex organ works will help a lot in fixing things that are wrong.

>> Eric Lander: Okay. All right. In that interim, I've seen flags from Mario, Jim, and Chris Cassel. The I'll go Mario and Craig. Mole

>> Mario Molina: Thank you very much for interesting presentations. Let me tell you what my question is about. It has to do with I heard some words like grand challenges and reverse engineering, okay. It turns out that few years ago, five years ago, I was a member of a group from the national Academy of Engineering and we came up with 14 grand challenges, okay, you might remember that, Larry Page, Craig Mentor were there, so was Ray Gertwa. One of the grand challenges maybe was the one that was most far-fetched is to reverse engineer the brain.

Okay. So what the point here is maybe that is indeed far-fetched, but to what extent can this be really connected and maybe you call that computational neuroscience or so. But to really make a big effort from the other end at the artificial intelligence and so on, to what extent do you think that can be connected or assisted to think about that sort of thing?

>> Francis Collins: Great question, Mario, there is intense interest to see what (inaudible) illuminate architecture for computational purposes and it's worth pointing out that is sort of a complimentary strategy and one that Europe just announced major investment in, the so-called human brain project, there the effort is to try to generate insilico, the kind of things the brain can do as way of basically testing out whether we have models right, I suppose. I'm actually pretty excited about the fact Europe is putting their investment in

that space, whereas I think what we at NIH and NSF particularly are investing in the basic understanding from experiments how it is that circuits work and somewhere in the intersection there, there will be very interesting discoveries that will relate both to human neuroscience and to computational architecture. I would predict. You all may want to add to that, this is intensely interested to NSF and DARPA.

>> It is, we have a number of programs that bring together engineering with computer information, science and engineering and everything related to artificial intelligence and using biological based neuro networks to work out ways in which they may be able to develop these prosthetics and so forth to improve human life, but perhaps also would have agricultural uses, as well. So again, I'm not an engineer, I can't go into many details, but we do have these programs. There is another one, I think called Smart Health, that is collaboration with NIH and brings in social, economic and behavioral sciences where they are trying to model various cognitive processes and for artificial intelligence and to understand the human brain.

>> Arati Prabhakar: Let me add time dimension to try to answer your question. If I think back over the history of AI and work done on neural networks, this isn't a new idea to be inspired by human intelligence for machine intelligence, but the -- I think from the computer science and computing side, we've made quite dramatic increases from not very sophisticated base and actually a lot of those technologies are embedded around us today. We have gotten some benefits and yet when you look at the sophistication of AI system as an example today compared to what the human brain does, we're very far from converging, I think from that, to me it's easy to imagine a future where the insights are going to get in this next period of time are going to refuel the efforts on the computer science side and the architecture side, so over a very long time, you can sort of imagine these fields coming together, but maybe we need a decade kind of time frame to think about it it.

>> My question lies exactly in between these things. The last few years, as Arati said, these ideas of machine learning and neural networks and things are not new. But there is I will say renaissance or dramatic change in just the last three years in terms of the progress we're making there and in a sense it's being driven now by the super scale machines that we built to run the internet and then the big data world which is driven by the sensors. When I look at all this, I mean a lot more focus I'll call it on the sensor part, you know, getting this stuff through imaging or other means, sort of electrical or

chemical and I think that there should be a very specific focus. The way these things are advancing on the EML side, deep neural met and the breakthrough comes because we now found we have computers that are many decimal magnitude bigger and amount of data and data diversity we had to feed them are many decibels bigger and that is creating a fundamental change in what we can do to train net works.

And so it seems like there needs to be in my mind a very specific focus now, not to try to create a model of the human brain, but this is a thing of stunning complexity and the one thing that these new machine learning things are doing is they are learning things of patterns of stunning complexity that we can't describe. So it seems like I guess my question is, is there enough focus now on direct coupling of these new ML capabilities in the private sector with the output of these historically separate programs in generating the data at scale?

>> Arati Prabhakar: That is a great topic. One of the reasons is such a fertile field is this collision of disciplines that is happening. So to that point, one of our program managers is just starting a new program, on probabilistic programming to try to really give tools and capabilities to accelerate machine learning and make it not this fine hand crafted capability it is today.

She's thinking about lots of different applications, but as I was talking with the neuroscience community, it really rapidly became clear there is a convergence opportunity exactly along the lines --

>> Talking about neuroscience people, I tell them what we do every day running super scale things and they say, wow, that is like way more than we ever thought we could do. And I'm worried right now that the class of computer science computer science research community is not coupled into this and those things that exist in the research environment don't have access to the super scale facilities that the commercial companies are now using in this for other applications.

>> Yeah, I think that is a great opportunity and are you all reaching out to the neuroscience community, doing anything specific in that area?

>> I will say more serendipity, I walk around and talk to people, I'm finding we already do that. You know. They say, really? And so I think the answer

is no, we're not systematically doing it and I don't see anybody else systematically doing it.

>> Is there any resistance, Craig, it would be great to take advantage of the synergy and I've heard about the (inaudible) and it wasn't quite clear just how much people are ready to open the doors to full collaborative enterprise to try to understand this field and how to tie it in with brain?

>> You know, I don't think, you know, except for the people who do the research in this, like MSR and very few other places, there is lots of people doing the research, but don't have access to these super scale machines. And that's where the difference comes. And so I don't know, I guess my plea is and I'm happy to personally sit and talk with you about this, I think there could be a more systematic attempt at engagement, I don't know whether it will be achievable or not, but seems like there is opportunity right now. None of them do this or have access to these facilities either.

>> Part of the charge to the Barkman Nusome team to identify synergies with activities that are going on outside of this traditional research funded enterprises and this seems like a great topic for one workshop when they intend to have quite a few of coming up.

>> (Inaudible) I notice, I have a friend who is a lawyer and because I'm on PCAST, we this friend pays more attention now to when things are going on in the political realm. When the BRAIN project was announced, my friend said, why can't they just say we're going to the moon or something more equivalence, very sharp, distinct goal in mind and say, this comes back to the point in mind Eric raised, if you are going to bring the public along, people are going to look for something they can hang on to, I would urge you with all that I can to come to grips with this.

>> Great point and one of our charges again to this ambitious dream team working group is to define specific mile stones with time tables you can say, we will hold ourselves accountable for getting to this particular outcome in a certain period of time and those need to be bold and but not unattainable. There is going to be a problem, though, it is not like the genome project where you can say, there are three billion nucleotides and we'll figure it out and get them out in the public domain, the brain, I can't imagine having a brain project where you would say, okay, now we're done.

Maybe some time 100 years --

>> Finite number (inaudible) -- but that might not be --

>> Francis Collins: Not declare as goal. We are after function here.

>> There might be a better choice of goals than that.

>> Francis Collins: You are right, we are lacking specificity people are hoping to hear pretty soon in terms of an electifying set of goals that would get the public excited.

>> Hudson: But continuing the genome analogy, when the project started, my mother didn't know what a genome was and the chairman of the science committee pronounce today genome in early hearings, so I think what we have as an advantage in the brain initiative is that everybody understands what the brain is and everyone is mystified about how their own brain works or their teenager's brain works. I think we have more general excitement at the get go than we did for the genome project, but we do need to come up with that specificity.

>> Eric Lander: Not artificially so, marketing shouldn't drive away the fact that there is an amazing array of technology. People understand the power of computing and information technology even though there is not a goal of exactly the one thing we're doing, the wonder is the variety of things that is makes possible. So I think it is just interesting to ask, you know, maybe you do want one single thing or want it to be understood in a different way, what neurotechnology make possible and while people may know what a brain is, they probably don't know what neurotechnologies are. It might be that if they understood the range of things that were neurotechnologies, they might get really excite body it, maybe we have to teach us all a new work. Chris Cassel raised her flag, perhaps provoked by this conversation.

>> Thank you, I was going to ask about the European project. Sure. But I'm reflecting on Jim's challenge and thinking that you know, in this one, I don't think you want -- this is a lot of the early press was describing a brain map, which is I think exactly what Francis is saying, you know. Even if you could set that as a goal, I'm not sure that would really help humanity in the way all of the ways that we can see coming out of this. So Jim, I'm happening getting back to what we were discussing this morning, combination of the three

agencies, plus the private sector interaction, there needs to be some playfulness and just curiosity about how things work that it is going to lead you to things you can't predict or don't even know and that's kind of the wonder of science and the way that young people get really interested in it is not imagining I'm going to build the internet, but maybe some of them do, but more kind of how does that work. And where does that take me. From my perspective, thinking about the tremendously frustrating journey with Alzheimer's research and how we keep thinking there is leads and they don't quite do what we thought they were going to do, that there is I think in that community great hope maybe with fresh thinking and new partnership we will get breakthroughs in that area, too. Other areas, as well. I would urge us not to be too focused on the result, we might miss the more interesting and important thing.

>> From NIH perspective, we are struggling a little bit with the part of this story that relates to disease application because clearly that is a strong motivator, we are the National Institute of Health and want to build this foundation that will apply to lots of diseases and improve ability to prevent and treat, but same time, would be mistake to put this forward as this is going to lead to insights in Parkinson's, epilepsy and schizophrenia by tomorrow or even next year because we all understand that this is coming at this from a very basic foundational perspective and those insights have disease relevance, I hope they come soon, they probably won't come as soon as many of us would hope for those who are afflicted. We have to somehow figure out how to describe this in a fashion that doesn't over promise, but still maintains the excitement that is under girting the potential.

>> Here, here. We are coming near the end of our time, to Francis' point, I want to turn to John for a second and just give you homework assignment. You were -- you can test the whole agency with it, it is fine. You cited two good examples beginning of your remarks about algae, how they get into the light and the dark and how that turns into optogenetics that might allow blind people to regain sight in their retina and you can draw a line between pond scum and potential blindness cures and you also talked about purple petunias sometimes being white and how that led to Nobel Prize winning sorts of areas like RNA interference and potential cures for disease or therapies for disease. I'd love it if you guys had a bunch more examples. I think for a lot of reasons right now it would be very helpful to have extraordinarily unlikely things that turn into impact, very much to the point what comes will come from unable

things, they come from well chosen scientific questions that to a person on the street --

>> The bio --

>> Eric Lander: I'd love 10 great example, not all in life sciences, I'm a big fan of prime factorization, giving us some best security for communications and various other things, I think it is important theme right now at a time when sometimes the public and others isn't fully understanding why you choose to do excellent scientific research in certain directions, the payoff can be very unpredictable, but very big. Finally, my last comment to the panel, we are going to need to close and move on, we're at the end of our time, before I say thank you this, is a great example of a grand challenge, there is a sense there is something in the air right now. We're still trying to define it and I'd love to hear and I think PCAST would love to hear from all of you about other areas where we should be thinking in the same way. I notice that this is not huge amount of money tis public and private money, the NIH is putting less than 1% of its funding in neuroscience behind it, but that can be quite catalytic and so I bet other such things will help us communicate with the public and importantly light the fires of imagination in the next generation when they see things well formulated. I know for (inaudible) thank you all.

(applause)

>> Moderator: Now we come to the portion devoted to public comment. And I'm going to turn to Maxine, who will chair the public comment session, we're not going to take actual break, but people might stretch for just a moment as our panel gets up and we will do public comment.

>> First public comment from Tanesha Boldin. If she will come -- come to the table. You have two minutes.

>> Thank you, I won't take that long. Just looking over the topics that were on the agenda today, I kind of thought about this and started asking my two children their comments, 16-year-old response and 10-year-old response very interesting. From that I kind of morphed this question. With constant push for innovation in every industry we see work environment like those at Google, apple and (inaudible) build team work. Even in an eight-hour school day, students have recess period. Studies show that allowing the brain to have a moment of rest or play increases concentration. Checking social media has

replaced the power nap. What steps can a company take to ensure their employees workday and environment has right balance of playtime and work time while seeking to foster innovation and maintain productivity standards?

>> Okay.

>> That was my comment.

>> Thank you, I'm glad you asked your children.

>> Yes, thank you.

>> Next comment will -- is from Notre Dame. Matt Anderson, who is our intern will read the comment, which we did receive by e-mail from Richard Taylor.

>> On March 15, 2013, I had the privilege to attend the PCAST meeting. The agenda included presentation of the American chemical society report on the future of graduate education and chemical sciences. This topic was of particular interest to me as professor of chemistry and biochemistry and associate dean for research at University of Notre Dame. The presentation and report itself accurately presented current state of graduate education and chemical science and serious issues university programs are currently facing including but not limited to graduate student funding, laboratory safety and employment prospects for trainees. Throughout the written document as well as presentation to PCAST on march 15, graduate education is most strongly justified by benefit to the individual, to employers and to site through the student training and development as independent scientific.

The report includes recommendations that evolve graduate education and training to benefit all three constituency in education of future scientific investigator in industry and economic research laboratories. I have no doubt the measures of ACS, including March 15, representative Barton and Jock, and president's council of advisors on science technology are well aware of this history of scientific research in our country and influence on current university research enterprise. Unfortunately, I believe the acs commission as well as specific individuals who presented to the council missed an important opportunity to reaffirm the social contract that generated the current model for --

>> 30 seconds.

>> The report stressed research studies as such graduate education is not system that provides future benefit to the individual, potential employers and in turn society in fact graduate students active participation research generates fundamental discovery that advance understanding of specific fields, provide foundation for future technological advances, solves problems in biomedical research and engineering and generates property for economic development. I believe that much of the current constriction of Federal funding for university research is due to the public and governmental representatives misunderstanding of the value of graduate education and research and contribution to society.

>> Back to John.

>> Well, that brings us to the end of our agenda for this public meeting of President Obama's council of advisors on science and technology. As usual, I want to thank our extraordinary staff for the work that makes these meetings run smoothly thank the PCAST members for their attention, thank the panelists, although they have all left, I think, for extremely interesting, instructive and in some respect provocative presentations, I'm sure that that has, the presentations have provided us with thought for further discussion among ourselves and with others in the relevant communities, both the community of folks who think about technology, innovation and employment and folks who think about neuroscience research and what the brain initiative might contribute to that domain going forward. So again, thanks, as well, to the people present in person to be part of this PCAST meeting and thanks to the folks who watched it on the web. I hope we will see you all next time when we meet in July.