

# TECHONOMY

TECHONOMY 2012 • NOVEMBER 11 – 13 • TUCSON, AZ

## Where's My Robot

### Speakers:

Rodney Brooks, Rethink Robotics  
Andrew McAfee, MIT

### Moderator:

John Markoff, New York Times

### Video:

<http://techonomy.com/2012/11/wheres-my-robot>

**Kirkpatrick:** The next session, if the panelists would come out. I'm very excited about the session on robotics. It's really a very strong group here. John Markoff, who doesn't need much introduction, one of the great journalists about science and tech in the world.

Rodney Brookes, a legendary roboticist who, you know, started iRobot and now he's got Rethink Robotics, which he'll tell us a lot about and is doing quite dramatic things that will have impacts that are quite unpredictable, I believe.

And then Andy McAfee, another good friend who is at MIT, and just a great thinker about a lot of tech issues. So the three of them together I know are going to make a great panel.

**Markoff:** Thank you, David. So our topic here is, Where's My Robot. I actually think the topic should be Where Isn't My Robot. If you start to look, they're everywhere. And Google's cars have now driven 300,000 miles without accident. I don't know if you know, but Volvo is going to have a self-driving car that will drive under 30 kilometers an hour in the market in 2014, and probably they won't be alone.

Microsoft's Connect, which was designed for the living room, has been seized on by the robotics industry, giving them higher quality and lower cost vision. Robots in the form of drones blanket the skies above Iraq and Afghanistan, and possibly soon the United States. Robots are used routinely in surgery.

So I want to begin by giving two quick snapshots from my reporting during the year. I went to the Netherlands, because I was looking for a consumer product that was being made by robots, and I found an almost completely lights-out factory at Philips. Philips was about to move the high end of their shaver product line to China, and instead they bought 128 U.S. made robots by Adept, and they now have a line that is almost lights out. 128 robots, they move at two-second intervals, capacity of about 15 million shavers a year, and they make this thing out of an ensemble of small products, and it just blew away my notion that robots can't do dexterous things forever, basically. At the very end of the line, there are eight women. They do the QA step at the very end. They listen to the shaver. A very good way to make sure it's complete. So that sort of really reset my notion of what can be made by machine right now with last-generation technology.

And then in Fremont, Flextronics has a manufacturing line that makes solar panels. They make almost as many as a very labor intensive factory they also have in Asia. I walked in, and on the wall there is a sign that says: Bringing Jobs and Manufacturing Back to California.

And I looked really carefully, and I maybe counted eight people on the line in that shift. So is it a good news/bad news kind of thing. The question is, obviously robots are increasingly a part of our society. The question is, what does it mean?

I'm particularly struck by the current rate of change, and I wanted to start by asking Rod, who both founded iRobot and Rethink Robotics, about the consequence of moving between the Roomba generation and the Baxter generation of robots. What is different in the two eras that matters?

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**Brooks:** Well, the Roomba was the first cheap mass market robot. That was the big thing. But it's a special-purpose robot. It just cleans the floor. There is a version of it which people use for research, but it's just mobility. Whereas Baxter—and maybe we could have the picture up—that's Baxter. We just announced that. And, in fact, John announced it in the New York Times on September 18th.

Baxter is a robot to go into factories and do simple cases of simple tasks that people do right now that are boring. But there's two important things about it. One is that the software on it is set up so that a line worker, a person who doesn't even have a high school diploma, can learn to program it in less than five minutes and retask it for new things over time.

And the other thing is, we're coming out with an SDK early next year so that other people can take this and program it to do all sorts of other stuff, which is not manufacturing. I have no clue what they're going to do. I'm hoping people will do really crazy things with it and lots of different things with it. But it's meant to be a platform. Hopefully out of that will come a whole bunch of new applications.

So the difference is, it's like when we had a special purpose Pong machine, we could play Pong. But then you got a PC or an Apple IIe that could have different programs run on it. This is meant to be programmable at that researcher end.

**Markoff:** One of the first things that obviously jumps out at you is Baxter has a face. Why does Baxter have a face?

**Brooks:** Baxter has a face so you can tell what it's up to without having to have icons or language, apart from the eyes. When it's about to reach somewhere, it glances where it's about to reach so you're not surprised by it, and you don't have to train someone that glancing before you reach means you're about to reach. People know that from interacting with humans. When it's confused, it looks puzzled. When you go up and grab its arms, that's how you program it, the eyes move down to the side and you get various icons on the screen when you interact to give it some task.

In case I was confusing in what I said, there's two different ways of programming. One is by regular workers in the factory and then developers who are going to use it for other stuff.

**Markoff:** You chose not to put feet on Baxter. Was there a particular reason that Baxter is not wandering around the world yet?

**Brooks:** With those two hands on there, there's 18 custom gearboxes in that robot already, and that's a crazy amount of development to do to put the product out there. So we just have a passive base. It bolts on there. We expect third parties will probably come up with mobile bases for it before too long, but too much to do all at once. So we tried to narrow it down.

**Markoff:** And my sense about Baxter too, it's not a one-motion-every-two-second kind of robot. It's slower, it's less precise.

**Brooks:** It's force based. It's not a precision. In fact, we had it in a little plastics factory somewhere, and someone came up and one of our engineers moved the robot three inches, and the owner of the factory said, oh, no, now we have to reprogram it. But it just kept doing its tasks, because it's not based on precise position, whereas those robots you saw in Philips were—and you said they were dexterous, but it was careful, careful dexterity that was programmed by hand over probably months of programming.

**Markoff:** One of the things I didn't say, what is the difference between an iPhone manufacturing plant, which is largely made by humans, and a shaver manufacturing plant. The shavers only change about once every half decade, and so you can invest the money in that programming in getting back. And the iPhone factory, from my understanding, if you're changing models every --

**Brooks:** Well, it's worse than that in the iPhone factory. They are changing components. Components suppliers come and go, and the shape of the components changes even in the same run.

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**Markoff:** What about adding Baxter style flexibility to those older-generation robots? Can you see a convergence?

**Brooks:** The current industrial robots that are out there are—the customers are pulling it to be more flexible. But I was with some major—one of the major suppliers the other week. They said: We're hearing some of the customers wanting to do tasks that are—they are only doing the same task for four months at a time. We are going after small customers who only do a task for an hour at a time. There's a bit of a gap yet.

**Markoff:** And commercialization is in the spring or early next year? In terms of when they're out there in the real world.

**Brooks:** They'll be out there this year.

**Markoff:** This year.

**Brooks:** Yes. And they're made in the U.S.

**Markoff:** And they're made in the U.S.

**Brooks:** And \$25,000 for that configuration.

**Markoff:** You were Heartland, which I thought was a great name. You became Rethink. Why did you change your name late in the game?

**Brooks:** Our customers thought we were maybe making fun of them.

**Markoff:** Interesting.

**Brooks:** Didn't occur to us.

**Markoff:** So Andrew and Erik Brynjolfsson wrote this provocative book called *Race Against the Machine*, and conventional wisdom on the automation debate is that technology always creates more jobs than it displaces. You came out with this book. What has been the reaction from the mainstream economics community to *Race Against the Machine*? And could you give us a short synopsis of what you guys set out to say?

**McAfee:** We set out to say basically that technology is accelerating. That's the theme of *Techonomy*. I think everyone here believes that. We do as well. The point we tried to stress in the book, though, is as technology races ahead, it is leaving a lot of workers behind. That is a trend that I fully expect to see continue.

I wrote the book with Erik Brynjolfsson, who we heard from earlier today. I'm only going to speak for myself, because I don't want to put words in Erik's mouth. I think when it comes to the impact of technology on the labor force, we ain't seen nothing yet. We're just on the other side of a tipping point where computers and robots and hardware and software are doing things that used to be, honestly, the domain of science fiction. That's going to have a lot of wonderful consequences for our society and our economy. It's going to have some very, very challenging consequences for the labor force, and particularly for the less-skilled, less-educated workers, of whom there are a lot in the States and all over the world.

So you asked about the debates that sprang up in the wake of the book. We have wonderful debates and conversations, particularly with our economist colleagues. And the weird pattern that I've noticed is that the better they're trained, the more classically they're trained, the better economist they are, the less likely they are to believe what I've just said. Because economists have a name for what I've just been articulating, it's called the lump of labor fallacy. The idea that as we automate something, that that takes up that part of labor and that humans are displaced permanently.

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A number of pretty smart people have warned about technological displacements. John Maynard Keynes did it in 1930. We haven't had it yet. We've always found new uses for labor as technology comes along.

What I think is different this time, and I think this time is actually really different, is that I see technology encroaching into human skills and abilities that have never, ever been the case before. So you mentioned dexterity. We see locomotion, we see mobility. You talked about the Connect, the ability to sense the world. If you drive the Google car, you see a lot of those abilities put together.

In the purely mental domain, we now have computers that can translate between human languages with decent fidelity that can automatically write prose, that can understand our speech and produce speech. When you combine that with Watson, which is another very general purpose kind of Q&A knowledge retrieval technology, I start to see a lot of what a human being offers to the workforce being encroached on by digital technology.

And just like no one at any wage now gets paid to add up long columns of numbers, because computers are just flat better at that, when the digital technology becomes better, the employers hire digital labor, not the human labor. I expect that trend is going to continue.

And I fully believe and accept that there are going to be new industries, new companies, new economic activity. What I don't think is that there are going to be new human skills discovered, and the current body of human skills is being encroached on quite quickly.

**Markoff:** When you put that argument to the economists, do you change any minds?

**McAfee:** Unclear yet. Because history is on the side of the job optimists. We've been talking about technology and encroachment for 200 years. We've had waves of incredibly powerful technology, so the argument from history is a calming argument. I just don't take any confidence from it these days, because the recent economic trends are pointing in a pretty different direction. And when I look into the future, again, we ain't seen nothing yet.

You mentioned the sign you saw about bringing manufacturing and jobs back to California. What I see going on is a decoupling of those two trends, where there's a lot of economic activity that doesn't need a lot of good old-fashioned labor activity.

**Markoff:** What does it look like then? Let's go backwards first. Let's look at our last slow recovery. Do you believe automation has played a role in the slowness of the --

**McAfee:** Yeah.

**Markoff:** And are you alone in that?

**McAfee:** No, we are not alone on that. And the longer the conversation goes on, the more consensus we hear that automation and technology is one of the factors. So I don't feel alone in making that argument.

There are two flavors of the argument, though. One is that we're going through a transition period, like we've gone through before with the electrification, with the automation of agriculture. Long, painful transition period, after which we're going to resume an economy of somewhat like—something like full employment. I find that the optimistic view. I don't share that view.

There's pretty broad agreement that this recovery that we've been through and the joblessness of the current recovery has a couple root causes. Technology is one of them.

**Markoff:** Yeah. Let's go back to the technology for a second. Rod frequently starts talks by putting his hand in a pocket and pulling out a key or a coin. And I had really hoped that Baxter would be able to do that.

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Where are we with respect to dexterity?

**Brooks:** The reason I do that, you're feeling with your fingers and adjusting what you're doing and you do manipulation without any vision and then you've pulled it out. We don't have anything like that dexterity.

In that Philips plant you talked about, if the keys were in the same configuration every time, they could have programmed the hand to pick it up. But not the generality that we do it.

So dexterity is something that we—actual dexterity, give a robot something it hasn't seen before and have it do something dexterous, it's really not there. One of the reasons—actually, if I go back to the late '80s, there were hardly any mobile robots in the world. Just a few papers about the idea of simultaneous localization and mapping, SLAM. Then there was lots and lots of research robots produced at a low cost, mobile platforms, and lots of researchers had them. And out of that SLAM became a dominant research area of the '90s, and that turned into the Google car.

So it was having the platform there that lots of researchers could do stuff. There hasn't been a platform for arms and hands that's low cost and safe to be around, so there hasn't been that takeoff. I'm hoping that's one of the things people will use Baxter for and get us to dexterity.

**Markoff:** You're giving a lot of them to students. There are going to be a lot of them on college campuses?

**Brooks:** Yeah, we've got a lot of orders from colleges already, yeah, absolutely. This is a tenth the price of anything they can get now.

**McAfee:** And I will vouch as an outsider and someone who is not an investor in the company, Baxter is a really impressive technology. Think what it's trying to do. It's a \$25,000 robot. That's discretionary budget for any decent-sized manufacturing facility. You take it out of the box. You plug it into the socket, the electrical socket in the wall. Your hourly worker trains it for on the order of half an hour.

**Brooks:** Less.

**McAfee:** Less. And then you can get a day's work out of it. I will vouch for almost all of that. Erik and I had the chance to go play with Baxter. Rod invited us to Rethink. And you walk up—it's humanoid, it watches you as you walk up. You grab it by these wrists, and you guide it through what you want it to do. So Erik and I were playing with Baxter. We were proud of ourselves because we got it to recognize a part on a shelf and pick it up, and then Baxter didn't do anything. And Erik and I are thinking, huh, it's kind of a failed demo, gotta reboot this thing. Rod walks up and says, Hey, if you're going to program a pick and place operation, you have to tell it where to place as well. Baxter is waiting for you.

Erik and I say, Great. Now, between the two of us, we have eight degrees from MIT and Harvard. I think that's the problem. We were probably just overthinking the situation. But you're saying you've seen hourly workers train this thing in a matter of minutes.

**Brooks:** Yeah. They'd never seen a robot before, and a few minutes later they are training it to do a task that's in their factory. And that, by the way, I've been arguing that this is not meant to replace people. It's meant to make them more productive. That was why I made it so that ordinary line workers could program it. Because it wasn't this technology that's coming down from above and they're not allowed to be part of the equation. Because I really think that's going --

**McAfee:** I hear that and I believe it. But you also know that the trend in manufacturing is incredibly clear. In America—well, talk about the crisis in American manufacturing. Let's be clear about some things.

The size of the American manufacturing industry grows every non-recession year. Value added by American manufacturing is huge and getting bigger all the time, while employment decreases year after year.

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And the obvious—the first explanation for that is an outsourcing one. We're sending all that to China. The peak manufacturing employment year in China was 1996. It's gone down most years since then, while output from China has absolutely skyrocketed. So the trend in manufacturing is super clear, output

going up, employment going down. I can't think of any economic law that says that's not going to apply more broadly across industries as technology continues to do its work.

**Markoff:** A question about China. I thought that China, if they automated, might suffer dramatically. But I've heard that China actually has this demographic sort of slot coming that they need robots more than we do, perhaps?

**McAfee:** I don't know about the demographic slot. I do know they're going to be at least as eager to buy robots as any other country's companies.

**Markoff:** Does that end the onshoring trend? If China follows us and automates, do they have a cost advantage and do jobs stay there?

**McAfee:** I think Rod's point is that if you take labor costs out of the equation, it makes a lot more sense to do your manufacturing close to your home market. Makes a huge amount of sense. But again, the trend is super clear: output economic activity going up, overall employment in the good old-fashioned, industrial jobs sense of the word going down.

**Brooks:** Just to give you the statistic, the productivity of American manufacturing workers has increased by 3.7 percent on average for 60 years. That's a pretty big growth.

**McAfee:** That's amazing. What you're doing is going to continue that healthy trend.

**Markoff:** What is the equivalent labor cost of—what does Baxter work for?

**Brooks:** We're saying it's under \$4 an hour.

**Markoff:** But at the same time you argue that Baxter is not a job killer, there are tasks on the factory floor that are displaced. Where do the workers go?

**Brooks:** Our argument is that it makes it more attractive not to outsource to other places, but to do it locally. And so that—and the people we're talking to, our customers, the—there are 320,000 manufacturing companies in the U.S. which have less than 500 employees. That's who our primary target is. They don't have robots right now, because the overhead of getting them in is way too high.

So they're viewing this as a way of increasing what they do with their existing labor forces. Because they're actually having trouble over their labor forces. People don't want to go into manufacturing as a job, and the age—the age of the average manufacturing worker is getting older and older. Some companies are very worried about where they can get replacement workers.

**Markoff:** I've been instructed to let people into the conversation sooner, but I have a couple more questions. I think we have about 15 minutes left. So we'll try to make this open sooner.

So go all the way back to SAIL, Stanford AI Lab, where you were, you know at the very beginning of the computer revolution, there were two laboratories in the Stanford area. One was on one side of Stanford, it was Doug Engelbart's laboratory. He wanted to augment the human being. The other was on the other side, it was SAIL, it was John McCarthy's laboratory, he wanted to replace the human being. I would argue there's been this tension in this world of designing these machines since then.

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Let me give you an example. There is a company now in San Francisco called Momentum Machines that is building a robot that can make hamburgers. It can make 400 an hour. It can make a perfect hamburger. It seems to me in the hamburger-making fast food industry, a machine like that would be readily adopted. I guess I'm posing that as an example. Should we automate everything we can automate?

**Brooks:** I think we will be having people and machines working closely together. Robotic machines. That's what's happened. The computer didn't get rid of the office worker. Now overall, the total number of office workers may have gone down, but it changed the nature of work office workers did. So they never add the long list of numbers. But a regular office worker was able to program the machine to add those numbers through spreadsheets.

So getting people and robots will be working together, I think, is where we'll have stuff happen more.

**Markoff:** You wrote a book a decade ago, I think it was called *Flesh and Machines*. I think it argued for a fusion of --

**Brooks:** Well, it did that too, which we're also starting to see. You know, there are hundreds of thousands of people walking around now with cochlear implants, direct connections to their neural system. A lot of work on eye implants.

**Markoff:** UCSD's chancellor talking about these Superman eyes.

**Brooks:** A lot of work on letting quadriplegics control things through their thought process. It's not going to be long before people start augmenting themselves. Plastic surgery started out as a clinical thing for burns, and now people use most plastic surgery just to improve themselves. And we started to see it in the last Olympics, the guy with the artificial feet was --

**Markoff:** You probably saw it a lot where you didn't see it, actually.

**Brooks:** Oh, it probably happened a lot. Yeah.

**McAfee:** But, John, you're posing a bit of a false dichotomy here about augmenting human labor versus replacing it. In the book, we put a quote from one of your stories about E-discovery software which lets one lawyer do the work of 500 during a discovery process. Okay. It's augmented that one guy by a huge amount. It's also fair to say that it replaced the work of 499 other ones.

So outside of these fairly narrow ranges, like putting cochlear implants in and augmenting our vision, that boundary between augmenting and replacing is an incredibly blurry boundary; the net effect is the same. Much, much greater productivity.

**Markoff:** Elder care, you didn't go there?

**Brooks:** I think absolutely elder care is going to be an incredible pull on automation technology, because people want to stay in their homes longer, and the demographics is much more older people. This, by the way, is true in China now too. You know, a young Chinese person now has two parents and four grandparents who don't have anyone else but that person.

So there's a real—going to be a real pull for how technology lets people be independent longer. And I'm hoping that someone will come up with some provocative things with Baxter for that.

**McAfee:** And this gets to the great double-edged sword of technology, is that it is going to let us improve the quality of our lives. Let older people live more autonomous lives for longer. That's fantastic. I'm as strong a technologist as I think anyone in the room, but at the same time what Rod and his entrepreneurial colleagues are doing is looking for expense and inefficiency out there in the economy, and they are throwing all their intelligence and all their might at it. What that's going to mean is automation of a lot of the workforce. I don't see any other outcome here.

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**Markoff:** Let's try to open it up, if we could, and see if the audience would like to ask questions or cite a point of view? We have a couple over there.

**Unidentified:** Hi. Mickey from MAYA.

So last year I went and studied with a bunch of researchers in China the emergence of how people use earth moving equipment, excavators and things like that. In America, we have Bobcats, those little weekend warriors you can drive around and do landscaping. And it turns out in China, they just throw ten people at it. But 20-year-olds, 25-year-olds are buying massive excavators to move whole buildings and dig entire things, so it's a matter of scale getting replaced, but it's wildly entrepreneurial.

Do you think there's sort of a potential in China for Rodney XL or, in other words, a different scale of what this might be here in the west?

**McAfee:** I mean, I certainly do. A couple more ticks of Moore's law and you've got automation that works more cheaply than Chinese labor does. So I can't see anything that would stop that trend.

**Brooks:** And, you know, the peak—you said the peak in labor was 1996. Things have been outsourcing from China from around that time. I was making toys in China in the late '90s, and it was too expensive to do the sewing in China then. We were doing that in Vietnam.

Now, more stuff has moved. It's labor—because of the entrepreneurship and standard of living going up in China, labor is harder and harder to get in China for a lot of these things that has been there since the '90s.

**McAfee:** My view is that outsourcing is a weigh station on the way to automation.

**Markoff:** You had a—let's see, a question there.

**Sprague:** Steven Sprague, Wave Systems. So what are we going to do with everybody? The really interesting challenge we have today, and you see it in the current employment crisis because of housing. Housing has been a fantastic absorber of those kids who have graduated from high school. A lot of them can learn to solder pipes. They might be much higher-functioning people, but for whatever reason, the opportunities in life put them in a position to build the cabinetry in your house after years of experience.

It strikes me that the vocational model and the training model really needs to be addressed. And education, we don't talk about that. You know, it would be interesting to have a study of how many grade schools already teach programming at a reasonably high level. In our part of the world, the answer is zero.

**McAfee:** So I heard two different questions there. One was about what are we going to do with all these people, the other one was about education. The first one I honestly believe is the \$64,000 question that we're going to confront over the next generation. I don't think we're having that conversation yet like we need to.

When we were writing the book, we came across this fantastic quote from Voltaire. He said that work saves us from three great evils: Boredom, vice, and need. Of those three, I think need is the easiest one to take care of. We're going to have a ridiculously affluent society because of all this technological progress. What does a meaningful life look like in a world where work is a lot more scarce? I don't know.

The second question, you ask about education. Amen. I don't think we're doing a great job of preparing the current work force. We talked to a lot of CEOs who said I want to build things in the U.S. and my factories are so much more productive now that I need hundreds of people inside them instead of thousands, like I would have a generation ago. The problem is I can't find those

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hundreds of people. The skills have moved on so much that I've got to work with multiple headhunting firms to staff the hourly labor needed for my factories.

**Brooks:** I don't know whether—there is another trend going on, which I find incredibly interesting, and I don't know whether it absorbs much. It's the whole do-it-yourself or maker trend. And 3D printers that are cheap enough for a person to have CAD tools that you can use. There's a lot of little entrepreneurial places. Some of them are enabled by a company called MFG.com. People may not have heard of it, but it's a marketplace where little one-, two-person companies, machine shops who used to have an addressable market of three miles now have an addressable market across the country because of standard CAD software, the existence of FedEx and online payment services and the Internet thing everywhere.

So all these new sorts of automation tools that ordinary people can interact with. There's going to be a lot of entrepreneurial activity, small people doing stuff they wouldn't have done before. And so the manufacturing corporation structure may end up changing. I don't know.

**McAfee:** It's absolutely true that technology is putting work back into the economy, be it via these micro multinationals you're talking about, via a lot of the crowdsourcing and group work platforms that are out there. So technology is not just taking work away; it's putting it back in.

That work tends not to look like good old-fashioned industrial era jobs that have benefits and healthcare and things like that. We don't quite know the balance of how much work is being put in versus being taken out.

One of the pieces of research that Erik and I are working on going forward is trying to get our minds around the new kinds of work taking place in this economy.

**Brooks:** It's sort of like what Erik was talking about this morning, this hidden free stuff. A lot of people put a lot of work into Wikipedia. What other physical stuff are they going to start putting work into on a free basis.

**Markoff:** That maker design thing. Boston Dynamics, which is a DARPA-funded company that's responsible for Big Dog, which you've probably seen the Internet videos, and Cheetah. Cheetah, they sent a CAD file of Cheetah's femur somewhere. And the next day by FedEx—or I guess two days, a titanium femur comes back --

**Brooks:** You can put that on MFG.com and you'll get bids.

**Markoff:** And it's stronger than standard titanium.

**McAfee:** This is a good time to be a smart, technologically sophisticated entrepreneur, all kinds of opportunities are open for you. If you're a mid-skilled, mid-educated, mid-ambitious knowledge worker, I think things look pretty chilly.

**Markoff:** Yes.

**Unidentified:** Hi, I'm John from Hyundai Motors. Car companies today are embedding the robot to create self-driving cars. Do you see perhaps an evolved form of Baxter driving the car instead of embedding the robot into the car?

**Brooks:** Well, that's actually one of the—there is a DARPA grand challenge now where the robot is supposed to drive the truck so you can get assets which are not made to be robotic into a dangerous, nuclear sort of situation.

But I think that things are moving along so fast in the automobile space that everything will be self-driving before long, will have those self-driving capabilities.

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**McAfee:** I mean, I got to ride in the Google car a little while back, and it went from being an absolutely terrifying experience to being a deadly boring one in less than a minute, because it drives the way you're taught to in driver's ed, and then forget about immediately afterward.

I cannot believe that 20 years from now at the outside that we error prone, attention-starved texting humans should still be driving cars. I honestly find that ludicrous, and the legislation should be going the other way.

**Brooks:** A good example is ABS brakes. You know, they first came in to the very high-end models, but they're so much better than what any person does, they are in the lowest-end models now. This foot controlling the actual brakes has gone away in the last 20 years.

**McAfee:** There's a faculty member on the AeroAstro department at MIT who used to be an F16 fighter pilot. And she said: The reason I left the military, left the Navy and went off to academia was the day that they no longer let me land my own plane on the deck of an aircraft carrier, when I had to hit a button to land the plane. So absolute high-end there. Coming down super quickly to the rest of the economy.

**Markoff:** I absolutely agree with you, but I have to note that I am one of the few people who has been in a robot car crash at speed, which is for a reporter the absolute best thing that happened, to be in a crash you can walk away from and write about. The Google car that won first, testing in Arizona, actually, 30 miles an hour on a desert road.

**Stathis:** Sam Stathis, Theometrics, not a construction question. Are we really afraid we're going to run out of jobs?

**Unidentified:** Yes, yes, he is. I am.

**Stathis:** I witnessed four recessions. I came into business in 1988, we couldn't get enough workers. 1990, end of '90s, couldn't get enough workers --

**McAfee:** After every one of those recessions, it took longer and longer for the employment peak to come back as we move deeper and deeper into the computer era. With this one, we're nowhere near the same employment we had, even though GDP is back. Even though business investment is back. Even though profits are higher than they ever have been, employment is not back.

**Stathis:** I'm not going to debate with an economist and four degrees from MIT. I do want to make a point. Many people do not want to work in the factory lines in America and other parts of the world, and they don't want to work in unskilled labor. So our children and our next generation is going to school and getting masters degrees and Ph.D.s so they don't have to do those jobs.

And if we look at the economics of the people retiring faster than the next generation coming into these manufacturing jobs and lower-skilled projects, we better look at the problem, which is a staggering problem, that when the baby boomers retire in ten years or so, and the next generation is not going to be taking these manual jobs, we better think if we don't have robots and other technology helping us, who is going to do them?

**Brooks:** Yeah, I agree with you. The fact that people don't want to do jobs is very important. The Roomba is experiencing fantastic growth in European markets. And the highest—fastest-growing market and the biggest proportion of vacuum cleaners sold anywhere is in Spain. Spain has over 20 percent unemployment. You think some of those people would clean the houses for someone else. But no, they—I think it's now over a quarter of all vacuum cleaners bought in Spain are robotic vacuum cleaners. People don't want to do that. You're exactly right.

**Markoff:** Other questions? Here is a question here.

**Ulanoff:** Hi. Lance Ulanoff from Mashable. So Kurzweil was talking about the Turing Test being passed in 2029.

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Rodney, you and I were talking about this a little bit. And you've talked a lot about manufacturing robots. I wonder if, especially you, Rodney, are willing to recalibrate the future of when we're going to have the more Android-like robots that everybody imagines. Last time I talked to some roboticists, they put it like 50 years out. But the kind that are in your house. Is there someplace that you and Kurzweil meet in the middle or is that still like --

**Brooks:** I don't know if Ray is still here, but Ray is going to die. I know he doesn't like that. He's going to die.

But—I've told him that before.

When I started this company, Rethink Robotics, I was not expecting to build a humanoid robot. Even though I'd done that in my lab for years. It turned out all the pressures conspired to make it the best form and customers wanted it that way for various reasons.

So, actually, I am willing to say that there will be lots of humanoids around, because we are starting to manufacture them in vast quantities, compared to the humanoid robots that have been around before. I suspect researchers will take them and use them in healthcare things. Four years ago if I'd gone to a VC and said I want money to build a healthcare robot, they would have rightly thrown me out, because there's no model for who's going to pay for the services, but having the platform there that people can experiment, I think is going to lead to some good ideas that come out of it.

So I think within ten years, you're going to start to see humanoid robots.

**McAfee:** We should keep in mind too, if Kurzweil is right, there are no jobs in 2029. It's straight mapping. I have my disagreements too with the singularity. But when we have that artificial mind, every rational employer would employ them.

**Markoff:** We're out of time. Go look at the Boston Dynamics Atlas video that's on YouTube right now. We are deeply into Terminator territory already. So thank you. I can't wait to watch Baxter, and I can't wait to read your next book with Erik.

**McAfee:** John, thank you.

[APPLAUSE]

**Kirkpatrick:** That was a real techonomic discussion, in my opinion. And I meant to say, actually, when I was talking about Detroit, one of the real motivators for us to even do Techonomy Detroit was the work that Andy and Erik did with the Race Against The Machine book and the idea that jobs really are in jeopardy. And that's a discussion that's not being had at the national level. And you heard nothing about that also in the presidential debate, which I find disturbing. Just sounds like, oh, get manufacturing back and we're cool. That is not true.