GUEST SPEAKER: It's a great pleasure to present-- thank you. Thank you, Steve-- at this conference, and it's a great gathering. And I thank Steve and John, because I feel the fire again.

The Auto-ID center went through a period of similar ignition, and it was fascinating. It is like a Petri dish with things, new life forms were being born. And then we moved into the execution phase and EPCglobal of whom the many representatives here started executing.

And meanwhile, the Auto-ID Lab refocused their attentions on new research, and we have a family of Auto-ID Lab members, professors, students, colleagues here, who have recreated this entire environment and Elgar Fleisch and John [? Marai ?] and John Williams and Peter Cole, of course, who's been involved with us for a long time, Dan Engels. It's fantastic to see this all come together again, Hal. So it's a great pleasure.

It's almost like-- I keep saying this every time I go to a Auto-ID-- it's like a wedding. It's like going back to a family wedding and recognizing all your friends. So it's a great pleasure.

What I thought I would do is talk about the future, as I see it, and actually funnily enough, I didn't have to change my slides from about seven years ago and just paint the landscape of what it is that academics that to do research. And I should tell you a little story. When I started this research seven or eight years ago-- David Brock and I, actually. Actually, David Brock gets a lot of credit for this-- I wasn't sure that-- I was coming up for tenure.

I was trying to write papers and make an academic field out of this. And as many of my former students sitting here will tell you, I wasn't sure this would be a tenurable topic. Could I write papers? Could this be academic? Is there some real researcher here, or am I just slapping tags on things and reading them and feeling good about it? Right? And has all the technology development been done?

And we as a group grabbed the tiger by the tail, and the tiger took us to places that we didn't know that even existed. And what I discovered in that process and-- perhaps this applies to other technologies as well-- is I think one needs to understand that, in any new technology and especially in RFID, there are embedded layers of richness that are revealed as you start making things practical, and the beauty is that they come in different colors. It could be in security. It could mean protocol. There's so many areas of richness that are waiting to be explored.

That's the first thing, and the second point I want to make was that we are very much at the beginning of the journey, and that's kind of where I'll start. So there is a lot of self-satisfaction, which is I think in some ways deserved, that oh, we're there. Let's start doing it. And that's great, we should be doing it. But I have to say that we are very much at the beginning of this journey. Thank you.

We're very much at the beginning of this journey. RFID been around for 50 years, and the Auto-ID center is only eight years old. But it would be very arrogant for anyone to suggest that somehow the research has been done. There's just so much exciting stuff to be done.

And if you look at the history, the first papers in this-- and I did a reference search. By the way, there's a wonderful paper called the "Shrouds of Time: The History of RFID" by Landt. It was published as an AIM publication. If you do a search on Google, you'll find it. It captures the history very well.

But if you do a reference search, the first papers came out in '48. Peter Cole, who's sitting right up front here, was involved with many of the early implementations of RFID in the '70s, automotive license plates. Is that about right, Peter? Is that about the first reference began to appear. And then RFID went into this highly specialized research phase.

We as a center started in '98, and then we developed standards in 2001. We couldn't get the rest of the industry to really join us, so we bucked the trend and developed our own protocols with some innovative startup companies, like Alien Technology and Matrix, and those were the Gen 1 protocols, and that's how we started getting the industry going. But the reason I'm putting that up there is that 2000's. This is 2006. It's not that long ago, and it would be very arrogant for any of us to suggest that somehow in five or six years we figured out everything that one needs to know about RFID.

And the first bulk tagging is only a year old, folks. Really, it's only one year old. The first mandate really hit in early 2005. Here we are, in January 2006. So there's a heck of a lot of work waiting to be done.

And what I did seven or eight years ago is I created a landscape. I looked at every research topic I could possibly do in RFID, because remember, I was trying to get tenure, write papers, and I wanted to create a landscape. And actually, that hasn't fleshed out very much. I'll put that up now, and I'll use that as a theme for the rest of my talk.

You can break it up in many ways. You can look at technology, and the beauty of RFID is it spans everything from semiconductor manufacturing to systems research and distributed discovery and things like that. So you have tags. You have semiconductors. You have antennae on tags.

You have material constants. You have material properties. You have the interconnect between the chip and an antenna by itself is a significant PhD thesis waiting to happen. Right? Just that, right?

You have packaging of the tag. You have how does the tag react to packaging? We had a wonderful project here that Dan Engels led on tag packaging and performance. You have protocols. Of course, the Auto-ID center did a lot of, and a lot of experts here, on tag protocols.

We're barely scratching the surface of protocols. We have Gen 1 which is Gen 1 UHF. We have some HF. Now we have Gen 2, but then there's ultra wideband. There's all sorts of interesting stuff just waiting to be done. I'll touch upon it in the next few slides.

You have reader antennae. Think about this. Everyone thinks of that-- I should say, there's a lot of thought that perhaps antenna, not that interesting. Maybe there's not so much research there, but think about it.

You have miles and miles and miles of store shelves. How on Earth are you going to read all the stuff on those shelves? Now, initially, people are looking at portal-based solutions. You put readers and doors, but eventually, you're going to want to get real-time inventory, not based on transit but on a real integrated measure that is a measure of actual inventory.

How are you going to put readers on these things? Is it going to be cheap antennae which multiplex using some sort of printed ink multiplexing over a chip wireless to a reader? Is that what's going to happen? Then, how do you power it? If you put readers everywhere, how do you power them? Right?

If you walk into a retail store, and you see a display of clothes, you will find that the clothes sometimes are right in the middle of the floor. How do you power them? Is it a battery, or do you need to run wiring underneath? Such mundane problems, power over Ethernet is a hot topic these days. Is that the solution?

I'm sure there are 10 other solutions we haven't even explored, and there's a tendency to take the cliched solution, where something very innovative and probably game-changing is just lurking around the corner. So there's some very interesting technologies just in these four topics waiting to be researched, and then there's readers. We predicted some 10, 8 years ago that readers would eventually be very inexpensive, hundreds of bucks. They're down to $1,000 now, but there's a long way to go. And the fact of the matter is the electronics in readers is not that complicated. So we have a lot of advancement.

Then, there's middleware. There's software. There's the actual middleware. One of the problems with RFID is that there's a tendency to believe that RFID tags will be read in the same way the barcodes will be. That is, you read the barcode, you know exactly what's there, and you're done.

The fact of the matter is the whole point of RFID is reading all the time, and you're going to miss a few. And missing reads results in phantom inventory, especially when you have a throughput model, where you look at things going in and out. Right? It results in negative and positive phantom inventory, and phantom inventory is going to completely jam up any inventory control system, any application that you develop.

So for example, let's say, if we all had tags, and god forbid, there was a fire. And we all went out, and there were readers of the doors, and the readers at the doors missed a few of us. This room would legitimately claim that those of us that didn't get read are still in this room, and it might send a fireman into the room looking for those people that the reader missed.

Now, you can see right away-- now, that's a dramatic example-- but you can see right away that, when you're doing inventory control, how terribly that could send an inventory control system out of control. Right? How do you manage things like that? Well, you know what, maybe there's a reader on the way out, and that picked me up. So you can say, listen, although this the reader didn't pick me up, a later reader saw me. So let's correct inventory here.

That's a very deep database concept. All right? It's a generalized predicate of consistency that you need to superimpose on top of a database to make sure that your data is consistent. Right there is a research topic just waiting for someone to look into.

And then there's databases. There's streaming data, fast and furious. How do you handle two joins on streaming data? There's actually a lot of research in various computer science departments on that.

There's enterprise architecture. Is this going to fundamentally change the way in which we do enterprise architecture? The world is built around databases today. Will we go to fundamentally a new enterprise architecture?

My own feeling is about 10 years we'll be in a completely different way of thinking about enterprise software systems based completely on events, as opposed to based on databases. That's my view, but I may be wrong. And then there are distributed systems, discovery. We developed something called the object name system. If you're familiar with it, it's just a way to find the company that owns a particular EPC.

That was a drop in the bucket. Already, we have seen that is useful, but it's 1% of the way to everything you need to do to really take advantage of RFID. Right? I can say that, because I was one of the people who wrote on it. So I can criticize it.

But I think it's very important for an academic community to point, focus a microscope, and critique these things and start improving on them. And it's just waiting to happen. Is it going to be, I don't know, the semantic web? What it going to be? Right? But you need to look at that.

Identity management, what's going to happen when you have hundreds and hundreds of companies trying to access data? How do you manage identity? Is it going to be using Microsoft Passport? Is it going to be using something else? Right?

What are the standards there? Is it going to be Federated? Fascinating, tens and hundreds of research topics waiting here. The problem will lie in making sure that these research projects solve the question with a clear understanding of the application. And that is why I think this conference is perfectly timed, because the industry is finally looking at this very seriously.

Mike Rose of J&J, we were just having breakfast this morning, and we were talking about how the industry really is struggling with some serious problems. And they have some experts, and they're academic experts, and finally now, there can be a real conversation. When we were doing this a few years ago, we were making stuff up and projecting our industry and hoping we were right. And by luck, dumb luck in many ways, we were kind of right, and we had great guidance from the early sponsors the Gillettes, the J&Js, the Walmarts, et cetera, Targets. Right? But now is a time to have a very high bandwidth conversation.

And finally, by the way, I think that RFID is going to change the way our business processes work. It's going to change the way that you go into a store, and you interact with the store. It's going to change the way a store is operated. The machinery is going to change, and that to me is a technology. It's not business. It's a technology, and that's going to be the most fascinating part of all this.

You can look at applications. Most of the attention has been on supply chain, but supply chain is barely a start. We talk about retail, health care, business to business, critical goods.

We just went through Katrina in the US and the tsunami and the earthquake in Pakistan. What happens when the next disaster occurs? How do we make sure that we route blood correctly? How do we make sure that if there's a bird flu episode somewhere in some town somewhere that we route flu vaccines or Tamiflu correctly? These are all, again, very fundamental opportunities for RFID, and it behooves us to start dealing with these things in a scientific way.

And so the very really ancient approaches we're taking to disaster, recovery with RFID, we should be able to of run-- we should have a map. It's like a weather map of the disaster and where your various resources are. And how do you map them, and what you need to wear?

Well, here's where the flooding is. We need to send certain equipment here. Here's where there's a disease outbreak. We need to send something here. We should be able to do this in a much more scientific way, and visibility is key.

Steve talked about the airline, the aircraft industry, and where what's happening there as the aircraft industry, which has historically been very inefficient-- I happen to have studied them in a past life-- is again waiting for a fundamentally new, efficient model. Boeing and Airbus cannot survive the way they have survived with gigantic government subsidies at some level of the other. Right? And they have done the right thing, and they're trying to reengineered their supply chains.

It's very different than even the automotive supply chain, because their lots are much smaller. And the products are much fewer, and they can get a lot more flexibility. And I think that's a great new opportunity to use RFID to get visibility through just-in-time manufacturing, delivery, et cetera.

So again, for people who do operations research-- Tully, right-- fantastic opportunity there. Now, if you look at just operations, factory operations, Airbus and Boeing are going to do it. DC operations, Brian Subirana, who's right there, spent a lot of time with Gillette looking at their DC operations.

When we started that research, we thought, is this boring? Are we going to find something new? Actually get into it, it's fascinating. You start peeling the onion, and you find that there's so many opportunities to make DCs. This boring, dusty box of a building, exciting, faster, more efficient, less error prone, and fundamentally, you can start reducing inventories. Right?

And of course, you can look at institutions, hospitals, hospital operations, huge opportunity. Right? You can do several [? PCDCs ?] probably looking at the logistics of hospitals and drug delivery, missed prescriptions in hospitals-- I'll talk about that in a second-- personal systems. So I barely scratched the surface of applications.

And then finally, the million question for an academic is so what's the analysis? Where are my creations? This is all fine, but where my creations? Can I write in an IEEE journal or an ACM paper on this and vie for the next Turing or what? I actually fundamentally think, yes, there are some fundamental intellectual opportunities at every level, everything from RF systems and communications.

Many years ago, I was sitting with Peter, and I said, Peter, what is the fundamental difference between RFID and other communication systems, and he summarized it to me. He said, in RFID, unlike in other communication systems, the bandwidths and the power are just very different in two directions, and you want to design protocols that work in these asymmetric channels. It's just very different.

Computing cycles, I'll talk about that, are expensive. Communication theory, very interesting, right? All the communication theory, error correcting codes, all the stuff doesn't necessarily map to RFID, because RFID is so different. System dynamics, security, I won't belabor it. Beautiful, challenging, frustrating, exciting problems wait to be attacked, and it's great to have this community come together and try and think about them.

The thing that makes RFID special is everything is different. Everything about RFID is different. Right? First of all, power is limited. So range is limited. Right?

You can't compute, because every compute cycle sucks up power. You can't put a lot of memory, because every piece of memory increases cost and power. Cost is an issue. So you're kind of boxed in. So it's like you have a little wiggle room, but yet you're trying to do everything.

Now, you add to that bandwidth is limited, because you're always operating in industrial scientific medical bands or some free band. At least the general RFID movement's always going to be in a free band, so bandwidth is very limited. You can't do much with this stuff. Memory is at a premium, as we discovered at the Auto-ID center.

You get a lot of data from RFID tags, but it's very fallible. In other words, it can be a lot of wrong data. Like as I said, it's not wrong in the sense that the reader is wrong, but the false negatives that is a misread can manifest itself in ways that can screw up your typical algorithm. Right? So you've got to correct for that.

Here's a very interesting one. Tag connectivity is sporadic. That's a very subtle one. Even my cell phone, let us say that Cingular Wireless decides that it wants to upgrade the firmware on my cell phone. It can kind of do, it because it's got-- 80% of the time it's on.

With an RFID Tag, you don't know where you're going to see it next. Let's say you wanted to write some data to it. You don't know where it's going to see it next. It could be in your company. It could be MIT. It could be at P&G. It could be at Walmart.

You don't know when you're going to see it. So what are you going to do, preposition all that information in every reader on the planet that you want to put on that tag? Well, you couldn't possibly do that either.

So there's some compromise, where you kind of know where stuff is, and you think you're going to sit there. And you push the information there in the hope that, when it shows up, you can push that information down. That's just a fundamental distributed computing challenge of extremely irritating but yet interesting magnitude. Right? So tag connectivity being sporadic compounds everything.

And to add to everything, cell phones are targeting a human being carrying this thing and holding it to their ear. That's it. Tags can show up on products. They can show up on animals. Right?

They can show up on pallets. They can show up on metal containers. They can show up inside metal containers. Right? They can have sensors on them? They could be active. They could be passive. So you've got to prepare for everything.

So if you have a reader here, it's got to be ready to read that passive tag sitting right there and possibly an active tag with a one kilometer radius which happens to be in the next building and make sense out of it. It's fascinating to think about it, and these are problems that people are facing today. These are not problems I just made up. This is just beginning to happen in real life. Right?

And finally, the range of technologies is huge. You will have active tags, passive tags. You're going to have GPS. Right? How do you in fact integrate GPS with these systems?

Actually, by the way, that's not bad news. It's all good news, and there's all these people that are doing these things, but there is no cohesive overarching thinking pulling it all together. You have cellular technology, readers inside cell phones, fascinating.

So what I thought it would do is I'll take this map. It's kind of like looking at a planet, and I don't have very much time. But I'd like to burrow down in a few places and just give you a taste of some of the research that the Auto-ID center did, other people did. And I want to show, if you haven't seen this, give you a sense of how rich it can get, how quickly it can get rich, when you burrow down.

So I picked, when I was making these slides, I created this landscape, and I said, let's look at protocols. Let's look at RFID protocols. How rich can that really be? Right? It was a question I asked myself, in 1998, when I was deciding with David Brock to get into this research topic. Could I write a paper here? Right?

What I can tell you now is there are probably a million papers there. At that time, I thought there was zero. Right? So when you get into it-- so let's zoom in. What's protocols? Well, it turns out, protocols are not just protocols.

There's a physical layer, and there's a logical layer. In the physical layer, there are different frequencies to consider. There are different schemes, like ultrawide band, that are popping up to consider. OK. Well, that's pretty good. Right?

And then there's a logical layer. In the logical layer, you need to look at readers interfering with each other. Dan Engels and I wrote a paper, in '99 I think, on readers interfering, and we thought it was just pie in the sky, just an intellectual problem we invented. Turns out, it's actually a very serious problem. Right?

So you need to make sure that readers don't interfere, and there are a couple of ways to do that. You can do something called tag sessions which actually is in the Gen 2 protocol. And you can do something called in-band reader coordination, which we couldn't get into the Gen 2 protocol, but there are other reasons for that, as well. There are technical challenges that need to be addressed to do that.

There's security. Right? How do you make sure that privacy is protected, someone can't eavesdrop on targets, reads and see what inventory they've purchased so they can game them. Right? There's different data types. There's the EPC. There might be sensor data.

Then, the sensors, how do you make sure, when you need a tag, let's say if it has a sensor, that you know it was a temperature sensor, that the data follows the EPC? Well, the temperature that are reported, is it in Celsius, or is it in Fahrenheit? Is it a time series, or is it the temperature taken at that moment? If it's a time series, what units are we using for time?

Is it compressed? Then, what's the compression algorithm? Right? Isn't that incredible? Just that question you can go on and on. Well, if you're going to compress it, what's the cheapest compression algorithm you can put on a low cost chip which has very little power or little bandwidth and a little memory and little computing power?

So OK. So there are a lot of things there. So let's focus in a little more. So suddenly in our protocols is a very rich topic. All right. Let's focus in a little more. Let's look at just security, just security.

So this happened to me in 2001, 2002. Was it 2002 when I gave a talk in Ron Rivest's group? He's a professor here. He is one of the security gurus at MIT, and I went and gave a talk there about RFID and some early thinking on security. So we dived into it.

All right. So let's look at security a little deeper. Well, that's not good enough, but if you get into security there are layers upon layers there. The reader to tag security making sure that the reader and tag communication is made secure, and we'll expand upon that.

There's making sure the middleware is secure. That is that the middleware talks to the reader in a way that is secure, especially if it's wireless. There's security between the middleware and applications-- base AP, bound, whatever it is. There's inter-corporation security. Right?

Let us say that you have a fridge at home that's reading tags inside the fridge, and someone is sitting outside looking at your ONS hits. They can figure out, Shriram, he likes margarine. Right? Maybe you're worried about that. Right? So that is a very rich problem. OK. That's getting too broad.

So now, we're two levels down, folks. All right? So that's too much. Let's look at reader tag security. Guess what, that gets very interesting too. Now, we're three levels down. Right? I had thought there wasn't a paper there in 2000, 2001.

Well, there's authenticating the tag. What's that? Authenticating the tag is making sure that the tag you read as not a spoof tag. It is that very tag that J&J put on a J&J product, so that you can prevent counterfeits. And that has fundamental business benefits, health benefits, social benefits.

There's authenticating the reader, which is a tag doesn't respond to a reader if it's not the right reader. That's privacy. Right? The cheaper tags, passive tags, the whole privacy discussion arose because the tag is promiscuous. Any reader can read it.

So if I have a bottle of some medication in my pocket, Trevor come and read it. And I certainly don't want Trevor to know what medication I have in my pocket. Right? But if the tags say, I will only respond to a reader that belongs to anyone but Trevor-- I'm sorry, Trevor-- then I am protecting my privacy from Trevor. Right? So there's authenticating the reader.

Then, I need to prevent eavesdropping which is all right. The reason a tag will authenticate each other, I want to make sure a third parity can't listen in and figure out what inventories in Target's warehouse. Oh, Target's running a back to school promotion.

I can see that. I'm at Staples. I'm going to compete with them. Right?

They're going a week early this year. So I'm going to go a week earlier. That's actually a big deal for these guys. Right?

There's preventing tracking, which is making sure that I don't know by put readers at every T-station in Boston, where an ex's girlfriend or boyfriend lives. Right? And then how do you personalize everything? When I buy socks and take them home, how do I make sure that only my reader can read my socks and my medicines? And if someone else tries to read them, these are personalized.

Even the maker of the product can't read them anymore. That's getting rich. Right? So now, we're three levels down, and again, it's turned into a really complex problem. Right?

And just for the flavor of it, let's brainstorm. It actually gets very complicated. My initial guess, I had a student called Joe Foley. We said, let's just encrypt the number on the tag. Privacy will be taken care of.

No. If you just encrypt the number on the tag and put it on the tag, yeah, I can tell that you have Gucci shoes on, but I know the number. Are they Gucci? Really? No. I know the number-- no. I know the number, and I can still track you.

So it doesn't actually solve the privacy problem. It solved the privacy of the shoes. It didn't solve Bernie's privacy problem. Right? Not that easy, right? So that doesn't solve the problem.

OK. Then, we thought, ah, we got it. Let's just kill the serial number. All right. So I don't know what that particular pair of Gucci shoes. I know it's a pair of Gucci shoes. Right? And a lot of people wear Gucci shoes, so it's OK.

But you know what, Bernie also has a Rolex pen in his pocket, I believe, and he may be the only person in Boston with high probability who has both Gucci shoes and a Rolex pen. So by constellation tracking, I know him, and I can track him. And maybe you add to that some particular brand of jacket, that's it, I've triangulated. So again, I don't solve the problem. Right?

I'm just trying to give you a sense of it. Tough problem, folks, we thought we had it. Wrong. Right? You go deeper and deeper. Right? And then you insist that tag needs to the reader. Well, that means that the tag needs to have the password of every reader? Well, that's not a cheap tag. Right?

I won't belabor everything, but it just turns into such an interesting problem. Preventing counterfeits, right? This traditional encryption is expensive. There's challenge response. That means you need to put secrets on every tag, very rich, very rich, just waiting for someone to go nail these problems.

Now, these we've looked at, and if you want to prevent eavesdropping, many of these things will kind of solve, but here's the secret. Right? Actually, we've solved some of these problems individually. We have not solved the bigger problem of addressing all these questions. We just haven't, and right there, it's just a huge research topic waiting to be addressed.

And for what it's worth, Steve Weis wrote a beautiful master's thesis on this, in which he provides some solutions. And he very explicitly lists other things we couldn't solve, but that's a start. Right? So that's a master's thesis that came out of one talk that I was pretty much saying there's not much research on. Right? And all the master's thesis, great thesis did was solve a couple of subparts, and list about 10 other problems that we didn't solve. OK?

So let's zoom back up. That was protocols, 1 of 30 things I've listed here, and you can look at everything. Retail, what are the opportunities in retail. What can I zoom in? Right?

Retail, what is retail really? What is the retail supply chain? Retail supply chain is a very interesting thing. Toothbrushes are made in units of one. You make one toothbrush at a time. OK?

What happens in the retail supply chain is you make one toothbrush at a time. You assemble toothbrushes into cases, so you have say six toothbrushes in a case. You put cases together, you make a pallet. You take pallets together, you make a container. You assemble them up, so that you can ship them together. All right?

So this is what the supply chain is. Then, you move them, you sort them, and you repeat until the end. Aggregate, sort, transfer, aggregate, de-aggregate, sort, transfer, and that's basically a supply chain.

It's a big mixing thing, where you make things as one, but all of the same kind, and that's a manufacturer. And people walk out with ones but all of a different kind, and that's the consumer. And trying to do that efficiently is the supply chain in the retail world as we know it. Right?

This is another fascinating research area, and this is the one where the industry has focused its attention most immediately. Because you're trying to do this in a timely fashion, with very few errors, and very little shrinkage. Well, if you actually look at it in real life, it turns out that that process is riddled with errors, too much, and that's excess, inefficiencies, losses, dilution, counterfeit, brand dilution. It's just incredible.

And you can look at the actual numbers that come out. We carry something like 30%, 40% of inventory we shouldn't be carrying. For all that, we are 10% out of stock as an industry. Right? And there's some fundamental research topics here waiting to be addressed. And whether they end up being looked at by companies, whether they end up being looked at by academics, the fact of the matter is that these are rich research topics waiting for academics to look at.

Now, I'll say this. You can actually map the space out in many ways. You can take, for example, the supply chain-- DC to back room, back room, back room the sales floor, sales floor, sales for the storage. And you can look at different parameters you can get time, quantities, configuration.

And if you map it out that way-- in the interest of speed, I'll just write it out. I don't expect everyone to see this. But what I'm saying is right there in that matrix, I've captured probably about 70% of the problems that most retailers are looking at.

They're looking at is my fresh food arriving in a timely fashion at the fresh food counter? So that when my consumer buys that lettuce, it is fresh. If not, where is it losing its freshness? Maybe, it's spending too much time in a DC. Maybe, it's spending too much time in a truck. Maybe, it's not cold enough in the truck, and so it's losing freshness.

And what RFID lets you do is it's like injecting a dye into your bloodstream and looking to see how the body is operating. And it lets you go through all that and figure out how your body is doing. And if you look at different retailers-- look at, for example, Walmart. This is publicly what they've said they're doing.

If you look at Best Buy, this is what they're going after first. If you look at Lowe's-- Lowe's is the big do it yourself store-- this is what they're going after. So everyone's looking at a different thing, going after a different piece of the puzzle.

I have lots of examples. I zoom in and look at various examples, and in this audience are hundreds of other examples, where you zoom into this landscape. It's kind of like using Google Earth, seeing something interesting and zooming in. Looking at a map, zooming in, looking at a house, you can do that, and I think fundamentally this is what this industry needs. And academics are the microscopes, and they're going to figure out what the opportunities are and figure out what the solutions are.

In the interest of time, what I'm going to do is I'm going to skip over most of what I wanted to say except this one slide. And I'll make two statements and end in about one or two minutes. When you have operations-- for example, actually, if you can ignore the slide for a second-- if you look at factory operations, you expect performance to be tight.

When you say, listen, Father's Day is coming around. I want to move inventory out of the store, shaving blades for Father's Day, because there's a big gift-buying event. I want to move it out two weeks before Father's Day, and then I'll start advertisement on TV. I'm going to spend millions of dollars.

You expect that things will work out quite well. Right? People will move stuff out, the retail supply chain is going to operate as you expected it, and things will happen as you expected. And you can run your ads and you're going to get good efficiency.

The fact of the matter is that in many systems where lots of human beings are involved-- and retail is one place and hospitals are another place-- if you thought that the performance you would get would be like that-- that is the bulk of the product would be moved out on the day that you expect it to be moved out, you're in for a disappointment. Because really, in most supply chains, performance is, unfortunately, despite the best efforts-- and we're talking about the top corporations on the planet-- they lose. All right?

If you're familiar with the statistical process control, the Six Sigma variation, the coefficient of performance of execution in most supply chains in many endeavors where RFID would be useful is rather poor. In fact, the coefficient of performance for a promotion that I looked at recently is something like 0.1, where it should really be 1.3. OK? So if you understand what statistical process control is, just a metric, I can tell you in a very succinct way, there is a whole lot of room for improvement in the supply chain to make it tighter, and that's why people are looking at the supply chain.

I'll end with this slide. OK? I just want to point to the bottom right. There's also a lot of exciting stuff on how RFID might fundamentally change the supply chain, and that's in some ways the most exciting part of all this. Right? Is it going to make some macroeconomic changes to the way we operate as an economy? Right?

Now, that's getting a little highfaluting and maybe getting a little beyond ourselves, but this is academics. This is what we should be doing. So I just wanted to say, let's fantasize a little bit.

The opportunities are vast, but perhaps-- excuse me-- perhaps, we need to start also thinking at an aggregate level. Will retailers finally say that, listen, with RFID, we own our own supply chains. We don't need them anymore, because it's not a competitive advantage anymore.

Maybe, Walmart essentially becomes, as many of you know this, essentially just real estate with the Walmart name on it or Target name on it. And all they do is they own the shelves, and the products there, it's like Amazon, and you go buy it, but it's completely up to the supplier to stock these shelves. That's called pay-per-scan for those of you that are familiar with this. Maybe that's what'll happen. Right?

Maybe what'll happen is the supply chain goes away, and UPS takes over the world, or Federal Express, and essentially, manufacturers, FedEx, or UPS, they're stuffed straight to the shelf. That's it. Who knows? Right?

Certainly, we're gaming this, and if this community doesn't, who's going to game it? In fact, Brian and I were fantasizing about that, and we call it the ultimately fragmented supply chain. Maybe that's where it'll go. Right?

Maybe in the end, this might change the way offshoring is working today. If you're familiar with Zara supply chains-- Zara is a Spanish retailer-- what they do is they change-- they're very tight in terms of fashion cycles. So every time, I suppose, Britney Spears has a concert, within a week, they have those exact clothes on the market for two weeks, and then they're gone.

So if you go to Zara, you get exactly what you want, right there, and because it's so fashionable, and it is so agile, very few other retailers are able to compete. But the only way they can do that is not by manufacturing in Asia, because the lead times are too long, but they're manufacturing locally. Why? Maybe with the visibility RFID enables, maybe a lot of retailers can do this sort of thing more efficiently, and maybe it's going to affect and impact the way we do offshoring.

We worry in this country about offshoring. I'm sure in other countries as well. Maybe some tectonic changes are awaiting us on the supply chain, and how will RFID play into that? I think it's worth discussing that.

So I'll conclude simply by saying that, obviously, the first place that technology is going to make an impact is by tweaking things the way they're done today. Eventually, there might be some evolution, but fundamentally, there's going to be transformation. And it's the right end of the spectrum, the stuff to the right, that this community and no other community will be able to study and enable.

And it's a great pleasure to address you and fantasize, but also, I look forward to talking to you about this. And have a wonderful conference, and thanks for letting me subject you to my crazy thoughts. Thank you.

[APPLAUSE]

PROFESSOR: So maybe a couple questions for Sanjay, while we set up the next panel.

GUEST SPEAKER: Any questions? Yes.

AUDIENCE: So there's a million papers to be written.

GUEST SPEAKER: Yeah.

AUDIENCE: How many need to be written before the diffusion curve starts to take off?

GUEST SPEAKER: Yeah. That's a great question. I think that every-- I don't know. I think that in every topic, every new area, there's a time of freshness, where the papers are fresh and different. And pretty soon, they start grinding into each other, and it's repetitive. Right?

I think we have a ways to go. If you take wireless, you take the internet, take Google. Right? Google is a research project out of Stanford. Right? We're 15 years into it. Take the internet for 40 years into it. Right?

I think we have a ways to go, but there's no doubt that's going to set in. I think we need to be watchful of that as well. So I agree. So we'll balloon, but then eventually, we'll kill ourselves and let it narrow So that's a great question.

AUDIENCE: Part of the goal of this gathering was to try to bring together end users and researchers. So the end user and the researcher, based on-- I'm sorry, the researcher that is doing the work based on that. How do we facilitate that to be the case so that the research is being driven in the direction that business is going?

PROFESSOR: I think that's a great question. When we started the Auto-ID center, we basically made some stuff up. Right? And we went and just evangelized it, and we were lucky.

We had some key end users involved in the very beginning. So we weren't completely making stuff up. We had some directed things we were going after, and we were right. It's lucky. Right? But we can't afford to wait on luck in the future.

The good news now is the end users really get this. In fact, in many ways, they get it more than the larger academic community. Right? And we have a lot of end users here. So I think that the time is now ripe for researchers to pick up esoteric topics which also happen to be practical. How rarely does that happen? Right?

Establishing that channel, there are two things that happen. One, the people need to be there. The good news is that they're there now. You have Mike Rose sitting there. You'll have Dick Campbell. You have Tim Mill. Right? You have Richard [? Esram ?] back there. Right? I believe Gillette, right?

So you have people now willing to have these deep conversations and they're very well equipped, but what's missing is the medium. Right? I think this is a great medium. I think we need to present research papers and have business guys go, that's pointless, but this I wish you would do. We're not doing that, and I think that applies to all of academia. Yeah, Chris.

AUDIENCE: I've got a general question for you. [INAUDIBLE] challenges is that we all present different search communities. [INAUDIBLE] conferences, whereas communication guys and RFID go somewhere. And every single time-- or at least at this stage, we can confirm that we can motivate any of the problems that you mentioned. [INAUDIBLE] sometimes people in those communities are not familiar with those special challenges of RFID. So do you think that in a couple of years time, we'll see a dedicated RFID conference that covers a range, maybe not all but a range of the issues you mentioned?

GUEST SPEAKER: I think that might happen. I think you're pointing at the deeper problem of systems design. Right? And first of all, I think we have too many conferences in academic field. They're too sub-selective, and only those people go to those conferences. It's a very nice, cozy shelter, where you don't really have to talk to the other guys. Right?

So I do think that an RFID conference, an RFID systems community will evolve, and maybe this is the start of it, which is why I congratulate everyone. But I think we also need to watch out that that doesn't become an ultra-academic conference not connected to reality which in itself becomes a kind of mutant animal that no one's interested in. So we need to keep the end user community involved. That's my view anyway, and that was the success, as you remember, from the Auto-ID center, but I hope we can do that.

PROFESSOR: Thank you very much.

GUEST SPEAKER: Thanks a lot, Steve.