

## "Future of Cyberspace"

Dr. Vincent Cerf

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**Dr. Cerf:** Good afternoon everyone. Thank you very much for inviting me to engage with you this afternoon.

Let me preface my talk by saying I'm not going to dwell deeply on cyber security, although I'll touch on a few points. It's not out of lack of interest, it's just that I want to offer a much broader range of observations about what's happening to the internet, some of which I hope will motivate serious interest, concern and thoughtfulness about how we defend this infrastructure which has become so important for us and many other around the world.

Let me start out by taking you back in history. This is the origins of the internet. It's the first four nodes of the ARPANET. It was the experiment, the Defense Advanced Research Projects Agency conducted in 1969 to experiment with packet switching as a technology for computer to computer communications. I was a graduate student at UCLA at the time, programming the Sigma 7 Computer to connect it to the first node of the ARPANET in September of 1969. The Sigma 7 is in a museum now and some people have suggested I should be there along with it. [Laughter]. Here I am.

If you fast forward a little you can get a sense for what the internet looked like ten years ago. This is an automatically generated diagram showing the autonomous systems of the internet in different colors and their topological connectivity. If we looked at a 2009 version it would simply look bigger and more colorful, which is as good a definition of internet as anything else I can think of.

So that's where we are. If we look at the scale of penetration around the world, what we find is that there are almost 1.6 billion people on-line probably more, since those data are now about six months out of date. And over 600 million servers on the net, and that's not counting laptops, PDAs and other episodically connected equipment on the system. In fact that's a low ball count because there are a lot of machines that are behind firewalls now that cannot be seen using the census method by which those numbers are derived.

Google is a good example. We have a classified number of computers that are running in our classified number of

data centers around the world, and they don't all show up in these statistics, I can guarantee you that.

The other observation I would make is that over the last 10 to 15 years an enormous number of mobiles have entered into the telecommunications landscape. An estimated four billion are in operation now. Probably 15 to 20 percent are internet enabled and that percentage, of course, will go up as time goes on.

One thing that is important for you to know is that in 2009 there are some very significant changes happening to the basic technology of the internet. This is probably the most significant period of time in the internet's history since Bob Conn and I did the original design in 1973.

IP Version 6 is being implemented not quickly enough in parallel with IPV 4. It was standardized in 1996. We're running out of IPV 4 address space. There are only 4.3 billion unique addresses and it's my fault. After a year of arguing during 1976 nobody could come to a conclusion about how many addresses were needed on the internet, and some people wanted 128 bytes, some 32, and some wanted variable length addresses. The variable length guys lost because that took too much horsepower to go find the fields of the packet if it were a variable length. You added two up cycles to do that, so that one went out the window. And I couldn't at the time argue with a straight face that we needed 128 bytes of address space to do an experiment, so I picked 32 bytes. It seemed like enough address space for an experiment. The trouble is the experiment never ended and here it is 30 years later and we need version 6 which has 128 bytes of address space, 3.4 times 10 to the 38<sup>th</sup> addresses, which is a number only the Congress can appreciate. [Laughter]. I hope our national debt doesn't approach that range. That would be a serious problem.

Internationalize domain names are being standardized and will enter into the system at the top level domain space during 2010. These are domain names expressed with scripts other than Latin characters. So Cyrillic and Hebrew and Arabic and Meliaum and Korean and so on will all be part of the internet domain name space.

The domain name system itself is vulnerable, as many of yo know. There is a major initiative underway to digitally sign the entries of the domain name system so as to illustrate the integrity of the binding between a domain name and an IP address, which is what the DNS provides. By digitally signing these things the recipient of a look up can verify that the data hasn't been changed since it was put into the domain name system by the originator.

There are also efforts afoot to digitally sign the allocations of IP address space so that during the routing updates that occur using the border gateway protocol, BGP, you can check to see whether or not a party announcing a particular address actually has the authority to do so by going back to a digitally signed table of assignments of autonomous systems to address space and if an AS is announcing an IP address space that it has not been assigned and you can detect that by checking the tables, then you should reject that particular routing update. It's a hijack attempt. And of course you probably should report that to an appropriate authority.

There are an increased number of sensor networks showing up in the internet environment and the presence of the smart grid initiative will simply exacerbate that aspect of the net. I'll have a little more to say about that.

Smart grid itself has some very significant and potential security issues associated with it, something that we are going to have to come to grips with. And by we here I don't mean Google, I mean generally, those of us who are working in the internet space.

Finally, mobile devices are increasingly common, not just mobiles that we use to make phone calls and surf the net, but other kinds of devices that are part of automobiles or transportation systems and the like.

So those are things that are all happening. Here's an example of some Chinese domain names which I offered while I was in Beijing a couple of weeks ago. I was going to say I was nervous about putting up [www.chinese.chinese.chinese](http://www.chinese.chinese.chinese). I said won't they be offended if I show them that? They said no, they have to enter all their stuff in using Latin characters anyhow because they put in phonetic equivalents of the Chinese characters they want and then a little drop-down pops up with all the Chinese characters that sound like that and they picked the ones they wanted. So actually Latin characters are quite commonly understood in China.

By the way, I should tell you that there are an estimated 338 million Chinese on the internet today. That's more than there are people in North America. They exceeded the North American count last year about mid year. They are aggressive about bringing their users on-line despite all of the issues arising and questions arising about access, control, filtering and everything else. The Chinese show strong understanding that the internet is an important part of the eco system and they are intending to make heavy use of it.

They have already implemented IPV 6 in their university environment. Full up, IPV 6, network management included,

at 10 Gigs in their Surinet 2 backbone. So make no mistake about it, there are other people who are paying more attention to IPV 6 than we are and we need to fix that.

I wanted to touch on a bunch of applications just to give you a sense for the scope and variety of things that are happening n the net, and that will give you a sense for the vector that we are watching the internet pursue. This is Gmail, and of course there are many other electronic mail services on the net. This is a popular product from Google.

Another example is chatting. Of course that has extended now from just simple texting to video and voice conferencing and interactions. It's pretty surprising, when you think about the net not being specially configured for a quality of service that would deliver voice and video, despite that the high speeds in the network, the 10 Gig backbones, the 1 Gig or 100 Meg interfaces, allow people to do a pretty reasonable job of conferencing on a very casual basis compared to what you and I are probably accustomed to where six engineers get wrapped around a video display and the audio system to try to get things to work right. This is just something that people do at home, and it's turned out to be an amazingly important morale booster for our troops overseas because they have an opportunity to talk with their families in a very casual and very personal way. So this is a technology that's rapidly gaining in popularity.

Skype is another example of the same sort of thing, inter linked with the telephone system, providing for a remarkably inexpensive way of making international phone calls. In addition to simply going end to end through the internet you can also connect to the public switch telephone net at near the termination of the call, hence the reduced cost. This system also has voice and video as well as texting.

Speaking of texting, Twitter is yet another example of a real time ability to send messages around to a large number of people. And despite the jokes that can be made about whoever is the CEO must be the Chief Twit, or the kinds of things that people Tweet about, I just put on my Adidas or what have you, in an emergency situation this turns out to be a pretty powerful way of getting a message out to a large number of recipients quickly. So there are some very nice things about this technology.

I have been struggling with the vocabulary for this. Twitter and Tweeting, and for a while I thought it was Twitting that was the verb for this, then I started wondering what the past tense of that was, and I decided I better not go there.

So this is yet another evidence of the way in which people are adapting what had started out to be fairly simple and straightforward technologies.

Google Wave is yet another interesting exploration of how to integrate all of the various communication methods that we have, whether it's texting and interactive instant messaging or email or blogging. All of those different means of communication have been wrapped together in this common interface so that one person may be Tweeting and somebody else is actually on a blog and the two are exchanging information in a convenient way.

This is very early days. We released this product knowing full well that A, it had bugs; and B, we weren't quite sure what people would do with it.

One example I would give you here is that certain kinds of interactions are always thought to be ephemeral. For example, just texting back and forth you don't normally think of as being an archival experience, but suppose that somebody else is part of that communication but is running a blog, so the blog now picks up the Tweets or the instant message and it becomes part of the blog record, maybe gets indexed by Google. So something which you thought was ephemeral may end up in the public record, so to speak.

We're still I think exploring what all the implications are of combining these various means of communication into one tool.

WebEx is another good example. Some of you I'm sure have used this tool before. It allows you to be communicating in a group using a voice conferencing bridge capability plus everyone is seeing a particular presentation, asking questions, pointing to things on the display, and generally collaborating. In fact I think it's probably like that collaboration is going to be an important tool.

Google Maps is another example of sewing together a huge amount of information and allowing people not only to use the tool to find places, but also to use the tool to present information. This is a theory that Google has followed from its outset, and that is the belief that we don't hold the corner on creativity, and that building application programming interfaces that are available to everyone, you can offer other people the opportunity to use this platform to display information in a useful way, and it's used in an incredibly large range of things. In emergencies you see the fire lines or the location of an earthquake or locations of evacuation centers and the like. The scientists use this to show where their sensors are. When you click on them you see the data that is being

accumulated, or the guy who's looking for an apartment types in his requirements and what you see are little icons that pop up as the apartments that turn up to match those needs. So it's a very powerful presentation tool.

Geography is an important way of organizing information, and so is time. Those two organizing principles are very powerful tools in the hands of people using the right APIs.

Google Earth is another example of stitching together a huge amount of information from many different sources and making it easily accessible not only to see the information but to use this also as a presentation interface, and as I'm sure many of you have visited Google Earth you'll see a number of layers of information that you can activate to see other kinds of information that people have geographically indexed and made accessible through Google Earth.

Google Ocean was a recent addition that we can now see something about topography under the sea. We also have Google Sky. So if you go to Google Earth and you pull down the icon that looks like the planet Saturn, you'll see some choices. Google Sky lets you look outward. We can zoom out quite a long distance. I don't know if I have a slide here to show you that. Here's another example of the sort of thing you can zoom outward to. Using the Hubble space telescope imagery we can zoom out to 14.5 billion light years away, seeing some of the first galaxies that formed in the universe.

We recently added Google Mars. This is, again, the same kind of information, in this case coming from NASA. We've wrapped it onto a globe. You can zoom around the Mars globe the same way that you can Google Earth. And we recently added Google Moon, using similar technology and data coming from NASA and other sources to allow people to not only look and explore, but also to place information about what we know about this nearest celestial body.

I mentioned before that mobiles are in wide use today, and I think that we all understand that these are programmable devices, they're not just telephones any more. People use them for a variety of things -- to access the net, to make payments. You have to work hard, though, to figure out how to present your applications. You have a fairly limited display area, about the size of a 1928 television set. And a keyboard that's suitable for people that are three inches tall. Or maybe no keyboard at all.

It's a challenging interface and we're very interested in it ourselves because we believe that a large fraction of the world's population is going to have its first and possibly only experience with the internet by using mobiles

rather than laptops or desktops, so this is an area of some interest.

We've noticed that when you carry your information window on your hip that you're more likely to ask questions that are related to geographically indexed information. I sort of understood that intellectually but I didn't fully appreciate it until my family went on a holiday to Lake Powell near Page, Arizona, and as we were driving in we were talking about what kinds of meals we would have on the houseboat we were going to rent, because we knew that there weren't any grocery stores on the lake, so we had to buy everything we needed before we got on the boat. So the talk turned to meals and cuisine. Somebody said how about paella. I said gee, that's wonderful, but you have to have saffron in order to make a good paella. Where do I find saffron in Page, Arizona? So I got out my Blackberry and got a good GPRS signal, so I went to the Google home page and Googled saffron, Page Arizona, Grocery Store, got back three answers, three telephone numbers, a little map showing how to get there, clicked on the phone number, the phone rings, a voice answers, and I say may I speak to the spice department please? It was probably the owner of the store, it's a little store, and he says this is the spice department. I said do you have any saffron? He said I don't know, he goes off, comes back and says yep, I've got some. So we followed the map, I ran in and I got my \$12.99 worth of saffron -- that's .06 ounces in case you care -- and we went off and made a really nice paella.

But as I was walking out of the store I thought holy cow, what just happened? In real time, just when I needed it, I found out how to find saffron in Page, Arizona, how to get there, and how to call the store to check. As opposed to getting a perfectly good answer yeah, you can get saffron in New York City, it's only 1500 miles away.

So I came away with a visceral appreciation for the power of geographically indexed information. And anybody sitting in this room who's had anything to do with any kind of wartime experience knows that geographical information counts for a lot in that game.

Another thing which is interesting about the penetration of the internet is the kinds of business practices that have arisen out of its availability, and I would say by extension, practices in the military and practices in the government. Our citizenry expect businesses to be open 24 hours a day. They expect to be able to transact business through the web at any time that they choose. And they are expecting the U.S. government to be available in the same way.

There are places where you can click on for help. Sometimes it's instant messaging. Sometimes it's actually a conversation for people who are trying to track the delivery of things. You can go click on a web site and type in your FedEx number and find out where your package was last seen.

You'll note there's a difference between it was last seen and where is it now, but the best you can do is where was it last seen.

Airplane flight status, another similar, very convenient thing.

The Kindle which has ignited quite a bit of interest, is another example of a device that people use. It can be on-line, it can download newspapers, download books at your leisure, then be conveniently available for whenever you want to.

Open source has been another major driver in the last decade or so. Linux is a very good example of that. Google has released open source software. Chrome, the browser; Android, the operating system; and Chrome OS which is coming next year, all open source, all intended to be available to anyone free of charge to explore, modify and adapt in useful ways to build network-based applications. So here's Android, and here's Google Chrome. I think the other thing which is pretty exciting is that Android, the operating system, has some built-in speech recognition capability, especially for people who are using mobiles and need hands-free operation. And while it's not perfect, we have experienced a great deal of improvement in our ability to do high quality speech recognition. It's at the point now where you can essentially make a query and surf the net orally and get back answers that way.

Another area where we're rapidly moving ahead is in automatic captioning. For example, if there were a video taken of this speech, it could potentially be automatically captioned.

We haven't got to the point where we can do literally speech recognition and captioning. What we've got at this point is the ability to take an already existing set of text which are the words that were being spoken, and recognize the speech well enough that we can match up the text of the captions with the instant that speech is being made, so automatically do that captioning step. But in the long run it would be really helpful to do this automatically. And even when the quality of the captioning isn't perfect, it may be good enough to do searching of the video material so that you could find out when did this person mention that particular topic, and then zip right to that particular frame.

We're also doing speech and txt translation. The quality is very good for many of the language pairs. Someday I hope we can do it in real time so a deaf person, and I happen to be one of them, could benefit from having automatic speech text recognition and maybe translation.

YouTube is another example of a popular application on the net. It's estimated now that we get 20 hours of video being uploaded into YouTube per minute. And every time I ask, the number keeps getting bigger. I have no idea how many hours per minute are being watched. It's possible that some things get uploaded and nobody watches. But it's like blogs. There are 150 million blogs and the average readership is 1.1, the blogger and his god. [Laughter].

But YouTube is turning out to be an example of the kind of democratization of access to information dissemination which we've never had in the past.

Here's an example of translation. This is an article that appeared on-line in a Spanish El Paiz newspaper. I sent the URL of that to the Google translate program and it rendered the exact same web page except that all the language it could see in Spanish was translated into English. This can be done for about 51 different languages and language pairs on the net today.

I'm predicting there will be more devices on the internet than people and I confess to you that over the course of the last 40 years or so I've been really surprised at some of the things that have shown up on the net, like refrigerators, picture frames, phones that look like phones but they're voice-over IP computers. But the guy in the middle is the one I like the most. He's a Dutchman who has invented an internet enabled surfboard. I've never met him, but I have this image in my head. He's sitting on the water waiting for the next wave thinking, you know if I had a laptop in my surfboard I could be surfing the internet while I'm waiting to -- [Laughter]. So he built a laptop into his surfboard, put a WiFi server on the rescue shack, and now he sells this as a product. I thought that was pretty amazing.

Here's another example of sensor networks. I'm running an IPV 6, 802.15.4, six low pan, radio base sensor net. These sensors are driven with batteries. Every five minutes they report the humidity, temperature, light levels in all the rooms of the house, and that gets accumulated in a server so at the end of the year I have a very good picture of how the heating, ventilation and air conditioning system has actually worked so when it's time to do some adjustments on the system I've got engineering data as opposed to anecdotal evidence.

One of the rooms in the house is a wine cellar. It's important to keep it below 60 degrees and above 50 percent humidity. That one is alarmed, so if the temperature goes above 60 degrees I get an SMS on my mobile that says your wine is warming up. This actually happened to me when I was visiting Argonne National Laboratory last year. Just as I was walking into the building for a three day visit my mobile went off. Your wine is warming up. My wife was away on a trip so she couldn't reset the cooling system, so every five minutes for three days I kept getting this little message saying your wine is warming.

I got home and it was about 70 degrees in there, which is okay, but I asked the vendor that makes this, this is commercial equipment, do you have an actuator that I can remotely activate? They said yes, so that's the next weekend's project is to put the activator in there.

But this is the sort of thing you're going to see more and more of over time. Particularly as the smart grid evolves, because it's a feedback loop to provide information to us about the consequences of the choices we make in our use of energy. We have lacked that feedback loop in the past. WE don't know why the electric bill is what it is. All we know is WYGIWYG, what you get is what you get. This is going to help us understand our choices and the consequences of them.

It also offers the opportunity for the power generation system to say something to the power consuming devices. Hey, why don't you knock it off for a little while, I'm in a peak load now and I don't want to do a rolling brownout.

These are all issues that will confront us in the next decade including, of course, the security of such a system.

One thing which I want to emphasize is the importance of broadband access to the internet. Right now it's the subject of a national level exploration, the FCC and the NTIA are intensely interested in that.

It creates all kinds of useful outcomes including new applications that work better when you have high speed, whether that's to reduce delay or to increase the ability to move data.

I am very concerned about policies that don't necessarily lead to open and non-discriminatory access to the net. It's been a cornucopia of innovation and it's been that way because you don't have to get permission from an ISP to try a new application, you just put it up and let people try. I think we need to preserve that capability substantially. I don't want to harp on this too much, but

we clearly need to do this in a way that will guarantee that we also protect against various harmful activity on the net.

Can I just finish with a status report on the interplanetary internet? Some people think okay, he's off his nut. I've been talking about this for a while. It was motivated by the exploration of Mars and the question of how to provide better networking capability while we are operating in deep space as opposed to just point to point links.

Here's a picture that you get from the Mars Rover. Google Mars allows you to zoom in on these pictures, so this is an exciting thing for kids and grownups, just to be able to virtually explore where our robotic devices have been.

We've been using relay satellites around Mars in order to do [storn] forward communications supporting both the Rovers and the Phoenix lander which has ended its service operation. So there's been some primitive [storn] forward networking going on in deep space, and I would like to enhance that.

NASA and the Jet Propulsion Lab and the other members of the NASA community have been working on this. We're at the point now where we are actually implementing a new set of protocols. TCPIP didn't work well with a 40 minute round trip time. The flow control is just a bit of a problem because you say stop and the guy who's transmitting doesn't hear you for 20 minutes when earth and Mars are farthest apart. Of course it gets worse when you get to the outer planets. It's also very disruptive. We haven't been able to figure out how to stop the planets from rotating. It's a pain in the neck, but when you're talking to something on the surface and the planet rotates, you can't talk to it any more.

Interestingly enough, and relevant to you, the delay and disruption characteristics of the deep space applications have their counterparts in military tactical communications. So DARPA supported testing of the new delay and disruption tolerant networking protocols very successfully over the past several years, showing that these technologies could be adopted and used for military operation, and something I'm very excited about.

But I'm even more excited about the fact that we now have a three node interplanetary system in test. This is to space qualify the new standards. We have earth surface based assets; the deep space net of the Jet Propulsion Lab; we have a system on board the International Space Station; and the Epoxy Spacecraft, which is on its way out to rendezvous with a comet is about 80 light seconds away, also

has the interplanetary protocols on board and we're running through a test now to space qualify this stuff.

We'll turn it over to the Consultative Committee on Space Data Systems and offer it to all spacefaring nations.

This is where we expect to end up, with standards for space-based communication if they are adopted by everyone, all of our spacecraft -- U.S. and otherwise, will be able to interwork. That will lead over time to the accretion of an interplanetary backbone as missions complete, but the platforms that conducted those missions continue to operate. They can be repurposed to be part of an interplanetary backbone.

That's the update, and I'm turning it over to you, sir for questions, and I thank you for your time this afternoon.

[Applause].

**Moderator:** Thank you, Dr. Cerf.

You can just imagine that you're probably sitting down one day with the lady who invented the Blackberry, and she said this is a great little device. If I knew how to get a network and use it, I'll just invent the internet. I can see that happening, especially for space.

**Dr. Cerf:** I'm going to do what I said I was going to do, which is come over there. I'm hearing impaired and this wonderful echo stuff from here makes it hard for me to understand him, so I can lip read him, if I have to. If you don't mind.

**Moderator:** We have a question from Captain Kirk. Where do you see the internet in 2035?

**Dr. Cerf:** Let's do some math here. Let's call it 2010. That's 25 years from now. Let's go back 25 years. That's 1981, right? Close enough for government purposes. [Laughter].

Standard joke number 402. [Laughter].

So the real problem is what could I have seen 25 years ago, and then project it forward.

Well, look, the trends are pretty obvious. Higher speed access, both mobile, wireless and wired. Increasing amounts of computer power in virtually everything. A deep dependence on the internet for e-commerce, for democracy, for social interactions, for research, for governmental operations, for politics and everything else. The current

penetration of the internet is 23 percent, 1.6 billion. By the time 2035 rolls around I would predict on a worldwide basis probably 80 percent penetration. In the United States we're already about 75 to 80. Some parts of Europe, especially the northern part, Scandinavian countries, are already there. We wondered why that was, and the answer was that during the winter months there isn't anything else to do except surf the net and call your friends on your mobiles. [Laughter].

So I would say by 2035 very very heavy internet penetration in everything. You can see devices around the house, devices in the car, things you carry around on your person, all being part of this internet environment. And of course the interplanetary backbone by that time should be pretty well established.

**Moderator:** Tell us, did you envision any hacking of malware, virus, spam or any of that kind of stuff when you thought about the internet?

**Dr. Cerf:** Yes, and no. Clearly we didn't envision it well enough because today that's a major problem for us. Although let me remind you that the primary hole in the system today tends to be the browsers, which downloads a page from a web site and then interprets it. The browsers are often operating at a higher level of privilege than is absolutely needed. They have more access to operating system resources than they absolutely have to have. The operating systems themselves are weak about protecting their assets. So the biggest way in which worms and viruses and other things get into the system is through the browser, which is well beyond the basic network level.

On the other hand, remember this was an experiment. It was being done primarily using academic resources -- graduate students, some research institutions. But in 1975 while I was still at Stanford University I began working on the design and implementation of a secured backbone with the National Security Agency. That led to the blacker program, eventually. The problem of course is that while this was going on in parallel with the work on the publicly visible internet, much of that work was classified and I could not share any of the architectural choices and design principles with any of my colleagues who didn't have clearances.

To make matter worse, public e-cryptopography wasn't discovered until 1977, not counting GCHQ which found it sooner but didn't say anything about it. So Whit Diffy and Marty Helmand get credit for publicly announcing this technology. But it didn't exist in any palpable form, RSA didn't get implemented until later.

I was standardizing PCPIP as you are using it today in 1978. So we just missed the boat on that.

If we were to do it over again I would put in a great deal more authentication mechanics inside the internet so we could actually know what am I talking to now? Who sent this email? Which host is this? Yes, I know I was routed to this destination, by the domain name system or the routing system, but do I know who I'm actually talking to?

And by who here I don't necessarily mean the personal identification, but just a way of authenticating that the device is coming from a source that we would recognize as legitimate.

So that's something we could do today and we should be reimplementing some of these ideas or just putting in ideas that are there. They just haven't been widely put together.

HETPS should be standard. We should be running IPSEC, we should be doing DNSSEC, we should be doing the RPKI to digitally sign the assignments of IP addresses to individual autonomous systems. There's a whole bunch of stuff we could do now, some of which his happening, and a lot more to come. That's probably the job for some of you people sitting in this room.

**Moderator:** What about the internet, as you look back, what about the internet when you first conceived, thought, has surprised you the most?

**Dr. Cerf:** I think probably the most surprise for me, apart from these unusual devices showing up on the net, was what happened after Tim Burner's WorldWideWeb became commercially available. And the internet itself because commercially available.

Commercial access to the internet comes in 1988, from my point of view 15 years after we started the program. Tim Burner's [inaudible] stuff shows up to the public around 1994 in the form of Netscape Communications, browsers, and servers. So looking at it from that point of view, that's like 15 years ago.

What happened, though, when the web became available, is an avalanche of information flowing into the net from people who just wanted to share their information. The surprise for me is the degree to which people actually wanted to offer things not for remuneration at all, just because they wanted to know that the stuff they provided was useful.

And yes, there's a huge pile of junk on the net, no question. There's also a huge pile of incredibly useful stuff, and I would like to argue that the useful stuff outweighs the junk. That we have that much ability to get information when we want it, when we need it, in real time is pretty damn stunning, and I did not honestly have in mind anything of that magnitude today. Of course Google was excited about this because our whole objective is to organize the world's information and make it accessible and useful and the internet's helping us do that.

**Moderator:** Terrific, sir. One more, from a fellow named Bill Gates, something about Google and Yahoo. Is there anything you can share? Any merger?

**Dr. Cerf:** Oh, you mean -- We're not doing anything with Yahoo of that sort. We tried to offer some help and we were told that wasn't a good idea, so we stopped.

So the Yahoo guys are looking for ways of surviving, and more power to them. We need the competition. [Laughter]. How's that for a diplomatic answer?

[Applause].

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