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Keynote Speech

The Future of Communications and Satellite Systems

by

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Ohayo Gozaimasu. Is there anyone out there? Good morning. Oh, good, there is someone. I felt I was actually in a church at first, because everyone is at the back of the church. It's a great pleasure to be here. When a professor goes into a classroom and says "Good morning," he can always tell what group he's talking to. The beginning undergraduate students just continue doing whatever they were doing. The upperclassmen get out their notes and get their books open and get ready for the lecture. And the graduate students write it down. So you can always tell who you're talking to.

It's really wonderful to be here. The arrangements have been impeccable. Dr. Iida, Dr. Wakana, and all of the Organizing Committee have done an excellent job, and I see this morning that they arranged good weather for us to come as well. So I'm very pleased to be here.

I have always had great pleasure to work with Dr. Iida, who came and visited my university back in 1991, when the first WINDS concepts started to evolve, and I was very happy to collaborate with Dr. Iida before then and after that.

Some of you may have known that Dr. Iida and Ed Ashford of SES Global and I have collaborated on a book called The Future of Communications, that's now available through the AIAA Press. I, in my part of the book, basically addressed the longer-range future. I always have a rule of thumb in terms of prediction, of never making a five-year prediction, because the regulatory constraints, the allocation of frequencies, and the licensing will slow you down, and you'll probably be off in your prediction. You'll be overly optimistic. And if you make a ten-year forecast, you will not anticipate a major future technology, and so you will, in effect, probably be too conservative in your prediction. I always try to make 25- to 50-year prediction, because no one will be around to check up on your prediction. So that's my rule of thumb, and that's why I get the longer-range part of the process.

I came here to Japan to learn about new networks, but I must admit that when I was out walking this morning, I came across something that I think you can only encounter in Japan. It was a sign, and it said, "Bridal Networks Detective Agency." I just couldn't quite figure out what the detective agency did, but it sounded like a very interesting network. But anyway, that was a real sign. I saw it this morning.

Let's start and go through a few slides. I'm going to take a much broader view of some of the issues. Can we have the next slide?

I believe that we, at the conference, need to explore a broader vision, that first of all, the future of satellites and wireless will be largely determined by applications and not technology, and by the merging of digital services and systems, the so-called 5 C's. The 5 C's are communications, computers, consumer electronics, content, and cable TV. And I think we are seeing a vast merger of all those types of digital services connected by digital technology. I guess what I'm saying is that I think we have been, in this conference, very much technology driven, and perhaps have not paid enough attention to the applications and at looking at satellites and the wireless world as integrated technologies and applications. Particularly the integration of broadband mobile services is key: satellite, wireless internet/intranets, even high altitude platforms, mobile phones, the various types of webmapping, messaging, multimedia, entertainment, and navigational systems. And we just heard an excellent presentation that really emphasized those kinds of integrated services and applications that broadband systems of the future can bring us.

Finally, I believe that satellite planners need to know a good deal more about the applications of tele-education, tele-health, multi-casting, broadcasting, the evolution of global corporations that operate 24 hours a day, 169-hour workweek, and telecommuting. I believe that telecommuting is perhaps the biggest new thing that will happen in the next 20 years. In the United States we have about 12 million telecommuting today, and I think that will increase to 75 million in the next ten years. And that's driven by energy conservation, by concerns about pollution, by the high cost of urban development in the most expensive parts of the cities, such as Yokohama and Tokyo, but finally there are also issues that relate to security. With the attack on the World Trade Center in New York, the idea of concentrating all your resources in one single spot, I think, will be another issue of concern. And finally, broadband and mobile applications.

And if you will, in merging the world of technology, push and pull is critical, and I think we do need to look much more at the pull of the applications.

So with that broad introduction, let's look at some historical perspective. Next slide.

If we look at the history of humankind on our planet, we find that for a very long period of time, there were about 100 million people on the planet. It was only when we got to about the 17th century, where first of all we had a series of major plagues, that killed off about a third of the world's population, but also where we had the start of a new agricultural revolution, where we could get several seeds back when we planted one, that there was a major population growth scenario unfolded. We are today well over 6 billion people, and it's projected by the United Nations that the world population will stabilize somewhere around maybe 10 billion or 11 billion, somewhere between 2050 and 2075. There have been some recent studies that suggest that in developed economies, such as Japan, the rate of population replenishment is currently about 1.85, when actually you need 2.1 to replenish the population. Therefore, we could even see population decline after that point is reached. Next slide.

If we look at the growth of cities, we find that in the 13th century, Beijing was the world's largest cities, and you could pretty much to any part of the city by walking miles or less. There was very little international travel, and everything was based on pedestrian traffic. Since that time, our transportation systems have become more and more sophisticated, and today we have vast population concentrations such as Tokyo to Yokohama, which can really only be sustained on very modern transportation systems, and increasingly on the basis of the telecommunications and information services. In Los Angeles, for instance, the Los Angeles Times used to have one printing plant to distribute the LA Times throughout all of Los Angeles. They could no longer sustain that. They now have at least four printing plants, all connected by telecommunications. They print and distribute them, and save millions of dollars in distribution and increased efficiency.

So basically, this is to say that the 21st century, our cities and our population will be based less on the evolution of transportation systems, and more and more on the basis of information systems and telecommuting and so on. Next slide.

If we look at the building of human historical development, and pretend that we have a 10,000-story building, 20 miles high, we find that since the beginning of human existence on the planet, the start of agriculture only comes on story 9,980, and that the age of computers, robotics, satellite, TV, spandex, all of the great inventions that my 20-year-old son considers to be the only existence on the planet, is only 10 inches from the top floor of the 10,000-story building.

However, if we look at this building again, in the next slide, not in terms of history but in terms of information development -- information perhaps more than knowledge -- we find in effect that all the knowledge up until the invention of the transistor is the 2,000th story. Since the start of Internet is the 4,000th story. And we've added some 6,000 stories since the start of the Internet. It's interesting, though, to contemplate where we'll be in just a few years. It's been projected, as we can see in the next slide, that information is doubling now, some people say every 3 years, and some say as frequently as every 9 months. But even if we assume it's just every 3 years, we find that on the same scale, by 2015 that building of information will be 150,000 stories high, and will extend more than 300 miles out into space. And remember, only the bottom 4,000 stories of those 150,000 predated the Internet. So this is a staggering amount of information to contemplate. We're now looking at databases that are as large as not only terabytes but even petabytes in size. Next slide.

We have seen a lot of changes by major technologies over the years. Lawrence Grossman said, "Printing made us all readers. Xeroxing and copying made us all publishers. Television made us all viewers. And digitization and networking has made us all publishers and information providers." And certainly, networked satellites and laser systems are now creating something that could be characterized as the "Worldwide Mind," or "The Global Brain." And in effect, in many ways, the Global Village is already a reality within the developed world. And again, in 20 years, we will see a completely networked global society. Next slide.

I mentioned earlier the merging of all types of markets, due to digital technology. On one side, we see manufacturers and suppliers, and below, we see service providers. But in effect, everybody is sort of in a vast digital market. Everything from cable TV providers to publishers to tele-education and tele-health providers are all operating in a vast digital market. That market, if we look at it in terms of information, communications, and education, is now on the order of some 4 trillion dollars. That's to say that every dollar or every yen in 12 is spent on some form of information, communications, or entertainment. Next slide.

So breaking that down, about 2 trillion dollars is in information, and that's everything from computers to books to newspapers to movies to computer games. All forms of telecommunications makes up about 750 million dollars. Entertainment, again all forms, is about a trillion dollars. These are sometimes called the ICE industries or the ICE age. And this is the world's largest single identifiable market. Next slide.

If we look at 150 years of digital growth, we'll find that on the top are the transmission technologies. And today, we're somewhere in the 100 billion to trillion to 10 trillion bits per second range. And below, we see the applications. In the early part of development, transmission systems, I think, drove the curve. But I think in the 21st century it will be the applications -- many of which we heard about in the previous presentation -- that will drive the curve and the demand for satellites and wireless communications. Next slide.

So let's look at some of the dynamic forces of the 21st century. The Cold War has been replaced by Globalization and the world-wide movement of capital. Today, there is on the order of 1 to 2 trillion dollars moved electronically in the world information and electronic capital and fund transfer market per day. So that's somewhere over 400 trillion dollars a year. It's many, many times the size of the global economy, which is close to 50 trillion dollars. In this super-speed world, electronic fund transfers just keep on growing, and certainly the innovations that we see in fiber, for example, are exceeding Moore's law. Fiber transmission is doubling once a year now.

Globalization is governed by a dynamic balance among nation states (military and political power), business (the commercial and financial power), and transnational individuals of great worth and influence, and culture and religious forces. Some people say we are seeing, today, the end of the so-called Westphalian system, where the nations controlled everything. The power of large multinational corporations, and the religious and cultural forces that transcend national boundaries, have led to some of the problems that we're currently experiencing. Next slide.

The global influence is often based on such factors as telepower, innovation, capital, and there is there are the economic theories of Joseph Schumpeter, who talks about the "creative destruction" that comes from information, that in effect the only way you really get progress is by getting new technology that replaces that which came before. As we see this creative destruction coming forward and this rate of information creation, we are also seeing this gap between the developed and developing world, between the so-called "fundamentalistic societies" and the advanced technology societies, and this gap at times seems to be widening. This is a major force of destabilization and concern.

In this new world, developed societies are vulnerable to Third World problems in a global economic and political system. There is a book by Tom Friedman called The Lexus and the Olive Tree, where he suggests that enhanced education, health care, and prosperity for the entire world is the key to stability and antiterrorist campaigns. One of Thomas Friedman's theories is that any country that has a series of McDonald chains in it will not engage in revolutionary activities. So far, he's been more or less right. Next slide.

The future of communications, and where does communications fit in to this changing world environment? Next slide.

In the next 20 years, it's been predicted by Mike Nelson, who used to be in the White House, and is now with IBM, that we'll see a thousand times more connections on the Internet, and the ability to access three orders of magnitude more information within the next 20 years. The idea that more and more development and more and more globalization will add to world peace, I don't know whether I accept it or not, but Tom Friedman makes a fairly good argument for it in his book, The Lexus and the Olive Tree.

We will see more than a billion access points to the global electronic machine, and I think that that will probably reach 5 billion within 30 years. Next slide.

If we look at telecommunication services, we see large trends. The blue represents existing services, the red represents new services coming online, and the yellow is new services that we will see within the next 20 years. And as you can see, the rates go up to even terabit/second types of applications. We also are moving toward more and more global applications. Next slide.

How do we predict the future? About 10 years ago, Nicholas Negroponte, the director the MIT Media Lab, essentially said that we're going to see a flip-flop (cf. Fig. 1), that all of the wire-based service -- the telephone -- would get all of the broadband services, which would go on cable and fiber, and that we will shift all of the broadcast-type of services -- the wireless services -- to wireless communications. And the reason he predicted this was a very technology-driven one. He said we were running out of spectrum, so that all of the broadband services would have to go on wire, and all of the narrowband applications onto wireless systems.

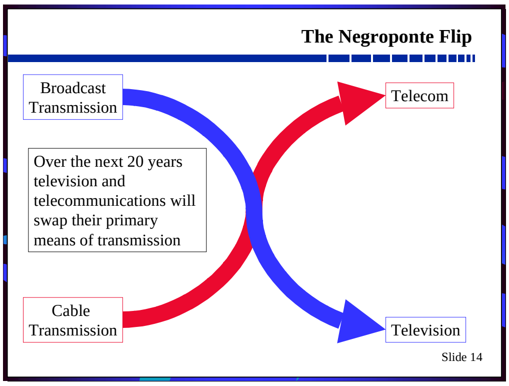

Figure 1　Negroponte Flip

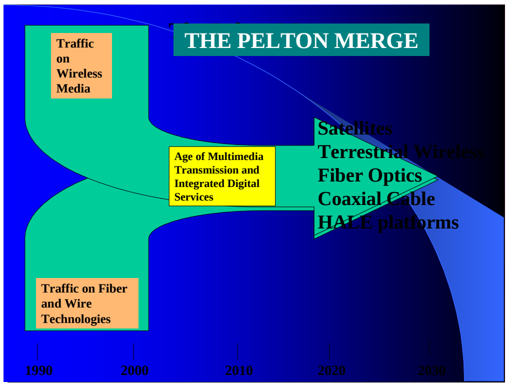

Figure 2　Pelton Merge

The trouble with making a prediction based on technology, without looking at the marketplace, is that often you can be wrong. I analyzed the model and basically suggested back in 1994 that no, I don't think that that's the way the market trends are going. In effect, once people get mobile and wireless services narrowband, they're just going to want broader band applications and services. Next slide.

So I came up with what was called the Pelton Merge (by Telecommunications Magazine, not by me), (as shown in Fig.2). In effect it said that we're really going to see a combination of satellite, terrestrial, cable, fiber optics, high altitude platforms, and that the traffic on wire and wire-based technologies, and wireless media, will go together. The real challenge is to create an open network architecture so that you can have a seamless interconnection of all of these services. And today, we find direct broadcast and direct-to-home satellite, which is a very broadband application, growing very, very rapidly around the world, with in the order of 100 million receivers. We are seeing the rapid deployment of 3G and a discussion of 4G broadband applications. There is no indication that a lack of spectrum is going to necessarily create problems that cannot be overcome. So we'll see more and more frequency reuse, smart beam technology, which I'll talk about in a few minutes, and of course allocation of higher frequencies, and perhaps a lot more use of KA and above band, millimeter-wave services, to support broadband wireless applications. Next slide.

If we look at the world of satellites, and our conventional trend line, we see the possibility that we will get satellites and wireless applications that can perform more cost-efficiently and provide higher throughput capabilities. But if we look at that not in terms of where satellites have been and where they're going, but where satellites may need to go to keep up with broadband applications and to be cost-competitive with fiber applications, you see the idea that maybe we need to create some totally new technologies and architectures to make this possible. And actually, this (Fig. 3) was a slide that was developed at CRL and by Dr. Iida, based on some of the collaboration that we have been doing. Our institutes have been doing some research for three years now with CRL on advanced satellite concepts. And so this is basically where we need to go rather than where we are going, if we just continue to extrapolate with conventional technology.

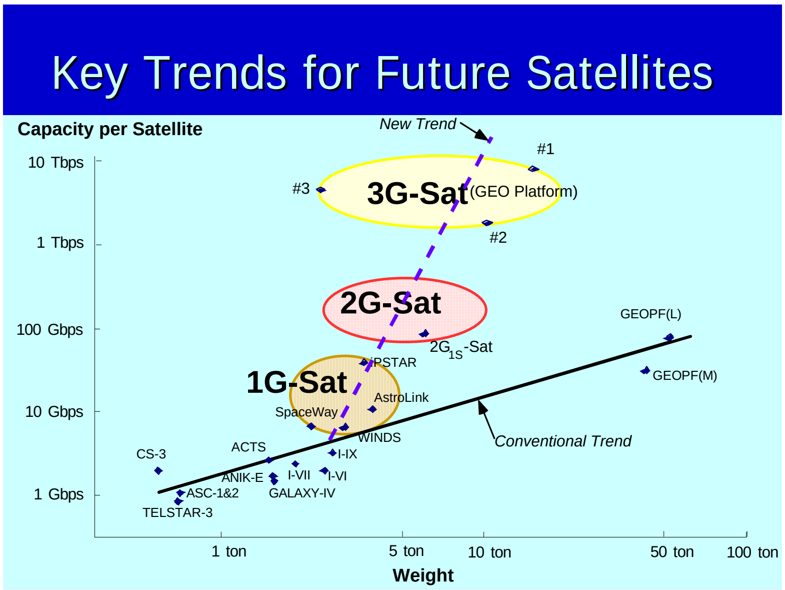

Figure 3　Key Trends for Future Satellites

So what kind of concepts would this look like, if we try to look to the future, and ask, "Where do we need to go?" rather than "Where have we been going." Next slide.

First of all, we looked at this sort of from the ground up. That we could get user terminals perhaps down to the 0.1 to 1 watt range. This is important for health standards and concerns, but also to keep down battery costs and the lifetime of the terminal before you have to recharge it. The evolution of voice to text interface, so you don't have to worry about punching in your information on a tiny keypad. A multifunctional device that includes voice data, paging, computing capabilities, Internet, interface, Web mapping, the ability to do Web searches, keeping a calendar, and basically PDA functions. The evolution of smart phased array or patch antenna designs. And an eye loop video for optical interface, so you can see what you're dictating and correct it in real time. These are some of the things that we thought the user terminal would have to have. Next slide.

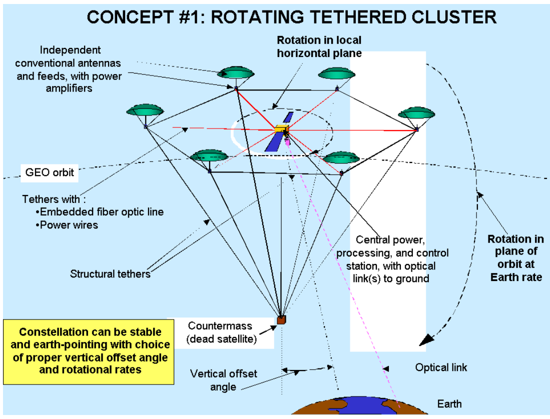

Figure 4 Rotating Tethered Cluster

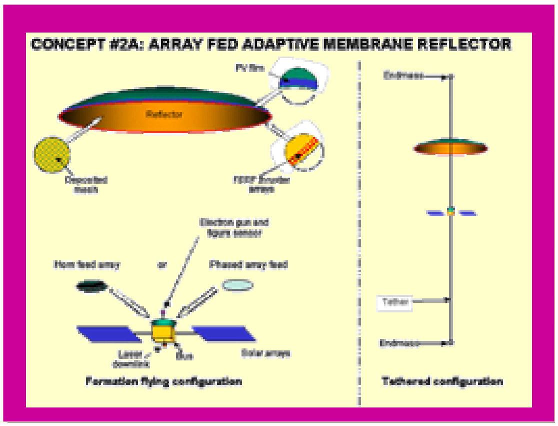

Figure 5 Array Fed Adaptive Reflector

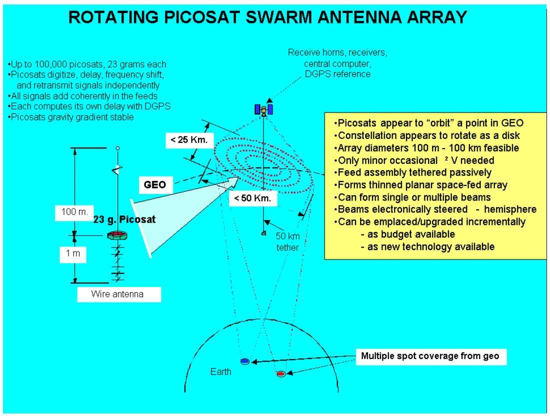

Figure 6 Rotating Picosat Antenna Array

The first concept (Fig. 4) we came up with was basically the idea that we wanted much higher performance, but with much less weight. So what we're looking at here are polymide types of antenna. NASA at Huntsville has developed antennas that are 7 meters in size, 22 to 23 feet in diameter, that weigh about 25 kilograms. The idea is that you could put a group of these together, with tether and fiber optical interconnection with your satellite feed system and power system in the middle, and just use a dead satellite as a countermass. This may look like it's very big, and it is pretty big, but the weight is not all that great. This is not much more than today's say 3,000 to 4,000 kilogram satellite in total mass. It looks a lot different, and it looks very big. But in terms of mass and deployment, it would not be that different in mass from today's satellites. Next slide.

We said, that looked kind of complicated (Fig. 5). Were there other ways that we could go further? Here, we're looking at a piezoelectric type of reflector, where the beam is formed by the electronic gun and figure sensor that you see below, that keeps this antenna, maybe an acre in size, to its necessary RMS characteristics. And on the right, you have a tethered system where you have two endmasses, a long tether, and the system all together as an integrated system with the one on the left. It's a free flying system, so that you just use fuel to maintain things in the proper configuration. This is concept 2A. We looked at a 2B, where instead of a parabolic reflector, we had a flat phased array design. But in terms of economics, we're not convinced that we can make that work economically. Next slide.

The most exotic concept that we came up with, and we thought we were pretty exotic in one and two, was a picosatellite (Fig. 6). It's about the size of a hockey puck, 23 grams in mass. The idea is that you would deploy these in geoorbit, and the gravitational characteristics would keep this in its location so you could deploy up to 100,000 picosatellites. There would be an electromagnetic change, so you could recollect them and redeploy the system. Above this massive phased array plane, you would have your satellite that would operate to the entire platform. So you could generate a very, very large number of beams. And again, this is just a concept of what can be done. We are currently in a phase 5 research mode, where we're trying to refine the concepts, looking really at phase 2. And if you will, we are also looking at other technologies that we might apply to make the system smaller and simpler. And the two technologies in particular that we're looking at are smart beam technologies, so that you can basically reuse the same frequency over and over again, with maybe 1 beam in 2 reused, and also very advanced modems so that we can generate information at 2 bits per hertz, and even up to 4 bits per hertz, so that we can simplify these systems. However, the objective is to create antenna systems of the future that are far most cost effective that anything we have today. And we would go on that high curve rather than the conventional curve. Next slide.

So for the future of satellites, we do believe that there are dramatic new satellite architectures that could be developed. They may not be the three that we developed in our design concepts, but certainly would be much different than just a conventional extrapolation. We think that there will be an evolution toward smarter, more user-friendly, even user-seductive antennas, wearable systems, that would be very low in power. We also think that there are new orbital concepts, such as the quasi zenith system that we saw in the previous presentation. That kind of orbital configuration can allow us to achieve look angles of on the order of 80 percent, and allow you to have mobile services not only on airplanes but also to downtown Tokyo or downtown Yokohama. We also think there's the possibility of hybrids of satellites and high altitude platform systems working in operation, where high altitude platforms operate over urban areas like Tokyo and Yokohama, and that these could be integrated with satellites for regional and global service. We also think that laser-based communications systems have a future that goes beyond even optical inter-satellite links. The rapid deployment of systems that allow broadband mobile services, lower cost service, much higher efficiency modems, as I say, up to maybe 4 bits per hertz, coding that allows the smart beams and intensive reuse of frequencies, much more than we have today, are I think all critical technologies. The main thing is that we need a new technical vision, with our advanced system service. Without that technical vision, the Advanced Service Vision is meaningless.

We just had, in Washington, DC, a workshop sponsored by NASA and by other parts of the US government, industry, and by lots of professional groups, and the conclusion was that we have seen a decline in aerospace employment from 1.2 million employees in 1989 down to some 600,000 to 700,000 today. The feeling is that part of the reason is that there's been a lack of vision, and that we need some sizzle in our vision of the satellite systems of the future. And so, things that we were talking about that could give us new vision are solar power platforms that could see the equivalent of 1,000 suns and be able to generate gigawatts of power, of space platforms along the lines that we were talking about, with totally new materials and architectures, lunar colonies and so on. Next slide.

So for next steps, I think that we have more cross disciplinary and interdisciplinary thinking, that merge technology and applications. The so-called ICE Age of looking at applications that integrate information, communications, and entertainment services. The current gap between service providers, researchers, and satellite manufacturers, in my view, is dangerous. We have the technologists looking at technology, we have other people who are looking at applications, and others in the service world working quite independently. And I think we need to see more teamwork through universities and other mechanisms, to get all these groups working together. We need a new reality in business plans, and we need to know that satellites can be a key part of the "World Wide Mind" if strategic steps are taken now. Next slide.

So just to end, we have the future of satcoms in the context of what I call the "Super Month." In this Super Month, we're taking the entire history of humankind, where every second represents two years. And if we look at that Super Month, we find that for 29 days and 22 and a half hours, it was the time we operated as hunter-gatherer nomads. And it's only in the last hour and a half that we took up agriculture. The Renaissance was the last four minutes. The Industrial Age is the last two minutes. And the last 15 seconds or so are the age of computers and satellites. And where we can go in the next 20 to 30 seconds, in terms of lunar colonies, in terms of solar power systems, in terms of advanced communications systems, of mass driver technology, so that we could create trains that could go under ground, in vacuums, from Tokyo to say New York in an hour or two. These are all things that are possible if we have a sense of vision, if we really feel that the satellite industry is a part of a global whole of technological advance that moves us forward.

So with that, I'd like to close, and hope I've given you some interesting things to think about over the next few days. I do hope to have the chance to see a lot of old friends that I haven't seen for a while, and meet some new friends as well. Thank you very much.