I am honored to join Karen Holbrook in this opportunity to speak on behalf of the academic community about the importance of high-performance computing. Most of you are familiar with Moore’s law, which says that the speed of computing doubles every 18 months or so. To give you a feel for what that means in practical terms – I’ve been using the same IBM Think Pad with a Pentium III processor for several years now, and it’s gotten to be pretty pedestrian as laptops go these days. But as recently as 1995 my laptop would have ranked as one of the fastest 500 computers in the world.

But even against that dynamic backdrop, we are seeing a surge in supercomputing power capacity that exceeds Moore’s famous law. Supercomputing, which had been in something of a decline as research focused on improving parallel processing and faster, more powerful personal computers, is now experiencing a renaissance.

It comes partially in response to Japan’s announcement in 2002 that its Earth Simulator was the most powerful computer in the world. That was a blow to our national pride, and we soon had several initiatives underway to build several supercomputers in this country that would exceed the Earth Simulator in capacity.

But the recent surge in supercomputing is more than just a matter of international bragging rights. It has also come in response to warning signals from federal defense, intelligence, and research agencies that our existing supercomputers were failing to deliver what we need for national security and for science and technology leadership. And it comes to the relief of an important group of university researchers whose research problems do not adapt well to parallel processing.

Yet, even beyond the specific applications our investigators envision, the deeper question is: How do we leverage supercomputing to serve the needs of government and keep our economy on the leading edge of innovation? Anticipating this issue, DOE has funded a major contract with the U.S. Council on Competitiveness to better appreciate the role of supercomputing and its economic effects. It will be considered as one of the key elements in the Council’s National Innovation Initiative, which I have the honor to co-chair with Sam Palmisano, the CEO of IBM.
Without delving too far, it is apparent that coordination and collaboration – among universities and between universities, government and industry – have never been more urgent in our high-performance computing endeavors, not only to keep from inventing the same wheel at multiple locations, but also to achieve a high level of strategic alignment in the use of our key resources, and this is particularly important in supercomputing. Later in my remarks I will address one piece in this puzzle that is now being put into place that will substantially enhance the opportunity for national and international collaboration using supercomputing resources.

Oak Ridge National Lab has been a leader in computing ever since 1954, which some of you may recognize as the year when ORACLE was created – the fastest, largest computer of its day. As a matter of fact, the first two letters of the acronym ORACLE stand for Oak Ridge. And I want to thank ORAU for continuing that leadership by sponsoring this timely forum to promote the discussion of high-performance computing in the context of our larger economic development strategy.

Research universities come into this picture as participants in the discovery of new technology that will first make supercomputers larger and faster, but also then allow for a remarkable expansion of university-based research in a wide variety of fields. The ability of supercomputers to complete literally trillions of computations per second enables them to embrace calculations of incredible complexity and manipulate gigantic databases with ease. They are also essential to the modeling and simulation that is increasingly characterizing scientific research. Back in the 1991 edition of *Advances in Computers*, Thomas DeFanti and Maxine Brown wrote, “Much of modern science can no longer be communicated in print; DNA sequences, molecular models, medical imaging scans, brain images, simulated flights through a terrain, simulations of fluid flow, and so on, all need to be expressed and taught visually.”

Supercomputers are becoming the test-tubes of the 21st century. They are used to model the behavior of virtually anything that is too big, too tiny, too far away, or too dangerous to deal with in person – from exploding stars to individual atoms, from earthquakes to disease outbreaks. Of course, high-end PCs and parallel processing are capable of modeling, but supercomputers enable a much more sophisticated level at a much faster speed.

High-performance computing is essential to solving some of the thorniest and most intractable problems facing our world today. Climate and environmental changes, for example, are both complex and complicated, presenting compelling questions that must be answered if we are to make accurate predictions of future change and ameliorate the impact of human activities. In July of 2000, the U.S. Department of Agriculture declared
the entire state of Georgia as a disaster area due to drought. Some 30 local water systems were down to less than a month’s supply of drinking water. Agricultural losses soared to $800 million. New forecasting models enabled by supercomputers could increase the preparedness and lessen the impact of events like drought. Similarly, the energy needs of the world are expected to double by 2050, but it is imperative to reduce the impact on the environment. This double challenge cannot be met with existing technologies.

High-performance computing is also essential in today’s emerging new interdisciplinary fields. The recent mapping of the human genome, for example, created a massive database that is about three terabytes in size – the equivalent of about 150 million pages if someone were to print it out. Needless to say, it requires a tremendous amount of speed and power to manipulate in a timely fashion. As a result, the new field of bioinformatics has emerged, bringing together biological knowledge with skills in computing and mathematics to manage, process, and learn from complex biological data.

Supercomputers are also important tools for nanotechnology, which has tremendous and far-reaching potential to touch virtually every type of technology in our lives. Tools like the Spallation Neutron Source and High Flux Isotope Reactor at Oak Ridge are essential to help scientists characterize materials with precision at the atomic level. But the development of computer models and simulations of how materials will behave at the atomic level is also critical. And later this morning Uzi Landman from Georgia Tech will tell you more about the ground-breaking computer modeling that won him the Feynman Prize in Nanotechnology. We can also look for nanotechnology to develop a symbiotic relationship with supercomputing, in which supercomputers enable research that in turn generates new atomic-level technology to improve computing.

New fields like bioinformatics and nanotechnology have tremendous potential to drive high-end economic growth. Bioinformatics was already a $9 billion industry in 2003, and nanotechnology is expected to develop into a $1 trillion industry over the next ten years. Given the dynamics of the global economy, it is essential that the U.S. be at the forefront in developing and taking advantage of breakthroughs in these new fields.

Although the need for supercomputing power is ubiquitous in the academic research environment, it is obviously not possible for universities to provide science and engineering professors with their own personal supercomputers. It is not even possible for every university to have just one, nor would it be efficient or effective. A cooperative approach among universities, the federal government, and private industry is essential to develop appropriate supercomputing capabilities and make maximum strategic use
of the resources they offer. NSF has recently been sending signals that it will shift toward fewer but larger grants to universities, favoring projects that involve genuine collaboration between universities.

There are a number of channels through which this happens. ORAU is a good example, providing its member universities with opportunities to collaborate with Oak Ridge National Lab and tap into its unique resources, including supercomputing.

The Department of Energy accepts proposals from research universities and makes awards in the currency of millions of hours of supercomputing time at its labs for the winning projects. In December, the department announced three awards that illustrate the kinds of projects that require high levels of computing power. One went to the University of Chicago to study thermo-nuclear flashes on stars, which are not only fascinating in themselves, but are also expected to shed light on a number of fundamental questions in astrophysics. Berkeley received supercomputing time to study the complex processes that occur within photosynthesis, to enable the breaking down of carbon dioxide and the storing of carbon. And my own institution, Georgia Tech, was awarded time to improve the accuracy of computer modeling techniques for fluid turbulence. Fluid turbulence is not yet well understood, but it has applications and ramifications for a number of disciplines, including meteorology, astrophysics, oceanography, environmental quality, combustion and propulsion.

Along with DOE’s investments, the National Science Foundation has funded several supercomputing centers in places like Chicago, San Diego and the Pittsburgh Supercomputing Center. To maximize the potential of centers like these and ORNL’s, they need to be connected in grids that create access to a wide variety of investigators. This calls for a new generation network that can match the speed and power of the newest supercomputers. Otherwise the impact of high-performance is minimized. You can have a huge vat of water, but if the hose that drains it has a tiny diameter, the size of the vat is not particularly relevant except to those who can drink directly from it.

This next-generation network is now taking shape in National Lambda Rail Inc., which is an initiative by a consortium of leading U.S. research universities and private sector technology companies formed to create what is essentially a third-generation Internet devoted exclusively to research. And the first leg, which came on line in November, connects the supercomputing centers in Chicago and Pittsburgh.

National Lambda Rail is probably the most ambitious academic research networking initiative since the ARPANET and the NSFnet, which were the forerunners of today’s Internet. And in some respects, what we are trying to do is get back to ARPANET and
NSFnet. These early networks were devoted exclusively to research, but as they morphed into the Internet and were opened to public and commercial use, major research projects were crowded out. The power of the Internet was also not keeping pace with research needs.

So Internet2 was developed. Internet2 is a high-speed, high-volume network created specifically for higher education, and Georgia Tech was one of the founding member universities. Internet2 has been a highly successful endeavor, but it was created with a much broader focus than academic research. Its original mission included serving as a testbed for Internet applications like distance learning, telemedicine, and digital libraries. Georgia Tech, for example, has a campus in Metz, France, and Internet2 enables our students who are located there to participate in real-time in classes and research that is going on at our Atlanta campus and vice versa.

However, as programmatic uses like these have grown and developed, Internet2 has become increasingly congested with video-conferencing and the delivery of real-time classes, leaving less and less capacity for research. It has, in essence, become a “production” network, with research once again elbowed aside and left searching for the bandwidth it needs.

Internet2 started out at 2.5 gigabytes in size and is now in the process of expanding to 10 gigabytes to accommodate more traffic. But it still presents limitations to researchers. For example, Internet2 does not offer an opportunity for network research. There is only one channel, which is in constant use for communication purposes. So it is not possible for researchers to experiment with the network itself – to push it to the max, for example, in an attempt to see what happens when it has been brought to its knees.

As Internet2 grew increasingly congested with production uses, a group of leading research universities began to explore the idea of a new, even more powerful network iteration devoted exclusively to research. And they saw a window of opportunity that had opened through the overbuilding of fiberoptic infrastructure that resulted from the deregulation of telecommunications. There was dark network capacity out there that could be purchased at marginal rates. This was a bargain compared to Internet2, which operates on leased bandwidth that comes at market rates.

So National Lambda Rail Inc. was born, and we are now in the early stages of developing a high-speed network devoted to research. In contrast to Internet2, which has only one channel, NLR will have 40 channels, each one of which will be the same size as the expanded 10-gigabyte Internet2. If network researchers crash one of the channels in the course of their experiments, the other 39 will still keep humming along.
We are beginning with just four channels – one of which will be devoted to Internet2 for its research demands – but the initial equipment is designed so that the additional channels can be opened simply by adding cards.

Georgia Tech is one of ten partners that make up National LambdaRail, Inc., and Ron Hutchins, who is heading that effort on our behalf, will tell you more about how it works a little later this morning.

The combination of expanded supercomputing capability and the National LambdaRail network which will connect it will offer university researchers expanded opportunities to tackle the complex climate and environmental problems that must be solved if the world as we know it is to survive. These resources also will enable the discovery of new knowledge and the invention of new technology that will allow the United States to maintain its technological leadership.