

Testimony  
of  
Dr. Irving Wladawsky-Berger  
Vice President, Technical Strategy and Innovation  
International Business Machines Corporation  
to  
The United States Senate Subcommittee on Technology, Innovation and Competitiveness

## Introduction

On behalf of IBM, I would like to thank the Subcommittee, and especially Chairman Ensign and Senator Kerry, for the opportunity to address the evolution of supercomputing during the 1990s, the priorities we should focus on, and the challenges we face.

First, by way of introduction, I am currently Vice President for Technical Strategy and Innovation at the IBM Corporation, and am responsible for identifying emerging technologies and marketplace developments critical to the future of the IT industry, and organizing appropriate activities in and outside IBM in order to capitalize on them.

My association with computers began in the summer of 1962, when prior to entering the University of Chicago, I was employed at the computation center where I worked part-time through my college years doing scientific programming. I later went on to get a Ph. D. in Physics, and did my research on computational atomic and molecular physics. After finishing my Ph. D. at the University of Chicago, I decided that I was better suited for computing than for physics, switched fields and joined the Computer Sciences Department at IBM's Thomas J. Watson Research Center in June 1970.

By then, IBM had decided, for a variety of reasons, to exit the scientific computing market, where it had been a leader for a number of years. We re-entered the market in the second half of the 1980s by adding what is called a vector feature to our mainframes, and a few years later in the early 1990s we became a leader in the emerging area of parallel supercomputing with our SP system. I was the general manager of both these efforts.

Today, according to the authoritative Top500 supercomputing rankings, IBM:

- Leads with the world's top three supercomputers: BlueGene/L for the US Department of Energy (DOE) with 280.6 sustained teraflops (trillion floating point operations per second), BlueGene/W at Watson Research with 91.3 sustained teraflops (or 114.7 teraflops peak) and DOE's ASC Purple at Lawrence Livermore National Laboratory with 75.8 sustained teraflops (or 92.8 teraflops peak).
- 
- Has supplied 240 of the world's top 500 supercomputers – more than any other vendor.

- Accounts for over 1.5 petaflops of aggregate performance in the TOP500 list (from a total of 2.79 petaflops).
- Has supplied more supercomputing systems than any other vendor in the TOP10, TOP20, TOP100 and TOP500.
- Has supplied the most cluster systems with 177 of 364 (48.6%)
- Has built the largest University supercomputer in the U.S - Big Red – a Cluster rated at 15 teraflops and installed at the University of Indiana.

IBM has held the number one spot in the Top500 list since June, 2005. Japan's Earth Simulator held the number one spot for the previous three years. IBM was the first to deliver a system that achieved over 100 teraflops -- that is a system that could perform over 100 trillion operations per second -- of peak performance; in fact Blue Gene/L has tested at 360 teraflops (peak). And we have achieved actual sustained performance of from 100 to 200 teraflops on a number of applications of real importance to the National Nuclear Security Administration. The BlueGene/L supercomputer has been measured at 10-times the energy efficiency (measured by Watts of electricity needed to attain a particular level of performance) of any of the top 20 supercomputers, and it is similarly efficient in its space requirements. In the process, we have demonstrated the practicality of using well over 100,000 microprocessors and then leveraging their computational capability efficiently on a single problem.

Along the way, we have learned many lessons, but I believe that two are especially significant. First, it is vitally important to work closely with lead partners in research labs and universities in order to "push the envelope" in terms of performance, applications and discovery. I cannot overemphasize the importance of these leading-edge pilots in propelling us forward and bringing together all the elements needed to develop working systems that can be used for real research in important application areas.

The second key point is the importance of the marketplace in guiding our actions. Through my professional career I have seen many supercomputing companies fail because they relied solely on government-based projects and were heedless of marketplace requirements for, not only leading-performance, but competitive prices and sophisticated software and applications as well. While we are very proud of IBM's leadership in the Top 10, Top 100 and Top 500, we are equally proud that supercomputing is a viable business for us with many clients around the world in both the private and public sectors.

What is supercomputing?

Supercomputing is defined by three key characteristics. First, the applications are information-intensive; second, they deal with computation-intensive simulations - both in the natural world of physics, chemistry and biology, and in virtual worlds, such as engineering objects and entertainment; third they enable the visualization of information and simulations so people can interact with the results - as exemplified by scientific visualization and the more recent emergence of video games played between myriad participants.

### Why is Supercomputing so Important?

Through the years, we have come to realize that supercomputing architectures and applications foreshadow the future of computing itself. Indeed, if one is removed from the advanced research, new ideas and creative minds in supercomputing, one will inevitably misread the major trends in computing. This is among the main reasons IBM re-entered the market in the late 1980s.

Beyond its role as a precursor, supercomputing has become essential to the pursuit of scientific inquiry. To quote the June 2005 report by the President's Information Technology Advisory Committee (PITAC), "Computational science has become the third pillar of the scientific enterprise, a peer alongside theory and physical experiment." Supercomputers enable scientists to either make discoveries that would be difficult (perhaps impossible) to accomplish experimentally or to point researchers in new directions.

Examples abound. They include (but are certainly not limited to) developing insight into the behavior of materials under extreme conditions that cannot be reproduced experimentally, enabling scientists to make reliable predictions about the behavior of our nuclear stockpile or the safety of aging nuclear reactors, for example. Supercomputers can also find previously undiscovered sequences in so-called "junk DNA" that may lead to new insights into its "function". They can also discover "docking sites" for new drugs, i.e. receptors on molecules where a drug can potentially attack a disease. Or supercomputers can perform multi-century simulations to understand trends in the earth's climate.

### Growth of the Supercomputing Market

Supercomputing was once confined to a niche market, because the hardware was so very expensive. That changed over time with the introduction of workstation and PC-based technologies, the latter becoming immensely popular in Linux clusters during the late 1990s. Today, we even use low-power, low-cost micros – consumer-based technologies -- to attain very high degrees of parallelism and performance, as in our Blue Gene system, which has reached a peak of 360 trillion calculations per second. Now, we are seeking to build supercomputers using technologies from the gaming world, such as the Cell processor.

All these approaches leverage components from high-volume markets, and aggregate them using specialized architectures; thus the costs are significantly lower than in earlier days and the potential markets are consequently much bigger.

Progress in supercomputing hardware has been nothing short of astounding. The real challenge, however, is software, both application software and systems software. In fact, both the 1999 PITAC report, with which I was personally involved, and the June 2005 PITAC report made precisely that point.

### Key Application Areas

But the real value of supercomputing to society is not in the technology, architecture and software, important as they are. The value of supercomputing is best appreciated by considering its application, so let me review the recent progress and the promise in a few key application areas, starting with the “classic” or more mature ones and then moving on to some of the newer opportunities.

#### *Defense and National Security*

Let me start by discussing Blue Gene/L and ASC Purple, two of the world’s top three supercomputers, residing at Lawrence Livermore National Laboratory (LLNL). They are vital to the National Nuclear Security Administration’s (NNSA) Advanced Simulation and Computing Program (ASC), which in turn is an essential element of our nation's Stockpile Stewardship Program. ASC provides the integrating simulation and modeling capabilities and technologies needed to combine new and old experimental data, past nuclear test data, and past design and engineering experience into a powerful tool for future design assessment and certification of nuclear weapons and their components.

Already, the simulation and modeling tools are improving the assessment of stockpiles far in advance of schedule. Indeed, weapons designers, scientists, and engineers now rely on ASC simulation and modeling capabilities and technologies to assess changes occurring in aging stockpiles of nuclear weapons and to assess and certify planned refurbishments of weapons system components.

On March 9, 2006, Lawrence Livermore National Laboratory and IBM announced a fundamental breakthrough using ASC Purple. IBM and LLNL demonstrated over 102 gigabytes per second of sustained read and write performance to a single file using specialized software that orchestrates thousands of processors and thousands of disk storage devices.

The breakthrough is expected to stimulate development of data-intensive applications in areas like customized medicine, online gaming, entertainment, and homeland security, as well as in traditional high-performance computing applications.

Then on June 22 of this year, the NNSA announced that it had achieved an unprecedented level of performance using our Blue Gene/L. This world record for a scientific application was set by achieving a sustained performance of 207.3 teraflops, running “Qbox” computer code for conducting materials science simulations critical to national security.

### *Science*

In addition, the unmatched cost/effective computational capability of Blue Gene has already resulted in new insights in biology.

The scientists at the T.J. Watson Research Center have applied supercomputing to demonstrate that “junk DNA” could have very startling ramifications on cell regulation and species evolution. In another computational experiment, they have shown that a single mutation in a protein can render it unstable, causing it to misfold. Similar techniques and computational models can be applied to better understand fatal diseases.

ASTRON, in the Netherlands, is using the Blue Gene supercomputer to develop a new type of radio telescope capable of looking back billions of years. This research project will enable scientists to examine the beginnings of the earliest stars and galaxies after the formation of the universe in the wake of “the Big Bang.”

Blue Gene/L will give ASTRON the flexibility and unparalleled speed it needs to gather and analyze information from its Low Frequency Array (LOFAR) "software telescope" network. Unlike current observatories that use big optical mirrors or radio dishes to point to distant galaxies, ASTRON will harness more than 10,000 simple radio antennas spread across the northern Netherlands and into the German state of Lower Saxony and interpret them using high-speed calculations.

In many domains, theory, experimental capabilities, and computational advances are coming together in a manner that will significantly accelerate scientific discovery.

### *Weather, climate*

Supercomputing is also taking weather forecasting, modeling and research to new levels. Research groups at several government agencies and research laboratories are moving traditional models to scalable supercomputer systems. These models are then used to test the validity of our current understanding of the physics of weather and to develop more detailed, robust, high-resolution models. When the models are considered trustworthy, they are used for operational forecasting by the National Weather Service and by environmental analysts to assess air quality.

In addition, there is emerging a generation of localized, high-resolution weather prediction capabilities customized for application one to two days ahead of time by businesses with weather-sensitive operations. Industries that would benefit are as diverse as aviation, agriculture, broadcasting, communications, energy, insurance, sports, entertainment, tourism, construction and others in which weather is a crucial factor. Extremely fast, ultra precise weather forecasts would be invaluable to these businesses' day-to-day decision-making. Such forecasts could be used for competitive advantage or to improve operational efficiency and safety.

### *Engineering*

Automobile companies run virtual car crashes using complex supercomputer simulations to ascertain how different designs react in collisions. This reduces the number of costly prototypes, and speeds the delivery of new models. With new regulations on safety in the auto industry and buyer preferences for safer cars, keeping this competitive advantage is of paramount importance to manufacturers.

Supercomputing is also being used to create more fuel-efficient automobile designs. Exa Corporation, a global provider of wind tunnel design simulation software uses our supercomputers to help major automotive manufacturers and smaller suppliers solve larger, more complex aerodynamic, acoustic and thermal engineering problems. With virtually unlimited amounts of compute capacity available as needed, Exa's clients can perform more analysis in less time -- improving quality and time-to-market and overall competitiveness.

Seismic imaging is an application critical to our energy future. Seismic imaging is the process by which acoustic waves are generated and their reflections off the earth's subsurface are collected. Seismic imaging applications then convert the reflected waves into a 3D image of the subsurface, revealing an image of a petroleum reservoir. This process is used by all major oil and exploration companies. Good quality seismic imaging is critical since dry holes can cost millions -- in the deep waters of the Gulf of Mexico as much as \$100 million.

IBM and Compagnie Générale de Géophysique (CGG), a world leader in geophysical services, recently announced deployment of Europe's most powerful seismic supercomputer to respond to growing global demand in the petroleum industry. The system is expected to significantly reduce processing times from the moment the geophysical data is collected to the point when it generates a seismic image. This clustered supercomputer will also allow CGG to boost its worldwide computing capacity to a maximum of 113 teraflops, and give them an unprecedented ability to respond to the extremely high performance requirements of the oil industry.

This supercomputer installation is a result of CGG's need to continually improve its performance in response to the demands of a highly competitive market by optimizing the quality and speed of processing in specific applications. The new system is being deployed at the company's premises in Massy (France), London, Kuala Lumpur and Houston, Texas.

Let me now focus on some of the newer application opportunities.

### *Energy*

**GNEP** (The Global Nuclear Energy Partnership) is a Presidential initiative to establish nuclear energy as the preferred emissions-free alternative source of electric power. By reprocessing spent nuclear fuel and recycling it for reuse in nuclear power plants we can control the process and share recycled fuel and technology with developing countries that

need inexpensive energy. The United States has been encouraged in this effort by China, France, Japan, Russia, and the United Kingdom as well as the International Atomic Energy Agency (IAEA).

Computer Simulation will be essential to the success of GNEP, allowing us to rapidly test innovative approaches and improve our ability to understand and control very sensitive materials. The President has requested \$250M in FY '07 for the program, while the House has recommended \$150M and the Senate \$250M. We support the effort and the concept of “making nuclear energy a renewable source of power”.

**ITER** is a large international fusion experiment aimed at demonstrating the scientific and technological feasibility of fusion energy and at trying to answer the question: Can we produce practical amounts of fusion power on earth? In fusion, heavy forms of hydrogen are fused at high temperatures with an accompanying production of heat energy. ITER is a step beyond the study of plasma physics and toward the possibility of fusion power plants actually producing electricity and hydrogen.

The international project is made up seven partners including the United States, China, the European Union, India, Japan, Russia and South Korea. The facility will be housed at a site in Cadarache, France. We support the United States’ participation in ITER and the funding requested by the President in the fiscal '07 budget.

### *Bioinformatics and Computational Biology*

These involve the use of techniques from applied mathematics, informatics, statistics, and computer science to solve biological problems. Genomes (an organism’s complete information set) are sequenced and assembled, and then become candidates for data mining. This data mining is often referred to as bioinformatics.

The objective is a better understanding of the relationship between specific genes and diseases, an understanding that is essential to the development of therapies. The point is to develop drugs that will target specific genes and focus on a specific disease. With the volume of genetic data proliferating, it long ago became impractical to analyze DNA sequences manually. Today, computer programs search the genome of thousands of organisms, containing billions of nucleotides.

Bioinformatics has great potential for expediting delivery of new, individualized therapies to patients.

Brain research is another promising scientific pursuit utterly dependent on supercomputing. It is also the purpose of a joint research initiative between the Ecole Polytechnique Fédérale de Lausanne (EPFL) and IBM. Nicknamed the “Blue Brain Project,” it is intended to take brain research to a new level.

Scientists from EPFL and IBM are working together using the huge computational capacity of Blue Gene to create a detailed model of the circuitry in the neocortex -- the largest and most complex part of the human brain. By expanding the project to model other areas of the brain, scientists hope eventually to build an accurate, computer-based model of the entire brain.

Relatively little is actually known about how the brain works. Using the digital model, scientists will run computer-based simulations of the brain at the molecular level, shedding light on internal processes such as thought, perception and memory. Scientists also hope to understand more about how and why certain microcircuits in the brain malfunction, -- a failure thought to be the cause of psychiatric disorders such as autism, schizophrenia and depression.

### *Health Care*

Medical science increasingly relies on advanced information systems to share information, mine that information for trends and insights, and use those findings to head off disease or improve treatment. This takes sophisticated computer hardware and software, and the technology has advanced to the stage where truly wondrous things that yesterday were only wishful thinking can now be tackled.

For example, The Scripps Research Institute and IBM researchers are working on new technology to anticipate, manage and contain infectious diseases like avian flu. Using Blue Gene, they are trying to devise a way to track the emergence of new virus strains and map human and animal responses to them. This capability will help scientists and governments to better understand viruses and respond effectively to potential pandemics. It could also enable vaccines to be created quickly enough to prevent massive outbreaks.

Likewise, QuantumBio Inc., a provider of software tools for drug, biotechnology, and pharmaceutical companies, uses the Blue Gene supercomputer to help satisfy its testing

needs. With Blue Gene, QuantumBio is able to provide users with the opportunity to study molecules of interest over a secure and integrated system on an as-needed or on-demand basis.

### *Business*

SmartOps, a leading provider of enterprise-class supply chain optimization solutions for the manufacturing and distribution industries, used the Blue Gene supercomputer to port and test their Multistage Inventory Planning and Optimization (MIPO) solution in preparation for offering a large-scale hosted solution for their clients.

Likewise, in the Finance Industry the most competitive firms are those that can maximize returns and minimize risk, all in the shortest time possible. Key to success is the ability to apply computational power to increasingly complex and demanding business processes. Workloads such as risk management, portfolio analysis, derivatives pricing and actuarial simulations can all benefit from the application of supercomputing's greater computational power.

### *Learning*

Highly realistic, visual interfaces first appeared with scientific applications as well as with flight simulators used to train pilots and with war game simulators used to train military personnel. These visual interfaces (along with the accompanying sounds) have been increasingly enhanced with digital animation and video games. Video games are particularly important because in addition to their very realistic visual images and sound effects, they are also highly interactive and increasingly collaborative, and thus a good launch pad for thinking about how people can best interact with all kinds of computer applications as well as with each other in the future. Furthermore, the success of video games with millions of people has stimulated the introduction of very inexpensive and powerful technologies, such those around Microsoft's Xbox and Sony's upcoming Play Station 3.

The new highly visual, realistic, and interactive interfaces now hold the promise of sparking a major round of innovation for computer applications in general, both in rethinking how to best integrate these new kinds of visual interfaces with existing applications, as well as inspiring whole new categories of applications that we cannot even envision today.

One application area that holds great promise is learning across the broad spectrum of needs, from K –12 all the way to the introduction of sophisticated new procedures for professionals. After all, since our brains are wired for sight and sound, these new applications should be able to approach humans on human terms, and thus significantly facilitate the learning process.

### Conclusion

Clearly, supercomputing has advanced to the point of being essential in myriad endeavors, in the laboratory certainly but most assuredly in the commercial world as well. It is indispensable to the process of innovation and to the ability of the United States to thrive in a globalized economy that grows more competitive by the day – something The National Innovation Act of 2005 (S 2109), which we support, is meant to foster.

The Federal Government has significant influence in setting the agenda for basic research and in turn the use of high-performance computing in pursuit of innovation and competitiveness. We, in our industry participate in that agenda as partners. In order to realize the full benefits for our country, Congress, in partnership with the industry, should clearly outline and invest in a long-term strategy. For example, the President's Budget request for fiscal year 2007 includes high performance computing activities funded by the Networking and IT Research and Development (NITRD) agencies including the National Science foundation, Department of Energy and the National Aeronautics and Space Administration. These activities range from biomedical computing to earth and space science research to weather modeling frameworks.

Clear direction and consistent funding will prompt industry and academia to invest as well, and in partnership we can address many of the serious challenges that face our nation. In the process, we will expand and deepen our knowledge of much of the world around us and our ability to influence it. These kinds of efforts unite government, universities and private industry in a productive collaboration – a partnership for which there is no substitute.