

TESTIMONY OF STEPHEN HARPER, INTEL CORPORATION
SENATE FOREIGN RELATIONS COMMITTEE
EUROPEAN AFFAIRS SUBCOMMITTEE
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Thank you, Senator Allen and Committee members, for this opportunity to discuss an important topic – nanotechnology in the context of US-European relations. I am Stephen Harper, Director of Environmental, Health and Safety Policy at Intel Corporation. I am here representing Intel as well as the European-American Business Council (EABC).

EABC is a trans-Atlantic, trans-sectoral alliance network of 43 US- and European-based global companies. EABC's mission is to enhance US and European economic competitiveness through government-to-government and government-to-industry policy collaboration. The EABC believes that smart trans-Atlantic regulatory alignment can truly add to productivity gains.

Today I want to emphasize several key themes:

- First, innovation in the semiconductor industry has been a principal driver of recent US gains in economic productivity and significant improvements in health care and other fields benefiting humanity.
- Second, looking into the not-too-distant future, continued progress in the semiconductor industry will depend on progress in the development of nanotechnology. Just as semiconductor technology is the competitive

edge of the Information Age, so nanotechnology will be the competitive edge of semiconductor technology in the future.

- Third, continued progress in the development of nanotechnology depends in significant measure on international cooperation in key areas of research and development. The opportunities and challenges simply are too great for one nation, or a national industry, to try to tackle them in isolation.
- Fourth, the evolution of an appropriate environmental, health, and safety (EHS) regulatory framework for addressing potential nanotechnology risks will be critical to the ultimate public acceptance of this new technology. International cooperation, especially between the US and Europe, will be key here as well.
- The US government, focused through the National Nanotechnology Initiative, can help ensure international cooperation regarding EHS regulation of nanotechnology.

Before I delve into each of these themes, let me first focus on Intel – who we are and why we care about nanotechnology.

Intel, as you know, is the largest and leading semiconductor company in the world. Founded in 1968, Intel today employs 87,000 employees worldwide, with 2004 revenue of approximately \$34 billion. Although known primarily for our Pentium® and Centrino® products, Intel markets over 450 products and services.

Intel also is a global company, with 294 offices and facilities in 48 countries.

Intel has a major manufacturing presence in the United States, with 49,000 US-based employees and major production facilities in Oregon, Arizona, New Mexico, Colorado, Washington, and Massachusetts. We continue to have major research, design, and other facilities in California, in addition to our corporate headquarters.

Importantly in the context of today's hearing, Intel also has a major investment in Europe. Leixlip, Ireland, in the suburbs of Dublin, is home to two Intel factories or "fabs," employing 3,300. In addition to Ireland, we have significant design and research facilities in the UK, Denmark, and Germany. Specifically focused on nanotechnology, we participate in the Irish Nanotechnology Research Center as well as a research center in Belgium. Reflecting our production, design, and research investments in the European Union, we also participate in a number of industry trade associations and coalitions, including the European-American Business Council. The important thing to stress is that our facilities in the US and Europe, and in Asia for that matter, are all part of an integrated enterprise. The success of each is important to the success of the overall company.

Intel's interest in nanotechnology is multi-faceted. In the immediate term, Intel today is creating devices that feature transistors that are smaller than 100 nanometers wide. These nano-sized features are why Intel's current Pentium 4® processors are packed with more than 100 million transistors and our Itanium 2®

server processor family includes a recently-prototyped chip that includes more than 1.7 billion transistors, a product we expect to launch commercially early next year. In terms of dollar value of product, advanced semiconductors represent the biggest slice of the current nanotechnology marketplace. We refer to our current nanotechnology as “nano-electronics.”

The width of our current transistors and circuits is so small they are difficult to fathom. The best way to appreciate their size is in relation to more familiar objects. Later this year, Intel will introduce chips that have 65 nanometer-sized transistors. The gates of the transistors – the switch that turns them on and off – measure only 35 nanometers across. At this size, approximately 100 of these transistor gates could fit inside the diameter of a human red blood cell. Another comparison: approximately 10 million of these transistors could fit in the area of the tip of a ball-point pen.

Looking ahead we believe that we can continue to evolve and improve current materials and technologies to drive transistor sizes down to approximately the 10 nanometer size range. For the foreseeable future, semiconductors will continue to rely on traditional silicon-based technology. But perhaps approaching 2020, we anticipate running up against the physical limitations of silicon-based approaches. At that point, chip manufacturing may rely on new nanomaterials such as carbon nanotubes and nanowires to continue progress in accordance with Moore's Law.

The year 2020 sounds like a long time away. But because of the complexity of the technical work that must be done to invent and implement the nanomaterial future, Intel and the semiconductor industry have begun investing in significant research and development to bridge to the nanomaterial future. Much of this work takes place within the context of the International Technology Roadmap for Semiconductors (ITRS). The ITRS lays out the key scientific and environmental challenges that must be met in order to continue progress along the path predicted by Moore's Law. It is important to emphasize that the ITRS, and much of the current nanotechnology R&D being undertaken in the semiconductor industry, is viewed as "pre-competitive" – companies from across the industry, from around the world, are pursuing a common basic research agenda, working through cooperative institutions like Sematech and the Semiconductor Research Corporation. The economic promise and technical challenges of nanotechnology require effective international collaboration.

Within Europe, Intel has been active in the Belgium-based Interuniversity MicroElectronics Center (IMEC), the European Nanoelectronics Initiative Advisory Council (ENIAC), and other industry-government cooperative ventures. We will also play a major role in the upcoming First International Nanotechnology Conference on Communication and Cooperation, scheduled for early June in San Francisco.

I have referred several times to “Moore’s Law.” What is Moore’s Law and why does it matter? Forty years ago, Gordon Moore, one of the founders of Intel, predicted in an industry magazine that the number of transistors in integrated circuits would double every year. Moore later updated his projection to a doubling every two years, accounting for the increased complexity of semiconductors. Moore’s observation really focuses on two phenomena – increasing density of transistors on semiconductors and radically decreasing cost per transistor. It describes the phenomenon in our industry whereby we etch ever smaller-sized features in silicon. Moore’s Law was a prediction based on an observation, not a true “law.” But it has functioned as a law in the sense that it has driven the pace of change and innovation in our industry, as we seek to continue the trend of past advances.

So who cares? As described, Moore’s Law perhaps is something interesting to semiconductor industry technologists only. But progress along the trajectory of Moore’s Law has translated into cost decreases for a wide range of products that depend on semiconductors – computers, telecommunications equipment, automobiles, scientific equipment, and many other devices. Falling prices for information technology products have driven the rapid proliferation of information technology. The diffusion of information technology has been the biggest reason for the recent, historic acceleration of US economic productivity growth. And productivity growth is the secret to improving our standard of living. In the words of Harvard Economics Professor Dale W. Jorgenson, “A consensus has emerged

that the development and deployment of information technology (IT) is the foundation of the American growth resurgence. The mantra of the 'new economy' – faster, better, cheaper – characterizes the speed of technological change and product improvement in semiconductors, the key enabling technology." (2005 Semiconductor Industry Association Annual Report)

Pre-competitive R&D cooperation has been central to keeping up with Moore's Law in the past. We believe it will continue to be critical as we move further into the realm of nanomaterials. And this cooperation needs to be international in scope, combining the best research minds in the industry, and in government and university labs, wherever they are located. This is somewhat at odds with the spirit of numerous governmental reports and communications – from the US, Europe, and Japan – that portray nanotechnology as the next "space race," as the proverbial "goose" that will lay the future economic "golden egg." Clearly, governments in many geographies view nanotechnology as a foundation of future economic growth.

My message today is that what we need is a balance of competition and cooperation. And international cooperation is critical in areas such as semiconductors, where the challenges are great and the cost of meeting those challenges is excessive. International cooperation is also critical in the realm of the implications of nanotechnology – especially the environmental, health, and safety (EHS) implications of this new "magic." Research initiatives launched

pursuant to the National Nanotechnology Initiative (NNI) need to be undertaken in cognizance of and, where appropriate, in cooperation with parallel activities in Europe and elsewhere.

At this point I want to stress the value we place on the activities of the NNI. In a very short period of time, the NNI, with support from participating agencies and funding from the Congress, has developed a very robust program of activities. And we are confident that the ongoing National Academy of Sciences review, mandated by Congress, will confirm this and make suggestions for the continued success of the NNI. In the semiconductor industry, we are participating in a series of joint NNI/Semiconductor Research Cooperation (SRC) workgroups under the auspices of the NNI's Consultative Board on Advancing Nanotechnology (CBAN). These issues range from meeting priority technology challenges to identifying and addressing environmental, health, and safety (EHS) research needs related to semiconductor applications of nanotechnology. NNI funding related to semiconductor nanotechnology research goes to many universities in numerous states across the US.

The NNI/SRC focus on the EHS dimensions of nanotechnology is part of a broader NNI trend of focusing on the "implications" of nanotechnology, not just "applications." We support those activities; indeed, we believe that more attention and resources need to be devoted to identifying and reducing the EHS risks of nanotechnology.

Intel has a proud record of accomplishment in our own EHS programs and activities. Our guiding EHS management principles commit us to preventing all injuries in the workplace, being an EHS leader in our industry and our communities, and reducing the environmental “footprint” of our products, processes, and operations. But “talk is cheap”: we have translated these principles into a world-class record of performance. Our worker safety record is among the best of any company in any industry. Across both safety and environmental realms, Intel has earned dozens of awards for leadership in the US, Israel, the Philippines, and many other geographies. Within the industry, Intel has been a leader in the development of the EHS element of the International Technology Roadmap for Semiconductors.

Intel’s EHS management activities in the nanotechnology realm have two primary focal points. In the immediate term, we are committed to ensuring the safety of our own employees as they work with innovative nanomaterials in our research labs. Longer-term, we have an interest in the responsible development and deployment of nanotechnology, ensuring that attention is paid to the “implications” as well as the “applications.” What we want to avoid is for the trajectory of nanotechnology to follow that of genetically-modified organisms (GMOs), the most recent “magic” technology. In the case of GMOs, in our view, deployment of applications outpaced attention to the environmental, health, and

safety implications of the technology. Public concerns that arose because of this have significantly retarded the realization of GMO's great commercial potential.

With this concern in mind, Intel has been an active participant in the CBAN NNI/SRC Workgroup 5 activities, focused on EHS research. Intel also has assumed a role in a nascent activity under the auspices of the International Standardization Organization (ISO) focused on developing international standards related to the EHS aspects of nanotech. We also are one of the founding supporters of the International Council on Nanotechnology (ICON), a multi-stakeholder initiative of Rice University's Center for Biological and Environmental Nanotechnology (CBEN). ICON is focused on advancing and coordinating nanotechnology EHS research. In addition, we are engaged in formal "benchmarking" activities with other companies to identify "best known methods" in the measurement and safe handling of nanomaterials in the research laboratory environment.

As a result of our engagement in these nanotechnology EHS initiatives, we believe there are two broad categories of research needs. First, much more needs to be known about the toxicity of nanomaterials. Second, there is a need for the development of standardized metrology techniques and EHS controls for application in both the laboratory and production environments. These needs are not unique to the semiconductor industry – they are common to a broad range of industries with an interest in the responsible deployment of nanotechnology.

Finally, I want to focus on governmental regulation of the EHS aspects of nanotechnology. Drawing lessons once again from the precedent of GMOs, governmental regulation of nanotechnology may be essential to the long-term public acceptance of new technologies like nano. This probably is especially true in the European Union, where the “precautionary approach” increasingly defines the governmental, and societal, approach to new technologies.

Here in the US, the Environmental Protection Agency is in the early stages of wrestling with some difficult questions concerning the applicability to nanotechnology of their regulatory authority under the Toxic Substances Control Act (TSCA). We understand that the Agency intends to convene a public workshop on this issue later this year.

In the European Union, we anticipate that regulation of nanotechnology will proceed under the broad umbrella of the REACH Directive. REACH is a fundamental revision of the EU’s approach to regulating new and existing chemicals. Because the REACH Directive is still in the legislative process, it is not entirely clear what the new chemical regulatory regime will look like, much less how it will address nanotechnology.

While the two governments – US and EU – are beginning to sort out how they want to regulate nanotechnology, there is a need for cooperation across the

Atlantic. Because progress on the scientific aspects of nanotechnology – at least in the semiconductor industry – will depend in part on international cooperation, there is a parallel need for cooperation in assessing and addressing the EHS implications of nanotechnology. The emergence of significant differences in regulatory approaches across the Atlantic could undercut cooperation on the science.

Specifically what is called for is open cooperation and sharing in the generation of data concerning the risks as well as the benefits of nanotechnology. Sensible regulations need to be based on good science and accumulating data from credible scientific studies. We need an international research strategy focused on the potential EHS risks of nanotechnology, with broad sharing of research results and the coordination of future efforts. The US Government can provide a significant service in this regard. The NNI, working with CBEN, ICON, and others, should clearly identify all past, current, and proposed nanotechnology research focused on human health risks and safety issues. Overtures should be made to the Europeans and Japanese to encourage them to add to this database. A collective, international effort of this kind will help to identify key research gaps and spur the development of an international EHS research strategy for nanotechnology. Execution of this strategy will inform responsible regulation of nanotechnology and, in our view, increase the prospects of public acceptance and commercial realization of nanotechnology's great promise.

Thank you again for this opportunity to testify. I will be happy to answer any questions.