- Sometimes these technologies fall into the hands of those who do not have good intentions. We have seen the horrible consequences of what even a common technology can do in the hands of terrorists. The thought of what such people could do with more advanced technology is truly frightening. Here are some recent examples of what has already been done:
  - A team of biologists recently created a polio virus in vitro "from scratch."
  - Researchers recently inadvertently published a technique that could be used to enhance the virulence of pathogens, such as anthrax or smallpox, greatly increasing their lethality.
  - Scientists have synthesized a key smallpox viral protein and shown its effectiveness in blocking critical aspects of the human immune response.
- Then there are the missives from respectable authors that raise even more profound concerns. Take, for example, Bill Joy's infamous piece about how the future doesn't really need us.

Faced with such fears about the impact of new technologies, people throughout history have sought to stop their advance:

- During the Industrial Revolution, Dutch workers threw their shoes—sabots—into the machinery in an attempt to damage the technology that they believed would take their jobs.
- Automobiles faced early opposition. When they first became available, some cities banned them. San Francisco had a law that mandated parking your car at the edge of the city and riding a horse or carriage into town.
- Thomas Edison attempted to use such fear to manipulate the public for his own financial benefit. With a vested interest in the success of direct current, Edison sought to undermine the use of alternating current by holding public demonstrations of its danger by electrocuting animals—dogs, cats, horses, even an elephant.
- "If man were meant to fly…" was a common refrain raised by the fearful and skeptical in opposition to commercial aviation.

The same technologies that have brought scientists together—I'm thinking information technology, in particular—have made our world smaller and have brought more people into the public square, people driven by their fears and concerns about the technology under development. And not only are more people involved, they are essentially looking over your shoulder, watching what you are doing in near real-time.

Seventh Message: The body politic is susceptible to the virus of fear

We also know from history that the body politic is susceptible to the virus of fear**.** When the public catches a public-policy cold virus, their elected representatives sneeze. Our democratic institutions are designed to be responsive to the public. To keep technology moving forward, we must prevent fear from taking hold among the public.

Eighth Message: We must identify legitimate ethical and societal issues and address them as soon as possible

So we can't afford to wait to deal with these things. We need to wrestle with them now.

The first thing we need to do is to sort legitimate concerns from imaginary ones, those that are based on science from those based in science fiction. Then we must debunk and dismiss the latter and devote time, attention, and resources to seriously address the former.

We cannot allow ourselves—or the public—to be distracted or misled by capricious claims, foundationless fears, wanton warnings, pompous pronouncements, and arbitrary assertions. We must devote our efforts to addressing the legitimate concerns.

One reason we can't afford to wait is because the public policy apparatus does not move quickly. It is not designed to move quickly. It is a very different environment than the dynamic, fast-changing one in which you work. So to engage effectively in the political arena, you must think and act far ahead.

Ninth Message: We need a holistic approach, with scientists and engineers playing a key role

To effectively address these questions, the NNI recognizes, we need a holistic approach that embraces ethicists, philosophers, theologians, historians, consumer advocates, business leaders, public officials, and others, with scientists and engineers playing a unique and critical role.

Scientists and engineers are in the best position to contribute to sound policy development, addressing legitimate concerns and allaying irrational public fear. Scientists and engineers alone have the scientific and technical knowledge necessary to sort the wheat from the chaff.

In addition, while not historically great communicators, scientists and engineers have unique credibility with the public in speaking to these issues. We need to communicate frequently, clearly, and proactively with the public about nanotechnology to ensure that Americans have all of the knowledge they need—complete and balanced—to make reasoned judgments on these issues, and scientists and engineers must play a central role in this effort.

Tenth and Final Message: Addressing societal and ethical issues is the right thing and the necessary thing

Finally, I want to leave you with this thought. Addressing societal and ethical issues is *the right thing to do* and *the necessary thing to do*. It is *the right thing to do* because as ethically responsible leaders we must ensure that technology advances human well-being and does not detract from it. It is the *necessary thing to do* because it is essential for speeding technology adoption, broadening the economic and societal benefits, and accelerating and increasing our return on investment.

Under the leadership of Secretary Don Evans, the Commerce Department has adopted the theme "American Jobs, American Values." While exploring and dealing with societal and ethical issues concurrently with our development and commercialization of nanotechnology, we can and must achieve both: creating American jobs, while honoring and upholding American values!

The good news is that throughout history, we have successfully managed the downsides of technology—often through great effort—while enjoying the extraordinary benefits it yields. Nanotechnology should be no exception.

This conference is one more critical step down that path. Thank you for your contribution to this important work.

NNI AFTER THREE YEARS (2001-2003): SETTING NEW TARGETS FOR RESPONSIBLE NANOTECHNOLOGY†

M.C. Roco, National Science and Technology Council, National Science Foundation

courtesy of the National Science Foundation

The National Nanotechnology Initiative (NNI) is a visionary research and development program that coordinates 23 departments and independent agencies; the total investment in fiscal year (FY) 2004 was about $1 billion. The program started formally in FY 2001 (October 2000) and was the result of the bottom-up proposal of an interagency group on nanoscale science and engineering that got started in 1996 [1, 2, 3]. The Federal nanotechnology investment per agency since the beginning of NNI is given in Table 2.1.

Table 2.1
Contribution of Key Federal Departments and Agencies to NNI Investment*

Federal Department or Agency	FY 2000 Actual ($M)	FY 2001 Actual ($M)	FY 2002 Actual ($M)	FY 2003 Actual ($M)	FY 2004 Actual ($M)	FY 2005 Estimate ($M)	FY 2006 Request ($M)
National Science Foundation (NSF)	97	150	204	221	256	338	344
Department of Defense (DOD)	70	125	224	322	291	257	230
Department of Energy (DOE)	58	88	89	134	202	210	207
National Institutes of Health (NIH)	32	40	59	78	106	142	144
National Institute of Standards and Technology (NIST)	8	33	77	64	77	75	75
National Aeronautics and Space Administration (NASA)	5	22	35	36	47	45	32
National Institute for Occupational Safety and Health (NIOSH)	-	-	-	-	-	3	3
Environmental Protection Agency (EPA)	-	5	6	5	5	5	5
Homeland Security (TSA)	-	-	2	1	1	1	1
Department of Agriculture (USDA)	-	-	-	1	2	3	11
Department of Justice (DOJ)	-	1	1	1	2	2	2
TOTAL	**270** (100%)	**464** (172%)	**697** (258%)	**863** (320%)	**989** (366%)	**1,081** (400%)	**1,054** (390%)

* Each Fiscal Year (FY) begins October 1 of the previous calendar year and ends September 30 of the cited year.

† This presentation and accompanying charts and tables have been updated by the author since the 2003 workshop.

The main goals of the NNI are to:

- Maintain a world-class research and development program aimed at realizing the full potential of nanotechnology
- Facilitate transfer of the new technologies into products for economic growth, jobs and other public benefit
- Develop educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology
- Support responsible development of nanotechnology

Indeed, nanotechnology's shift in focus from the microscale to the molecular and nanoscale will be essential for future advances in both the digital revolution and modern biology—and may change the very foundation of education, medicine, manufacturing, and the environment. Initially, the NNI was driven by science as outlined in "Nanotechnology Research Directions" [4], but after 2002, technological innovation rose in importance. Industry has become a strong supporter and its long-term R&D nanotechnology investment is expected to surpass the Federal NNI expenditures next year. Also, more than 20 states in the United States have realized that nanotechnology has economic potential and made multi-annual financial commitments in 2003 to nanotechnology that total more than half the NNI annual budget. The worldwide government investment in nanotechnology (in part stimulated by the NNI) is about $4 billion in 2005, a ninefold increase as compared to about $430 million in 1997 (Table 2.2, Fig. 2.1).

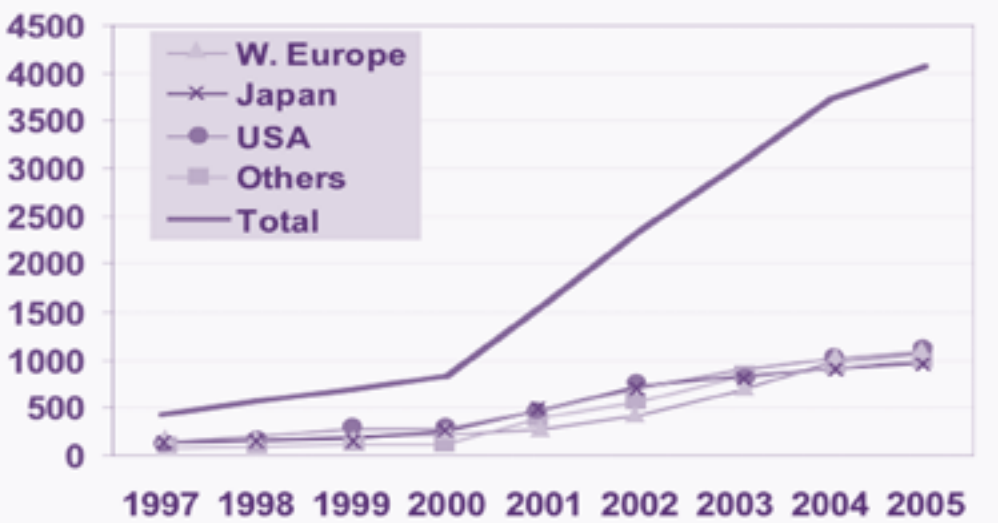

Figure 2.1. International Context—Government nanotechnology R&D investments in the past eight years, 1997-2005.

Nanotechnology is expanding in a natural and robust way. We are creating the systematic control of matter at the nanoscale. We have clear research and education needs in the national and international context. The White House and Congress have recognized the importance of nanotechnology in the future of the United States through the *NNI Supplement to the President's FY 2004 Budget* [5] and the *21st Century Nanotechnology Research and Development Act* [6]. The NNI, in collaboration with other worldwide nanotechnology programs, has the potential to bring broad societal changes, from