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Global Governmental Investment in Nanotechnologies

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Abstract

Nanotechnologies seem to have huge potential to bring benefits in areas as diverse as drug development, water decontamination, information and communication infrastructures, and the production of stronger, lighter and perfect nanomaterials. This potential attracts global investment from governments and private sectors in nanotechnologies with the hopes that R&D and commercial applications of nanomaterials, nanodevices, nanoparticles and nanodrugs will provide new impetus, after the ebb-tides of biotechnology and dotcom, to turn faltering economies around. The global governmental funding has been actively promoting industrial and academic cooperation to realize big prosperity from the nanotechnologies. This article summarizes historic trends and status of global governmental supports for nanotechnologies.

Keywords

Nanotechnology; Governmental nanotechnology funding

The term “nanotechnologies” means the science and technology that will enable one to understand, measure, manipulate, and manufacture at the atomic, molecular, and supramolecular levels, aimed at creating materials, devices, and systems with fundamentally new molecular organization, properties, and functions. Nanotechnologies are one of those rapidly growing fields that are attracting international gold rush. Unlike biotechnology, in which the United States took a lead from the start in the early 80’s, countries are now competing on a more equal basis for a slice of the nanotech pie. Marked advances in nanotechnologies are the result of years of work by scientists and millions of dollars of research funding. In addition, nanotechnologies tend to be highly interdisciplinary, involving scientists from different backgrounds and with various skills. Nanotechnologies are receiving increased publicity globally. The nanotech gold rush may stem from political supports, investor recognition and the fact that startup companies and individuals already have some products on the market. Potential intellectual property right is also driving the nanotechnology revolutions, and patent portfolios may soon turn into the currency.

Nanotechnologies are attracting increasing investment from governments and industry around the world [1]. Worldwide investment in nanotechnology-related R&D by government organizations has increased nearly 20-fold in the past seven years, from \$432 million in 1997 to almost \$8.6 billion in 2004, of which just over half (\$4.6 billion) is directly from central governmental agencies (www.luxresearchinc.com/TNR2004). The US National Institute of Standards and Technology estimated that there are about 1,700 nanotechnology companies worldwide. Large industry currently supports about half of the R&D in nanotechnology in the

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U.S.— about \$2 billion per year. The other half comes from small business and investors, as well as Federal, state and local governments.

Full-scale R&D initiatives for nanotechnology in many countries were spawned by the National Nanotechnology Initiative (NNI) in the USA (<http://www.nano.gov>), announced in January 2000 by former President Bill Clinton. The NNI stresses long-term research looking 20 to 30 years ahead, on the conviction that prioritizing basic and challenging research will lead to breakthrough technological developments. The USA's 21st Century Nanotechnology Research and Development Act (passed in 2003) allocated almost \$3.7 billion to fund nanotechnologies during 2005–2008, which excludes a substantial defense-related expenditure. Since the NNI, the American Government's nanotechnology research funding has increased by more than eight times, starting from \$116 million in 1997 to a proposed budget of \$982 million in 2005 (Table 1). On July 2, 2002, the National Institutes of Health (NIH) announced a trans-NIH Bioengineering Nanotechnology Initiative to invite grant applications for nanotechnologies useful to biomedicine. Six months later, on December 12, 2002, the NIH launched another trans-NIH initiative aimed at enhancing nanoscience and nanotechnology research approaches that have the potential to make valuable contributions to biology and medicine (<http://nihroadmap.nih.gov>). Within the NIH, on September 13, the National Cancer Institute (NCI) launched the NCI Alliance for Nanotechnology in Cancer an integrated \$144.3 million, five-year initiative to develop and apply nanotechnology to cancer prevention, detection, diagnosis and treatment (<http://nano.cancer.gov>). The NCI's Cancer Nanotechnology Initiative is separate from, but coordinated with NIH Roadmap activity (<http://nihroadmap.nih.gov>) and the NNI. In addition, NCI has been developing collaborations with the US Food and Drug Administration (FDA), the US National Institute for Standards and Technology (NIST), and the Department of Defense in order to leverage resources. The NCI Alliance encompasses researchers, clinicians, and public and private organizations to translate cancer-related nanotechnology research into clinical practice. As part of a \$250 million series of grants for nano research in 2004, the US National Science Foundation (NSF) has awarded \$69 million in five-year grants to create six new Nanoscale Science and Engineering Centers. The US National Institute of Standards and Technology has selected 32 projects for Advanced Technology Program funding totaling \$80.1 million.

Other countries around the world are keeping up (Table 2). According to the source of European Commission 2004, current funding for nanotechnology R&D is about €1 billion, two-thirds of which comes from national and regional programs. The analysis by European Nanotech Alliance [2] illustrated that the European Union member countries with the largest research and development expenditures for nanotechnologies are Germany, France and the United Kingdom, while those with greatest interest in nanobiotechnology are Sweden, Denmark and Belgium. In fact, when calculated as a percentage of the national income, Sweden and Finland outspend Germany and France overall, with Sweden contributing over 3% of its national income to nanotechnology R&D. Whereas, France contributes barely 2% of its national income to nanotechnology R&D [2]. As part of the European Union's sixth framework program, the European Union has approved a 4-year €26 million project that aims to transform macroscale medical devices into nanotools for regenerative medicine. The program, cellPROM (cell programming by Nanoscale devices), is expected to bring together total 27 academic and industrial researchers from 12 European countries, coordinated by the Fraunhofer Institute for Biomedical Engineering. Partners include France's Institute Pasteur, The Ecole Polytechnique Federale de Lausanne in Switzerland, Sweden's Royal Institute of Technology, and universities in Spain, Portugal, Austria, Italy, Slovenia, Lithuania, and Israel, as well as industrial partners. The United Kingdom Government's Department of Trade and Industry has already started its €128 million macro and nanotechnology manufacturing initiative. The allocation of over €21 million will cover up to 50% of 25 projects, which include both applied research and new facilities. With the launch of its nanotechnology strategy in 2003, the UK Government pledged

£45 million per year from 2003 to 2009 (www.nanotec.org.uk). Projects range in scope from the development of new fuel cell materials to medical devices and diagnostics to production techniques for carbon nanotubes and nanowires. Commissioned by the UK Government the Royal Society & The Royal Academy of Engineering published on July 29, 2004 a report entitled 'Nanoscience and nanotechnologies: opportunities and uncertainties'. The report illustrates the fact that nanotechnologies offer many benefits both now and in the future but that public debate is needed about their development. The Center for NanoScience at Ludwig-Maximilians-University in Munich, Germany, aims to spin out nanotechnology-based companies. It has already launched several, including two in nanobiotechnology that employ about 100 young scientists and technicians. In Leuven, Belgium, the Interuniversity MicroElectronics Centre is building a micro- and nanoelectronics facility with a €37-million (US\$44-million) grant from the Flemish government and a €46.8 million bank loan. The facility is designed to handle 300-mm silicon wafers for integrated circuit design and will soon be completed [3]. France is also going into nanobiotech. Minattec — a €400-million micro-and nanotechnology centre in Grenoble, is hosting Nanobio, a collaboration between the nuclear research agency (CEA) and Joseph Fourier University. Nanobio aims to develop miniaturized systems for single-molecule tracking, improved drug delivery and analysis.

In Japan, the total budget for nanotechnology research was about 82.5 billion yen in 2002 and increased to about 90.4 billion in 2003. This makes Japan's budget fairly close to the national budget for nanotechnology in the US. Of the five Japanese government ministries that play a role in nanotechnology research, Ministry of Education, Culture, Sports, Science and Technology (MEXT) and Ministry of Economy, Trade and Industry (METI) are the dominant ones [4]. Japan's Ministry of Education, Culture, Sports, Science, and Technology has submitted requests for sizable spending increases in fiscal year 2005's budget. Those requests, for the fiscal year starting in April, include increases of 46% for nanotechnology. The ministry also wants to pump up spending on competitive grants in a last-ditch effort to fulfill a promise to double such research over 5 years. The bulk of the boost for nanotechnology and materials sciences, for example, would go to a \$56 million competitive grants program [5]. It is estimated that Japan has been outspending the United States by \$1 billion a year although the official numbers would show that funding in Japan is just now exceeding the US government's outlay [6].

Justified by the nation's buying power, China actually beats all others in their commitment to nanotechnology. Already this commitment has paid off for the Chinese. According to a study published in *Asia Pacific Nanotech Weekly*, the past few years have witnessed that the numbers of publications on nanotechnology coming from China rose to several hundred a year, next to the United States [7]. The development of nanotechnology in China began with China's ten-year 'climbing up' project, which supported nanomaterial research between 1990 and 1999 [8]. This project was very much ahead of its time — and was started many years before the American NNI created in 2000. There are several sources of funding for new technology in China, including the National High Tech R&D Program of China, the National Natural Science Foundation, the Ministry of Science and Technology and the Chinese Academy of Science. The method of gaining funding from the government has been recently adopted in China to allow start-up companies to apply for grants. The country now has its own small-business innovation research program, called the Innovation Fund for Small Technology-Based Firms. This funding focuses on early-stage technology development, where the benefit to mankind is potentially high, and where the risk is perceived to be too high for corporate investors [9]. The high number of papers at recent nanotechnology conferences in China provides evidence of the significant amount of research and development that is being carried out by Chinese researchers, and shows that significant commercialization efforts are being focused around Shanghai and Beijing. The establishment of the NanoScience and Nanotechnology Center of the Chinese Academy of Science and the Shanghai Nanotechnology Promotion Center are good

indicators of the level of interest. The Chinese patent office is now flooded with applications that are relevant to nanotechnology. Recent enforcement of intellectual-property rights since China joined the World Trade Organization has led to greater respect for patents in China and has improved the country's investment climate. Of particular interest in medicinal applications of nanotechnology lies in nanoparticle formulation of the traditional Chinese medicine, which may greatly increase therapeutic efficacy of traditional Chinese medicine, and improve its standardization, modernization, and internationalization.

Additionally, South Korea, Taiwan and Singapore have joined the research and development in nanotechnologies (Table 2). Ambitious government programs are providing the impetus for new ventures in these regions [10]. Singapore has got in on the act with a new nanotech institute housed in the country's 18.5-hectare Biopolis, which opened in 2003 [11]. The current 90 staff will eventually grow to 250, including scientists, technicians, postdocs and graduate students. The Singapore centre exemplifies the field's fragmentation, as it is focusing primarily on biotech applications for nanotech, such as tiny diagnostics. The country already has a more traditional materials-science centre, which also has a nanotech component. In Taiwan, the National Nanoscience and Nanotechnology Program (<http://nano-taiwan.sinica.edu.tw>) was approved in July, 2002 at the 5th Science and Technology Congress of the National Science Council to achieve academic excellence and to promote commercial applications of nanotechnology. The program's annual budget in 2004 was \$90 million, and the total budget for 2003–2008 is estimated to be about \$625 million in order to fuel research institutes, universities, and private companies [12]. The Taiwan's Nanotechnology Community, and the Taiwan Nanotechnology Industrialization Promotion Association were established in 2003 and 2004, respectively, with the goal of finding commercial applications of nanotechnologies.

In summary, the distinct technological advantages of nanoscience are not only about the realization of devices, constructs, methods, and techniques at this size scale, but also about the functional enhancement gains over conventional technology. The booming nanotechnologies are being supported by massive governmental investments in many countries. However, technology cannot be advanced by a single institute, corporation, or even a single country. A cooperative system should be developed to structure liaison and foster competition among the research groups of academic institutions, industries and governments. Governments have historically funded R&D where there is potential for a technology to greatly impact national economy. Today, collaboration between government-funded researchers and private industry is critical to technology transfer and commercialization of nanotechnology. Such networking and partnering is now facilitated and encouraged by government-funded programs in order to leverage public investment.

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Table 1

The U.S. National Nanotechnology Initiative Budget (\$ in million) Listed by Agencies

Federal Agencies	2003 Actual	2004 Estimated	2005 Proposed
National Science Foundation	221	254	305
Department of Defense	322	315	276
Department of Energy	134	203	211
National Institutes of Health	78	80	89
National Institute of Standards & Technology	64	63	53
National Aeronautics & Space Administration	36	37	35
Environmental Protection Agency	5	5	5
Transportation Security Administration	1	1	1
Department of Agriculture	0	1	5
Department of Justice	1	2	2
Total	862	961	982

Table 2

Global Governmental Funding in Nanotechnologies (\$ in million/year Unless Indicated Otherwise) in Fiscal Year 2003. The Order of Countries is Listed According to the Funding Size of Governmental Investment

Japan	\$810
USA	\$774
European Union	\$1.2 billion/4 years
China	\$280
Taiwan	\$625/5 years
South Korea	\$1.2 billion/10 years
Germany	\$118
Australia	\$93
United Kingdom	\$90
France	\$50
Canada	\$80/5 years
Switzerland	\$45/3 years