# Tracking Nanotechnology in México

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**ABSTRACT**

*In Latin America, Brazil, Argentina and México are the leading countries in nanotechnology research and development. However, México is the only one from this group without a national plan concerning the development of nanotechnology and the nanosciences. Regardless, México has signed several multilateral agreements between research centers, foreign universities and industries from overseas to promote the development of the diminutive science. For the most part, there are two features that distinguish the Argentinean and Brazilian initiatives from the Mexican. On one hand, México is missing a tangible plan for the development and research of nanotechnology. On the other, the United States plays an important role in most of the cooperation agreements signed by México and in the creation of new positions inside Mexican high technology industries. This article examines the paths that México has taken in the development of nanotechnology.*

## I. INTRODUCTION

In Latin America, Brazil, Argentina and México are countries where nanotechnology research is being further developed.[1] However, there are differences between them. In 2001, Brazil introduced a national plan to form scientific research networks with a one million dollar budget. Later, in 2004, it announced the Nanoscience and Nanotechnology Program, within the framework of the *Plano Plurianual de Desenvolvimento 2004-2007* (The Pluri Annual Plan for Development 2004-2007), for which the Brazilian Government allocated thirty-nine (39) million dollars.[2] Additionally, there are several funds from federal, provincial and international sources to sponsor nanotechnology research in Brazil. Most of these resources are centrally managed by the Ministry of Science and Technology in Brazil with the objective of advancing nanotechnology research.

The Government of Argentina, on the other hand, in 2005 created the *Fundación Argentina de Nanotecnología* (the Argentinean Foundation of Nanotechnology), with an estimated budget of ten (10)

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[1] Guillermo Foladori, *Nanotechnology in Latin America at the Crossroads*, 3 NANOTECH. LAW & BUS. 205-216 (2006). Cuba has made important advances in nanobiotechnology and there are research teams at various institutions in other countries, which should not be overlooked; but Cuban advances are not discussed herein. This article uses the term "nanotechnology" to also refer to all nanosciences.

[2] *See* Ministério da Ciência e Tecnologia ("MCT"), *O Programa do PPA 2004-2007* (2004), *available at* http://www.mct.gov.br/index.php/content/view/27136.html (last visited April 22, 2007); *see also* MCT , *Portaria MCT nº 614, de 1º.12.2004* (2004), *available at* http://www.mct.gov.br/index.php/content/view/11847.html&objMct=Legislação (last visited April 22, 2007).

million dollars to cover research in nanotechnology for five years. This project was criticized due to the vague rules and procedures that its implementation entailed. One and a half years later, civil society groups were still censuring the project.[3] Even so, the Argentinean and Brazilian governments are trying to regulate all nanotechnology related research by controlling budgets and by implementing supervisory procedures. Neither Argentina nor Brazil have set up discussion panels to examine the political, social and economic implications of the use of nanotechnology. In both countries, the exchange of ideas about the use of nanotechnology can only be associated with the idea of becoming more competitive.[4] In 2005, Argentina and Brazil signed an agreement which lead to the creation of the *Centro Brasil-Argentina de Nanociencias y Nanotecnología* (Brazil-Argentina Center of Nanotechnology and Nanosciences). This center offers training courses and encourages scientific exchange between diverse research networks.[5]

It is worth mentioning that neither Brazil, nor Argentina, nor México have created programs to examine the possible social, economic, environmental, political and ethical impacts of the use of nanotechnology.[6] In contrast, most of the industrialized countries have solid agendas to promote the discussion of these issues. The absence of such schemes in Latin America indicates a lack of public awareness about the use of this technology and shows the profound hope that the governments in the region have in nanotechnology to conquer international markets, even though its use would entail risks and impacts not fully understood.

The Mexican case is somewhat different from the Argentinean and Brazilian cases. There is no specific plan or national program linked to nanotechnology in México, even though nanotechnology is considered a strategic sector for development, as identified in 2002 in the *Programa Especial de Ciencia y Tecnología 2001-2006* (Special Program on Science and Technology 2001-2006). There have been efforts from a group of scientists to promote such a plan.[7] The United States-México Foundation for Science ("FUMEC") has shown support as well. In addition, nanotechnology research and development in México has been conducted by individuals and regulated through the bilateral and multilateral agreements that some research centers have signed. However, this reflects a path where specific interests regulate the development of nanotechnology.

## II. NANOTECHNOLOGY IN MÉXICO

For the most part, there are two features that distinguish the nanotechnology initiatives in Argentina and Brazil from the Mexican. On one hand, México is missing a tangible plan for the development and

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[3] Guillermo Foladori, *Nanotecnología en Argentina, Corriendo tras la Liebre*, EURORESIDENTES-NANOTECNOLOGÍA (2005), *available at* http://www.euroresidentes.com/futuro/nanotecnologia/articulos/nanotecnologia-en-argentina.htm (last visited April 22, 2007); *see also* Guillermo Foladori, *La Influencia Militar Estadounidense en la Investigación de las Nanotecnologías en América Latina*, REBELIÓN.ORG (Nov. 8, 2006), http://www.rebelion.org/noticia.php?id=40794 (last visited April 22, 2007).

[4] *See* Foladori, *supra* note 1.

[5] Carla Almeida, *Brazil and Argentina Launch Joint Nanotech Center*, SCIDEV.NET (Dec. 12, 2005), http://www.scidev.net/news/index.cfm?fuseaction=readnews&itemid=2537&language=1 (last visited April 22, 2006).

[6] Brazil has a Network of Nanotechnology, Society and Environment centers which gather social scientists interested in those themes. See http://nanotecnologia.incubadora.fapesp.br/portal. In 2006, the Latin American Network of Nanotechnology and Society was formed, with similar interests across the region and headquartered in two Mexican institutions: The Doctorate in Development Studies at the Autonomous University of Zacatecas, and the Sciences and Humanities Interdisciplinary Research Center at the National Autonomous University of México ("UNAM"). See www.estudiosdeldesarrollo.net/relans.

[7] Instituto Potosino de Ciencia y Tecnología ("IPICyT"), *Programa Nacional de Nanociencia y Nanotecnología Para Desarrollar Nuevas Bases Tecnológicas* (2002), *available at* http://www.ipicyt.edu.mx/eipicyt/eventosynoticias/Reunion2002Nanotecnologia.pdf (last visited April 22, 2007).

research of nanotechnology. On the other, the United States plays an important role in most of the cooperation agreements signed by México and in the creation of new positions inside Mexican high technology industries. This last feature is, to some extent, logical since México and the United States are neighbor countries and both are members of the North American Free Trade Agreement ("NAFTA"). However, this relationship gives a special character to the development of nanotechnology in México.

## III. MEXICAN SCIENCE AND TECHNOLOGY POLICY IN RELATION TO NANOTECHNOLOGY

At the beginning of 2002, all nanotechnology-related research became an area of strategic importance, with some funding directed to support its development. The *Programa Especial de Ciencia y Tecnología 2001-2006* (Special Program for Science and Technology 2001-2006), which is embedded inside the National Development Plan 2001-2006, views nanotechnology as a strategic area within the science of advanced materials. In the same document, the core areas to be developed are depicted in detail and include nanostructures, semiconductors, metallurgy, biomaterials, optical components, advance ceramics and modulation of materials and processes. Additionally, the Development Plan reviews the available resources in research centers with a special focus on human resources, equipment and the connections they have with industry. The *Programa Especial* points out the pressing need for creating a national plan on nanotechnology development and the necessity to encourage the formation of networks for scientific exchange in the area.[8] Moreover, the National Development Plan 2001-2006 identifies nanotechnology research as an important subfield inside the energy sector, above all others within the framework of the *Instituto Mexicano del Petróleo* ("IMP") (Mexican Institute of Petroleum). The conditions and provisions to create and implement a National Initiative for Nanotechnology Development were present, but the lack of funding and the absence of an executive plan created barriers to fully develop a national initiative for nanotechnology. In this regard, the budget for Science and Technology ("S&T") has dramatically decreased in the last five years. In the National Development Plan, it was expected that the disbursement for Research and Development ("R&D") would reach 1% of Gross National Product ("GDP") by 2006. By 2004 this estimate was reduced to 0.5% of GDP and by 2005 it barely reached 0.4%. This could change at any time. One indicator of change is the report issued by the Committee for Science and Technology of the Senate of the Republic in 2005. In this document, the Committee pronounced itself in favor of preparation for a National Emergency Program for investment in research and teaching of nanotechnology.[9]

Several researchers and specialists in the nanoscience field worked in a partnership to create the *Programa Especial de Ciencia y Tecnología 2001-2006*, reviewing a large number of national programs for nanotechnology research in other countries, particularly the National Nanotechnology Initiative of the U.S. After a review of nanotechnology initiatives, it is surprising that the *Programa Especial* does not make any reference to the possible risks to health and the environment related to the use of nanotechnology—neither its ethical and legal implications, nor the public participation in what many scientists see as the most important technological revolution of the 21st century. The absence of concern

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[8] Consejo Nacional de Ciencia y Tecnología ("CONACYT"), *Programa Especial de Ciencia y Tecnología 2001-2006* (2002), *available at* http://dct.cicese.mx/cuaderno.pdf (last visited April 22, 2007); *see also* CONACYT, *Programa Especial de Ciencia y Tecnología 2001-2006,Tomo II* (2002), *available at* http://www.siicyt.gob.mx/siicyt/docs/contenido/PECYTII.pdf (last visited April 22, 2007).

[9] Comisión de Ciencia y Tecnología, Senado de la República (2005), Dictamen de la Comisión de Ciencia y Tecnología a la propuesta con punto de acuerdo por el que el Senado de la Republica exhorta al CONACYT, a la UNAM y al Instituto Politécnico Nacional, y a todas las demás universidades y centros de investigación públicos y privados, así como al sector empresarial, para que instrumenten un programa nacional de emergencia. Gaceta Parlamentaria, 145, Dec. 15, 2005, *available at* http://www.senado.gob.mx/sen60/sgsp/gaceta/?sesion=2005/12/15/1&documento=101 (last visited April 22, 2007).

associated with the use of nanotechnology in México becomes worrying because of the increasing number of laboratories in the area. Furthermore, many of them are already using clean rooms and very sophisticated equipment with the main objective of encouraging the production of nanocomponents for the industrial sector. In the same vein, Argentina and Brazil do not have a program to discuss the implications and risks of nanotechnology, or a plan to supervise the activities related to nanotechnology research and development. In this regard, it is clear that the distance between Latin America and its European and North American counterparts is expanding.

Due to the absence of a National Nanotechnology Initiative, México has turned its attention to different research centers in search for bilateral or multilateral agreements to foster the creation of scientific networks in the area. A report, written by Malsch Technovaluation relating to micro- and nanotechnology in México, points out that there are eleven research groups located in three universities and two research institutes, with ninety researchers in the area of nanotechnology.[10] Other sources estimate the number of researchers working on nanotechnology in México at between 300 and 500. It is beyond the aim of this article to provide a complete picture of the status of nanotechnology in México, but it is worth mentioning some of the efforts made in this regard.

The *Universidad Nacional Autónoma de México* ("UNAM") (National Autonomous University of México) is by far the university with the highest concentration of researchers working on nanotechnology and some of the most ambitious projects. For instance, the *Impulsa* program was created to promote multidisciplinary research in a variety of areas with the aim of solving problems at the national level. One such approach is the University Project for Nanotechnology, approved in December 2004, in which the main objective is to develop nanostructured materials as catalysts for environmental improvement. This project manages one million dollars per year and has thirty (30) researchers from eight (8) different departments at UNAM.[11] In addition, UNAM has an internal research network for nanotechnology called *Red de Grupos de Investigación en Nanociencias REGINA* (Research Network Groups on Nanosciences), which groups together 40 or more researchers in 8 research centers of UNAM. Most of these centers are located in México City, but there are others in the provinces such as the Center for Condensed Matter Sciences in North Baja California, or the Center of Research in Energy ("CIE") in Morelos.

The *Centro de Investigación y Estudios Avanzados* ("CINESTAV") (Advanzed Studies and Research Center) of the *Instituto Politécnico Nacional* ("IPN") (National Polytechnical Institute) is one of the most important research centers in México. It has several campuses doing nanotechnology-related research. The physics department, located in México City, has a laboratory focusing on semiconductor nanostructures. On the Guanajuato campus you can find the National Laboratory in Genomic Science. Nanotechnology is also the subject of study in the physics department at the Merida Campus; metallurgical engineering at Coahuila; electrical engineering at Guadalajara and special materials at Querétaro. The academic production from CINESTAV is present in several scientific magazines and in dozens of international symposiums.

The *Instituto Potosino de Investigación Científica y Tecnológica* ("IPICyT") (Potosí Institute of Scientific and Technological Research), a center within the *Consejo Nacional de Ciencia y Tecnología*

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[10] VOLVER LIEFFERING, STUDY ON THE NANOTECHNOLOGY AND MICROSYSTEMS TECHNOLOGY SECTOR IN MÉXICO (2004); *see also* Ineke Malsch & Volker Lieffering, *Nanotechnology in México*, NANOTSUNAMI.COM (2004), http://www.voyle.net/Guest%20Writers/Drs.%20Ineke%20Malsch/Malsch%202004-0001.htm (last visited April 22, 2007).

[11] Proyecto Universitario de Nanotecnología ("PUNTA"), Proyecto Universitario de Nanotecnología, Investigacion de PUNTA, (2004), http://inter.fciencias.unam.mx/punta/index.php?option=com_content&task=category&sectionid=5&id=22&Itemid=39 (last visited April 22, 2007); *see also* A. Calles, Collaboration between the U.S. and Mexican National Academies of Sciences (2004), *available at* http://www.fumec.org.mx/ingles/programs/newopp/3-Alipio%20Calles.pdf (last visited April 22, 2007) (power point presentation).

("CONACYT") (National Council of Science and Technology), promotes research and training in nanotechnology. In cooperation with FUMEC, it has been fostering the development of a National Plan on Nanotechnology Research. The Advanced Materials Research Group studies the properties of nanostructures and materials. The research conducted there has been internationally recognized for its quality. The IPICyT is also a member of the European consortium NANOFORUMEULA.

The *Benemérita Universidad Autónoma de Puebla* ("BUAP") (Honorable Autonomous University of Puebla) stands out, particularly in the area of semiconductors, and is the center of operations for the International Network of Nanoscience and Nanotechnology. There are several researchers involved in the network, coming from different institutions such as BUAP, the *Instituto Nacional de Neurología y Neurocirugía* ("INNyN") (National Institute of Neurology and Neurosurgery), which is part of the National Institutes of Health in México, the *Sección de Estudios de Posgrado e Investigación de la Escuela Superior de Ingeniería Mecánica y Eléctrica* ("SePI-ESIME") (Department of Postgraduate Studies and Research of the Advanced School of Mechanical and Electric Engineering) of the IPN, the *Universidad Autónoma Metropolitana-Iztapalapa* ("UAM-I") (Autonomous Metropolitan University-Iztapalapa), the Zacatenco and Merida units of CINESTAV, UNAM and the *Instituto Nacional de Investigaciones Nucleares* ("ININ") (National Institute of Nuclear Research).

One of the most important public enterprises doing nanotechnology-related research is the IMP, which currently has several research projects. Scientists from IMP have patented some successful results and they have a special program with the objective of creating human resources in the area of molecular engineering. In addition, this institute has signed several agreements within México, such as the Electrochemical Accord with UAM-I. This agreement included the establishment of an advanced laboratory and the financing of an R&D project in the university.[12] UAM-I, through its laboratory of Nanotechnology and Molecular Engineering, has several agreements with other institutions.[13]

In México, there are other universities and research centers working with nanotechnology, several of which participate in international agreements and form clusters of industrial development. For instance, the *Centro de Investigaciones en Materiales Avanzados* ("CIMAV") (Center of Advanced Research Materials) of CONACYT; *la Universidad Autónoma de Nuevo León* ("UANL") (the Autonomous University of Nuevo León) has a nanotechnology laboratory doing research on health issues and The *Universidad Veracruzana* ("UV") (Veracruzana University) has a research center on micro- and nanotechnology specializing in magnetic sensors. Other centers include the *Universidad Autónoma del Estado de México* ("UAEM") (Autonomous University of the State of México), the *Universidad de Guadalajara* ("U de G") (University of Guadalajara), *la Universidad Autónoma de San Luis Potosí* ("UASLP") (Autonomous University of San Luis Potosí), the *Instituto Tecnológico de Estudios Superiores de Monterrey* ("ITESM") (Technological Institute of Higher Studies of Monterrey), the *Instituto Tecnológico Superior de Irapuato* ("ITESI") (Technologic Institute of Higher Studies of Irapuato), the *Instituto Nacional de Astrofísica, Óptica y Electrónica* ("INAOE") (National Institute of Astrophysics, Optics and Electronics), the *Universidad de Guanajuato* ("UGTO") (University of Guanajuato), the *Universidad Tecnológica de México* ("UNITEC") (Technological University of México), the *Universidad Autónoma de Ciudad Juárez* ("UACJ") (Autonomous University of Ciudad Juárez), the *Centro de Investigación Científica y de Educación Superior de Ensenada* ("CICESE") (Center for Scientific Research and Higher Studies of Ensenada) of CONACYT, the *Centro de*

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[12] Claudia Ramos, *Al pie de la Segunda Revolución Industrial*, MILENIO DIARIO (June 23, 2004), *available at* http://cquick.conacyt.mx/QuickPlace/direccion_de_comunicacion_social/Main.nsf/2a1fb3846ca1432205256708001 67222/0cf3012e6c6f1e8a86256ebc0048e72e?OpenDocument (last visited April 22, 2007).

[13] *México, com Científicos de Alto Nível en Nanotecnología, Pese a la Falta de Impulse*, QUIMINET.COM (Aug. 18, 2005), *available at* http://www.quiminet.com.mx/nt3/nt_%259F%25D0J%25C7WQ%257B%255B.htm (last visited April 22, 2007).

*Investigación en Química Aplicada* ("CIQA") (Research Center of Applied Chemistry) of CONACYT, the *Centro de Investigaciones en Óptica* ("CIO") (Research Center for Optic Science) and the *Universidad Politécnica de Pachuca* ("UPP") (Polytechnical University of Pachuca).

There are important international accords in which México is participating. In 2004, México and Europe signed an agreement on Scientific Cooperation and Technology. This agreement allows the participation of Mexican research centers within the *Programa Marco de Desarrollo Tecnológico de la Unión Europea 2002-2006* (Program for Technological Development of the European Union). Nanotechnology is a priority theme. There is also a bilateral agreement ("PROBICYT") in science and technology to strengthen and promote the creation of a national system of innovation, improve both human resources and infrastructure and to endorse competitiveness. In addition, México, together with other Latin American countries, participates in programs such as @Lis (Information Society), AL-Invest (Investments), ALBAN (Education) and Urbal (Urban Development).[14] NANOFORUMEULA, on the other hand, is a project on Nanotechnology R&D. The following partners are involved in the consortium: The University of Twente in Holland, the Superintendent of the Franca Zone of Manaus (SUFRAMA) in Brazil, the CEA-LETI-MINATEC in Grenoble, France, the Fraunhofer IWS Institute of Dresden in Germany, the Universidad Autónoma de Madrid in Spain and the IPICyT from México. This project shows that the European Union is interested in encouraging long-term relations between European institutions and their counterparts in Latin America.[15] In addition, the Anti-American Collaboration on Advanced Materials ("CIAM") is an institutional program created in 2002 to support research collaboration. Institutions from Argentina, Brazil, Canada, Chile, Colombia, México, Trinidad and Tobago, Jamaica and the U.S. are members of this organization. Several Mexican researchers have received grants to foster nanotechnology research.

## IV. COLLABORATION WITH THE UNITED STATES

The association between México and the U.S. operates in three main areas, all focusing on different forms and connections. These main areas include the scientific-academic association, the political-business interests and the scientific-military accords.

The role of FUMEC in this regard has been of increasing importance. George E. Brown Jr., the man behind the creation of the Office of Science and Technology Policy in the U.S. executive branch (created in 1976) and recognized for his position regarding the development of science oriented to satisfy social needs, published an article in 1998 with other scientists stating that most of the agreements on scientific collaboration signed by the U.S. only embodied diplomatic purposes with no further interests for the U.S. These agreements lack funding or follow-up associated with the implementation of the projects. The only exception, in his view, was FUMEC (which has been operating since 1993), because its research has focused on the treatment of water and health issues along the U.S.-Mexican border since the beginning. Brown saw FUMEC as an example of scientific cooperation.[16] After thirteen years it continues to connect U.S. and Mexican institutions, especially the ones alongside the national border. FUMEC is trying to integrate nanotechnology research between Mexican and U.S. industries. One of the main

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[14] Claudia Berlanga Subyaga, Cooperación Ciencia y Tecnología Unión Europea–México (2005), *available at* http://www.cudi.edu.mx/primavera_2004/presentaciones/CLaudia_Berlanga.pdf (last visited April 22, 2007) (power point presentation).

[15] Superintendencia de la Zona Franca de Manaus ("SUFRAMA"), *NANOFORUMEULA: Colaboraciones de Investigación y Desarrollo en Nanotecnología entre La Unión Europea y América Latina*, MINAPIM NEWS (2007), *available at* http://www.suframa.gov.br/minapim/news/visArtigo.cfm?Ident=374&Lang=ES (last visited April 22, 2007).

[16] George E. Brown Jr. et al., *Update: International Scientific Cooperation*, ISSUES IN SCI. & TECH. (1998), *available at* http://www.issues.org/15.1/update.htm (last visited April 22, 2007).

activities of FUMEC, with the Ministry of Economy (2001), is to facilitate the design, development, packaging and commercialization of MEMS/NEMS (Micro- and Nano-Electro Mechanical Systems). To this end, it has created the MEMS Design Center Network where 11 Mexican higher education institutions cooperate to design MEMS/NEMS, to develop industrial projects and to strengthen related academic programs. Another important FUMEC action was the creation of the MEMS Productive Articulation Center in 2004 to facilitate the collaboration between industry, academy and decision makers in order to develop new products and businesses. A third action was the creation of the Network of Innovation Laboratories, where all the partners have a specific role to play. The MEMS/NEMS prototypes are developed by UNAM and by UACJ, the manufacturing takes place in the INAOE laboratory in Puebla and the packing takes place in the UACJ in Chihuahua.

FUMEC also played an important role in the implementation of the Binational Sustainability Laboratory ("BNSL"), a not-for-profit and non-governmental organization that fosters business partnerships along the border. It came into existence in 2005. Among the main partners of BNSL are the Sandia National Laboratories, which are military laboratories based in Albuquerque, New México. They work under the Advanced Concepts Group philosophy with the main objective of fostering sustainable development in the border region, reducing stress, increasing local capabilities and expanding business. The strategic areas of work include MEMS Packaging to support the Paso del Norte Packaging Cluster regarding R&D and commercialization, energy and advanced materials in order to decrease costs within the border, and water, with technical developments appropriate to the region. In all cases, several scientific institutions from México participate, such as UACJ, the ITESM and CIMAV together with U.S.-based enterprises. In addition, FUMEC has become an important collaborator in various workshops on nanotechnology, specifically in the agreements regarding academic exchange and other *ad hoc* activities. In recent years, Canadian representatives have also become part of the meetings, converting the workshops into trilateral activities.[17]

Other foreign institutions also have collaboration agreements with Mexican institutions. The International Center for Nanotechnology and Advanced Materials ("ICNAM") is a consortium emerging from a previous agreement between the UT-Austin and CIMAV, signed in Chihuahua in 2003. The purpose of this accord is to promote bi-national research and the exchange of faculty, researchers and alumni. The Mexican centers and universities involved in the project are UASLP, the ITESM, UNAM, the UANL, IPICyT, CIQA, CINVESTAV and CIMAV.[18]

For its part, CIMAV signed an agreement in 2005 with the University of Albany College of Nanoscale Science and Engineering at Albano NanoTech to collaborate on nanotechnology research and on nanoscience education. The agreement is focused on specific research in optoelectronics, nanophotonics, chemical and biological sensors, molecular and carbon nanostructures, nanoparticles and computer simulation, scale-modeling of nanostructures and nanosystems.[19]

CIMAV is also the headquarters, since 2004, of the Consortium for Projects in Nanotechnology, which is part of the national System of networks and research centers of CONACYT. IPICyT, CIQA,

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[17] Fundación México-Estados Unidos para la Ciencia ("FUMEC"), *Biennial Activities Report 2004-2005* (2005), *available at* http://www.fumec.org.mx/ingles/annual/informe_completo_eng.pdf (last visited April 22, 2007).

[18] University of Texas, Austin, International Center for Nanotechnology and Advance Materials, http://www.engr.utexas.edu/icnam/ (last visited April 22, 2007).

[19] *UAlbany NanoTech College Signs Agreement with México's Leading Materials Laboratory Fostering Research and Student Exchange*, AZONANO.COM (May 3, 2005), http://www.azonano.com/news.asp?newsID=847 (last visited April 22, 2007).

CICESE, and INAOE are members of this consortium along with several enterprises (Chihuahua Cement, Peñoles Mining Group, Delphi, Lexmark, Mabe and Cydsa).[20]

Texas, meanwhile, is trying to promote itself as a leader in the application of nanotechnology. To this end, it has several associations. One of them is the Strategic Partnership for Research in Nanotechnology ("SPRING"), a network between UT-Austin, UT-Dallas, UT-Arlington, Rice University in Atlanta and the Air Force Research Laboratory in Dayton, Ohio. Related to this partnership, we find other consortiums such as "Nano at the Border," where several units from the University of Texas participate (Arlington, Austin, Brownsville, Dallas, and Pan American). It was created to facilitate academic exchange and to share infrastructure related to the research of nanotechnology like the Center for Nano and Molecular Science and Technology of UT-Austin. Another important objective of "Nano at the Border" is to include students and human resources from the Hispanic community.[21] These consortiums and partnerships have been facilitating the creation of new agreements with Mexican universities directly and via CONACYT. This is the case for the agreement signed between ICNAM and CIMAV in Chihuahua as previously mentioned and the one between UT-Dallas, using its NanoTech Institute, and the University of Guanajuato. These last two have created a workshop entitled "Nanoscience for Advanced Applications: At the Crossroads of Disciplines."[22]

One of the most promising contacts in science and engineering between academics and students from Latin America and the U.S. is the Pan American Advanced Study Institutes ("PASI") project:

> . . . [PASI] is a jointly supported initiative between the Department of Energy (DOE) and the National Science Foundation (NSF). Pan American Advanced Studies Institutes are short courses of two-to-four weeks duration, involving lectures, demonstrations, research seminars and discussion at the advanced graduate and post-doctoral level. PASIs aim [is] to disseminate advanced scientific and engineering knowledge and stimulate training and cooperation among researchers of the Americas in the mathematical, physical, and biological sciences, and in engineering fields.[23]

In 2001, Costa Rica held the first PASI meeting dedicated to nanosciences (physics and technology at the nanometer scale).[24] At least eight other PASI meetings about nanotechnology have taken place across Latin America. México took part in many, if not all of them, with presenters. These workshops create friendly environments where both students and academics can meet and exchange ideas regarding nanotechnology.

The political-business interests are present in the creation of high technology industrial parks. The idea is to provide the infrastructure and general conditions to allow national and transnational enterprises to open their doors, supported by research centers on high technology. The scientific and technological parks are centers to foster innovation. The success of these parks in México depends on reversing the exodus of manufacturing enterprises, which has been affecting the economy for the past decade. Costs have declined worldwide due to several technical advances in telecommunications, storage systems,

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[20] CONACYT, CENTRO DE INVESTIGACIÓN EN MATERIALES AVANZADOS S.C. ("CIMAV"), ANUARIO CIMAV 2004(2004), *available at* http://www.conacyt.mx/Centros/Anuarios/2004/ANUARIO-2004-CIMAV.pdf (last visited April 22, 2007); *see also* CONACYT, INFORME GENERAL DEL ESTADO DE LA CIENCIA Y TECNOLOGÍA, MÉXICO (2006), *available at* http://www.siicyt.gob.mx/siicyt/docs/contenido/IGECyT_2006.pdf (last visited April 22, 2007).

[21] Ctr. for Nano- & Molecular Sci. & Tech. ("CNM"), About CNM, http://www.cnm.utexas.edu/partnerships_nanoatborders.htm (last visited April 22, 2007).

[22] University of Texas, Dallas, Nanotech Institute, Nano at the Border (2006), http://www.nanotech.utdallas.edu/community/natb/index.html (last visited April 22, 2007).

[23] Nat'l Sci. Found., Pan-American Advanced Studies Institutes Program ("PASI") (2007), http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5327 (last visited April 22, 2007).

[24] Sergio E. Ulloa, *Nanoscience in Latin America*, 4 J. OF NANOPARTICLE RES. 175 (2002).

transportation and the reduction of regulations. This has encouraged U.S.-based enterprises to move to South-East Asia. That trend includes the mobility of qualified personnel and most activities related to prototype design and, sometimes, the entire production process. At the same time, China, Thailand and Singapore have increased the production share of the manufacturing industry within their Gross National Product ("GNP"), while that share has decreased in the U.S. and México.[25] This tendency contradicts the creation of R&D industrial parks and puts them at risk. Moreover, these circumstances add more pressure to scientists and technicians who, due to the lack of opportunities, migrate to other countries. The lack of scientific training at the basic education, high school and university levels reduces the possibility of obtaining nanotechnology-related positions. A basic but comprehensive training in science and math is essential to encourage several countries to jump from underdevelopment to development (e.g., South Korea), a possibility that México is not realizing.[26]

The Silicon Border Development Science Park is portrayed as the first high-tech park specializing in nanotechnology R&D in Latin America. Located in Mexicali, Baja California Norte, it covers a 400-hectare area.[27] Its main purpose is to encourage the formation of supply chains for the semiconductor industry and other related areas. The project began in 2006 and is expected to be completed in ten years.[28]

The State Government of Puebla is trying to create a high-tech park in Huejotzingo. It is expected that this cluster would offer spare parts and supplies for the medical industry and for the automobile sector.[29] INAOE also operates there, building the National Laboratory of Nanoelectronics. It is expected to have a top class clean room thanks to the donation by Motorola, in 2004, of a complete manufacturing line of integrated circuits.[30]

The State Government of Nuevo León has been building the Research Park for Technology Innovation since 2005. This park is one fraction of the project called *Ciudad del Conocimiento* (City of Knowledge). The plan is to attract the most important centers for research and education and convince them to set up shop in Monterrey. The UANL participates in this project with the Center for Innovation, Research and Development of Engineering and Technology. One of the laboratories, included as part of this center, is the Laboratory of Nanotechnology and Nanosciences, and there are other research institutions that are interested. For instance, CONACYT is taking the Engineering Center for Industrial

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[25] W. N. P. Hung & V. J. León, Micromanufacturing to Bridge Macro and Nano Worlds, Conference Presentation at the SME/CIRP International Conference on Manufacturing Engineering Education at California Polytechnic State University in San Luis Obispo, California (June 22-25, 2005), *available at* mnmlab.tamu.edu/publication/MfEE_Hung_Leon_21may05.pdf (last visited April 22, 2007).

[26] In a meeting hosted by the World Bank in February 2007, the President of the Bank urged developing countries to support science, but said cautiously,"[t]he current danger lies in promoting policies that see S&T as *drivers* of social progress and economic development, rather than components of innovation programmes in which other factors—from regulatory policy to education and training—are just as important." *See* David Dickson, *Investing in Science: A Cautionary Tale*, SCIDEV.NET (Feb. 22, 2007), http://www.scidev.net/Editorials/index.cfm?fuseaction=readEditorials&itemid=211&language=1 (last visited April 22, 2007).

[27] Presidencia de la República (México), *Las Buenas Noticias También son Noticia, Construye México Frontera de Silicon*, (June 12, 2006), *available at* http://fox.presidencia.gob.mx/buenasnoticias/?contenido=25519&pagina=73 (last visited April 22, 2007).

[28] *Silicon Border Breaks Ground in Mexicali: Science Park Becomes a Reality*, TMC.NET (July 11, 2005), http://www.tmcnet.com/usubmit/2005/jul/1162162.htm (last visited April 22, 2007); *see also* Silicon Border, Welcome to Silicon Border! (2006), http://www.siliconborder.com (last visited April 22, 2007).

[29] Mauricio García León, *Una Realidad, el Clúster Tecnológico en Puebla*, INTOLERANCIA (2007), *available at* http://209.85.7.40/~wwwinto/cgi-bin/cgis/Seccion.pl?id_seccion=12&anio=2006&mes=9&dia=7&pagina=1 (last visited April 22, 2007).

[30] Wilfredo Calleja Arriaga, Laboratório Nacional de Nanoelectrónica, *available at* http://www.fumec.org.mx/espanol/recursos/15-INAOEP.pdf (last visited April 22, 2007) (power point presentation).

Development and CIMAV to Monterrey, the ITESM is taking its Research Center for Strategic Design, the UAEM will open a center specializing in advanced packaging, IPN will be present with CINESTAV, the Institute of Water of Nuevo León will be present and several software enterprises will form a cluster there.[31]

The Paso del Norte MEMS/NEMS Packaging Cluster intends to create a technological corridor between Albuquerque, NM, and the city of Chihuahua in México. In between lie the cities of Ciudad Juárez and El Paso, with the UACJ and UT-El Paso playing a key scientific role in this cluster. This cluster includes research centers, enterprises and the Sandia Military labs. It also has support from FUMEC.

There is one military agreement that stands out. In 2005, the Security and Prosperity Partnership of North America ("SPPNA") treaty was signed between México, the U.S., and Canada. It includes R&D in several areas, including nanotechnology, under a framework influenced directly by the military.[32]

In April 2004, the Navy and the U.S. Air Force hosted an event in Washington, D.C., called the *Latin America Science & Technology Forum*, with the purpose of "increasing the U.S. leadership's awareness of the progress of Science and Technology ("S&T") in Latin America."[33] Top representatives from civil institutions related to S&T from Argentina (Vice-Director of CONICET), Chile (Director of FONDEF-CONICYT) and México (Director of Scientific Research of CONACYT) presented the status of S&T in their respective countries. This is just an example of the connecting ties between scientific interests and the military.

Another example of the military connection is the support from the U.S. Navy to nanotechnology-related research. This is coordinated by the U.S. International Technology Center, whose main objective is to "support the identification, acquisition, integration and delivery of foreign technology solutions to the war fighter to ensure technological superiority on the battlefield."[34] This center has divisions according to geographical area. Thus, the ITC-Atlantic covers Europe, Africa and one part of Asia, including one section of the former Soviet Union; the ITC-Pacific covers the rest of Asia and the southern cone of Africa; and, in 2004, the ITC-Américas was created in Santiago de Chile, to cover America and the Caribbean, including Canada.[35]

The U.S. Navy, in association with the Air Force, held three international workshops in Latin America on multifunctional materials, a topic of interest for the U.S. Defense Department.[36] The first

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[31] Monterrey, Ciudad Internacional del Conocimiento, Parque de Investigaciones e Innovación Tecnológica, Noticias (Sept. 4, 2006), http://www.mtycic.com.mx/noticias_innovacion05sep.htm#3 (last visited April 22, 2007).

[32] SEC. & PROSPERITY P'SHIP OF NORTH AMERICA ("SPPNA"), REPORT TO THE LEADERS, PROSPERITY ANNEX, *available at* http://www.spp.gov/report_to_leaders/prosperity_annex.pdf?dName=report_to_leaders (last visited April 22, 2007); *see also* Roberto Gonzalez Amador, *Abre el Gobierno la Puerta a los Experimentos con Nanotecnología*, LA JORNADA (July 31, 2006), *available at* http://www.jornada.unam.mx/imprimir.php?fecha=20050731&nota=024n1eco.php&seccion=nota (last visited April 22, 2007).

[33] Ofc. of Naval Res. Global ("ONRG"), Regional Offices—Latin America (2004), www.onrglobal.navy.mil/scitech/regional/latin_america_forum.asp (last visited April 22, 2007).

[34] U.S. Army International Technology Center—Atlantic Atlantic, *Mission Statement*, *available at* www.usaitca.army.mil/home.html (last visited April 22, 2007).

[35] The mandate of ITC-Américas is: ". . .to foster cooperative relationships between the U.S. Army and private sector, university, and civilian government research and development (R&D) entities that result in leading-edge scientific and technological cooperation that benefit the civilian institutions and support the U.S. Army's current programs and future goals." *See* Int'l Division, U.S. Army Res., Dev. & Eng'g Command, *U.S. Army International Technology Center of the Americas Opens in Santiago*, REDECOM (2004), *available at* http://www.rdecom.army.mil/rdemagazine/200411/part_ITC.html (last visited April 22, 2007).

[36] *See* NAT'L MATERIALS ADVISORY BD. ("NMAB"), MATERIALS RESEARCH TO MEET 21ST CENTURY DEFENSE NEEDS (2003). Multifunctional materials are materials that unite the double properties of structural integrity

took place in Chile, in 2002. There was only one researcher from México present. The second was held in Huatulco, Oaxaca, México, in 2004, at which there were three researchers from México. The third was held in 2006 in Argentina.[37]

Despite the little knowledge there is about the military accords, either bilateral or multilateral, it is a subject that should be closely examined since the "nanotechnology revolution" initiated in the U.S. was strongly linked to military research. Ever since the U.S. launched it's National Nanotechnology Initiative in 2000, between a third and a fourth of the federal budget for research has been directed to military research.[38] This policy forces other countries to invest into nanotechnology for warfare.[39] In addition, most of the larger universities in the U.S. have projects financed by the Defense Department ("DOD") and some even have agreements with the military industry. Therefore, once the Mexican research centers are brought into the formula, the integration of military interests is facilitated. For instance, the cluster of Paso del Norte includes the Sandia National Laboratories of Albuquerque and the Bi-National Sustainability Laboratory. In this regard, even though military institutions can conduct civil research, is this just a sub-product of the research directly related to the military, according the Mansfield amendment of 1973?[40]

## V. FINAL CONSIDERATIONS OF THE NANOTECHNOLOGY PATHWAYS IN MÉXICO

The pathway followed by México in nanotechnology research is surprising, both for its fast growth in recent years and for the ambitious objectives it has undertaken. However, there are several issues worthy of further examination. Consider the following facts.

From the U.S. to Thailand and from Brazil to México, all countries justify the public funding directed to nanotechnology with the argument that it is urgent to increase competitiveness. This, they say, is to be done by using nanotechnology, as it promises to be the next industrial revolution. The world economy bases its success on technological innovation, which in turn puts countries that do not invest in technology in disadvantaged positions. In this context, nanotechnology appears to be a necessity more than an option. But competitiveness is not only the result of individualized efforts. To be competitive, it is necessary that someone else lose. This is the law of the market. The race between several regions and/or states in México to build scientific-industrial parks could increase the competition between them, thus increasing the possibility of failure and encouraging environmental degradation. In the absence of a national plan, could this increase intra-national competition and, as a consequence, weaken the international position of México?

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(durability, survivability, security) and at the same time, electrical, magnetic, optical, thermal, and biological functions. The core of these new materials is micro- and nanotechnology, and is one of the basic interests in R&D in Latin America and the United States Air Force. *See* Air Force Ofc. of Sci. Res. ("AFOSR"), *AFOSR Research Interests for Latin America, available at* http://72.14.253.104/search?q=cache:4fVmsg2SZygJ:www.prp.rei.unicamp.br/portal/mensagens/2005%2520AFOSR%2520Latin%2520American%2520Research%2520Interests.pdf+AFOSR+Research+Interests+for+Latin+America&hl=en&ct=clnk&cd=1 (last visited April 22, 2007).

[37] Ofc. of Naval Res. ("ONR"), ONR International Workshop on Multifunctional Materials I, II & III, http://www.phy.ohiou.edu/~isfmm/index2004 (last visited April 22, 2007).

[38] EXEC. OFC. OF THE PRES. OF THE UNITED STATES ("EOPUS"), THE NATIONAL NANOTECHNOLOGY INITIATIVE: RESEARCH AND DEVELOPMENT LEADING TO A REVOLUTION IN TECHNOLOGY AND INDUSTRY (Mar. 2005), *available at* http://www.nano.gov/NNI_06Budget.pdf (last visited April 22, 2007).

[39] JÜRGEN ALTMANN, *MILITARY NANOTECHNOLOGY: POTENTIAL APPLICATIONS AND PREVENTIVE ARMS CONTROL* (2006).

[40] The controversial Mansfield Amendment of 1973 expressly limited appropriations for defense research (through ARPA/DARPA) to projects with direct military application.

Why would transnational enterprises like to set up shop in México? Geography can be an answer, but not necessarily the most important one. Perhaps it has something to do with the paucity of regulations and lax rules. In the U.S., the potential risks to health and the threats to the environment derived from nanoparticles are part of the political agenda. As a consequence, the costs for nanotechnology R&D might increase. It is likely that some enterprises will seek to avoid these costs by migrating to countries where these rules are nonexistent. Is this condition a potential risk to countries such as México where there is no consideration about the possible environmental effects of the use of nanotechnology? Further, can the lack of regulations unbalance the possible positive benefits of nanotechnology?

Building high-tech scientific parks is not only a matter of infrastructure. If the projects are successful, the requirements for technical personnel and highly qualified human resources will increase. Even though there are several graduate programs in nanotechnology in México (IPICyT, BUAP, IMP, UANL, CIMAV, UNAM, UANL, CINVESTAV, etc.), the public budget directed to R&D has been decreasing in the last decade. Additionally, there is no proper training in math and science at the lower levels of the education system, which can affect enrollment in highly technical graduate programs in the future. In the U.S., Canada and Europe there is serious concern about the scarcity of scientists in the area of nanotechnology. Is it possible that México, with a scarce number of technical and scientific personnel, will be able to supply the demands of the scientific parks and the recently created research centers? Could the increasing number of partnerships and agreements, such as ICNAM, which allows Mexican students to pursue graduate studies in the U.S., be a threat to increase the brain drain from México to the U.S.?

It is clear that nanotechnology research in México is associated with the possibility of increasing competitiveness. It is also done to attract foreign capital. Both the increase of competitiveness and the attraction of capital are regulated by profit-making. Under current conditions in México there is no regulation or public discussion about the use of nanotechnology. Is it a latent risk to allow the development of nanotechnology without appropriate oversight? Could this exacerbate the prevailing internal inequity?