Mexico-U.S. Scientific Collaboration in Nanotechnology

Colaboración científica México-Estados Unidos en nanotecnología

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Abstract
This work is based upon an exploratory analysis of scientific bilateral agreements on nanotechnology (NT) that exist between Mexico and the United States. The analysis was done through the identification of the main NT research centers in Mexico and the available information they have made public via institutional websites. A second survey was performed to identify key funding institutions. The general conclusion is that there are few opportunities for bilateral collaboration between the countries in the broad NT area. This contrasts with the European Union-Mexico scientific collaboration policy. It seems reasonable to conclude that Mexican NT will likely see its traditional US partnerships decline, relative to those with European countries.

Keywords: 1. nanotechnology, 2. science and technology policies, 3. science collaboration, 4. research and development, 5. Mexico-United States of America.

Resumen
Este trabajo está basado en un análisis exploratorio de los acuerdos de colaboración científica en nanotecnología entre México y Estados Unidos. El análisis fue realizado mediante la identificación de los principales centros de investigación en nanotecnología en México y la información disponible en las respectivas páginas *web* institucionales. Un segundo relevamiento fue realizado para identificar las principales agencias de financiamiento. La conclusión general es que existen pocas oportunidades para colaboración bilateral entre los países en la amplia área de las nanotecnologías. Contrasta esta situación con la política científica de colaboración entre México y la Unión Europea. Resulta razonable concluir que las nanotecnologías en México van a ver a Estados Unidos, su tradicional socio, declinar a favor de los países europeos.

Palabras clave: 1. nanotecnología, 2. políticas de ciencia y tecnología, 3. colaboración científica, 4. investigación y desarrollo, 5. México-Estados Unidos.

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INTRODUCTION[1]

This work is based on an exploratory analysis of scientific bilateral agreements on nanotechnology (NT) that exist between Mexico and the United States (US). In the absence of any relevant database on the part of the federal institutions of Science and Technology (S&T) from Mexico or the United States, this analysis was carried out through the identification of the main NT research centers in Mexico and the available information they have made public via institutional websites. A second survey was performed to identify key funding institutions.

From the US position, there is an established belief that a policy of decentralized research provides greater independence, more competition and greater efficiency in the overall scientific process. In Mexico, the main scientific policy institution (Conacyt–Consejo Nacional de Ciencia y Tecnología–Science and Technology National Council) seeks to foster scientific progress through individual research centers' ability to initiate projects, particularly by fostering cooperation agreements inside and outside the country.

The general conclusion of this survey is that there are few opportunities for bilateral collaboration between countries in the broad NT area–and those that do exist tend to involve seed funding. This contrasts with the European Union (EU) scientific policy developed over the last decade, which allocates more resources for medium and large projects.

METHODOLOGY

No database of scientific collaboration agreements between the United States and Mexico exists in either country. Our research, which seeks to remedy this deficiency, followed three paths. First, based on articles on NT development in Mexico (e.g. CIMAV, 2007; Záyago & Foladori, 2010), we identified the main institutions that conduct NT research in Mexico and collected the information on international agreements with U.S. institutions that was publicly available on their websites. We selected only those agreements that had funded projects, since many agreements were signed but not yet initiated. The second path was to survey the work

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carried out by FUMEC (Fundación México-Estados Unidos para la Ciencia), since it is the most important institution specifically dedicated to improving Mexican-US scientific collaborations, and also one of the most important projects related to NT. The third path was to survey all international collaborations administered by Conacyt. In all cases the single criterion for selecting projects on NT involved searching for the word "nano." It is worth noting that many research centers have outdated websites, not all provide efficient search utilities, and that not all NT projects necessarily include the word "nano" in their agreements.[2] These results should therefore be taken as exploratory and preliminary.

THE NANOTECHNOLOGY REVOLUTION

Nanotechnology is the manipulation of matter at the atomic and molecular scale. The ability to work with matter on such a small scale represents a technological revolution, since at that level, matter expresses physical, chemical and biological properties that are quite different from those they possess on a larger scale. This is akin to discovering a world of entirely new materials. This change in the behavior of matter arises from two effects: *a*) the *quantum effect*, in which nanoscale materials have different optical, electrical, thermal, mechanical (resistance/flexibility) and magnetic properties. Metals, for example, become denser and stronger at the nano level. Carbon in its graphite form (as in pencils) is soft, but when processed on the nano scale and carbon nanotubes are created, it becomes 100 times stronger than steel. The optical properties of materials change, acquiring a different color and reflecting light in a new manner and *b*) the *surface effect*. The smaller the size, the greater the external surface area and, therefore, increased reactivity with the atoms of neighboring materials also exists. The atoms that are on the external surface interact more easily with the atoms of adjacent materials. For example, gold –which is non reactive– once manipulated at the nanoscale, becomes reactive and can be used as a foundation upon which to create sensors.

There are many products on the market that incorporate nanoparticles or nanostructures. These include food, cosmetics, appliances, computers, cell

[2]A more systematic approach involves developing a search algorithm comprised of specific inclusionary and exclusionary terms that capture nanoscale processes, metrology, nanostructure chemistry, nanomaterials, devices, electronics, biology, medicine, etc. Kostoff and his colleagues have developed what has become the standard bibliometric methodology employing this approach; in future research we plan to refine our results using this method (see e.g. Kostoff, Koytcheff & Lau, 2007).

phones, medicines, textiles, ceramics, industrial construction material, sports gear, packaging, weapons and so on. In foodstuffs, nanotechnology is applied to the products themselves, to the packaging, in dietary supplements and in agricultural production. There are more than 200 companies that research and/or produce in this field. Nanotechnology is used in the product, for example, to homogenize texture and stabilize the taste of creams and ice cream, or to reduce the fat content, areas under investigation by Kraft, Unilever Nestle and Blue Pacific Flavors. It is also applied in the form of nanocapsules in dietary supplement products, such as Omega-3, and thickening/thinning agents. Research is also undertaken in applications such as cosmetics, where L'Oreal works in association with Nestlé and BASF. Nanotechnology is used in packaging, to make longer-lasting products/maintain freshness/increase the shelf-life of goods in supermarkets, such as the beer bottled in nano-ceramics from Miller Brewing; or as a preventive to keep materials from spoiling–an application employed by McDonalds and Mr. Kipling. The largest chemical/seed corporations such as Syngenta, Monsanto, Bayer and Dow Chemicals research and produce agro-toxins and nano-encapsulated seeds.

The greatest share of the nanotechnology-enhanced marketplace belongs to the cosmetics sector. The vast majority of these transnational companies, such as Chanel, Clinique, L'Oreal, Revlon, Johnson & Johnson, Proctor & Gamble, and Lancome market anti-wrinkle creams, sunblock, and shampoo. Applied to sunblock, nanoscale manipulation results in a transparent cream, in place of the usual white color. Nanotechnology is also used to diffuse the sun's rays, conceal wrinkles, and many other functions. There are toothbrushes and toothpaste with silver nanoparticles acting as germicide, a technique also applied by Samsung and LG to air conditioners, refrigerators, washing machines and dishwashers. Nanotech coatings are used to cover floors, while nanoparticles are incorporated into paints and aerosols for application on furniture and floors. Windows are processed with nanotechnology to create non-stick surfaces, preventing dust and dirt from accumulating, while facilitating water-only cleaning without the need for detergents. In textiles, nanotechnology applications create stain-resistant and wrinkle-free clothing. In some cases, silver nanoparticles are incorporated with germicidal properties for medical uniforms or special clothing for nurses. This also is applied to sheets, towels and dressings. Nanotechnology-processed medicines are promoted as being more efficient and having fewer side-effects. Nanotechnology is present in sporting goods, from tennis rackets, golf clubs, sneakers, climate-specific clothing, etc. The top brands in computers, cell phones, and videogame consoles utilize lithium batteries with anodes coated in nanotechnology, and make use of nanoscale electromechanical mechanisms. Luxury automobiles are already incorporating more than 30 parts that contain nanoscale devices or combine nanoparticles. The military industry is one of the principle consumers of nanotechnology products; it is also a sector that has had profound effects on the nanotechnology field, driving development. From precision missiles and high-yield explosives to sensors and bulletproof vests, military interests are tied to the advance of nanotechnologies.

Although the nanoscale properties of matter have been systematically investigated by many countries since the 1980s, it was after the launch of the National Nanotechnology Initiative in the United States in 2000 that public financing was applied to drive nanotechnology research in depth, spreading throughout the developed world and many underdeveloped countries. In Latin America, Brazil and Mexico have been at the cutting edge of this research. Brazil has over 150 firms that research, produce and/or sell nanotechnology-based products. In Mexico the list totals more than 60 firms (Foladori, *et al.*, 2012). Nanotechnology is the first scientific revolution to take place in the age of the Internet. This is important because it is only since the mid-1990s and more clearly since 2000 that researchers around the world have been connected with their counterparts via electronic networks across the Web. This has made the dissemination of information and the consolidation of distant research groups easier and faster. At the same time, concern has been expressed about how and who determines research issues; and if the researchers in the developing world are driven by national interests or whether they are increasingly burdened by the criteria and demands of developed nations (those who tend to provide funding).

In this article, we begin to analyze the relations of nanotechnology research in Mexico, undertaking an exploratory analysis of the collaboration agreements between Mexico and the United States.

SCIENCE AND TECHNOLOGY IN A GLOBAL CONTEXT: EFFECTS ON MEXICAN POLICY

As of the 1990s there was a change of policy regarding S&T within international institutions such as the World Bank and the Organization for Economic Cooperation and Development (OECD). Scientific research was identified as a key engine for development (Masood, 1999). The World Bank's *World Development Report 1998-1999* carried the subtitle *Knowledge for Development*, referring to the gap in knowledge between rich and poor countries.

During the early 1990s several Latin American countries embraced the implementation of the knowledge economy as an alternative path to development. The European Union became an active promoter of this approach, as did the United Nations, whose General Assembly included the promotion of S&T as a key factor for development in its Millennium Development Goals Declaration in 2000.

In 1994, Mexico became a member of the OECD and requested an external evaluation of its scientific-technological system. The OECD recommended various measures to create a technologically competitive industry, including the following: The creation of a single institution to control all of Mexico's S&T, the creation of a S&T policy addressing business sector needs, the identification of sources of external financing, and the restructuring of Conacyt (OECD, 1994).

The first *Special Program on Science & Technology 2001-2006* had already identified the importance placed on the participation of the business sector, but still emphasized the linear (so-called *science-push*) model of innovation, where science offers results that businesses then adopt (Solleiro, 2002). However, in the second *Special Program on Science & Technology 2008-2012*, the change towards a model in which business demands a particular kind of research from scientific institutions is made explicit. The great majority of the programs providing financial support for research become oriented toward enterprises or to academic societies in partnership with private business. "Competitiveness" became the banner of the entire regulatory framework in S&T from the beginning of the 21st century onwards.

The *National Development Plan 2007-2012* continued in the spirit of previous regulatory changes, ensuring that development would be oriented toward international competitiveness and citing S&T as a means towards that end.

In 2009, the Science & Technology Law was modified. As a result of this change, the Public Research Centers (CPIS), which are quasi-state entities under public administration, were empowered and tasked to promote private spin-offs. Furthermore, the modified S&T law facilitated the transfer of scientific and technological knowledge to enterprises, granting up to 70 percent of the royalties for intellectual property to the researchers who developed commercial applications for the technology (DoF, 2009: 28).

These changes in Mexican S&T policy not only fostered the integration of government, academy, and industry, but also pressured Mexican universities and research centers to look outside their own budgets for research funding. Agreements with other institutions within Mexico and outside the country became a key activity for any scientific institution, spurred by the Internet revolution that allowed cheaper and easier long distance communication as well as immediate access to scientific journals. As will be seen later, most of the scientific collaborations between Mexican and US institutions were established during the first decade of this century.

The incorporation of Mexico into the OECD in 1994 also fostered several scientific collaboration agreements with the European Union (EU) and other countries. In 2004, an agreement for S&T collaboration was established between the EU and Mexico, with a specific program fund (€20-million jointly provided by the EU and Conacyt) named Foncicyt (Fund for International Cooperation in Science and Technology) established in 2008 (Conacyt n/d a; Polo, 2010). Within the field of NT the initiatives with the European Union are of importance due to the significant amount of funding.[3] As Polo (2010) noted, the EU is gaining importance vis à vis the United States in scientific collaborative activities with Mexico. Still another example is the creation of the Matuem (Material Network EU-Mexico) funded through the Foncicyt. Robles-Belmont & Vinck (2011), from a network research analysis perspective, also come to the conclusion that Mexico is primarily working with Europe (considering as a political unit), followed by the US.[4]

MEXICO-US S&T COLLABORATION PROGRAMS ON NT

Types of collaboration

For Mexico, international scientific collaborations are mostly coordinated by Conacyt. Another important institution specifically oriented toward Mexican-US collaborations is FUMEC (Mexican-US Foundation for Science). Apart from these institutions, many public universities or research centers and some private institu-

[3]One example is the Conacyt-EU call for research proposals that assigned around US$ 1 million (11 700 000 Mexican pesos) to the BisNano project (Functionalities of Bismuth-based Nanostructures) in 2010. Another example is the 2010 Mexico-EU call for research on NT for mining (FP7-NMP-2010-EU-Mexico), adding value to mining at the nanostructure level.

[4]Mexico is also establishing strong ties of scientific collaboration with other countries in Asia (e.g. Japan) and with South America (Brazil, Argentina, Chile), although in those cases, the available funding cannot approach that available from the European Union.

tions have bilateral scientific agreements with the United States and are also working in NT areas. The Mexican Academy of Sciences (ACM) also supports research, but although it included NT as a key area for development in an agreement signed with the University of California in 2005, no project has yet been funded.

For analytical purposes we distinguish the scientific research agreements by their scope and budget size, separating them into three groups: long-lasting projects (large scope), projects that last over five years and include several institutions –here only FUMEC's initiative has been included; medium projects, projects costing between $50 and $500 thousand USD and normally last between three and five years; and, short term (seed) funding projects that last up to three years and/or have a small amount of money (normally no more than US$30 000). Table 1 organizes the main projects by scope. In addition to the Research and Development collaboration projects mentioned, we also include bilateral agreements with educational objectives. All the programs in Table 1 had at least one NT project in the last decade.[5]

First, for Mexico, most of the funds come from Conacyt. Although Conacyt encourages universities and research centers to pursue international collaborations, most Mexican public research institutions (except for some large universities) do not have funding money to engage in international collaborations on their own, and rely heavily on Conacyt. Conversely, many US universities have resources to fund multi-annual international collaborations, in addition to those provided by the National Science Foundation.

Second, only one program was specifically created to promote NT collaborations; the rest have no such restriction, although in some cases, such as in the Inter-American Materials World Network and with the Southern Office of Aerospace Research and Development (SOARD), the majority of the projects approved involved NT.

[5]There are additional projects between Mexican and US institutions, some under way and others completed, which do not appear in Table 1. These will require field research in order to obtain data. These include collaborations between Rice University and ITESM-Monterrey for the design of biomedical devices; UT-Austin and the Nanotechnology Cluster of Nuevo León; CIMAV and SUNY-Albany; CIQA and SUNY-Stony Brook, Brookhaven Nat Lab, SNL, Oak Ridge Mat Lab, Center for Integrate NT, University of Tennessee, UT-D, UT-El Paso, UT-A&M, and UT-A. UNAM and UC-Berkeley, ASU, UC-Riverside, UC-San Diego, UC-SB, Hawaii State University, Lehigh University, University of Oakland, and University of Michigan. IPICYT and University of Florida-Gainesville, University of Illinois-Urbana-Champaign, UC-SF, University of Mississippi (Cancer Institute); UACJ and SNL. Few collaborations exists between Mexican research centers and U.S private firms. Exceptions include FUMEC (Aeri-Mems) and Team Technologies (NM); INAOE and Motorola; INAOE and StarMega Corp. (NM); INAOE and Intel Corp. (CA).

TABLE 1. *Scientific collaboration projects between Mexico and U.S. with activities in Nanotechnology*

Project name	Mexico	U.S.	Characteristics ($ in US dollars)
Large scope			
FUMEC (Mems project, 2003) (FUMEC, 2003)	FUMEC	FUMEC	Several projects; MEMS/NEMS being the most important in NT
Seed projects			
UCMexus-Conacyt (Collaborative grants, 1998. (UCMexus, 2011)	Conacyt	UC (Center for Mexican and Latin Culture)	Several types. Between them, • Collaborative grants (up to 25 000) for 18 months
Texas A&M-Conacyt Collaborative. Research Grant Program -2001. (TAMU-Conacyt, 2010)	Conacyt	University of Texas A&M	• Collaborative grants (up to 24 000) for one year
Tunable Radio Frequency Materials for OTM (On-The-Move) Communications Systems	UACJ (Universidad Autónoma de Ciudad Juárez)	ARL (Army Research Lab), Maryland	• 30 000
Medium Projects			
Inter-American Materials World Network -2003) (Conacyt, n/d b)	Conacyt	National Science Foundation (NSF)	• Several projects varying in amount between • 70 000 and 320 000
ICNAM (International Center for NT and Material Sciences-2003) (ICNAM, 2003).	CIMAV (Centro de Investigación en Materiales Avanzados)	University of Texas-Austin (UT-A)	• Up to 100 000
ASU/ITESM/CINVESTAV (Arizona State University/ Instituto Tecnológico y de Estudios Superiores de Monterrrey) Centro de Investigaciones Avanzadas), Binational Research Initiatives -2006. (Subramanian, n/d)	ITESM (Instituto Tecnológico y de Estudios Superiores de Monterrey)	ASU (Arizona State University)	• 100 000 for 2 years
US Air Force Office of Scientific Research-Southern Office of Aerospace	CIMAV (Centro de Investigaciones en Materiales	AFOSR-SOARD (Air Force Office of Scientific Research–Southern	• Up to 500 000 for 3 years.

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Research and Development (afosr-soard-2009. (onr-a, itc-a, soard, n/d).	Avanzados) /Conacyt	Office of Aerospace Research and Development)	
Prototypes of mems-2007. (Estrada *et al.*, n/d)	uacj	Sandia National Laboratories	• 100 000
Parkinson Treatment -2011. (*El Universal,* 2011)	fi-unam (Instituto de Física–Universidad Nacional Autónoma de Mëxico) & innn (Instituto Nacional de Neurología y Neurocirugía)	Tulane University	
North American Cluster on Nanotechnology. (cimav, 2008b; Lara, n/d)	cimav	asu	• 1.5 million by each partner for 5 years
Educational Projects			
icnam (International Center for nt and Material Sciences-2004) (icnam, 2003).	cimav/uanl Conacyt/uv	ut-Austin	Co-PhD title on Material Sciences between ut-a & uanl
ut-Dallas & Conacyt-2011. (ut-Dallas n/d)	Conacyt	ut-Dallas	Postgraduate studies at UT-Dallas in Science and Technology
snl & UdeG -2011. (snl, 2011).	UdeG	snl	UdeG students. taking courses at snl on mems/nems. 2 million
pasi (Pan American Advanced Studies Institute). First on nt held in Costa Rica in 2001. Several held in México. (Fuentes *et al,* 2010)		nsf/US DoE	To facilitate the interaction of participants from. all countries in the Americas at advanced graduate and postgraduate levels
Textbooks on nt for Elementary and Secondary School (Fuentes *et al*, 2010)	cimav	Northwestern University	Introducing a Material's educational program created in Northwestern to Chihuahua
Workshop: Nanoscience for Advanced Applications: On Crossroads of Disciplines (Nano at the Border consortium -2002-2006). (NanoTech Institute, 2008).	University of Guanajuato (UdeGto)	University of Texas- Dallas; University of Texas-Brownsville; University of Texas-El Paso (ut-d; ut-b; ut-pa)	Joint NT workshops in Guanajuato and Dallas. NanoTech Institute (2008).

Four conclusions can be drawn from Figure 1.

Third, most of the collaborations involve adjoining US and Mexican states: California, Arizona, Texas and New Mexico in the United States, and –excluding collaborations administered at the national level by Conacyt – Chihuahua (CIMAV, UACJ) and Nuevo León (ITESM) in Mexico.

Fourth, except for the case of the UCMexus-Conacyt collaborative grants, all the other programs are in their first decade. This is probably because the knowledge economy paradigm was adopted as the necessary path for development in the late 1990s, with its emphasis on networks and international collaborations.

PROGRAMS-BRIEF SUMMARIES

FUMEC

The United States-Mexico Foundation for Science (FUMEC) was created in 1993 to promote and support S&T collaboration between Mexico and the United States. FUMEC began working on the implementation of a plan to develop MEMS (micro-electrical mechanical systems) in Mexico in 2001-2002, in collaborative workshops with Sandia National Laboratories (SNL) and University of Texas-El Paso.

One of the outcomes of this collaboration was the strong belief on the part of both institutions that the MEMS/NEMS (micro- and nano-electrical mechanical systems) research area could be developed in Mexico. This could have significant economic repercussions, since they are key inputs for the large electronics and automobile transnational corporations already located in Mexico. As a result of the agreements done by FUMEC, and seven years after its inception, a network of MEMS/NEMS Centers for Design was created, with the participation of at least twelve universities or scientific research centers in Mexico (most of them public), at least three US universities with the participation of several companies on the United States side, and the strong participation of Sandia National Laboratories (with its recognized international expertise in MEMS). A binational business facility was created (BNSL–Bi-National Sustainability Laboratory) together with a bi-national cluster for encapsulation of MEMS/NEMS, where the Sandia National Labs also have a key role.[6, 7]

[6]The collaboration agreement between SNL and the UACJ is a spinoff from FUMEC's program.
[7]The list of institutions and companies forming part of the cluster and/or the Networks includes: UACJ, UNAM, INAOE, CIMAV, UV, CINVESTAV, IIE, UPAEP, ITESI, ITESM, UdeG; UT-A, UT-El Paso, UT-D, Suny-A, ASU, SNL, New Mexico Int. Tech, TVI College, White Sands Lab, BNSL.

UCMexus-Conacyt

UCMexus-Conacyt is a scientific and academic collaboration agreement between the *C*enter for Mexican Studies and the Latin Culture at the University of California and Conacyt in Mexico. It is one of the earliest sustained academic and scientific collaboration agreements between the countries, starting in 1997. Within this agreement grants of different types are awarded annually. Among these are collaborative grants between research groups in Mexico and the University of California, which are seed grants with the aim of establishing future, deeper collaborations. This fund awarded 121 collaborative grants between institutions in both countries for research on topics related to NT between 2002 and 2010; two additional individual grants for Mexican investigators were funded at different research levels. Within the grants allocated to Mexican institutions, the National Autonomous University of Mexico (UNAM) received half (six), followed by the Metropolitan Autonomous University (UAM) with three awards. Among the UC campuses, UC-Los Angeles has received three awards, followed by another four campuses with two awards each, and several other campuses with one award each.

Texas A&M-Conacyt Collaborative Research Grant Program

Texas A&M University and Conacyt entered an agreement to offer seed grants between researchers from both institutions, with the aim of fostering cross-border collaborations. From 2001 when the program began, two grants have been given to projects on NT; one in 2006, and another in 2008.

ICNAM (International Center for Nanotechnology and Material Sciences) UT-Austin

The Center for Nano and Molecular Science and Technology (CNM) at the University of Texas-Austin was founded in October 2000. Since 2005, it has partnered with Conacyt to become the International Center for Nanotechnology and Material Sciences. Several other Mexican research centers and universities immediately joined the project (UNAM, Cinvestav, CIQA –Centro de Investigación en Química Aplicada–, UANL, IPICYT, ITESM and UASLP). A total of 14 research projects have been approved. Researchers from the UANL received two, CIMAV three, CIQA three, UNAM two, Cinvestav two, with one designated for ITEMS and the IPICYT.

ASU/ITESM/Cinvestav Binational Research Initiatives (ASU & ITESM, 2006)

An agreement signed in 2006 between Arizona State University and Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), initially for the area of biotechnology, was subsequently expanded to other scientific areas. Only one project for NT was awarded in 2007-2009 ($175 000 USD) with the participation of Cinvestav (Centro de Investigaciones Avanzadas).

Interamerican Advanced Materials Network

This program is financed by the U.S. National Science Foundation and is open to many countries. In recent years, various bilateral collaboration projects with Mexico have been approved; Figure 2 summarizes these projects. Awards range from $70 000 USD to $320 000 USD without including extensions awarded in some cases. Of the nine projects identified, the Mexican institution that garnered the most funding was IPICyT.

TABLE 2. *InterAmerican Advanced Materials Network projects that include bi-national US-Mexico collaboration in nanotechnology*

Year	Project Title	Institution (USA)	Institution (México)	Initial Disbursement
2010	Effects of Precursor Nanostructure on Geopolymer Structure and Properties	NJIT (New Jersey Institute of Tech).	UNAM (Universidad Nacional Autónoma de México)	209 222
2008	Fabrication of Polymer Composites and Sensors using Doped Nanotubes (RPI) and William Marsh Rice University	National Science Foundation (NSF), Rensselaer Polytechnic Institute	IPICyT (Instituto Potosino de Ciencia y Tecnología)	288 000
2008	Alloys at the Nanoscale; The Case of Nanoparticles	NSF. University of Texas-Austin	UANL (Universidad Autónoma de Nuevo León), IPICyT and UASLP (Universidad Autónoma de San Luis Potosí)	71 509

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2007	Fabrication of Polymer Composites and Sensors using Doped Nanotubes	NSF. RPI	IPICyT	96 000
2007	Anomalous Thermoelasticity in Liquid Crystalline and Semicrystalline Polymer Networks	NSF. University of Syracuse	UNAM-Cuernavaca	320 000
2006	Alloys at the Nanoscale; The Case of Nanoparticles	NSF. UT-A	UANL, IPYCIT, UASLP	202 000
2003	Novel Preparations and Characterizations of Polymer-Clay Nanocomposites	NSF-State University of Ne York (SUNY)-Stony Brook	UASLP	150 000
2003	Large Scale Synthesis of N-doped Carbon Nanotubes for the Fabrication of Novel Polymer Composites and Related Low Dimensional Materials	NSF-RPI	IPICyT	246 000
2003	Synthesis, Processing and Atomic-Scale Characterization of Nanostructured Materials	NSF-Arizona State University (ASU)	IPICyT	162 000

Source: Based on Conacyt (n/d b); and NSF (2004).

AFOSR (Wright-Patterson Air Force Base, 2009)

The US Air Force Office of Scientific Research (AFOSR), like its naval equivalent, the Office of Naval Research (ONR), has offices around the world tasked with driving scientific research in cooperation with research centers in other countries. The SOARD (Southern Office of Aerospace Research and Development) was created in 2009 with its headquarters in Santiago, Chile, to engage with Latin America– where an ONR office was already established in 2004.

The objective of these offices is to identify talent and form partnerships with the Latin American scientific community. The Air Force Office of Scientific Research has identified NT development as an area where opportunities exist in Korea, Taiwan and Mexico (Russell, 2011). It is empowered to support the organization of events and bestow funding for research into topics of mutual interest between participating institutions and the AFOSR (Russel, 2011; Callier, 2010). In 2009, the SOARD –with the ONR and Centro de Investigaciones en Materiales Avanzados (CIMAV)– provided support for the organization of an event in Mexico (Multifunctional Materials Workshop, 2009).

A meeting of the US-Mexico Basic Research Initiative took place in Washington, DC in 2009, organized by Conacyt, CIMAV and AFORS. Various bi-national collaboration projects were presented, with four institutions approved for $500 thousand USD in funding (CIMAV, 2010): CIMAV-Monterrey–University of Texas-Dallas; CIQA (Centro de Investigación en Química Aplicada)–University of Akron; Centro de Investigación Científica y de Educación Superior de Ensenada (Cicese)–University of California-Riverside; Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional (Cinvestav-Querétaro–University of California–Santa Bárbara.

TABLE 3. *Projects with SOARD 2009*

Institution	Project	Dollars	Duration in years
CIMAV	Aluminum alloys reinforced by nano-particles dispersion	75 000	3
	High temperature oxide of superalloys and intermetallic compounds	75 000	3
	Predicting failure initiation in structural adhesive joints	65 000	3
CIQA	New Meta and NT for photorefractive 2-Bm Coupling	40 000	1
	Synthesis of Chromophores for Nonlinear Optics Applications	39 000	1
IPICYT	Catalyst matrices preparation for the elucidation of carbon nanotube growth	28 700	1
	Biocompatibility of Doped, Functionalized and Pure Carbon	30 700	1
	Polymer Composites using Aligned Carbon Nanotubes for Efficient Heat Transfer	38 700	1
U de Guanajuato	Nitrogen Rings and Cages Stabilized by Metallic	74 400	3
INAOE	Beam coupling in semi-insulating semiconductor-liquid crystal hybrids	20 000	2
ITESM-CEM, Atizapan	Simulation of Mechanical and Physical Properties of Carbon Foam Materials	59 000	3

Source: Based on ONRG-A, ITC-A, SOARD, n/d

MEMS PROTOTYPES (2007)

This project was designed at the Universidad Autónoma de Ciudad Juárez (UACJ) in collaboration with Sandia National Laboratories for the creation of a joint program among various research centers in Mexico, with the aim of providing training and capacity-building in MEMS design and fabrication. Support for the program came from FUMEC and the MEMS CD Network in Mexico.

PARKINSON'S TREATMENT

This tripartite project between the UNAM Physics Institute, the Nanotechnology Laboratory of the National Institute of Neurology and Neurosurgery and the University of Tulane sought the creation of a therapy for the treatment of Parkinson's disease, based on controlled drug release into the nervous system via the use of a nanostructured sol-gel.

North American Cluster on Nanotechnology

This initiative is between Arizona State University and CIMAV in Chihuahua, with each partner putting up $1.5 million USD in funding. Its objective is to bring together research centers and businesses interested in research and nanotechnology production.

CONCLUSION

Among the various kinds of programs and collaboration projects in NT between Mexico and the US, the largest, in terms of dollar investment, number of institutions involved, and participating researchers, is FUMEC's MEMS effort. Although it focuses on the area of semiconductors, the widespread application of these products across various economic sectors magnifies its importance beyond the semiconductor sector. However, this is a program created by an institution tasked with promoting bilateral partnerships, but not to permanently fund the research programs it promotes. This raises concerns for long-term sustainability. MEMS research development in Mexico is also concentrated in the first-virtual stages of the production process, far behind the possibility of producing MEMS in industrial quantities, which also raises doubts about the long-term viability of the strategy.

The seed fund programs, some of which have an important history –such as UCMexus-Conacyt– have awarded funding for projects related to NT, but this is secondary and forms no part of the explicit funding stream of the participating institutions. A number of other programs or partnership projects between Conacyt and US institutions exist, the majority of which are temporary and do not extend beyond three years, with funding amounts that barely exceed half a million dollars.

Even though the grant programs require bilateral participation, most of the projects are US administrated, which tends to orient research funds towards US institutional interests. It is not clear whether this also reflects Mexican research interests, which is difficult to analyze in the absence of a Mexican national nanotechnology strategy.

If one compares the US-Mexican funding programs in NT with those between the European Union and Mexico, it is evident that there is a significant difference in time horizon: the European partnerships are far longer-term than those with the United States, and are funded at substantially higher levels as well. Unless these circumstances change, it seems reasonable to conclude that Mexican NT will likely see its traditional US partnerships decline, relative to those with European countries.

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