Nanotechnology in Chile: Towards a Knowledge Economy?[1]

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Introduction

Nanotechnologies are rapidly growing worldwide. Poor countries are also taking part in the development of this technological revolution. In Latin America, Brazil, Mexico and Argentina are the leading nations in the area; however there are other countries pursuing important efforts to develop nanotechnologies and nanosciences. Chile has several research projects underway across five universities.

The promotion of nanotechnology research is a strategy inserted in the paradigm of encouraging development via the knowledge economy. The World Bank, as the main institution promoting this paradigm, selected Chile as the pioneer to implement the Scientific Millennium Initiatives, which have supported some research projects related to nanotechnology.

In this chapter we analyze the development of nanotechnology in Chile within the framework of the paradigm of the knowledge economy and we question the sustainability of the Centers of Excellence. In addition, we elaborate on the weaknesses of using nanotechnology as a tool for development in Chile.

1. The World Bank's Promotion of the Knowledge Economy in Latin America.

In Latin America the promotion of nanotechnologies is associated with the reorientation of its economies to make them less dependent on crop exports, the mining industry and sectors linked to the exploitation of natural resources. The idea is to base the development process on what has come to be known as the Knowledge Economy. The transition from industrial economies to knowledge economies is happening already in developed countries such as the United States, the European Union and Japan. In general, experts use the percentage of high-tech manufactures being exported — which presumably are the direct outcome of intense research and development (R&D) — to measure the advance of the knowledge economy. There are several industrial branches that structure the high-tech sector in an economy, such as aerospace, pharmaceuticals, computers, scientific instruments and electrical machinery. In 2004, 34% of overall exports in the United States were high-tech manufactures; 24% in Japan, 34% in South Korea and Ireland. In Latin America, Argentinean high-tech manufactures make up to 8% of its exports, in Chile 5%, in Brazil 12% and in Mexico 21% (World Bank, 2006a). In the case of Mexico, the weight of maquiladora production and the strong intra-firm trade of US transnationals suggest that there is a need to be cautious in the analysis (Delgado & Invernizzi, 2005). There are other indicators used to show the degree in which a given country is incorporated into the knowledge economy, such as the KAM (Knowledge Assessment Methodology) of the World Bank. This indicator includes several variables like patents, access to education and telecommunications, institutional environment and others (World Bank, 2006b).

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During the 1980s, the World Bank concentrated its efforts in economic liberalization. A part of that orientation involved closing the Department of Science and eliminating the position of Scientific Advisor of the World Bank. From the early 1990s there was a change of policy recognizing scientific research as the motor 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. The basis for this change was the recognition that the economic liberalization implemented during the 1980s had not attained the anticipated results, but rather had increased the gap between rich and poor countries, and increased their foreign debt. In addition, the Bank pointed out that the patents regime (accepted by the World Trade Organization)[4] had not promoted private research in areas with a large impact on the development process, but with little return of profits, such as the so-called *neglected diseases* (i.e., in the case of drugs to treat malaria). According to the World Bank, in cases like this one, the public system should subsidize research (*Nature*, 1988). The Bank also showed concern for the extension of intellectual property rights beyond products, particularly to cover biotechnology achievements (Butler, 1988). The proposal from the World Bank, at the end of the 1990s, was to incorporate the topics related to innovation, science and technology and technological transfers, in policy implementation for achieving development in poor countries.

The development orientation towards the knowledge economy was not and has not been an exclusive paradigm of the World Bank. In Latin America, at the beginning of the 1990s, several countries achieved the implementation of the knowledge economy as an alternative path to development. The European Union has also been promoting the knowledge economy. Chile, for instance, and parallel to the agreements previously signed with the World Bank, became part of another effort with the European Union in 2001. The objective was to encourage, develop and facilitate R&D activities between Chile and the European Community, in scientific and technological areas. The agreement was articulated within the framework of a flagship program which identified areas with strategic priority, such as nanotechnology (SICID, 2002). In 2006, within MERCOSUR, Chile signed a declaration to create the *Espacio Regional de Investigación en Ciencia, Tecnología e Innovación* (Regional Space for Scientific Research, Technology and Innovation) (CONICYT, 2006 May).

In order to confront the challenge of implementing knowledge economies in underdeveloped countries the World Bank followed the strategy of creating nuclei of excellence in research. At the end of the 1990s, the World Bank and other institutions created a global network of Millennium Initiatives. These initiatives would become centers of excellence in research in underdeveloped countries with the purpose of encouraging Science and Technology (S&T) under equal conditions of infrastructure and resources as exists in research centers in the developed countries (Macilwain, 1998).

[4] TRIPS (Agreement on Trade-Related Aspects of Intellectual Property Rights) was created to guarantee patent protection of foreign trade operations. TRIPS sets down minimum standards for many forms of intellectual property regulation. TRIPS also established a legal system and mechanism for dispute settlement, including sanctions, for countries that do not comply with the legislation.

2. Nanotechnology and the Centers of Excellence in Chile

Nanotechnologies are part of a technological branch that is growing worldwide and are associated with both the knowledge economy and the innovation paradigm.[5] The investments in nanotechnology have been growing steadily since 2000, particularly after the United States launched its well funded research program (*National Nanotechnology Initiative*). Later, many other countries followed the example. Lux Research (2006), a company that investigates the investment and the commercialization of nanotechnology in the world, estimated that in 2005, 9.6 billion dollars were allocated to R&D in this area. In 2005, private investment in nanotechnology R&D surpassed public funding. The latter indicates that corporations and enterprises doing research in this area judge their investments according to the profits they will attain. Lux Research estimates that, even though the nanocomponents market is still small, in 2005, $32 billion were sold, doubling the figure from the previous year, and for 2014, the estimate is $2,6 trillion.

In Latin America, Brazil, Argentina and Mexico are countries where nanotechnology research is underway (Foladori, 2006). In 2001, Brazil created several networks in nanotechnology research. In 2004, it announced the Nanoscience and Nanotechnology Program, within the framework of the *Plano Plurianual de Desenvolvimento 2004-2007* (The Multi-Year Plan for Development 2004-2007) (MCT, 2004a, 2004b). In 2005, the Argentinean government created the Argentinean Foundation of Nanotechnology. In Mexico, on the other hand, there are several laboratories doing nanotechnology research, including the construction of several high-tech parks where nanocomponents have a strong presence (Foladori & Zayago, 2007).

The interest of the Chilean Government to use technological innovation as a tool for development has been present at least since the beginning of the 1990s. Between 1992 and 1995 it implemented the *Programa de Ciencia y Tecnología* (the Science and Technology Program) with the support from the Inter-American Development Bank. In the following years, it created the *Programa de Innovación Tecnológica* (the Program for Technological Innovation) (1996-2000). Both programs were followed, since 2001, by a program called *Chile Innova* (Chile Innovates), which was the program for technological innovation and development of the Chilean Ministry of Economy. It concluded at the end of 2005 (Chile Innova, 2006). The main objective was to increase international competitiveness by supporting innovation and technological development in strategic areas. To secure this purpose, *Chile Innova* defined five strategic areas to be developed: Technological Perspectives, Information Technology and Communications, Biotechnology, Clean Production Systems and Quality Standards.

During the government of President Ricardo Lagos (2000-2006), the World Bank financed seven projects in the country, allocating US$215 million for six central projects. Some examples are the program of *Tecnología e Innovación* (Technology and Innovation) (World Bank, 2006) and the *Programa Bicentenario de Ciencia y Tecnología (PBCT)* (Bicentennial Program of Science and Technology) (2004-2010) which is an

[5] For the purpose of this article the term nanotechnologies will be used to include the concept of nanoscience. The Royal Society & The Royal Academy of Engineering (RS&RAE) (2004) defines both terms: "We define Nanoscience as the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale; and nanotechnologies as the design, characterization, production and application of structures, devices and systems by controlling shape and size at the nanometer scale." (Summary, 2)

initiative worth US $100 million, equally financed by the Chilean Government and the World Bank in two phases of three years. The main focus is on the development of a knowledge economy is stated by the same program: "*The purpose of PBCT is to support and direct the process towards a society and an economy based on knowledge, by investing in science and innovation areas linked to the business sector in the country and the world wide networks of science and technology" (CONICYT - Banco Mundial, s/f.a).* This idea falls under the presumption that S&T would allow Chile to be competitive with the world (CONICYT, 2005).

In 1997, the *Comisión Nacional de Ciencia y Tecnología* (CONICYT) (National Commission of Science and Technology) opened its Centers of Excellence via the *Programa Fondo de Investigación Avanzada en Áreas Prioritarias* (FONDAP) (Program of Advanced Research in Strategic Areas). These centers, in addition to maintaining a high level of excellence, offer Doctorate Programs evaluated by CONICYT. The purpose is to encourage the formation of links between the scientific and technology sector and businesses. The idea is to orient research towards innovative processes, products or services to be commercialized and also to facilitate technological transfers amongst enterprises (FONDAP, s/f). This is similar to what in later years the Ministry of Planification and the World Bank launched as the Millennium Initiative; however the two programs are not integrated. The FONDAP supplies funding to a program conducting nanotechnology research via the creation, in 1999, of the *Centro para la Investigación Interdisciplinaria Avanzada en Ciencia de Materiales* (Center of Advanced Interdisciplinary Research in Science of Materials) in the Universidad de Chile. The following chart shows the centers created by FONDAP.

FONDAP Centers of Excellence and Nanotecnology Presence

Date	Name of the Institute or Nucleus	Headquarter
1997-1998	● Center of Mathematic Modulation ● Center of Cellular Regulation and Pathology	● Universidad de Chile ● Pontificia Universidad Católica de Chile
1999	● *Center of Advanced Interdisciplinary Research in Science of Materials* (Research on Nanomaterials)	● Universidad de Chile
2001-2002	● Center of Pacific Oceanographic South-Oriental ● Center of Advanced Studies in Ecology and Biodiversity ● Center of Astrophysics ● Center of Cellular Molecular Studies	● Universidad de Concepción ● Pontificia Universidad Católica de Chile ● Universidad de Chile ● Universidad de Chile

Source: Own elaboration from Sabater Villalba, 2004.

The Center of Advanced Interdisciplinary Research in Science of Materials of the Universidad de Chile is researching nanotechnology with the intention of developing new patents to commercialize, particularly with copper as a base (FONDAP, s/f). Between 1999 and 2003, FONDAP allocated 15.9-million Chilean pesos, while in the same period the Millennium Initiative of the World Bank supplied 18.4 million Chilean pesos (Contreras *et al*, 2006).

Another program of the CONICYT associated with the financing of individual projects, the FONDECYT, included nanotechnology and it is estimated that more than 37

projects in this area were financed, bringing benefits to researchers working at 6 public universities and one private (Fajardo, s/f).

The Scientific Millennium Initiative, encouraged by the World Bank, was implemented in Chile as the prototype to be further developed in other countries.[6] In 1999, the Chilean Government created the National Commission of Millennium Initiatives, with the purpose of developing research and scientific capacities and, of course, developed further connections with the World Bank (DORCH, 1999). In consequence, the World Bank granted a loan of US $5 million for the first stage of two-and-a-half years on top of the US $10 million provided by the national government (ICM, s/f.a). The objectives of the Millennium Scientific Initiatives (MSI) were:

> …encourage scientific research, taking advantage of and stimulating the best talent in the country, as key factors for encouraging sustainable socio-economic development. The Program objective is the formation of Centers of Excellence to stimulate the creation of Scientific Institutes and Scientific Nuclei, under the principles of competitiveness and transparency. These centers will push the boundaries of science by training scientists, will contribute to the dissemination of new knowledge using educational programs and will contribute to the establishment of links between the productive sectors and other institutions (ICM, s/f.a).

It can be argued that instead of adjusting the research agenda according to the interests of a national plan for development, the program identified Chilean talents within outside of the country to support their particular research agenda. This scientific policy seems to be elitist, but it was based on the idea that whatever direction innovation can take, at the end it will increase competitiveness to guarantee development. Other objectives included attracting talents from overseas and avoiding brain-drain.

The pilot policy suggested by the World Bank and implemented in Chile is a *top-down policy*. Some of the prominent scientists established centers of excellence for themselves. The idea thereafter was to wait for them to form partnerships with the private sector to foster productive innovation. Although the spirit of the plan was to create the conditions for the researchers to stay in Chile and not migrate, it is debatable whether this could be achieved in enclaves of excellence with short support and without a concurrent basic educational reform effort to nourish and allow the replication, in the long-term, of a path for technological innovation. These enclaves of excellence would have to survive in a country where only 0.6 % of the GDP is meant for S&T; a very low figure, only a few decimals above México's commitment and clearly inferior to the Brazilian and the Venezuelan budget for S&T in the Latin American context. It was clearly inferior to the budget supplied for S&T in developed countries and some others that have encouraged innovation in previous years:

> In 2004, Chile invested 0.68% of GDP in R&D. South Korea invested 2.4% when it had a GDP per capita similar to the one in Chile, or Ireland (1.3% of GDP) or Slovenia (1.4%). At the same time, compared to the funding invested in R&D in developed countries, the difference is even higher: Israel is at top of the ranking with 4.9%, Sweden comes second with 4%, then Finland with 3.5% and the US with 2.6%. As a conclusion, with the exception of Hong Kong, all countries similar or more developed than Chile invest more in R&D, as a fraction of the GDP, since their development was similar to the one in Chile (CNIC, 2007).

In the case of Chile, the lack of infrastructure and human resources were the justifications supporting the implementation of the Millennium Initiatives. In the first stage of the MSI three institutes and five nuclei were created. One of them was created to perform nanotechnology research (Physics of Condensed Materials) headquartered in the

[6] Venezuela, Mexico and Brazil later initiated similar programs.

Universidad Técnica Federico Santa María (ICM, s/f.a). During the second stage, five research nuclei were created, but none of them oriented towards nanotechnology research. For the third stage, inaugurated in 2002 and implemented in 2003, a new project related to nanotechnology research was approved. It was headquartered at the Universidad Andrés Bello (Material science and nanotechnology, organic physiochemical and theory of densities) and the program of Physics of Condensed Materials was extended for another three years (ICM s/f.b). The next chart provides a summary of the initiatives in chronological order, highlighting the ones related to nanotechnology research;

Scientific Millenium Initiatives. Chile 1999 -2006 [7]

Year	Number of Institutes or Nuclei created	Name of the Institute or Nuclei	Headquarters
1999	3 Institutes 5 Nuclei	● Physics of Condensed Materials	● Universidad Técnica Federico Santa María
2001	5 Nuclei	------	-----
2002	3 Institutes	● Quantico Applied Mechanics and chemical informatics (Nucleus)	● U. Andrés Bello
2003	3 Institutes 8 Nuclei	● Physics of Condensed Materials (Nucleus- renewed)	● U. Técnica Federico Santa María
2004	3 Institutes 12 Nuclei	-----	-----
2005	3 Institutes 15 Nuclei	-----	-----
2006 (increased with "Royalty Law Funds"[8]	5 Institutes 17 Nuclei	-----	-----

Source: ICM, 2006; ICM s/f.a; ICM s/f.b).

The MSI's provided marginal support for nanotechnology development; they oriented their research efforts toward other areas, such as biotechnologies and biology. Areas that had a stronger research tradition received greater support in Chile (however it is possible that in the area of biotechnology they had some projects dealing with nanobiotechnology not considered in the previous chart). Despite the lack of support, the only two research projects dealing with nanotechnology provided an important framework for a country where the support to this kind of project was scarce. Although the spirit of the MSI's was to create institutes and research nuclei able to compete with their counterparts in developed countries, in practice they were under-funded. These projects had a medium budget of US $290,000 for three years but with the possibility of just one renewal, which in the long term weakened the feasibility of the projects (Angel, 2003). Some extra

[7] The information on Nanotechnology is approximate. The criteria employed were keyword indicators in the title or project description (nanotechnology, nanosciences, nanoscopic, nanostructured, nanocapsules).

[8] The resources that were coming from the Royalty Law to encourage innovation and competitiveness increased in 100% in 2007. This will allow the financing of another five institutes and 17 research nuclei in the country (MIDEPLAN, 2006).

resources came from the "Royalty" Law approved in 2006. This regulation imposes taxes over the exploitation of natural resources used for scientific innovation. This would increase the resources used in the implementation of new projects and the development of new research nuclei.[9] However, it is worth mentioning that the total amount of resources are miniscule in relation to the size of the economy, as pointed out by the Chilean economist and member of the council of the Millennium Initiative, French Davis (2006).

As part of the Bicentennial Program of Science and Technology, the *"Anillos de Investigacion de Ciencia y Tecnologia"* (Research Rings of Science and Technology) were financed for three years. These rings are research networks formed by universities and research centers. Calls for grants were organized in 2004 and 2005 but only in 2006 some research rings doing nanotechnology research were approved, as illustrated in the following chart;

"Rings" oriented to nanotechnology research and approved by The Bicentennial Program of Science and Technology in Chile (2006)

	Name of the ring	Associated University
University U. de Chile	Molecular Simulation of Nanomaterials and Biological Experimental Systems	Universidad de Talca
U. de Santiago de Chile	Magnetism: From Nanoscale to Macro scale	Univ. Técnica Federico Santa María Universidad de la Frontera. Pontificia Pontificia Univ. Católica de Chile
U. Técnica Federico Santa María	Multidisciplinary Research of Hybrid Nanostructures	Universidad de Valparaíso.
U. Técnica Federico Santa María	Subatomic Research Center	Pontificia Univ. Católica de Chile Universidad Austral de Chile

Source: CONICYT – World Bank, s/f.b.

Within the framework of the Bicentennial Program of Science and Technology several *"Talleres de Articulacion"* (Articulation Workshops) were implemented to motivate academics and students to pursue subjects related to technology and innovation. At the end of 2005, two workshops dealing with nanotechnology were opened. The first was organized in May 2006 by the Universidad Técnica Federico Santa María in partnership with several universities (CONICYT – Banco Mundial, s/f c). The second was organized by the Pontificia Universidad Católica de Chile and the Universidad de Santiago de Chile, and the participation of some others in October 2006 (CONICYT – Banco Mundial, s/f d).

3. Nanotechnology Research Areas in Chile

Zumelzu (2006) offers a revision of the current research projects in nanotechnology in Chile. He identifies several main institutions: the Universidad de Chile, the Universidad Técnica Federico Santa María; the Pontificia Universidad Católica de Chile and the Universidad de Santiago de Chile. The following chart provides a summary of the institutions, the research projects and the sources of funding;

[9] In order to allocate the resources coming from The Royalty Law, the National Council of Innovation and Competitiveness was created. The name reflects the main interest of Chilean S&T policy: international competitiveness. It remains to be seen if competitiveness can encourage development, understanding it as the reduction of poverty and inequality.

Research Groups in Nanotechnology and Main Research Topics for Chile

Universities	Topics	Fund
Universidad Técnica Federico Santa María. Red con varias otras universidades	● Physics of Condensed Materials (Magnetism in low dimensions)	ICM (1999-2005)
Centro para la Investigación Interdisciplinaria Avanzada en Ciencia de los Materiales. Universidad de Chile.	● Quantic materials to produce confined effects detectable in the ionic, electronic and photonic properties. ● Surface characterization and preparation of nanodusts deficient in oxygen via hydrogen condensation ● Thin films working in the superficial dispersion of electrons over the transport mechanisms of electricity surrounded by rough surfaces ● Production of Nanoparticles of copper to elaborate high conductivity polymers ● Magnet Nanoparticles to treat cancer and Alzheimer's	FONDAP 1999…
Pontificia Universidad Católica de Chile	● Electrical conductivity in thin films of copper and palladium under oxidation ● Magnetic exchange analysis	FONDECYT
Universidad de Santiago de Chile	● Nanocristaline evolution and micro structural research during the processes of mechanic alloying ● Research of the phenomena and processes of the transport of fluids at the micro and nanoscales in non-conventional systems ● Transport of micro and nano particles using biological systems ● Transport of fluids and heat with microelectronic and nanocomponents ● Transport and characterization of fluids in arteries and brain aneurysms ● Characterization of nano fluids in the interphase between the hard disk surface and the reading/writing component of a high speed storage systems ● Nanofluids and heat transfer at the nanometric scale, artificial organs and chaos theory in fluid mechanics	
Universidad de Concepción	● Advanced compounds and polymers, such as the production of Nanoparticles of copper for the industry particularly to be used in the energy sector; the creation of new nanostructure surfaces based on cellular membranes and their biological and chemical effects; nanocoloidal particles and research of new materials ● Synthesis and application of organic compounds, development of macromolecular matrix, including metallic Nanoparticles	

Source: Data taken from Zumelzu (2006) with addition from Correa (2005), CONICYT (2005, March); Universidad de Santiago (2007), and own data.

Despite the number of institutions and projects created to support nanotechnology development in Chile there were not many researchers working in the field. Guzman (in Rojas, 2006) estimates that today 15 researchers are directing nanotechnology in Chile. Although this number does not take into consideration the scientists working in the area of nanobiotechnology, the fact of the matter is that the number of researchers working with nanotechnology in Chile is very small.

Surprising, however, is he lack of information regarding the creation of programs looking at the possible risks of using nanotechnology, as well as the social and economic impacts of applying it. This is particularly important if we consider that more than 80% of the Chilean research is conducted in public institutions. Social sciences seem to be absent in the discussion about chilean nanotechnology development.[10]

4. The Dark Side of Nanotechnology in Chile: The United States' Military Presence

Another kind of nanotechnology research in Chile is the one led by US military interests. The US interest in developing S&T in Latin America is explicit and despite much of the information about the financial and human resources is available on line via the internet; direct contacts are always made to facilitate future collaborations. For that reason, in April 2004, the US Navy and the Air Force held a forum in Washington D.C., called *Latin America Science & Technology* Forum, with the main purpose of "increasing the U.S. leadership's awareness of the progress of Science and Technology ("S&T") in Latin America"(ONRG, 2004a). Top representatives from civil institutions connected to S&T from Argentina (Vice-Director of CONICET), from Chile (Director of FONDEF-CONICYT) and from Mexico (Director of Scientific Research of CONICYT) presented the status of S&T in their countries. It gave the impression that top officials had the obligation of informing the US military about the condition of S&T in Latin America. At any rate, these schemes of collaboration have been complemented by official visits to Latin America. At the end of March 2002, the Associated Director of the International Area of the Naval Research Office of the US visited la Universidad de Concepción in Chile with the purpose of identifying the research areas that could be integrated inside an agreement (Panorama en Internet, 2002).

The US Armed Forces have, at least, 3 branches financing scientific research (including nanotechnology) in public, private universities and research centers, in many countries: Army, Navy, and Air Force.[11] These three branches work in partnership with the International Technology Centers to execute research programs on S&T. To organize this, there are centers such as the ITC-Atlantic, headquartered in London to cover Europe, Africa and Asia, including the area of the former Soviet Union; the ITC-Pacific headquartered in Tokyo to cover the rest of Asia and the Southern part of Africa.

In 2004, the ITC-Americas headquartered in Santiago de Chile is created to cover Latin America and the Caribbean, including Canada (U.S. Army ITC-Atlantic, s/f b). Equally to the other regional ITCs, the ITC-Americas in Chile has the objective:

> ...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." (International Division U.S. Army Research, Development

[10] ...despite the lack of analysis about the social and economic impacts of nanotechnology, as well as the potential risks of using in this technology. However, there is a law presented in 2006 against the importation of products containing nanocomponents. (Navarro 2006).

[11] In 1940, just before the United States entered into the Second World War, U.S. President Franklin Roosevelt created the OSRD. The purpose of this office was to orient research to develop the military needs and armament. Traditionally, the military system used to encourage engineering and production, but not basic research. The OSRD became the first official governmental office to take care of basic research. For the first in US history, the relationship between S&T and the military interests was clear (White, 2002).

and Engineering Command, 2004).

The direct support received by research projects working with nanotechnology in Latin America was never delayed. According to the web page of the US Navy, since 2004 it has been financing a joint project between the Atomic Center of Bariloche in Argentina, the University of Michigan, Brown University and the Naval Research Laboratory; another project was created in the same year with collaboration of the Universidad de São Paulo in Brazil (ONRG, 2004b). However, in order to finance these research projects, the US Army had to first know which scientists could meet its needs. For this reason, the US Navy, in association with the Air Force, held three international workshops in Latin America. The main focus of these workshops was on one topic of strategic importance for the US Defense Department: multifunctional materials (NMAB, chapter 3, 2003). The multifunctional materials are materials that have at least two particular properties. On one hand they can develop structural integrity (durability, survivability and security) and on the other, different kinds of new functions such as electrical, magnetic, optical, biological and others. The basic tools for developing these new materials are provided by micro and nanotechnology: this is why the US Navy and the Air Force have so much interest in shaping R&D in Latin America (AFOSR, 2005a).

> The multifunctional implies coupling between structural performance and other as-needed functionalities such as electrical, magnetic, optical, thermal, biological, and so forth. Structural integrity includes durability, survivability, reliability, and maintainability. This program thus focuses on developing and applying multifunctional mechanics principles and design methodology based on physics, chemistry, biology, and artificial intelligence to model and characterize the processing and performance of multifunctional material systems and devices at multiple scales. (AFOSR, 2005b).

These seminars were organized by Latin-Americans working at US-based Universities together with other US citizens in order to facilitate contact with Latin-Americans. Initially, most of the participants were from the US, but the presence of Latin-American scientists increased in the following seminars. The first seminar was held in Pucon, Chile, in October 2002, and from the 44 participants 3 were from Argentina (Centro Atómico Bariloche y Universidad de Buenos Aires), 2 from Brazil (Laboratório Nacional de Luz Sincrotón y Pontificia Universidad Católica de Río de Janeiro), 1 from México (Centro de Investigaciones en Materiales Avanzados del Instituto Politécnico Nacional) and 3 from Chile (Pontifica Universidad Católica de Chile y Universidad Técnica Federico Santa María). In short, 9 Latin-American scientists overall. The second was held in Huatulco, Oaxaca, México, in 2004. From the 35 participants, 12 were coming from Latin America; 5 from Argentina (CAB, UBA, Centro Atómico Constituyentes y Comisión Nacional de Energía Atómica), 1 from Brazil (LNLS), 3 researchers from México (CINVESTAV-IPN, Universidad Nacional Autónoma de México), 2 from Chile (PUC-Chile y UTFSM) and one from the Universidad del Valle of Colombia. The third seminar was held in March 2006 in Bariloche, Argentina, where 35 scientists met: 6 from Argentina (CAB, CNEA, CAC and UBA), 3 from Brazil (LNLS, Universidad de Estadual de Campinas-Física and the Universidade Federal da Bahia), 2 or 3 from México (CINVESTAV-IPN and with the invitation but unconfirmed attendance of the Instituto Potosino de Investigaciones en Ciencia y Tecnología[12]) and one from Chile (Universidad de Chile) (ONR, 2002, 2004, 2006; U.S. Embassy Chile, s/f; Ulloa, 2004). This means that in the first meeting, less than a quarter of the participants were

[12] In this case both sources consulted did not match.

Latin-Americans. At the next meeting they made up one-third of the audience, but in all three seminars there was always at least one Chilean scientist.

The US military presence in nanotechnology research in Latin America has not been exclusively of military institutions encouraging S&T. There are broader possibilities to foster nanotechnology research that fell under different kinds of agreements such as the *Security and Prosperity Partnership of North America* (SPPNA) signed in 2005 by México, the US and Canada. This agreement encourages R&D in partnerships in areas such as biotechnology and nanotechnology, under a framework controlled by the US military (SPPNA, 2005). The US military presence is not reduced to the partnership between the civil sector and the military; there is also involvement from the Latin-American armed forces. An example of this would be the meeting held in Buenos Aires in June 2006, called "*The Contribution of Science and Technology to support Peace Keeping Operations and Disaster Relief Operation in Catastrophes"* where military experts from different countries such as Argentina, Bolivia, Brazil, Canada, Chile, Uruguay, Colombia, El Salvador, Mexico, Guatemala, Nicaragua, Paraguay, Peru, Uruguay, the Dominican Republic and Venezuela were present. The results went beyond what the title of this conference entailed, since it was agreed that in the future, conferences topics such as "the application of non-lethal technologies for crowd control; water purification and distribution; electric power generation and food preservation" were to be discussed (USARSO, 2006).

Final Reflections

Nanotechnology is a scientific area of rapid growth worldwide; many consider it as the basis for the next industrial revolution. It is possible that in the near future no country would be able to escape from the necessity of researching and developing this technology. Today, many countries argue in favor of investing public funds to develop nanotechnology in the search for increasing competitiveness. That is the case of Chile.

Despite all good intentions, there are several aspects to be taken into consideration in the case of Chile, such as the health risks and the environmental consequences of the potential use of nanotechnology. It is known that the small size of nanoparticles and nanocomponents makes them more reactive and mobile than any other components of regular size. In an article published by the British magazine *Nature* in 2006, 14 leading researchers in toxicology warned about the potential risks of the use of nanoparticles. They warned about the need to take into consideration the surface area, the chemical attributes of the surface, the solubility and of course, the size when researching and using nanoparticles because most of these aspects are not considered when scientists work with macro particles (Maynard, et al, 2006, 267).

Another area of concern is the commercialization of products containing nanocomponents that could change the international division of labor. This can, without any doubt, undermine the conditions of the working classes. On one hand, nanotechnology can reduce the amount of labor in many areas of production such as: the productive process, during the manipulation of the product, the storing process and during the transportation. On the other, because the substitution of natural resources will change the geographical requirements to open industries and in consequence the work force will be displaced in the search for jobs.

Another important area of concern inside the Chilean case is the one related to

property ownership and patents. It is difficult to comply with the rules controlling nanocomponents and to fully obey the patents regime; particularly because most of these products are not considered under current regulations. In the US, there has been an increase in the number of trials dealing with nanotechnology patents. In addition, there is the issue of foreign trade agreements that make the dynamic more complicated to follow. In practice, all trade agreements have clauses that regulate property rights, but little has been researched about who gets the benefits and the obstacles imposed to patent registration under the legal framework of these agreements (Chimuris & Galindo, 2007). The justification to allocate public funds for nanotechnology development in Chile is the increase in competitiveness. However, the fact of the matter is that the production of nanocomponents is being centralized and is subordinated to the control of large multinational corporations (Científica, 2007). Underdeveloped countries must therefore be cautious about the possible role they would play in the international division of labor after developing and using nanotechnologies.

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