

Bionanotechnology and Iran

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This paper will explore institutional factors in order to understand potential international security implication of Iran's bionanotechnology research and development programs, infrastructure, and capabilities emphasizing the biomedical engineering applications. The work seeks to enable the development of models of strategic interaction to assess the prospective implications of the nanotechnology for international conflict and cooperation. This project contributes to the development of a theoretical framework to assess motivation to pursue offensive versus defensive (or civilian) applications of bionanotechnology. Technically robust scenarios may illustrate the potential malfeasant cooption of nanotechnology.

Motivation

Among the highest priorities for the United States is preventing the acquisition and use of advanced chemical and biological agents by hostile states, sub-state actors, or terrorists. At the onset of the 21st Century, this has emerged as a national and international priority for today and also important for a wider range of future challenges.³ Understanding and anticipating the types of threats that may emerge as science and technology advance; the potential consequences of those threats; and the motivation for enemies to seek, to intentionally pursue proliferation, and to obtain unconventional weapons is necessary for preparing for the future security of the nation and allies.

While in the second half of the 20th Century, biology was a leading driver of technology, nanotechnology is emerging as the major science and technology focus of the 21st Century. Proponents assert that nanotechnology will revolutionize life as we know it; others have argued

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³ The US National Security Strategy (<http://www.whitehouse.gov/nsc/nss.html>), *the National Strategy to Combat Weapons of Mass Destruction*, (<http://www.whitehouse.gov/nsc/nss5.html>), and the *Quadrennial Defense Review (QDR) Report*, February 2006.

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that nanotechnology will yield doomsday scenarios and military applications of nanotechnology have even greater potential than nuclear weapons to radically change the balance of power.⁴

Today, all developed nations are vigorously pursuing nanotechnology developments with well-funded programs in the United States, China, Russia, Brazil, Iran, Israel, Taiwan, India, Japan, and all of Europe. The global nature of this research means that much of the nanotechnology advancement recently achieved, and that projected for the future, will likely be available to friends and foes.

Given the advances in and the ubiquitous nature of nanotechnology and biotechnology, understanding potential proliferation challenges and threats that states, sub-state actors, or non-state actors may wield through application of these and emerging analogous technologies is critical. Understanding analytically the social, political, economic, institutional, and motivational factors that contribute to pursuit of benevolent versus malevolent use of new technology is a national security concern and may aid in countermeasure development for emerging threats.

Nanotechnology in Iran

Currently, Iran is the leading country in technology research of all Muslim nations.⁵ Scholar Zi-Feng Yan states, “Today Iran is in a good position in the world of science, and nanotechnology is progressing rapidly in this country.”⁶ The potential threat of Iran has been a debated topic throughout the last decade. As a state considered to sponsor terrorism, there has been controversy and speculation over Iranian intent of technology development. As the debate continues about the threat that Iran possesses on a regional and an international level, it is necessary to analyze the role of its newly developed bionanotechnology programs in strengthening its defense strategy and implications for international security.

⁴ DE Jeremiah, “Nanotechnology and Global Security,” (Palo Alto, CA; Fourth Foresight Conference on Molecular Nanotechnology), 9 November 1995.

⁵ “Iran's Nanotechnology Ranks First In Region.” *Fars News Agency*. 20 July 2009.

⁶ “Iranian Nanotechnology Initiative Honors Chinese Scholar.” *Fars News Agency* [Tehran] 6 December 2008.

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For Iran, nanotechnology is largely seen as a means to achieve scientific prestige and technical prominence, particularly regionally. Iran has made steady scientific progress since 2001 in nanotechnology and has recently had significant achievements such as a ten-fold increase in scientific production and papers in just three years.⁷ In 2006, Iran submitted 250 nanotechnology-related papers to the Institute of Scientific Information placing the nation-state first among Muslim nations and thirty-second worldwide in terms of nanotechnology research.⁸ Five year plans have also been implemented aiming to increase innovation and resources for technology. While specific funding levels are difficult to assess, Iran has a nanotechnology strategy that has many similarities to the US National Nanotechnology Initiative (NNI), including a nanotechnology coordinating office.

In 2003, the Iranian Nanotechnology Initiative was established to gain access to develop, science, technology, nanotechnology within industry. Saeed Sarkar, head of the Iranian Nanotechnology Initiative recently noted Iran's advancement, "[w]hen the headquarters for nanotechnology (in Iran) was established in 2004 we ranked 57 in the world and we aimed to stand among the first 15 progressive nations in the field in 2015."⁹ The continued advancement is celebrated as a sense of pride throughout the nation. There are presently fifteen M.S. programs and five PhD programs in nanotechnology throughout the nation.

Iran is not only developing nanotechnology, but it is also discovering methods to apply it in several fields. Recently, Iranian researchers have announced that they have created a nano-bioactive dressing with purpose to accelerate wound healing.¹⁰ At the University of Kashan, students at the nanotechnology research center are dedicated to harnessing the new technology to develop magnetic capacitors at nano dimensions as well as creating nano catalysts to improve water purification techniques.¹¹ The application of bionanotechnology to various fields signifies a substantial advancement from basic research. With Iran's pursuit of expanding its regional influence, it can be assumed that Iran will seek progress through all methods of application of

⁷ Firouzeh Mirrazavi. "Scientific Advances of Iranians." *Iran Review*. 5 February 2008.
<<http://www.iranreview.org/content/view/663/37/>>.

⁸ "Iran's nanotech progress impressive: ISI figures." 15 January 2007.

<<http://www.iranmania.com/News/ArticleView/Default.asp?NewsCode=48869&NewsKind=Current%20Affairs>>

⁹ "Iran's Nanotechnology Ranks First In Region." *Fars News Agency*. 20 July 2009.

¹⁰ "Iran Makes Nano-Bioactive Dressing." *Fars News Agency*. 1 December 2008.

¹¹ "Iranian Provincial TV Shows Nanotechnology Activities at University of Kashan." *Fars News Agency* 23 October 2008.

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bionanotechnology, whether for peaceful purposes or for those of concern to international security is not clear.

Organization and Innovation System

Under the President of Iran, the Ministry of Science, Research, and Technology (MSRT); the Technology Cooperation Office; and the Supreme Council for Science, Research, and Technology have been created to fund and to promote innovation and specific research goals. The MSRT serves as the coordinating body for science and technology policymaking and national innovation across a large number of vertically integrated ministries. Some of the asserted strategic goals of the Ministry are to design an innovation strategy, to strengthen measures to support transparency and accountability, to implement innovation strategies, to foster research and technological capacity through joint ventures and licensing agreements, and to target the industry. In return, the research institutions and universities help ministries facilitate decisions relating to research priorities by monitoring technological developments and providing feedback. Additionally large enterprises are seen to rely on research institutes for product development and process innovation. Since 2006, there have been 216 research institutes under the MSRT.

While still overwhelmingly dominated by the state, there have been small steps recently to incorporation of competition between companies for different products and ideas. The main actors in the Iranian innovation system remain state-owned research institutes, universities, and enterprises. Other private organizations or groups have not traditionally had significant impact on innovation. Foreign company operations have largely been restricted to specific free zones where these operations were permitted. Impact on the overall economy and innovation has not been substantial. Demand and private enterprise were weak and motivation was low to develop new products. Although the hierarchy of ownership and production has not changed much, the government is slowly becoming more open to changes and augmenting research centers.

In Iran, nanotechnology research is not limited to one organization but is spread over numerous universities, research organizations, and specific research groups. Directly attached to the Ministry of Science, Research, and Technology is the biggest research center in Iran, the Iranian

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Research Organization for Science and Technology (IROST). Established in 1980 under the Revolutionary Council to financially and intellectually support innovators, inventors, researchers, and start-up companies, IROST reviews proposals from researchers and funds the projects and prototypes deemed worthy. It is estimated that one quarter of all Iranian university students are pursuing engineering curricula and 10% life or physical sciences. For engineering, the total number of Iranian graduates has increased from approximately 5000 in 1991 to over 14,000 a decade later.¹² With respect to innovation, IROST provides support services such as aiding technology transfer to third parties, acquiring production facilities and licenses from the Ministry of Industry and Mines for innovators, and recommending researchers to banks for low interest loans.¹³ It also offers policy recommendations for decision-making in development of national science and technology development.

Research Funding

The government of Iran has expressed its desire to expedite nanotechnology research. It continues to establish research institutes and university programs solely dedicated to nanotechnology research. Mohammed Mehdi Zahedi, minister of Science, Technology, and Research has emphasized the millions of dollars that Iran spends on nanotechnology each year.¹⁴

By far, the largest reported funder of research overall is the state (96%), with the remained from private enterprises.¹⁵ Less than 1% of the GDP is spent on research and development (R&D), and some 7 to 8% of the overall research budget is dedicated to basic research. The R&D budget is distributed roughly across the Ministry of Science, Research, and Technology (MSRT), which funds universities (20%); medical universities (10%); the agricultural sector (40%); and the remainder of the R&D budget (30%) is distributed among other sectors.

¹² United Nations Conference on Trade and Development. "Science, Technology and Innovation Policy Review The Islamic Republic of Iran." February 2005. <http://www.unctad.org/en/docs/iteipc20057_en.pdf>.

¹³ Ministry of Science, Research, and Technology: Iranian Research Organization for Science and Technology (IROST). 9 April 2009 <<http://www.irost.org/en/main.asp?code=1>>.

¹⁴ "Iran Spends Millions of Dollars of Developing Nanotech Each Year." *Fars News Agency* [Tehran] 29 Oct. 2009.

¹⁵ United Nations Conference on Trade and Development. "Science, Technology and Innovation Policy Review The Islamic Republic of Iran." February 2005. <http://www.unctad.org/en/docs/iteipc20057_en.pdf>.

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Although Iran has been expanding its technology in various areas, nanotechnology is a relatively recent area of much interest and support has been increasing significantly over the last few years. In 2006, the Iranian President Mahmoud Ahmadinejad told first Vice-President Parviz Davoudi to increase nanotechnology research by providing incentives for state and private companies, experts, scientific research and industrial centers.¹⁶ He indicated that all government organizations should spend a certain amount of money in their annual budgets for the progress of nanotechnology, as well as having national headquarters give reports every six months on the status of nanotechnology. Nanotechnology has been recognized repeatedly by the members of the Iranian parliament, the Majles, whose statements suggest that there is a substantial prestige factor associated with nanotechnology.

Rising Numbers of New Scientists and Engineers in Iran

The number of scientists and engineers graduating from Iranian universities has increased markedly from 1991 to 2001 although still representing a small percentage of the overall population. Iran’s science and engineering graduates more commonly come from private universities than in the US. The table below illustrates the total number of graduates in science and engineering, and the significant increase in a span of a decade. As seen for engineering, the total number of graduates more than doubled in ten years, increasing from 5649 to 13,838 between 1991 to 2001.¹⁷ The number of new scientists increased by a factor of three, rising from 4667 individual receiving degrees in scientific fields of study in 1991 to 13,959 in 2001.

Year	Sciences				Engineering			
	B.Sc	M.Sc	Ph.D	Total	BE	ME	Ph.D	Total
1991-92	4204	452	11	4667	5106	541	2	5649
1996-97	7332	861	37	8230	8075	1469	39	9583
1999-2000	10763	1058	128	11949	10497	1914	65	12476
2000-2001	12516	1300	143	13959	11467	2241	130	13838

Figure 3: The Number of university graduates in sciences and engineering (annually).¹⁸

¹⁶ “Iranian President Calls for National Nanotechnology Organization”. Defense and National Security Nano, Nanomaterials, and Nanotechnologies. 18 August 2006. <<http://nanomat.blogspot.com/2006/08/iranian-president-calls-for-national.html>>.

¹⁷ James J. F. Forest, Philip G. Altbach, “Iran” in International Handbook of Higher Education, Springer, 2006.

¹⁸ James J. F. Forest, Philip G. Altbach, “Iran” in International Handbook of Higher Education, Springer, 2006.

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In comparison with the United States, Iran has more students in private universities. There are currently about 3.4 million students enrolled in private universities in the US, approximately twenty-one percent of the population enrolled in universities is in a private university.¹⁹ Although in 2008, Iran's population reached 70 million, with approximately five percent of the population in universities or 3.5 million people.²⁰ While the absolute number is much smaller, the percentage is quite similar to the United States in which five percent of the population (15.9 million students) was enrolled in a university or college in 2004.²¹

Universities and Research Programs

Among Iranian universities, the Sharif University of Technology and Shahid Beheshti University have a prominent impact currently with respect to nanotechnology. The Sharif University of Technology is one of the most pronounced science and engineering schools in Iran. This public school is sometimes called the “MIT of Iran.” As Sharif University continues to emphasize research, efforts in nanotechnology are increasing. In 2005, the Institute for Nanoscience and Nanotechnology (INST) was established at Sharif University as an independent center that incorporates faculty members from various backgrounds.²² The INST is promoted as a national hub for nanotechnology in the country and purports to provide a network of researchers from various disciplines and supporting activities that are related to nanotechnology.²³ Its mission is to promoting nanotechnology in the university and in the country.

Currently, nanotechnology research projects are being pursued and incorporated in the laboratories of the Departments of Electrical Engineering, Physics, Materials Science and Engineering, and Chemistry and Chemical Engineering. For example, silver nanoparticles are

¹⁹ National Association of Independent Colleges and Universities. “Quick Facts about Private Colleges and Universities.” 23 April 2009. <<http://www.naicu.edu/about/quick-facts-about-private-colleges-and-universities>>.

²⁰ Payvand News. “Five percent of Iran's population are university students: Minister.” 20 August 2008. <<http://www.payvand.com/news/08/aug/1204.html>>.

²¹ U.S Census Bureau. “Facts for Features.” 6 July 2004. <http://www.census.gov/Press-Release/www/releases/archives/facts_for_features_special_editions/002263.html>.

²² Sohrabpour, Saeed. “From the President.” Sharif University of Technology. 2008. <<http://www.sharif.ir/en/about/president.jsp>>.

²³ Institute for Nanoscience and Nanotechnology: Sharif University. 15 April 2009 <<http://nano.sharif.ir/home.php>>.

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being used on fibers for application in antibacterial textiles. Nano electronics includes studying the thermoelectric effect in carbon nanotubes which can be further used for various applications such as electrical circuits. One of the leading academic groups in nanotechnology, the Nano-Coating Group, is currently researching new classes of inorganic nano-materials to produce phase-change nanostructured films by chemical routes, such as solution-phase deposition. These films will be used and evaluated in electronic devices. INST reports ten to fifty publications on nanotechnology related topics depending on the year.

An example of work in nano-medicine and nanobiotechnology being pursued in Iran can be found at Shahid Beheshti University of Medical Science. Considered one of the top five universities in Iran, its research and postgraduate programs are technically robust with a strong emphasis in nanotechnology research.²⁴ One example of nanobiotechnology research work is the reported synthesis of a nanotechnology-based vaccine for multi-drug resistant tuberculosis.²⁵ A single nanoparticle was found to alter the structure of a mycobacterium that causes tuberculosis and to subsequently destroy the pathogen. Researchers claimed to have developed a form of nanoencapsulation, which they call ‘nanocups,’ that specifically target a drug or any other compound to an infected organ and indicate success with clinical trials in patients.

Conclusions

The research groups and the universities described are prime examples of Iran’s efforts toward expanding its nanotechnology science and technology capabilities. Iran has made a considerable leap in terms of scientific achievements in the past few years. More institutions have been built and more limited foreign free zones have been established. This suggests that scientifically there is segment that is trying to become more involved abroad. Although the vast majority is still government-funded, it is gradually becoming more open to private institutions as a way to increase competition between companies and in return, the goal is to increase the innovation leading to more prestige for Iran’s science and technology sector.

²⁴ Payvand’s Iran News. “First nanotechnology center established in Kashan University”. 19 November 2004. <<http://www.payvand.com/news/04/nov/1161.html>>.

²⁵ Nanotechnology Now. “Iran treats multidrug-resistant TB”. 20 April 2008. <http://www.nanotech-now.com/news.cgi?story_id=29034>.

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Given this preliminary work to understand institutional factors, the implications for international security related directly to Iran's nanotechnology science and technology endeavors are ambiguous. Iran has recently begun collaborating more overseas with reputable institutions, including some in the United States. As Iran continues to produce new products and increase its research in various fields, it is likely to develop additional capabilities. In addition to Iran's progress, the funding that was once completely government owned is starting to expand slowly.

The tactics as to which to approach the Iranian situation are challenging to delineate. With Iran's insistence that it is developing its nuclear programs for benign purposes and continual doubt about this claim from the rest of the world, it is difficult to arrive at a conclusion about how to deal with the nation pursuits in other potential weapons technology areas. The ambiguous nature of Iran's programs provides a temporary safety net for their defense program, but it presents confusion among the rest of the international community. The exact vagueness can be seen through the following quote from Iranian President Ahmedinejad: "We have not invaded any country, we have not attacked any country, and we will not do so. The strategy of the Islamic Republic is not aggression against any country. We wish to improve knowledge in science."²⁶ He furthermore states, "The Iranian nation will never succumb to foreign hegemony, as it is endowed with enormous human and intellectual capabilities."²⁷ These contradicting statements demonstrate the continual vagueness surrounding Iran's security climate and the intertwining with the scientific and technological sectors.

In conclusion, a dual use conundrum exists in technology development. There will always be players who are determined to use technology to accomplish their malevolent intent. Both scientists and security officials must continually remain aware of this factor in order to proceed with new developments. Iran is an extremely complex state that must be understood better in order to formulate policy recommendations for dealing with the potential international security implications of bionanotechnology. Iranian internal politics and public opinion deeply influence their international policy.

²⁶ "Iran's President Praises Supreme Leader's Role in Guiding the Nation." *Tehran Mardom Salari*. 12 February 2009.

²⁷ "Iran's Not to Bow to Foreign 'Hegemony'" *Tehran Press TV Online*. 30 May 2009.