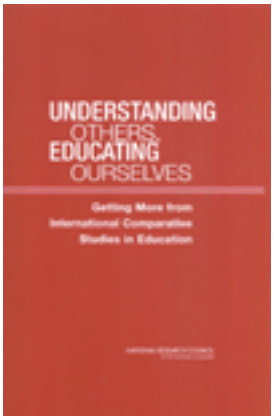

Science and Technology in Armenia: Toward a Knowledge-Based Economy

Committee on Science and Technology in Armenia, Office for Central Europe and Eurasia Development, Security, and Cooperation, National Research Council

ISBN: 0-309-54490-4, 135 pages, 6 x 9, (2004)

SCIENCE AND TECHNOLOGY IN ARMENIA

TOWARD A KNOWLEDGE-BASED ECONOMY

Committee on Science and Technology in Armenia
Office for Central Europe and Eurasia
Development, Security, and Cooperation
Policy and Global Affairs
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, N.W. Washington, DC 20001

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This publication was made possible through support provided by the U.S. Agency for International Development Mission to Armenia, under the terms of Award No. 111-A-00-03-00080-00. The opinions expressed in this publication are those of the National Research Council Committee on Science and Technology in Armenia and do not necessarily reflect the views of the U.S. Agency for International Development.

International Standard Book Number 0-309-09278-7 (Book)
International Standard Book Number 0-309-54490-4 (PDF)

Additional copies of this report are available from the National Academies Press, 500 Fifth Street, N.W., Lockbox 285, Washington, DC 20055; (800) 624-6242 or (202) 334-3313 (in the Washington metropolitan area); Internet, http://www.nap.edu.

Printed in the United States of America.

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Wm. A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. Wm. A. Wulf are chair and vice chair, respectively, of the National Research Council.

www.national-academies.org

NATIONAL RESEARCH COUNCIL (NRC) COMMITTEE ON SCIENCE AND TECHNOLOGY IN ARMENIA

John D. Baldeschwieler (chair)
J. Stanley Johnson Professor (emeritus)
California Institute of Technology

Robert P. Anex
Associate Professor of Agricultural and Biosystems Engineering
Iowa State University

Barry C. Barish
Linde Professor of Physics; Director, Laser Interferometer Gravitational-Wave Observatory
California Institute of Technology

John R. Filson
Scientist Emeritus
U.S. Geological Survey

Norman P. Neureiter
Director, Center for Science, Technology and Security Policy
American Association for the Advancement of Science

Abigail Salyers
Professor of Microbiology
University of Illinois at Urbana-Champaign

Biographical information on the committee members may be found in Appendix O.

NRC STAFF

Glenn Schweitzer
Director
Office for Central Europe and Eurasia

Kelly Robbins
Senior Program Officer
Office for Central Europe and Eurasia

Amy Moore
Program Assistant
Office for Central Europe and Eurasia

Acknowledgments

The committee greatly appreciates the assistance and hospitality of the organizations in Armenia that received its members. The National Academy of Sciences of the Republic of Armenia was particularly helpful in arranging visits to its institutions and facilitating visits to other organizations as well.

Ambassador John Ordway and the staffs of the U.S. Embassy and the U.S. Agency for International Development Mission in Yerevan also provided indispensable assistance to the committee in the form of information and contacts with Armenian organizations.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We wish to thank the following individuals for their review of this report: G.J. Reza Abbaschian, University of Florida; Mihran Agbabian, University of Southern California; Vartan Gregorian, Carnegie Corporation of New York; Charles Hess, University of California, Davis; Irving Lerch, The American Physical Society; Gerard Libaridian, University of Michigan; Bill Long, Organization for Economic Cooperation and Development (Retired); Edwin Przybylowicz, Eastman Kodak Company (Retired); and Joseph Silva, University of California, Davis.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Charles Tilly, Columbia University. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Preface

In February 2004, the National Research Council (NRC) arranged for a six-person committee of American specialists in scientific research, engineering, science and technology (S&T) policy, higher education, and small-business development to travel to Armenia at the request of the U.S. Ambassador in Yerevan. The purpose of the visit was to carry out an analysis of the current status and future development potential of Armenia's science and technology base that would be helpful to the Armenian government, the U.S. government, and other organizations that support economic and social development in the country, as well as the Armenian S&T community itself.

The U.S. Agency for International Development (USAID) provided financial support for the activity. USAID's five-year strategy for addressing development challenges in Armenia is updated annually. The most recent strategy is set forth in the USAID Armenia Strategy for 2004-2008 (available on-line at *http://www.usaid.gov/am/strategy.html*), and a description of current USAID program activities is set forth in Appendix A. Although support for science and technology is not indicated in these documents, USAID has assured the NRC that it would seriously consider the recommendations in this report.

The Statement of Task for this project was as follows: "An NRC ad hoc committee will analyze the current status and future development potential of Armenia's science and technology base, including human and infrastructural resources and research and educational capabilities. The committee will identify those fields and institutions offering promising opportunities for contributing to economic and social development, and particularly institutions having unique and important capabilities, worthy of support from international financial institu-

tions, private investment sources, and the Armenian and U.S. governments. The scope of the study will include both pure and applied research as well as education in science-related fields. The committee will prepare a report addressing the existing capacity of state and private research institutions, higher education capabilities and trends, scientific funding sources, innovative investment models, relevant success stories, factors hindering development of the science sector, potential domestic Armenian customers for scientific results and products, and opportunities for regional scientific collaboration."

The committee divided into three subgroups and visited 47 Armenian organizations (see Appendix B for a complete list). While many other entities are involved in S&T activities in Armenia, the visits provided a sampling of the capabilities and activities of the nation's leading organizations. The committee then prepared this report, supplementing their in-country findings with additional information gathered prior to and after the trip. Given the limited time in-country and the many other Armenian organizations involved in the topics of interest, this report is not intended to be comprehensive but rather to be indicative of impediments in developing a strong, self-sustaining S&T base in the country and of opportunities for cooperative activities. It emphasizes the contributions of S&T to economic development, which is an essential precursor to broad social development.

In accordance with the sponsor's request, the committee gave special attention to the following themes:

- Existing institutional capacity of research and development institutions, state research centers, small innovative firms, and medium-sized technology-oriented enterprises
- Higher education capacity and trends
- Funding sources for S&T
- Innovative investments in industry, agriculture, and business
- Success stories in S&T
- Factors hindering development of the science and engineering sector
- Customers in Armenia for products of science- and engineering-related investments
- Opportunities for regional scientific collaboration

Also, the committee considered the following issues set forth by the sponsor in varying levels of detail depending on the availability of information.

- Which sectors should be supported by private investors, large donors, small donors, and the limited budgetary resources of the Armenian government?
- What are the expected payoffs from investments in these sectors?
- What is the potential for job creation from investments in these sectors?
- What is the customer base in Armenia and in export markets for scientific findings and for science-based products?

- Does Armenia have unique scientific capabilities or existing infrastructures that are in short supply regionally or globally? Could these become scientifically significant and/or commercially useful?
- Which areas of S&T are unprofitable for investments in terms of job creation or other economic impacts?
- How can development assistance in S&T best be sustained so that Armenia can benefit?

In May 2004, the U.S. government established the Millennium Challenge Corporation (MCC) as a new mechanism for supporting development in selected countries. Since Armenia was selected as one of the 16 countries eligible for participation in the programs of the MCC, this report may take on greater significance than originally anticipated.

JOHN D. BALDESCHWIELER
Chair, NRC Committee on Science and Technology in Armenia

GLENN E. SCHWEITZER
Director, NRC Office for Central Europe and Eurasia

Population: 3.1 million

Area: 29,800 Km^2. (11,500 square miles); slightly larger than Maryland

Per capita GDP: $880 per year

GDP growth rate: 13.9%

Principal Industries: chemicals, electronic products, machinery, processed food, synthetic rubber, and textiles

Exports: $678.1 million—diamonds, scrap metal, machinery and equipment, brandy, copper ore

FIGURE P.1 Background information on Armenia. SOURCE: *Information*: U.S. Department of State, Background Note: Armenia, posted at *http://www.state.gov/r/pa/ei/bgn/5275.htm,* March 2004. Economic figures cited are from 2003. [Footnote revised in final editing.] It is generally believed that the actual population of the country is less than the most recent official census figure cited above due to high recent emigration. *Map*: U.S. Central Intelligence Agency, The World Factbook, posted at *http://www.cia.gov/cia/publications/factbook/geos/am.html,* May 2004.

Contents

List of Tables and Figures

TABLES

FIGURES

Executive Summary

Armenia has a long tradition of excellence in science, technology, and education. During the Soviet era, Armenian capabilities were oriented to a significant degree toward supporting the Soviet military-industrial complex. Research activities, particularly in physics, were well financed. Education in science and engineering received strong support. A number of industrial facilities operated throughout the country, providing goods for local consumption and for more distant markets within the Soviet Union.

With the disintegration of the Soviet Union, Armenia became isolated from many of its markets, and exports rapidly declined. As the economy spiraled downward, the budgets for research and education plummeted. A major exodus of technical talent began. Although many research and education institutions and a few industrial facilities remain, their capabilities have eroded considerably. Many laboratories and much equipment are obsolete, with little hope of replacement. Funds to cover costs of experimental work are scarce, and the funds that are available are not always directed to activities with high potential to build research capacity and lead to economic development. Paying customers for the results of research products are few in number. While educational standards remain high, the infrastructure supporting students continues to decline, and the "brain drain" has resulted in a serious deficiency of practicing scientists in the 25 to 40 age bracket.

Nevertheless, Armenian scientists who remained have persevered and have achieved impressive results despite severe financial limitations. Now more than ever, science and technology (S&T) are critically important to the future of Armenia. With few export sectors remaining from the Soviet era beyond foodstuffs, alcoholic beverages, and precious and non-precious stones, Armenia's

scientific manpower has become one of the country's strongest assets. From the scientific, economic, and political points of view, this asset should be nurtured and promoted to the fullest extent possible.

For the past decade, the international community has recognized Armenia's technical wherewithal and has provided substantial financial support for its maintenance, although the support is far from adequate to meet the demand. The International Science and Technology Center headquartered in Moscow has become the most important external source of funds for research, and the U.S. Civilian Research and Development Foundation also plays a significant role in supporting research, both directly and through the National Foundation of Science and Advanced Technologies (NFSAT). Various projects supported by the World Bank, the European Bank for Reconstruction and Development, and bilateral assistance programs of a number of donors also have technology dimensions. As is well known, remittances from Armenians living abroad are important in financing small activities (e.g., tuition for university students), and their donations occasionally support large projects (e.g., road construction).

However, in the aggregate, programs supported by more than 20 donors, together with programs of the Armenian government, are barely able to meet the subsistence-level payrolls of the science and engineering workforce. There are few funds for new activities that could eventually generate their own financial resources.

For Armenia to realize its science and technology potential, the following suggestions are offered:

- Strong Armenian government leadership is needed, including a long-term budgetary commitment, for upgrading the S&T base. While the Armenian government has set a reasonable target of devoting 3 percent of the total national budget to S&T, actual funding has been only about one-third of that level. This low level of support by the government has led to excessive dependence on foreign sources of funding for maintaining the nation's S&T capacity. Insistence by foreign funders on cost sharing by the Armenian government should be considered as a means of encouraging it to fulfill its budget commitments.
- A government mechanism should be established and funded to jump-start small entrepreneurs interested in developing promising innovative ideas with good market potential. U.S. experience with Small Business Innovation Research programs, which are operated by a number of federal departments and agencies to provide grants to stimulate technological innovation in the private sector, might be helpful in this regard. The appropriate funding level for this program could reach $10 million annually if the initial results are positive.
- A limited number of centers of excellence should be established through a competitive process to serve as focal points for research and for science services, with financial support from both Armenian and international sources. The cost of this program should reach a level of $10 million annually within several years.

- NFSAT is a model institution for the support of peer-reviewed research funding in Armenia and deserves a severalfold increase in its funding. Funding for new S&T programs such as those recommended in this report should be administered through NFSAT or organizations with comparable peer review processes.
- Armenian institutions of higher education should continue to modernize their structures and curricula and should make strong efforts to recruit young, foreign-educated faculty. A sustained program of visiting professorships would provide a useful mechanism for distinguished foreign faculty who could not only enrich curricular content but also contribute ideas on university organizational and administrative practices. In addition, selected laboratories for use by faculty and students in the universities should be upgraded.
- CANDLE (Center for the Advancement of Natural Discoveries using Light Emission) is an ambitious attempt to create a state-of-the art, next-generation facility with applications in a wide range of fields, from basic physics, chemistry, and biology to applied research in drug design, medical diagnostics, and environmental remediation. It should be supported through the next pre-construction phase of detailed engineering design and of testing the concept of manufacturing equipment in Armenia. This phase will require funding of up to $4 million over a two-year period.
- Efforts should be launched to improve the overall intellectual property rights system in Armenia, with particular attention to promoting better understanding among potential inventors of the importance of protecting intellectual property rights and of the procedures to obtain such protection. The intellectual property rights program of the International Science and Technology Center should be extended to serve Armenian institutes.

There have been a few successes in recent years. Private entrepreneurs in the information technology sector have developed an industry with annual export sales reported at $50 million. Also on the international scene, the Byurakan Observatory remains an important facility for optical astronomy. Modernization of the agricultural sector is leading to increased exports to countries of the former Soviet Union. Foreign students are paying substantial tuition to study at Armenian universities. Medical services are being offered to patients from nearby states as well as to Armenians. Small specialty companies are beginning to find niches in high-technology markets such as the production of fuel cells and the design and manufacture of circuit board components.

Areas that seem to offer promise for further development include the following:

- Information technology, and particularly software development
- Semiconductors
- Infrared detectors
- Large single crystals

- Laser technology and light detection and ranging (LIDAR) systems
- Precision electromechanical instruments
- Analytical services for the pharmaceutical, food, and chemical industries using advanced systems such as nuclear magnetic resonance
- Specialty chemicals
- Specialty materials
- Specialty agricultural products and processing
- Nutraceuticals and functional foods
- Genetic testing and other clinical laboratory services
- Human clinical trials
- Regional health centers
- Geological consulting
- Earthquake engineering
- Mineral refining

But in all of these areas, successful economic development based on S&T will require more than merely identifying research and technologies that seem to have economic potential in more mature market economies. It will require building the value chains that have the capacity to finance, develop, and market those promising technologies in a manner that returns value to the Armenian economy.

The handful of successes to date and the long menu of areas of potential interest for the future are encouraging, as is the resourcefulness of Armenian scientists in establishing and maintaining linkages with the international scientific community despite enormous challenges. Yet there will continue to be great difficulty in developing an internationally competitive S&T base and commercially viable innovative businesses. Limited research funds are currently spread over too many institutes and too many programs, and those activities that are not making significant contributions to science or economic development should be abandoned. At the same time, steps must be taken to provide more opportunities for young scientists and engineers to assume responsible positions with adequate compensation within the universities and research institutes that command international respect. With reasonable funding and more focused and determined efforts in the areas highlighted in this report, Armenia should be able to move forward toward a viable knowledge-based economy.[1]

[1]A knowledge-based economy is defined by the Organization for Economic Cooperation and Development as an economy that is "directly based on the production, distribution, and use of knowledge and information" (see *The Knowledge-Based Economy*, Organization for Economic Cooperation and Development, 1996, posted at *http://www.oecd.org/dataoecd/51/8/1913021.pdf*).

1

Overview of the Science, Technology, and Higher Education Infrastructure

HISTORICAL BACKGROUND

Following the collapse of the Soviet Union and the restoration of the independence of the Republic of Armenia in 1991 and continuing through the present, there has been a significant exodus of skilled professionals and talented students from Armenia due primarily to reduced economic opportunity. The depressed economy has resulted from the continuing effects of the devastating 1988 earthquake, economic blockades preventing trade with two neighboring states, and dislocations caused directly and indirectly by the conflict with Azerbaijan over the enclave of Nagorno-Karabakh. Combined with the serious energy shortage that Armenia experienced in 1992-1994, these hardships have caused a drastic reduction in national income. Although the Armenian government's economic restructuring efforts have produced encouraging growth indicators every year since 1995, with particularly strong improvements in the most recent years, poverty, unemployment, and underemployment remain substantial problems for the country.

Although Armenia is small and does not have oil, gas, or other natural resources in significant amounts, it possesses most types of science and technology (S&T) institutions characteristic of modern economies—from important educational institutions to state research institutes to innovative science-oriented firms. Almost all of these institutions are struggling with inadequate financial resources and with little evidence of impacts they are making on the lives of individual Armenians or on the country's economic development as a whole. Unlike most developing countries, however, there is an S&T tradition in Armenia

and a cadre of highly qualified specialists trained and educated during the Soviet era. Of course, during Soviet times their efforts were directed primarily toward serving the needs of the Soviet military complex and providing civilian products to other Soviet republics. The challenge now is to direct their skills and energies to endeavors that will help improve an economy that largely collapsed when access to these markets disappeared.

EXISTING INSTITUTIONAL CAPACITY

Structure and Role of Research

Successful scientific research requires institutions that can fund and guide research by identifying important problems, assembling research teams, and training future scientific leaders. Of no less importance are efforts to integrate the country's S&T capacity with national programs to promote economic development. In order to do this, the embryonic private sector must be able to draw on the resources of the state S&T sector for support of innovation activities.

The institutes and centers of the National Academy of Sciences of the Republic of Armenia (NAS-RA) include most of the country's research organizations. The NAS-RA has 37 institutes and centers organized into three divisions (see Appendix C for a complete list). According to the NAS-RA leadership, the Academy and its various institutes and centers employ nearly 4,000 people. By way of comparison, according to official Armenian government statistics, the entire Armenian research and development sector, including non-NAS-RA institutions, employed 6,737 people in 2002.[1]

The size and structure of the NAS-RA is a product of Armenia's Soviet past. The Academy was founded in 1943, as Armenia became a center of S&T research providing support services for the entire Soviet Union. The NAS-RA was organized to address both general areas of science and specific development issues. Now, there are a significant number of "orphan" science organizations, which had been created to meet a crisis or a need that has since disappeared or greatly diminished.

The collapse of the Soviet Union in 1991 significantly reduced the economic base that supports the NAS-RA and scientific research in Armenia in general and also reduced the demand for products of research. Diminished economic opportunity combined with the effects of the devastating 1988 earthquake in Armenia led many young scientists and engineers to seek jobs outside the country and often outside science. The war with Azerbaijan over the enclave of Nagorno-Karabakh further decreased the number of young scientists, both directly through the

[1]National Statistical Service of the Republic of Armenia. 2003. Statistical Yearbook of Armenia. Posted at *http://www.armstat.am/StatData/*.

requirements of military service and indirectly through dislocation of populations, reduction in government resources, and economic disruption.

These developments have led to an increase in the average age of the scientists of the NAS-RA, with relatively few between 30 and 50 years of age. The lack of scientists in their most productive years reduces the research capacity of the NAS-RA and limits its ability to attract and train new scientists. The problem is exacerbated by the fact that retirement from a position with a subsistence-level salary to a lower-paying pension is not a viable option for older NAS-RA scientists.

Some NAS-RA institutes and centers have strong capabilities and are making important scientific contributions. Others are of marginal viability—scientifically and financially. However, their employment of a significant number of people provides an important social safety net. Some NAS-RA employees are older workers who spent most of their careers within the Soviet science system and have few currently marketable skills. Although salaries are meager, they exceed the pensions that could be expected on retirement. Thus, the NAS-RA budget and organizational structure have a social rationale. Reorganization of the NAS-RA, which has been suggested many times, could entail significant social costs. It might also be difficult to reallocate funds saved from reduced Academy programs to support more productive scientific projects.

Government-funded research is performed under the auspices of government ministries, universities, and other institutions. Research performed by the ministries and non-NAS-RA institutes is often of an applied nature tailored to meet specific needs in Armenia. As such, this research may have limited transferability beyond the borders of Armenia, but it could be quite valuable where circumstances and technology needs are similar to those in Armenia.

Scientific research is also performed by a few companies, primarily small innovative firms. Such ventures have the potential to be important engines of economic development, but face several significant hurdles, including (1) a shortage of qualified specialists trained in technology transfer, marketing, and management; (2) a general lack of understanding of intellectual property issues and laws among technology entrepreneurs in Armenia; and (3) a lack of available credit on reasonable terms. Together, these factors make it very difficult for successful commercialization of the products of research.

An important objective of scientific institutions should be to promote high-quality research. Ideally, a focused effort to achieve this goal can lead to a "virtuous circle," with research and development leading to market opportunities, which then support training and more research and development. The engine that drives this cycle of economic development through S&T is high-quality, targeted research. This report examines public and private science and technology activities, ranging from basic to highly applied, but always with the objective of identifying those areas that have a potential economic and/or scientific return on investment.

Leading Institutions of Higher Education

Armenia has several important public institutions of higher education, including Yerevan State University, the State Engineering University of Armenia, the Yerevan State University of Architecture and Construction, the American University of Armenia, Yerevan State Medical University (YSMU), the Academy of Agriculture, and the Institute of Health. The committee concentrated on these major public institutions because they set the standard for the level of education in Armenia and provide leadership in curriculum development and research. A list of all institutions of higher education, public and private, is included in Appendix D. Table 1.1 provides data on the enrollment of students in Ph.D. programs in various disciplines.

In Armenia there is a strong popular aspiration for education, with every family striving to have its children at least finish high school. In the former Soviet Union, Armenia was the republic with the highest percentage of higher education attendees per capita. Science was a particularly popular field of study, and that

TABLE 1.1 Enrollment of Ph.D. Students by Discipline, 1998-2002

Discipline	1998	1999	2000	2001	2002
Physics and mathematics	106	120	90	95	101
Chemistry	12	16	26	27	30
Biology	69	71	52	83	75
Geology and mineralogy	12	6	8	26	48
Engineering	189	157	62	230	239
Agriculture	32	67	29	39	40
History	12	8	8	14	26
Economics	31	37	33	59	63
Philosophy	4	10	51	3	1
Philology	17	13	28	20	28
Geography	5	2	5	3	1
Law	5	8	12	8	19
Education	11	7	23	11	5
Medicine	48	64	66	95	73
Pharmacy	—	—	2	3	3
Veterinary medicine	10	15	66	45	45
Art	9	11	39	11	21
Architecture	20	8	7	11	9
Psychology	5	3	7	2	3
Sociology	1	4	3	7	4
Political science	1	—	—	3	—
Total	599	627	617	795	834

SOURCE: National Statistical Service of the Republic of Armenia, 2003. Statistical Yearbook of Armenia. Posted at *www.armstat.am/StatData/*.

trend still continues, although to a lesser extent. However, most students terminate their education after receiving the bachelor's degree, and few go on to obtain a Ph.D. This presents the problem of developing replacements for university faculty.

Armenian universities have several important strengths. First, the country has a long tradition of respect for all areas of science and for science educators. The pride of educators in their profession is evident at each of the institutions. Second, Armenian educators survived even the disastrous economic period that followed the disintegration of the former Soviet Union. Administrators at YSMU and other institutions are proud that in contrast to many other universities in the region, classes continued to be held despite severe shortages of electricity, heat, and other basic services during the worst years of this period. Although the decayed infrastructure that remains as a legacy of this period is still creating a drag on educational progress, the tenacity and inventiveness that the period of privation fostered are impressive. Armenians are not only survivors, but professionals who came through very tough times with their morale intact and their standards high.

There are many problems in higher education. At the top of the list is the missing cohort of middle-level faculty due to the mass emigration of scientists during the difficult economic times. Currently, the science faculties of the major institutions of higher education consist of a number of older scientists, many of whom are close to if not past retirement age, and a limited group of young scientists. The replenishment of the science faculties with younger members is being hindered by the lack of open positions and the low salaries offered for the jobs that are available. There are numerous stories about young scientists who had completed their training in the universities but ended up working as waiters or retail clerks because of a lack of opportunities to pursue scientific careers. Still, the number of current graduate students is far short of meeting needs to replace faculty members who will soon retire. In particular, software companies pay more than the universities, so graduates are going directly to salaried jobs, when available, instead of graduate school.

Another major problem is the lack of programs for students to travel to the United States or Europe or to otherwise interact with foreign scientists without encouraging "brain drain." University students and young scientists alike characterize older Armenian scientists as generally being distrustful of foreigners and not giving a high priority to providing opportunities for young scientists to travel. At the same time, older scientists speak frequently of their trips to meetings and their contacts with scientists in other countries. This contradiction reflects the disproportionate distribution of scarce funds for conference travel and research grants that favors senior scientists or those with connections. Although this pattern of resource allocation is by no means unique to Armenia, it is having a severe effect on the morale and education of young scientists who are vital for the continued development of Armenia.

Attracting talented young students to science and retaining them in the professions for which they are trained are also difficult. As mentioned previously, there are not enough scientific or technology-related jobs, and most that do exist are poorly paid. Investments in the science and technology sector of Armenian education and industry should place a high priority on salaries for young scientists, reflecting the great respect that scientists are accorded by the general population. Continued lack of support for those students who spend the considerable time and effort required to master a scientific area could well erode the esteem currently accorded scientists in Armenia.

Beyond financial support, exemptions from the military draft that accompany certain places for aspiring Ph.D. and master's degree candidates have a significant impact on interest in these places (see Table 1.2 for a breakdown of the number of slots available on a free and paid basis, with and without draft exemptions). While most students accepted for graduate studies are talented and deserving, the heavy competition for draft exemptions apparently creates opportunities for inequities, with places sometimes going not to the best students but to those with the resources or connections to secure them. In February 2004, the Armenian government attempted to address this issue by introducing a bill in parliament that would have eliminated all draft exemptions for postgraduate students. Students and others in the research and education communities protested, arguing that mandatory service for all would either spur prospective graduate students to leave the country or leave them hopelessly behind in their studies and unable to continue after their two-year term in the army. In the face of this

TABLE 1.2 Available Places in Master's and Ph.D. Programs at All Institutions in the 2003-2004 Academic Year

Master's Programs		
Free of charge		350
With draft exemption	250	
Without draft exemption	100	
Tuition charged (with draft exemption)		180
Total		530
Ph.D. Programs		
Free of charge		224
With draft exemption	150	
Without draft exemption	74	
Tuition charged (with draft exemption)		40
Free of charge, part-time study		145
Total		409

SOURCE: Government of Armenia Decree 289 according to Official Gazette No. 20 (255), as posted by the Economic Development and Research Center at *http://www.edrc.am/user_files/33.pdf.*

criticism, the government withdrew the proposal, stating that the matter would be given further consideration.

Yerevan State University

Yerevan State University (YSU) was founded in 1919. It renewed the ancient traditions of Armenian scholarship in language and history that during 600 years of foreign occupation had flourished only among the diaspora abroad. YSU continued to operate after Armenia became a Soviet Socialist Republic in 1921, and in 1999 it was reestablished as a self-governing, higher-educational, scientific, and cultural state institution. It is restructuring its program to confer degrees at the bachelor's, master's, and doctoral levels and currently has 20 faculties (divisions) comprising a total of 102 departments.

Of 74 graduates who received Ph.D.s in recent years, 36 percent stayed at the university as staff members. Of the 1,300 Ph.D.s currently on the teaching staff, one-half will retire during the next 10 to 15 years. At this rate, YSU is not generating enough Ph.D.s even to replace its retiring staff.

Yerevan State University has about 12,000 students, including 9,000 undergraduates. Some 4,000 are in the natural sciences. University leaders express the opinion that not enough Ph.D.s are awarded in the natural sciences and that Armenia should confer about 1,000 science Ph.D.s per year. They are less specific as to job opportunities, however. They attribute the shortage of science Ph.D. graduates to a lack of resources and advocate more financial support to keep graduate students in school.

YSU also has about 400 research fellows, and their output reportedly represents about 40 percent of all Armenian scientific and scholarly publications. Their work is supported primarily by grants from the Armenian government. These funds cannot be used to buy equipment, however. Additional support is thus needed from elsewhere, and foreign grants currently provide five to six times the amount of money received from Armenian government grants. The university currently has 10 grants from the International Science and Technology Center (ISTC)[2] and receives lower levels of support from the North Atlantic Treaty Organization (NATO), the Copernicus Program and other funding mechanisms of the European Union, the Initiatives for Proliferation Prevention program of the U.S. Department of Energy, the U.S. Civilian Research and Development Foundation (CRDF), and other foreign sources. Some researchers from the NAS-RA also work part-time as YSU faculty members. The university's rector has proposed to

[2]Headquartered in Moscow, the ISTC is an international organization established by the governments of the Russian Federation, the United States, the European Union, and Japan. It provides grants to former weapons scientists in the former Soviet Union to promote the redirection of their skills toward civilian-oriented research.

the NAS-RA that YSU and the Academy should create centers of excellence to integrate their capabilities in those areas of S&T in which they are strong.

The university's biggest problem lies in the need to modernize its infrastructure for the sciences. With the exception of isolated pieces of equipment, laboratories are woefully outdated and unable to provide students with the hands-on research experience they need to meet current scientific standards. Grants to support individual research projects alone are not adequate to the magnitude of the task at hand. According to YSU officials, modernizing all the research and teaching laboratories would cost about $5 million. Buying additional major pieces of specialized equipment could cost up to $2 million to $3 million for some purchases.

State Engineering University of Armenia

The State Engineering University of Armenia (SEUA) was established in 1991 as a reorganized successor to the Yerevan Polytechnic Institute, which was founded in 1933. Today SEUA has about 9,000 students studying at the main campus in Yerevan and four branch campuses, 200 of whom come from other countries. The university offers five different types of degrees[3] and includes departments of chemical and environmental engineering, computer systems and informatics, cybernetics, electrical engineering, mathematics, mechanical engineering, mechanics and machine sciences, mining engineering and metallurgy, power engineering, radio and communication systems, and transportation systems. SEUA has 1,022 full-time faculty and confers approximately 1,500 undergraduate and 200 graduate degrees each year. Tuition and fees for undergraduates from Armenia range from $300 to $400 per year; tuition for foreign students is about twice that amount.

SEUA developed a strategic plan in 2002 that clearly states the mission of the university, presents a vision of its aspirations, and sets forth its leading values and goals. These goals are broad, but the description of each includes specific actions that are needed and directions of growth in specific fields. The plan is clear and concise and offers a model that should be considered by other institutions in Armenia interested in orderly, long-term development.

Yerevan State University of Architecture and Construction

Yerevan State University of Architecture and Construction (YSUAC) specializes in fields related to architectural design and civil engineering. Within the

[3]Degree programs include the three-year junior engineer degree, the bachelor of engineering degree, the five-year diploma specialist degree, the master of engineering degree, and the two-year research engineer degree, the last of which, when followed by three years of supervised research, leads to the *kandidat* (Ph.D. equivalent) degree.

university there are five faculties: (1) architecture, (2) civil and industrial construction engineering, (3) construction technology and management, (4) hydro construction and urban administration, and (5) transport construction. Courses from all of these schools except for architecture are also offered on a correspondence basis. Within the five faculties there are 18 departments. The university has 350 faculty members and 2,250 students, with some 250 of the latter coming from outside Armenia. Master's degrees are awarded in engineering after a five-year course of study and in architecture after six years. The university is evolving toward a system of awarding credits toward degrees for specific courses.

The major problems facing the university are obsolete laboratory equipment, lack of modern computer equipment, and employment for graduates. The problem with computer equipment is not as acute as that with laboratory equipment. Some graduates are finding employment immediately after graduation, but job opportunities are not balanced evenly for graduates from all of the departments.

The YSUAC faculty members conduct research on about 40 topics, including transportation networks and energy issues related to closing the nuclear power plant, with funding for these efforts coming primarily from various Armenian government agencies.

American University of Armenia

The American University of Armenia (AUA) was founded in the early 1990s by Mihran Agbabian of the University of Southern California and Armen Der Kiureghian of the University of California, Berkeley. It maintains an affiliation agreement with the University of California system. Currently enrolling approximately 450 students, it offers master's programs only (no undergraduate or Ph.D. programs) in the following fields, with instruction conducted in English:

- Industrial engineering and systems management
- Business administration
- Computer and information science
- Law
- Comparative legal studies
- Political science
- Public health
- Teaching English as a foreign language

The AUA administration and faculty in general display an enterprising, can-do attitude. The School of Business and Management is of particular interest and importance. Its most recent graduating class included 57 M.B.A. students. All graduates in this program complete a semester-long practical internship in their second year of study, serving as consultants to small- and medium-sized businesses, manufacturing companies, government agencies, or nonprofit organi-

zations. AUA M.B.A. graduates are already beginning to have an impact on both the private and the public sectors in Armenia due to the excellent training they received.

The operating budget of the AUA is $3.5 million per year. Approximately $800,000 is contributed by the U.S. Agency for International Development (USAID), $600,000 per year by the Armenian General Benevolent Union, and $400,000 per year by the Lincy Foundation. Tuition provides an additional $200,000 per year ($1,500 per year per student), although most students are supported with fellowships.

Yerevan State Medical University

Yerevan State Medical University is the leading medical school in the country, with more than 4,000 students currently enrolled. Instruction is offered in three languages—Armenian, Russian, and English. YSMU leaders are very forward looking and stress their efforts to maintain the highest level of medical education. In terms of objectives for the quality of medical education offered, university officials aim to ensure that their students are able to transfer to other leading universities and pass medical examinations to practice in other countries. About one-half of the students come from foreign countries, principally China and India, thereby validating the quality of the program. Recently, students from Iran and other Middle Eastern countries have also begun to apply, and a small population of such students is currently in residence. Of course, medical universities in other countries of the former Soviet Union and beyond have similar ambitions and may provide significant competition for foreign students, which in turn provides added incentive for YSMU to continue upgrading its facilities and programs.

The success of YSMU in recruiting such a high proportion of foreign students suggests an interesting opportunity for economic development. Although Armenian students pay only several hundred dollars per year in tuition, foreign students are charged more than $2,500 per year. University leaders hope that the tuition for foreign students can increase and still attract these students, with $8,000-10,000 a year as the goal. There is currently an excess of doctors in Armenia, particularly specialists. Perhaps market forces will limit the number of domestic students considerably, with an increased influx of foreign students compensating for this reduction, thereby increasing the tuition income of the university.

The university has recently acquired funds from an Armenian-American sponsor to build a state-of-the-art ultrasound facility. Gynecological services will also be available. Construction is under way on a modern diagnostic imaging facility. It is hoped that such facilities will attract patients from other countries and that YSMU will become a center in the South Caucasus region for certain types of medical services.

University leaders indicated that the institution had already been involved in small human clinical trials and that the expertise to run such trials is certainly available, should U.S. or European pharmaceutical companies be interested. There is, however, no current marketing program and no infrastructure for handling the legal factors that are involved. Nonetheless, this area merits further exploration. Also, YSMU has the expertise for animal testing for pharmaceutical companies if assistance were provided to make the initial contacts and to establish the necessary quality control procedures.

Armenian Academy of Agriculture

While the Armenian Academy of Agriculture is overseen by the Ministry of Agriculture, the Academy itself has direct control over 80 percent of the programs involved in agricultural education and extension activity within the country. The Academy has recently completed an extensive revision of its curriculum. Emphasis is now being placed on agribusiness, food technology, and agricultural engineering.

In particular, the Center for Agribusiness Education has been established. Admission to the center is highly competitive, and all instruction is in English. There is also a strong emphasis on economics. Although the curriculum has been updated to include subjects such as agricultural economics and marketing, the Armenian agricultural sector has not yet matured sufficiently to absorb all of the graduates with these skills, and job placement for students in these fields remains a problem. The Academy has strong ties to Texas A&M University, which has helped with development of the agribusiness curriculum. The Academy has also obtained support from the U.S. Department of Agriculture (USDA) for the development of education in marketing assistance and other agribusiness topics and the administration of an extension program that serves Armenian farmers.

With funding from the USDA and the World Bank, the Academy participates in a program that offers grant support to faculty members and collaborating farmers for short-term scientific projects (approximately one year in duration) that have the potential for immediate application. About 25-30 of these projects are funded each year. The Academy is pursuing fundraising among Armenians in the United States and Europe that is intended to provide a continuing basis for support of this type of activity.

The size of the student body has been increasing, and its makeup is changing. Previously, most of the students came from Yerevan or other cities. Now, more than one-half come from rural areas. This trend is important because there are many new landowners in Armenia who have little agricultural training. The student population comes almost exclusively from Armenia, but the Academy hopes to attract foreign students, primarily from the South Caucasus region. The Academy's goal is to be a center for agribusiness in the area that will serve as a model not only for education, but also for research and agricultural practice.

The rector has identified several pressing concerns. First, the tuition paid by Armenian students is only about $200-300 a year, the lowest among Armenia's universities. This tuition barely covers expenses and leaves little for the development of research and extension activities. Second, there is a desperate need for new equipment for the teaching laboratories. Currently available laboratory equipment is 20 to 50 years out of date. Faculty members also lack modern equipment in the research laboratories. Students are expected to do research as part of Academy programs, but the quality of such projects is limited by the lack of equipment. Third, the number of veterinary graduates is insufficient to meet the needs of Armenian farmers and is below the number of veterinarians mandated by government policy. Finally, the Academy currently trains students in more than 30 specialties. Demand for some of these specialties has been low. The greatest demand is for students trained in such areas as food processing, enology, and veterinary medicine. The demand for specialists is increasing, but the Academy is reassessing the number and nature of the specialties in which it trains students with a view toward making students more employable.

Institute of Health

The Institute of Health is a government organization that conducts post-diploma programs for continuing medical education (CME) of doctors, dentists, and other health professionals. Each year, 2,500 of these professionals pass through the CME programs. The Institute administers a residency program that lasts from one to four years. Completing the residency program is now a legal requirement for all physicians who want to have their own practices. Institute officials are confident that the content of the residency programs and the quality of instruction are now up to international standards.

The Institute also oversees research projects and is responsible for such areas as quality control, establishment of guidelines for good medical practice, and development of diagnostic tests. Research projects address fields such as household safety, epidemiology, microbiology, endocrinology, and genetics. Although there is no central source of funding to support the Institute's research scientists, researchers have achieved some success in collaborating with U.S. and European universities to obtain grants. Also, they have obtained funds for equipment from Armenian-American foundations. Two Institute scientists recently obtained access to the Boston University library via the Internet, an interesting model for increased access by scientists to journals.

Several problems remain to be solved. First, there are too many specialized physicians and not enough general practitioners in Armenia. The World Bank is supporting a program to retrain more than 2,000 specialists to become family practitioners by 2008. Meanwhile, the Institute is working on determining the appropriate number of physicians that should be trained and the areas in which training is most needed. A second objective is to strengthen links with the U.S.

National Institutes of Health and with large U.S. and European universities to improve training and research opportunities. Improvement of contacts could be important for Armenian medical institutions to qualify as sites of human clinical trials in the future.

FUNDING FOR SCIENCE

There are three primary sources for the funding of research in Armenia: the government, international sources, and the private sector. Most government funding flows through the NAS-RA to its various institutes and through individual ministries to associated institutes and agencies. International sources support research and development in the NAS-RA, government institutes, the universities, and the private sector. Support for science from and in the private sector, where it exists, is directed toward specific applications or development of specific products.

Government Funding

Accuracy in numbers for the "funding of science" is always a matter of degree, even within the United States, since definitions of "science" funding vary among government agencies, nongovernmental organizations, and private enterprises. Scientific knowledge is applied in basic research, development of new products and techniques, and production of goods and services. In this report, the definition of funding for science is limited to funds devoted to basic and applied research and to the development of national scientific competence and capacity. Even in this restricted sense, the data on funding for science in Armenia are relatively unreliable.

In February 2004, the Armenian ambassador to the United States stated that "the government consistently increased science funding: this year's budget allocates approximately $6 million (1 percent of total government expenditures) to the scientific institutions" (see Appendix E for the complete text of his statement). Based on materials supplied by the NAS-RA, funding for the Academy in 2003 was $6.3 million, with almost $3 million coming from the government, $800,000 earned by performing services, and the remainder received from various international and private sources (see Figure 1.1 and Table 1.3). Thus, it appears that one-half of government funding for science goes to the NAS-RA to support 37 institutes and a total staff of about 4,000. On average, this is about $75,000 per year for each institute and less than $800 per year per staff member. These numbers may double if the total funding for the NAS-RA, including nongovernmental sources, is considered. However, reimbursable and international funding is not spread evenly over all Academy institutes. In addition, much of the international funding goes for equipment, travel, and field work, although the overall situation regarding the equipment infrastructure remains poor due to the limited

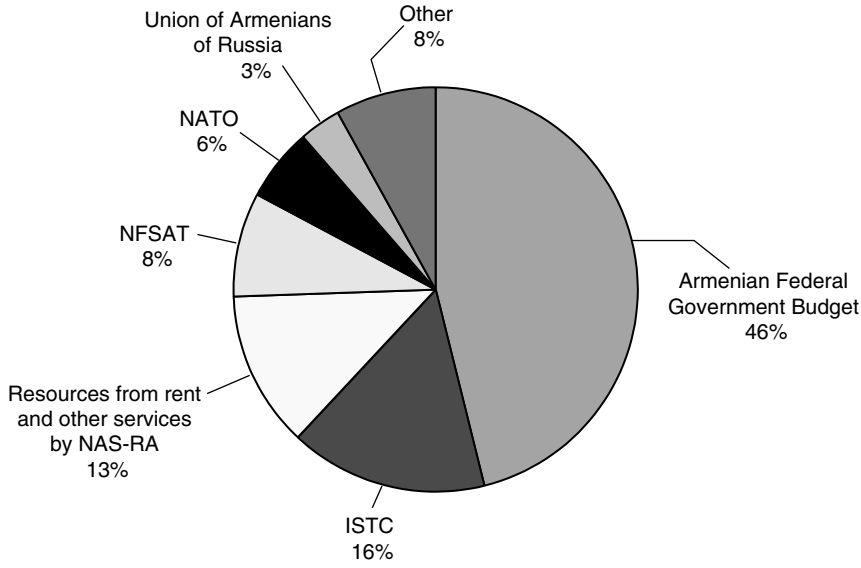

FIGURE 1.1 Sources of financing of the National Academy of Sciences of the Republic of Armenia, 2003. SOURCE: National Academy of Sciences of the Republic of Armenia, February 2004.

amount of funding available. Distribution of government funding for science is detailed in Table 1.4, which shows the 25 separate budget line items.

International Sources

Foreign sources have provided substantial support for science in Armenia since the breakup of the Soviet Union. These sources include international organizations, foreign governments, and nongovernmental organizations and individuals.

The International Science and Technology Center is an intergovernmental organization established in 1994 to engage weapons scientists, technicians, and engineers of the former Soviet Union in peaceful, civilian S&T activities. Non-weapons scientists can be included in ISTC projects. ISTC is the largest external funder of S&T in Armenia, and since its inception it has provided $20.4 million in support.[4] Among the projects most recently funded are efforts to develop new

[4]Figures provided by the ISTC, April 2004.

TABLE 1.3 Financing of the National Academy of Sciences of the Republic of Armenia, 2003

Financial Sources	Amount (dollars)
Budget (Armenian federal government)	2,925,927
ISTC	990,450
Proceeds from rent and other services	797,509
NFSAT	531,000
NATO	371,000
Union of Armenians of Russia	210,000
CRDF	89,300
INTAS	67,500
ANSEF	65,000
H. Vardanyan Foundation	64,789
USDA-FARA	55,100
DAAD	35,000
COPERNICUS-2	20,000
EU IST	20,000
Jinishyan Memorial Fund	15,000
UN SICS-WL	15,000
SCOPES	10,000
Nagao and Matsumae Foundations	9,900
M. Aschyan Foundation	8,921
U.K. Royal Society	8,600
Union of Armenians of Ukraine	8,500
UNESCO	8,000
National Assembly	4,942
Total	6,331,839

NOTE: ANSEF = Armenian National Science and Education Fund; DAAD = Deutscher Akademischer Austausch Dienst (German Academic Exchange Service); EU IST = European Union Information Society Technologies; FARA = Foundation for Applied Research and Agribusiness; INTAS = International Association for the Promotion of Cooperation with Scientists from the Newly Independent States of the Former Soviet Union; NFSAT = National Foundation for Science and Advanced Technology; SCOPES = Scientific Cooperation between Eastern Europe and Switzerland; UNESCO = United Nations Educational, Scientific, and Cultural Organization; UN ICSC-WL = United Nations International Center for Science and Culture–World Laboratory. SOURCE: National Academy of Sciences of the Republic of Armenia, February 2004.

drugs to treat AIDS and cardiovascular disease, to design a safer cooling system for the Metsamor nuclear plant, to create new polymer materials for the treatment of burns, and to synthesize new glass ceramics for a variety of industrial applications. Currently, more than 40 institutions in Armenia receive funding for at least one ISTC project. Many institutes collaborate on these projects and share support, and some institutes have multiple projects. In 2004, for example, Yerevan

TABLE 1.4 Financing for Science Provided by the Armenian Government Budget, 2003

Project	Amount Funded (million drams)	Percentage of Total Science Budget
Subsidies to the NAS-RA Presidium for the Maintenance and Development of Scientific and Scientific-Technical Infrastructure Program[a]	269.2	9.1
NAS-RA communications network	17.3	0.6
NAS-RA Arboretum	17.5	0.6
NAS-RA State Microbial Depository	7.2	0.2
NAS-RA Armenian Genocide Museum	14.5	0.5
Matenadaran (Mesrob Mashtots Research Institute of Ancient Manuscripts)	39.9	1.3
Subsidies for conferment of degrees in sciences	24.3	0.8
Institute of Management and Economic Reforms of the Ministry of State Property Management	19.0`	0.6
Subsidies for editing summary list of Armenian monuments	14.1	0.5
NAS-RA Center for Molecular Structure Research	8.0	0.3
Circular accelerator of the Yerevan Physics Institute and the Aragats and Norhamberd Cosmic Ray Analysis Stations	60.0	2.0
Contractual (subject) financing of scientific and scientific-technical activities under state contract	2,045.0	69.1
Subsidies to scientific-technical information network	12.5	0.4
NAS-RA Byurakan Observatory	9.0	0.3
NAS-RA Center for Medical Genetics	34.1	1.2
Big Radio Optic Observer of Radio Physics Measurement SRI and 11 national standards within the Program for Maintenance and Development of Scientific and Scientific-Technical Infrastructure	31.7	1.1

TABLE 1.4 Continued

Project	Amount Funded (million drams)	Percentage of Total Science Budget
Greenhouses of the NAS-RA Botanical Garden	2.3	0.1
Psychological Research Laboratory of the Abovyan Pedagogical University	3.8	0.1
Garni Observatory	1.9	0.1
NAS-RA Institute-Museum of Biology	2.5	0.1
Yerevan State University	10.0	0.3
State contract for NAS-RA Ph.D. and doctor of sciences degree programs	25.6	0.9
State contract for Ph.D. and doctor of sciences degree programs operated by the Ministry of Science and Education	24.4	0.8
Special research and design work requested by the Ministry of Defense	240.0	8.1
Program of targeted use of scientific potential	27.7	0.9
Total	2,961.5	100.0

NOTE: At the February 2004 exchange rate of approximately 560 drams to the dollar, the total figure of 2.96 billion drams equaled about $5.3 million.

[a]It is likely that a substantial portion of these funds goes toward maintenance of the existing infrastructure because the facilities visited by the committee held little if any new equipment that was not purchased with foreign grant funds.

SOURCE: Economic Development and Research Center, Simplified State Budget of Education and Science for 2003, posted at *http://www.edrc.am/user_files/33.pdf*.

State University had 19 ISTC projects and the Yerevan Physics Institute had 11. As indicated in Appendix F, 11 new ISTC projects valued at nearly $3.1 million were approved for Armenian institutes in 2003.

The U.S. Civilian Research and Development Foundation is a private, nonprofit organization created by the U.S. Congress in 1995. In addition to a wide range of other activities supporting scientific initiatives with the countries of the former Soviet Union, CRDF supports individual collaborative research projects

between U.S. and Armenian scientists through two programs: its region-wide Collaborative Grants Program (CGP), which offers grants for research partnerships involving most of the countries of the former Soviet Union, and its Bilateral Grants Program for Armenia only, which is administered in conjunction with the National Foundation of Science and Advanced Technologies (NFSAT). In 2003, CRDF approved seven U.S.-Armenian CGP projects at a total cost of $467,000 (see Appendix G). In addition to the collaborative research grants, CRDF also promotes industrial development through travel grants that allow foreign scientists, engineers, and managers, to travel to the United States in order to visit relevant companies and attend conferences and trade shows. To date, CRDF has supported a total of 235 grants in Armenia (60 of which were awarded and administered by NFSAT using CRDF funds) with an overall value of $4.3 million.

NFSAT was established by CRDF and the government of Armenia in 1997. An independent nonprofit organization modeled on Western competitive science funding agencies and principles, its mission is to offer merit-based support for Armenian investigator-initiated scientific and engineering research projects, with the ultimate goal of promoting scientific research and technological development in Armenia. Despite its rather brief history, the foundation has already become a significant mechanism for science funding, with the NAS-RA reporting NFSAT as its fourth-largest funder in 2003, at a level of more than one-half million dollars. In addition to the CGP mentioned above, which awarded 27 grants totaling more than $860,000 in 2002, NFSAT made the following awards in 2003:

- Instrumentation for scientific infrastructure: 6 grants, totaling $270,000
- Scientific conferences and workshops: 6 grants, totaling $41,800
- Travel grants: 31 grants, totaling $77,500
- Long-term travel grants and fellowships for scientists under age 35: 4 grants, totaling $22,500

It is also launching a new program entitled Basic Research in Universities and Integration of Science and Economy of Armenia. Although funding for NFSAT's other programs was provided entirely by CRDF, the Armenian government has announced that it will contribute approximately $200,000 for this new initiative.

According to NFSAT officials, the foundation is able to fund only about 10 percent of the research grant proposals it receives and many other proposals deserve support. Given the impressive peer review and grants management infrastructure that NFSAT has already created, a severalfold increase in its funding could provide support for important and scientifically worthy projects

Various U.S. agencies provided about $120 million for a wide range of bilateral programs in Armenia in fiscal year 2003 (see Appendix H), with democracy building, public health, agriculture, and small business development being the primary areas of focus. Except for support channeled through CRDF, none of these programs was narrowly defined in terms of S&T development, but several

programs, such as energy and water management and assistance in information technology and agribusiness, help nurture this development.

Various private organizations such as the Gulbenkian, Lincy, MacArthur, and Gates foundations and Armenian national groups such as the Union of Armenians of Russia and the U.S.-based Armenian General Benevolent Union and the Armenian National Science and Educational Fund provide limited support either directly or indirectly for the development of science in Armenia. NATO and the Organization for Security and Cooperation in Europe support scientific research and technology development projects in Armenia, such as the South Caucasus River Monitoring Project, but these investments are not large. Similarly, the United Nations Development Program (UNDP) and the United Nations Educational, Scientific, and Cultural Organization (UNESCO) support small, individual projects. One UNDP grant was to support a project at the Institute for Informatics and Automation Problems, and a UNESCO grant ($8,000) went to the Center for Ecological-Noosphere Studies to identify priority sites for biosphere reserves.

2

Review of Selected Sectors

This chapter sets forth an overview of those sectors of the Armenian economy in which science and technology (S&T) can play an important role in promoting economic development. The committee did not review all sectors or all institutions within selected sectors, but rather focused on those areas of particular relevance to S&T capacity and on those organizations they were able to visit. For each sector, the market for S&T products and services, impediments to development, potential payoffs in terms of job creation and other economic benefits, and potential sources of funding are discussed to the extent information is available. Several existing and potential examples of regional collaboration are also identified.

As far as technology development was concerned, the committee concentrated on applied research institutes and small firms and was unable to identify any large public- or private-sector firms. The large technology-oriented firms that existed during the Soviet period either downsized sharply or ceased operations, while the firms created since Armenia's independence remain small.

ENERGY AND ENVIRONMENTAL SCIENCES

The energy sector is stable at present after serious difficulties in the early 1990s due to the shutdown of the Armenian Nuclear Power Plant (ANNP) at Metsamor and the disruption of natural gas pipelines in the wake of disputes with neighboring Azerbaijan. This stability is threatened by political pressure from the international community to close the ANNP within the next decade and by the continuing reduction in hydroelectric power generation due to environmental problems caused by the lowering of the water level of Lake Sevan.

Privatization of the energy sector is nearly complete, and energy efficiency, metering, and cost recovery have been improved in the past few years. The distribution of natural gas and electricity in Armenia is controlled, or at least influenced, by private interests outside the country. A joint venture of the government of Armenia, Russia's Gazprom, and the Itera International Energy Corporation controls the distribution of natural gas. The electrical distribution company of Armenia was recently privatized and purchased by Midland Resources Holding, a company registered in the Channel Islands. The government is seeking investment partners to expand the thermal-steam production of electricity.

The contribution of renewable energy sources to the national energy pool is insignificant, and except for small hydropower plants, the government does not give high priority to development of these technologies. Because of its geology, topography, and climate, however, Armenia has the potential to develop renewable energy from water, wind, solar, and geothermal sources. Small private companies are developing and producing solar hot water and photovoltaic systems, biomass gas generators, fuel cells, and long-term uninterruptible power supplies. There also is private interest in developing pilot wind-driven power generation sites, but the economic benefits are not clear.

There are about 7,000 renewable energy companies and organizations around the world. The renewable energy sectors of national economies worldwide are usually based on small firms, at least in application. Some investments in this field in the United States and elsewhere have proven profitable. There are at least two examples of interesting private initiatives in Armenia. SolarEn is a company that employs about 25 people and produces solar-electric, solar-thermal, and biogas systems. The company also provides consulting services to the government, nongovernmental organizations, and the private sector. H_2 ECOnomy is a company involved in the production of prototype hydrogen fuel cells, backup power supplies that function over extended periods, and related electrical conversion and stabilization equipment. The domestic and foreign markets for environmental assessment and consulting should also be a source of employment and contribute to economic growth.

Domestic use of renewable energy is potentially quite high. With the lack of fossil fuels and eventual closing of the ANNP, Armenia must either develop the financing and infrastructure to import oil, gas, and electricity or develop independent internal energy sources. High-capacity, centralized internal sources will require investments in large facilities and extensive distribution systems. Small-scale, but widely used, renewable energy sources might substantially advance Armenia's energy independence.

The key question is: Can a significant small-scale renewable energy sector be established on a commercially feasible scale without subsidies, either to the developers and manufacturers of the generating equipment or to the customers who will purchase the products? This is difficult to determine without the development of a detailed and credible business plan, without greater insight into plans of

major power companies for the development of electrical and natural gas transmission networks in Armenia, and without a stable cost structure for energy from conventional sources. It is difficult to imagine that apartment dwellers in larger cities could provide a large customer base for alternative energy sources. The greatest application of small-scale renewable energy sources would probably be found in rural areas, but the ability of subsistence-level farmers to purchase the necessary equipment may be limited. Thus, it appears that the development and wide application of small-scale energy sources seem unlikely without subsidies at some level in the product chain.

The foreign market potential for renewable energy products such as fuel cells might be quite high, particularly if Armenian companies can develop a competitive edge based on technological innovation. Regional markets in nearby countries and perhaps in more distant states might create opportunities for Armenian entrepreneurship in this field.

In 2002, the Armenian government identified new energy sources as one of the S&T priorities for the country. The extent to which this action will direct research toward renewable energy is currently unknown. Also, large energy importers may be reluctant to permit the growth of renewable energy capacity that would threaten their profits.

The potential for job creation in renewable energy, although not large, could be significant, not only in the manufacture of renewable energy systems but also in their installation at home and abroad. Potential funding for the development of this sector will likely have to come from foreign sources, either as assistance, investment, or both. The Armenian government could help stimulate the sector with investment in research and development.

Because of past and present emphasis on the rapid development of Armenian natural and agricultural resources, there are domestic needs for environmental research and consulting services. These needs relate to support of environmental restoration efforts by the government and to expansion and development activities undertaken by private investment. Attention to the latter is of particular importance so that mistakes of the past are not repeated and exacerbated.

The competition in foreign markets for environmental consulting is expected to be high, and the potential for Armenian interests to capture a large part of this market is limited. However, with regional knowledge and experience, there should be some opportunity for international environmental consulting.

Energy- and environment-related research is conducted in the Ministry of Energy, with its Institutes of Energy Research and Atomic Energy, the Ministry of Nature Protection, and the Center for Ecological-Noosphere Studies of the National Academy of Sciences of the Republic of Armenia (NAS-RA). The Ministry of Nature Protection has laboratories for monitoring and sample analysis but has little interest in developing new techniques or monitoring equipment. The Center for Ecological-Noosphere Studies is an active group with strong leadership carrying out fundamental and applied studies in ecology and the health

of the environment. These studies involve South Caucasus river monitoring, quality assessment of nontraditional forages, and research on the paleoecology of Lake Sevan. The staff is relatively young, with many university students using the laboratory and computer facilities of the center for research.

Of particular relevance to the interests of the two ministries mentioned above is the Armenia Tree Project. Established in 1994 by a U.S-based foundation, the project is intended to reverse the denudation of forested areas that have been indiscriminately cut to provide urgently needed fuel during the past 15 years. In 2004, the project focused on expanding fruit tree production, extending community tree planting to local villages, and renewing devastated areas by regenerating abandoned stumps through the use of coppicing.

As the result of a gift provided by a private donor, the American University of Armenia (AUA) has created an Environmental Conservation and Research Center that offers courses and conducts research in environmental conservation and sustainable development. One of the center's recent products is the comprehensive book *A Field Guide to Birds of Armenia*.[1] It has a format familiar to generations of amateur ornithologists in the United States. It is hoped that the Armenian people will use the publication in birding and other outdoor activities and will increase their awareness of the problems of habitat preservation.

The Institute of Energy Research concentrates on domestic issues and does not engage in regional cooperation. The Center for Ecological-Noosphere Studies had six active grants from international organizations in 2003 that led to cooperation with scientists in the United Kingdom, Japan, Georgia, Belgium, and Norway. The Environmental Conservation and Research Center at AUA has cooperative efforts with the Ministry of Nature Protection in Armenia, the University of California at Santa Cruz, and Johns Hopkins University.

In principle, the countries of the South Caucasus—Armenia, Georgia, and Azerbaijan—could derive mutual benefits from cooperative studies of alternative energy sources and environmental issues. Energy transmission and distribution facilities might be more effective and efficient if considered in a regional context. Similarly, environmental problems caused by pollution of the atmosphere or hydrosphere in one country could have impacts in a neighboring state. Remedies for large-scale environmental problems are likely to require concerted regional actions. However, such cooperation in the near future seems unlikely due to the political standoff over Nagorno-Karabakh.

AGRICULTURE

Agriculture in Armenia changed dramatically when the highly centralized planning and production of the Soviet system was replaced by private ownership.

[1]Martin S. Adamian and Daniel Klem, Jr. 1997. A Field Guide to Birds of Armenia. American University of Armenia: Yerevan.

Land reform resulted in a large number of very small farms. Some new landowners had never been involved in managing or operating a farm. Another result of this restructuring was that much of the farm equipment and infrastructure designed for large-scale production was suddenly obsolete, and the agricultural production system had to be rebuilt to meet the constraints of disaggregated farm ownership. Despite these challenges, agricultural production is gradually increasing, and agricultural products are being exported to several markets.

Although Armenia is not fully self-sufficient in food production, it has the potential to gain economically through the export of high-value agricultural products. Historically, Armenia has exported significant amounts of fresh fruit and vegetables; however, many nearby markets for fresh produce are now closed to Armenia due to regional conflicts. Also, the transport of fresh produce to distant markets has become more complicated. As a result, the focus of current export efforts is on processed foods such as wine, preserves, smoked meats, dried fruit, and cheese. The U.S. Department of Agriculture (USDA) and the World Bank have implemented a successful, integrated marketing program aimed at agricultural products that may serve as an example for programs in other sectors.

The USDA program takes a holistic approach, one that considers the entire value chain from markets back through processing and production to education and research. After the dramatic restructuring in the agricultural sector, it became evident that there is a lack of training, technology, and information throughout the value chain. The USDA approach begins with identifying potential markets and working not only to provide marketing assistance but also to educate a new generation of people in appropriate marketing skills. In working back from markets to production, critical weaknesses related to financing, training, and technology are identified and solutions are designed to build local capacity. The USDA has responded by implementing a set of integrated programs designed to address the specific infrastructure, resource, or personnel needs at each stage in the value chain.

Many of the same vital value chain components that are missing in the agricultural sector are missing in other technology sectors. Indeed, skills, resources, and institutions critical to science- and technology-based economic development—such as knowledge of marketing, finance, and intellectual property protection; access to capital; and product development skills—are missing or undersupplied throughout the technology sectors of the Armenian economy. In Armenia, successful economic development based on S&T will require more than merely identifying research and technologies that seem to have economic potential and would readily realize this potential in more mature market economies. It will require helping to build the value chains that have the capacity to finance, develop, and market those promising technologies in a manner that returns value to the Armenian economy.

In addition to the traditional food products that are at the core of the USDA marketing program, the agriculture sector can produce goods with significantly

more added value. Functional foods or nutraceuticals—foods that provide health benefits beyond simple nutrition—represent a range of such products in the early stages of development in Armenia. Some examples are margarine with cholesterol-lowering natural additives, tea and juice enhanced with antioxidants reputed to prevent disease, and yogurt with added cultures to stimulate the immune system and promote healthy digestion. The Armenian Drug and Medical Technology Agency has developed several such functional food products based on apricots and other plants native to the region. Since the raw materials for producing these functional foods have traditionally grown in Armenia, the farming infrastructure is already in place.

Scientists at the NAS-RA Institute of Molecular Biology and the Microbial Repository are working on projects utilizing nitrogen-fixing bacteria that could result in useful products for agriculture. For example, researchers at the Microbial Repository have mixed nitrogen-fixing bacteria with zeolite, a volcanic material found in Armenia. They report that this product has increased yields of certain crops in field experiments and has been tested by a French company. Other scientists have been developing methods for producing cyclodextrins, oligosaccharide compounds used in pharmaceuticals, flavors, and fragrances. One method has been implemented in a production facility in Malaysia.

The microbial culture collections of the Microbial Repository and other institutes represent a resource that may have potential for development. There is a continuing need for novel strains of bacteria and fungi, particularly in the pharmaceutical and agricultural industries. There are Western companies that specialize in finding novel enzymes for diverse applications such as health care, food processing, oil recovery, and paper manufacturing. These firms find novel biochemicals by sampling microbial diversity all over the globe. Assessing the quality of the culture collections in Armenia will require additional effort, but licensing agreements might be possible between Armenian institutes that isolate and characterize microbes and companies that are seeking unusual microbes.

Although promising, the projects mentioned above involving implementation of technology related to nitrogen-fixing bacteria and cyclodextrins illustrate a fundamental weakness in the Armenian scientific community that must be remedied if economic development of such processes and products is to be successful. This weakness is the lack of expertise in protecting intellectual property rights. In both cases, technology was apparently revealed and transferred without proper intellectual property right protection or even clarification of payment terms. There is a need for scientists and engineers to understand intellectual property right issues and have access to expert help in gaining protection for their intellectual property and placing an appropriate economic value on it.

Another significant barrier is the lack of access to up-to-date information regarding scientific developments and markets. Armenian scientists are isolated due to regional conflicts and limited budgets and, as a result, are unable to keep up with the latest scientific developments and unaware of market possibilities in

other parts of the world. The lack of up-to-date equipment in research laboratories also hinders their efforts.

The potential for economic development in the non-food agricultural sector, although not large, could be significant. International markets in this area are growing rapidly, and functional foods, for example, are high-value products that are easily exported.

Funding for development of the agriculture sector is now coming from foreign assistance. Funding for non-food agricultural research and development might also be linked to foreign investment if intellectual property rights are protected so that the value of such investment can be captured.

COMPUTERS AND INFORMATION TECHNOLOGY

The general technological level of the computing and telecommunications infrastructure in Armenia is rather limited in terms of modern computer hardware, software, and bandwidth. Limited fiber-optic telecommunications exist; however, issues of monopoly control of the telecommunication systems in Armenia inhibit both access and development. Computing use in general is widespread but mostly at the level of personal or desktop computers. There are no large computer facilities available even in research laboratories. Also, there is very little integration of modern computing equipment into research laboratories, in terms of either controlling equipment or recording data. This situation reflects the lack of resources for such equipment.

On the other hand, developments in the software industry have been impressive, and the government has given high priority to this general area. Growth in information technology (IT) sales has been nearly 20 percent per year for the past several years, and IT sales now account for 2 percent of Armenia's gross domestic product.[2] Many small, private software firms have emerged in recent years, working primarily through outsourcing contracts with large Western software firms. Some Western firms have established branches in Armenia.

In general, IT is a natural high-technology growth area in Armenia. As long as connectivity is adequate, the land-locked nature of the country presents less of a problem for IT than for other types of research and development activity. The large Armenian diaspora in Europe and the United States has facilitated contracts, connections, and business partnerships. Armenia has a highly educated and talented workforce requiring comparatively low salaries.

Foreign-owned software firms pay higher wages and are better financed and thus more stable than domestically owned firms. However, all are typically small (fewer than 100 employees) and therefore subject to the fluctuations of external

[2]As reported by André Andonian, Avetik Chalabyan, and Pierre Gurdjian in Armenia's Software Advantage, *McKinsey Quarterly* 1, 2004.

contracts. In contrast, in India, where the IT industry has thrived, very large companies have created stability in the industry. Since there are about 200 small IT companies in Armenia,[3] some consolidation probably will occur, although such a process is not yet apparent.

The pipeline to produce future IT workers appears quite good, with an estimated 200-500 qualified specialists in this field graduating from Armenian universities each year.[4] The availability of jobs and relatively good salaries, combined with the promise for a growing and bright future, is attracting talented young people to the field. According to IT company managers, however, these new graduates have little hands-on experience and require months of on-the-job training to meet the specific needs of their companies. Increasing opportunities for student internships at IT firms and other technology-oriented companies could help improve the productivity of new hires.

Although this industry is expected to continue to grow in the future, some limitations are apparent, mainly on the business management side. New small companies are being developed with the help of incubators, and the Union of Technology Enterprises brings entrepreneurs together to address common goals and problems. Despite these bright spots, however, a general lack of business and technical management skills and experience makes it difficult for Armenian IT firms to compete in the international market. The talented young entrepreneurial directors of these small companies are typically technical specialists with little or no business or management background.

Within these companies, low salaries are linked to the low productivity of the workforce, a reflection not of any weakness in the technical skills of the workers but of the lack of efficient project management practices. With better sales and management practices, the Armenian share of this market should be able to maintain its impressive growth. How to integrate good practices is a challenge and possibly an attractive target for economic development funds.

Another area of concern is the lack of experience with intellectual property rights, which inhibits the development of products. This limitation leads to contracting difficulties because of the inability of companies to guarantee proprietary use of developed software. Western companies are reluctant to invest or even to outsource portions of projects if they fear their intellectual property is not secure. In the longer term, perhaps an even more serious consequence is the inability to develop profitable software products with ownership vested in Armenia.

In conclusion, IT is an area of successful, albeit limited, economic development, with further expansion possible. The sector exemplifies the way in which high-tech international business, combining Western experience and investment

[3]Data from the Ministry of Trade and Economic Development of the Republic of Armenia, 2003, posted at *http://wwww.minted.am/en/information_technology.html.*

[4]Ibid.

with native technical skills, can be successful in Armenia and how the lack of business and managerial expertise and problems with intellectual property rights can have a negative impact.

BIOTECHNOLOGY AND HEALTH CARE

Thanks to contributions from Armenian-American groups and other international donors, substantial progress has been made toward construction of a high-quality health care infrastructure. The existing infrastructure, and particularly expertise from the Yerevan State Medical University (YSMU) and the Center for Medical Genetics, might provide a base for clinical trials for U.S. and European pharmaceutical companies. The ethnically homogeneous nature of the Armenian population could make it an appropriate site both for trials of medications to treat diseases specific to Mediterranean peoples and for tests of the effectiveness in this population of drugs used to treat conditions common worldwide. The country already has the necessary infrastructure for such trials, and there is no shortage of physicians to run them. For this type of undertaking to be feasible for Armenia, it would first be necessary to establish connections with U.S. and European pharmaceutical companies. Financial support and guidance in facilitating such connections could be productive.

Yerevan State Medical University has identified two areas of opportunity that might be expanded. The first is medical education for foreign students. Further investments in multilingual professors, curriculum enhancement, and laboratory upgrades should in turn yield increased income from more foreign students paying higher tuitions. Second, with assistance from the U.S. Agency for International Development (USAID), YSMU is developing resources that could make it a leading medical center in the South Caucasus region. Services ranging from ultrasound to heart surgery are already well developed and might be expanded not only to serve Armenians, but also to attract people from other countries, much as Singapore is a magnet for patients from other countries.

The Center for Medical Genetics, a small research and clinical facility that specializes in genetic screening procedures, is also an important institution in the biomedical field. It was built with support from Armenian-Americans in California and continues to receive funding from them. The facility and its staff are impressive, and the center could serve as a resource providing pre-cancer screening and tests for various genetic disorders. The center has developed the capacity to do genetic testing as well as molecular testing for infectious diseases, activities that might also be expanded as a service not just to Armenians, but also to the populations of nearby countries. Arrangements would have to be worked out with the Institute of Health, which controls certain aspects of laboratory testing, if the center is to be brought into this type of activity. A second issue is the cost of genetic tests. Currently, the fees that the center can charge for its genetic testing services are lower than the actual costs of the tests. Local patients are simply

unable to pay more. Improved access to reagents at lower prices, perhaps through a cooperative arrangement with a Western clinical testing organization, might address this problem.

Another key organization is the Armenian Drug and Medical Technology Agency (DMTA), which develops and tests products related to human health and offers laboratory testing and consulting services. Approval by the DMTA is required for a pharmaceutical product to be sold in Armenia. With help from a grant from the U.S. Civilian Research and Development Foundation (CRDF) supporting the acquisition of modern analytical instruments, the DMTA is now a well-equipped operation that is functioning at an impressive level.

On the development side, the DMTA specializes in nutraceuticals, including ApricoTabs, an herbal supplement in chewable pill form that according to DMTA reduces cholesterol and provides anticancer compounds such as carotenoids. It has also developed health-enhancing oils from apricot, grape, pumpkin, and sunflower seeds. This agency's activities provide a possible model of how agricultural products and fruit and vegetable wastes might be processed to create high-value products that could be transported economically. Potential markets include Southeast Asia, China, the United States, and Europe. Expanding output would require investments in production facilities as well as more marketing research to identify niche markets in health food stores or Internet sales.

Although education is not usually thought of as a product, it is worth considering seriously as service that could produce significant income. YSMU and the Academy of Agriculture both have a potential market in the education of foreign students. YSMU is already involved in this endeavor, as described in Chapter 1, and the rector of the Academy of Agriculture is interested in admitting students from elsewhere in the South Caucasus and China into its agribusiness program. Fostering such programs, for which a strong foundation has already been laid, is recommended.

Armenia might also serve as a regional center for certain types of medical procedures such as cardiosurgery, gynecological procedures, and hip replacement. Armenian-Americans have generously donated a good deal of relevant state-of-the-art medical equipment to Armenia, upgrading the facilities of the privately-run Erebuni Hospital and establishing advanced dental and ophthalmological programs, to name only a few examples. The expertise needed to run and maintain the equipment already exists in the country, although in some cases individual physicians and scientists may require additional training in the United States or Western Europe.

EARTH SCIENCES

Mineral deposits and surface and underground water are the principal natural resources of Armenia. The estimated economic value of the known mineral resources is more than $120 billion. About 30 percent are metallic ores; the rest

are nonmetallic ores and construction materials.[5] Foreign corporations and investment interests are heavily involved in the development of these resources. Mineral deposits are considered state property, but they are leased to private interests for 20 to 50 years, with the government receiving royalties of about 2 percent of the value of the extracted ore. A closed state-owned joint-stock company called Geoeconomics is engaged in the economic evaluation of mineral deposits and mines for all of Armenia. The Ministry of Nature Protection conducts environmental monitoring of mining operations and has a role in the regulation of mining activities.

Renewable surface water resources amount to about 7 billion cubic meters per year and underground water resources to about 4 billion cubic meters per year. Total water use is about 1 billion cubic meters per year; however, local conditions such as availability, storage capacity, microclimate, and weather can cause shortages. Hydroelectric power provides about 7 percent of the energy consumed.[6] Efforts are under way to increase the use of hydropower through the development of small hydropower plants with capacities of several hundred megawatts.

There do not seem to be any particularly promising scientific and technological innovations that can be applied to general mining operations or water distribution systems and then easily and competitively exploited. Although rich, undiscovered deposits of minerals and fossil fuels may exist, most of the mineral wealth of country has been adequately assessed, at least on a reconnaissance basis. Therefore, it is unlikely that an extensive, new national exploration effort would find rich, easily exploitable deposits. Similarly, no previously unconsidered or unavailable mining, recovery, or transportation techniques appear to offer inexpensive exploitation of existing resources. Most difficulties and impediments have complex causes, related to the lack of local manufacturing and markets, world metal prices, and costs of transporting ores and construction materials to outside markets. "Quick fixes" from new discoveries or applications of heretofore untested recovery and distribution techniques are unlikely. Therefore, Armenia must attempt to use its current knowledge in light of the realities of domestic and world markets.

Responsibilities for assessing, developing, and regulating natural resources are distributed widely throughout the government. Financing for the development of natural resources usually involves foreign investment interests, which are not directed to the overall economic growth of Armenia. Thus, the current approach

[5]Armenian Ministry of Nature Protection. 2003. *Ministerial Report—From Aarhus to Kiev*. Yerevan, p. 37.

[6]Figures on water resources and consumption are taken from pages 40 and 41 of the Armenian Ministry of Nature Protection, 2003, *Ministerial Report—From Aarhus to Kiev.* Yerevan. Figure on hydroelectric consumption is taken from U.S. Embassy, 2003, *Armenia: Energy Market Brief*, April, Yerevan.

to managing natural resource development does not seem to be effective in contributing to the development of the national economy.

A new model is needed that considers all aspects of the development of existing natural resources. How can the innovative application of modern concepts in science, technology, management, and business be used to develop these resources in economically viable and environmentally safe ways and in the best interests of Armenia? A comprehensive and integrated approach is needed, involving many skills: geology, hydrology, mining engineering, ore processing, mineral product development, water resources distribution and use, business management, and market economics. Currently, independent activities in the relevant fields should be more effectively linked and more sharply focused on commercial goals.

Two options for putting such changes into effect should be considered: reorganizing and consolidating existing institutions and functions within the government, and creating a nongovernmental enterprise (or enterprises) with the flexibility to assemble and direct diverse talents to work on the rational development of Armenia's natural resources. Perhaps the government will be unable to stimulate the economy through development of natural resources. These activities might best be left to private enterprise, mostly foreign, and centralized national study and planning might have no place in a country trying to enter a modern global economy. In any event, detailed study and planning could potentially identify certain national policy changes or programs that would improve the climate for development of resources. If Armenia could realize economic rewards each year from a small fraction of its known mineral wealth and unused water resources, a substantial impact on the national economy is possible. Without some bold, new approach, however, it is unlikely that these dormant resources will have a major effect on the economy.

The Institute of Geology has a strong tradition of classical geological research, and a small cadre of young scientists is building on this tradition and expanding it with new tools and applications. This group has established a private geological consulting company, Georisk, which has conducted small-scale (regional) mineral exploration and assessment studies for the government and foreign interests. The company could be a model for the private enterprise approach. It has worked on a fee basis on natural resource and natural hazard assessments. The staff seems competent, but they lack the ability to develop the practical applications identified in their studies. Their assessments of mineral deposits currently are given to other government agencies or private concerns for action.

Georisk or a similar entity should have the capability to address all issues related to realizing the economic potential of discovered deposits and other resources. It should be able to provide holistic recommendations and plans—from discovery, to development, to market—for intelligent exploitation of the natural resources of the country. It should have the ability to bring in outside and foreign technical experts to address specific problems. Also, it should be asked to

determine what can be done through the application of innovation and modern technology to realize the actual value of rich mineral deposits, valuable construction materials, and excess water resources.

No single organization will possess all of the skills, knowledge, and experience necessary to address all the issues, systems, and technologies requiring study and analysis. However, a single organization is needed to integrate results from appropriate centers of expertise. The integrated approach will benefit from the participation of university faculty and students. For example, the College of Engineering and the School of Business and Management of the American University of Armenia could bring fresh perspectives to development and environmental issues. The Department of Mining Engineering and Metallurgy of the State Engineering University of Armenia and the Department of Geology at Yerevan State University should also make valuable contributions. All institutions must be convinced that a new approach is needed and that the status quo is not sufficiently flexible or focused.

With regard to regional and international cooperation in this field, the Institute of Geology has contacts with universities and institutes in Georgia, Russia, Tajikistan, Kazakhstan, Iran, Greece, France, Italy, and the United States. The National Seismic Protection Survey and four other Armenian institutions participate in the Caucasus Seismic Information System, a major project funded by the International Science and Technology Center that involves collaboration with partners in Georgia, Greece, France, and the United States (see Appendix I).[7] The Ministry of Nature Protection has an active international section. These collaborations have included joint field studies and joint publication of papers in English in European scientific journals. The state universities and AUA have attracted international students and faculties that can help develop wider and stronger regional collaboration. This collaboration demonstrates a respect for and appreciation of foreign research and approaches to problem solving. Knowledge of resource development experience in other countries cannot but help similar efforts in Armenia.

In addition to the potential benefits from resource utilization, there are opportunities for economic benefit and job creation in the area of geological consulting, another avenue in which Armenian specialists can apply their knowledge and expertise to problems of interest to domestic and foreign entities in both the government and the private sectors. Some countries in southwestern Asia have a similar geologic setting and face economic challenges analogous to Armenia's, as well

[7]This initiative is probably the best developed regional program in any field at present. In August 2004, CRDF announced a new effort to encourage regional cooperation in this area. Funded by the U.S. Department of State under its Freedom Support Program, the South Caucasus Cooperative Research Program will award one grant for up to $250,000 to support a collaborative project involving researchers from the United States, Armenia, Georgia, and Azerbaijan. Projects may be in any field of basic or applied science and will be selected on a competitive, peer review basis.

as similar natural resources and resource development problems. Many international firms would offer the same type of services, but the regional experience and knowledge, as well as lower costs, should make Armenian efforts competitive.

The potential for job growth in fields involved in resource development studies is not great. However, implementation of the recommendations of such studies could potentially have an enormous impact on future employment. Job creation in mining, product development, and manufacturing could contribute greatly to the country's economic recovery and development.

CHEMICAL AND ASSOCIATED PROCESS INDUSTRIES

At present, there is little activity in Armenia in the chemical, petrochemical, and petroleum process industries. Production of chloroprene for markets in other Soviet republics and Iran before the breakup of the Soviet Union, as well as limited production of polyvinyl acetate, has been severely curtailed. Production of acetylene and of ammonia for fertilizer use is limited, as is the volume of electrolytic refining of metallurgical copper. Specialty chemicals are mostly imported at present, although Armenian production of specialty chemicals such as catalysts, intermediates for pharmaceutical production, and specialty research reagents might be possible. Such specialty chemical syntheses are technical-manpower intensive, and lower labor costs as well as existing expertise in this area might be a competitive advantage for Armenia.

The chemically oriented institutes of the NAS-RA conduct little research that would be competitive in worldwide markets. Initiatives in chemical synthesis will have to come from investments by large international corporations in research and development facilities in Armenia, early-stage start-up ventures seeded from research programs at the universities, and initiatives coming from outside Armenia led by successful members of the Armenian diaspora.

ELECTRONICS

During the Soviet period, the vast majority of Armenian research in such fields as computers, semiconductors, lasers, acoustics, and mathematics was oriented to meeting the needs of the Soviet military complex. When this market ceased to exist, these sectors were left without major customers, and they have had difficulty reorienting themselves. For example, in the field of consumer electronics there are currently no facilities of significant size or economic importance. A number of small companies engaged in chip design and associated research and development have sprung up in the past few years, including both Armenian-owned firms and branches of foreign companies. However, the local Armenian market is far too small to support a sizable consumer electronics industry, so these enterprises have no choice but to aim to serve a broader regional or even international market as well.

One promising firm, Mshak, is a small but growing company making automated, computer-controlled machines and a variety of computerized controllers and custom software. It has designed and built a high-precision machine for punching holes in multilayer boards for mounting electronic circuits and claims that this is the fastest machine of its type in the world. Mshak managers are working to build ties with foreign firms to increase potential markets for their products. They claim strong demand for their goods but feel their sales and growth potential to be severely constrained by the lack of available credit.

OBSERVATIONAL PHYSICS

The most famous twentieth-century scientist in Armenia was Victor Ambartsumian, who founded the Byurakan Astrophysical Observatory in Armenia. This observatory was one of the most important astronomy centers in the world and was known for its studies of Seyfert galaxies and observations of supernovae and flare stars, as well as for having conducted some of the earliest important survey work under Benjamin Markarian, another famous Armenian astronomer.

The main scientific instrument at Byurakan is a 2.6-meter telescope placed at an altitude of 1,500 meters. The observatory also includes several smaller instruments. After the disintegration of the Soviet Union, conditions at the observatory became very difficult, and at present its much reduced staff does not have funds to conduct an active observational program. Neither are they able to modernize the instrumentation on the telescope. Nevertheless, the 2.6-meter instrument is a world-class single-mirror telescope and installation that represents a valuable financial investment, worth probably on the order of $50 million. The core scientific staff of internationally known astronomers who remain at Byurakan is also first rate. Given these strengths, this observatory is a good candidate for investment in basic science.

The Cosmic Ray Station conducts a rather broad program in cosmic-ray physics. This program is centered on fundamental science using cosmic rays—research studying the astrophysical sources of cosmic rays and acceleration mechanisms through ground-based surface detectors. In addition, this research group studies solar energetic particles, detected on earth by low-latitude neutron monitors and muon telescopes, as well as the acceleration and transport of such particles. The group has developed instrumentation for monitoring and forecasting space weather and investigating modulation effects of coronal mass ejections, and it is sophisticated in multivariate data analysis using Monte Carlo techniques.

This cosmic-ray program operates with funding of approximately $250,000 per year, including salaries, overhead, and infrastructure upgrades. The program involves extensive international collaboration and is supported by a combination of international grants from CRDF, the National Foundation of Science and Advanced Technologies, the North Atlantic Treaty Organization, and the Euro-

pean Community's INTAS (International Association for the Promotion of Cooperation with Scientists from the Newly Independent States of the Former Soviet Union) program, as well as significant diaspora funding. This cosmic-ray program is among the most advanced and scientifically productive research programs in Armenia, having found a niche in which it competes well internationally. Although this work has few direct practical applications and is not likely to generate technology that could help promote economic development, the program is doing well with the funds it has obtained. It represents a good investment in basic research as well as in the education of the next generation of scientists and engineers.

CANDLE

CANDLE (Center for the Advancement of Natural Discoveries using Light Emission) is an ambitious proposal to build a 3 GeV synchrotron light source facility in Armenia. The goal of CANDLE is to develop a third-generation light source as an international facility. Several such light sources are being developed around the world, but none in the Caucasus. The motivation is to provide a springboard to help revive Armenian science to its previous standing and reverse the "brain drain" from the region. Such a facility would have a broad research and education program that would include work in the areas of physics, chemistry, biology, geology, electronics, crystallography, and medicine.

This proposed synchrotron radiation source would yield a type of radiation that has extremely high flux and other features for studies at the molecular and submolecular levels. The continuous spectrum of synchrotron radiation provided by such a facility would be more than five orders of magnitude increased in flux and more than ten orders of magnitude increased in brightness over more conventional sources. The wavelengths of emitted photons could be varied from atomic to cell structure dimensions, enabling a very broad research program.

A group in Armenia has completed a design study for CANDLE, and in August 2002 a committee of accelerator experts issued a favorable technical review of the project for the U.S. Department of State.[8]

The CANDLE facility is housed in a remodeled laboratory and office complex outside Yerevan. About 25 technical staff members are located on-site. This group includes a team of experienced accelerator experts, some of whom have returned to Armenia from Western Europe and the United States. The quality and dedication of the team and its articulation of the goals of CANDLE are impressive. In addition to the design report, team members have successfully produced a first prototype magnet. They envision a complex of science centers in different fields on this site, with the centerpiece being the synchrotron radiation facility.

[8]Report to the U.S. Department of State Relative to the CANDLE Project, August 20, 2002, posted at *http://www.candle.am/revrep/revrep.PDF*.

Financing is a major issue. Not only are there the initial construction costs, but there must be enough interested users and research activities to sustain the facility's operations. These issues, of course, deserve priority during further consideration of the technical feasibility of the project.

The Armenian government has provided the site and physical support facilities, while funding to develop the proposal was provided by the U.S. government as well as an Armenian-American advocate. The present estimate of construction costs is about $50 million, and expenses for operating the facility are projected at approximately $7 million per year. For this to be a robust project, it will require up-front funding that would cover construction with adequate contingency, plus the first few years of operations. This requirement probably means that at least $75 million is needed to undertake the project with a reasonable chance for success.

The CANDLE initiative would be unique among the research and technical development efforts under way in Armenia. It has already drawn young, technically skilled Armenians home from abroad. If Armenia is to build a successful, technically oriented economic sector, it will be essential that there be centers of excellence for science in the country. Potentially, CANDLE could be such a center.

Research in many disciplines can be carried out with a synchrotron source, which would help to break down the stovepiping that characterizes Armenian research activity. Significantly, the project has received the endorsement of the rector of Yerevan State University, even though his own institution has serious financial needs. There is potential value in having a major regional facility in Armenia. For these reasons, it may have the kind of inspirational value needed to reinvigorate all of Armenian science and technology. It is also possible that international funding organizations, which view S&T as an essential element in the development process, might be interested.

CANDLE has created a singular bright spot of enthusiastic young people who have done a fine job thus far on the synchrotron design. Yerevan State University and the NAS-RA strongly support the project. The next step, probably costing about $4 million and requiring about two years, would be for the CANDLE team to carry out a design and prototyping phase for the major components, including having Armenian companies acquire the capability to make dipole magnets and, if successful, quadrupole magnets and other items.[9] Once the team knows whether such components can be built to specifications in Armenia, it can perform a realistic cost estimate and try to attract the large amount of

[9][Footnote added in final editing.] The cost and time estimates for the next step are the result of the committee's preliminary analysis of the project requirements and are consistent with Armenian projections. Of course, more precise costs will depend on detailed negotiations among the organizations that would participate in project implementation during the next step.

money that would be needed to build such a machine and provide for initial operations.

In sum, CANDLE is a place where investment to enable the next step might lead to a major improvement in the S&T infrastructure in Armenia.

3

Conclusions

Armenia's geographical location and paucity of natural resources inspire little optimism for the growth of traditional economic activities. At the same time, the Armenian culture has long respected literacy and learning, and looking toward a knowledge-based economy is a realistic approach for both the government and international donors. The recent inclusion of Armenia among the countries eligible to participate in the activities of the new Millennium Challenge Corporation provides an excellent opportunity for the country to seek Millennium Challenge Account assistance for particularly promising science and technology (S&T) development projects (see Appendix J).

STRENGTHENING THE S&T INFRASTRUCTURE

The Armenian National Academy of Sciences (NAS-RA) has been the leader of S&T research in Armenia for decades. However, many of its laboratories are not in good condition. Many scientists are aging, and some are struggling unsuccessfully to adjust to market economy conditions. Its research is supported largely by international sources. With presently available resources, the NAS-RA has increasing difficulty sustaining its huge physical plant and multiple laboratories, which often engage in overlapping research activities.

There should be some realignment of the overall governmental research structure with the establishment of a few centers of excellence, both within and outside the NAS-RA. Much of the progress of contemporary science comes from interdisciplinary research, and these centers should be designed to break down the narrow focus that characterizes Armenia's S&T organizations. As noted in

Chapter 1, adjustments in the S&T infrastructure will present challenges in minimizing social costs and countering the potential for corruption and waste, but these changes are nevertheless urgently needed.

In 2002, the Government of Armenia issued a resolution on Science and Technology Development Priorities in the Republic of Armenia (see Appendix K for full text). These priorities are as follows:

- Armenian studies
- Basic research promoting applied research of vital importance
- Special-purpose research
- Information technologies
- Advanced technologies (biotechnology, nanotechnology)
- New energy sources
- Risk factors and human health
- New materials

These areas are somewhat general, but they provide an indication of the Armenian government's research priorities. However, given the high staff-to-budget ratio within the Academy and at other institutions, it is likely that most of the available funding will simply cover salaries of current staff members, with little discretionary funding to initiate new programs even in priority areas. As to the quality of proposed research to address the priority areas, the committee found no evidence of mechanisms for external peer review of research activities funded by the Armenian government at NAS-RA institutes or other institutions. Such reviews could be helpful in ensuring that Armenian researchers are up to date on international efforts in their fields and in linking them with counterparts with similar interests in other countries.

In 2003, the NAS-RA presented to the government its proposals for future directions for S&T in Armenia and recommended the following research priorities: Armenian studies, information technology, laser physics and technology, nanotechnology and semiconductor nanoelectronics, biotechnology, new materials, and environmental risk factors and human health (see Appendix L for an abridged translation). Most of these topics were included in the Armenian government's October 2002 resolution.

The NAS-RA proposals included some very practical elements, such as the following:

- Improving the water quality of Lake Sevan;
- Developing hydroponic production of high-value plants that are usable in medicines, perfumes, and flavors;
- Developing new materials such as high-temperature superconductors;
- Protecting the Arpa-Sevan tunnel from deterioration;
- Using biological means to separate copper and gold from ores;

- Synthesizing new biochemical preparations for treating immunodeficiency and infectious diseases; and
- Establishing a government-wide computer network and a scientific computer network for Armenia.

The NAS-RA is to be commended for its efforts in making constructive suggestions regarding the management and funding of S&T and recommending specific research priorities. However, the ability of the NAS-RA to achieve meaningful objectives in these areas is inhibited by both limited resources and fragmentation of efforts. Its detailed plan lists cooperating institutions, but leadership always appears to be vested in an Academy institute.

Many areas of science currently funded through the institutes of the NAS-RA are unlikely to yield significant returns in terms of economic development. With limited resources, Armenia should emphasize a limited number of topics with significant potential to produce jobs, increase income, and enhance social welfare. Redirecting resources to a few targeted areas such as those identified later in this chapter should be undertaken. Many researchers will oppose such a limitation on S&T activities, since they naturally want to maintain even the meager funding they have. The changes should, however, benefit a large number of people in the long term and should help to harness the potential of those talented young scientists who have remained in Armenia.

In addition to weaknesses in structure, funding, and priorities, Armenian S&T is faced with other impediments to its development. Many scientists left Armenia after the collapse of the Soviet system. University programs in S&T are in need of strengthening, and the present number of graduating Ph.D.s in science will not be sufficient to replace the aging university staffs. Programs to bring in foreign faculty members and to persuade émigré scientists to return should be considered.

In short, the entire Armenian university system has to be developed further. It is plagued by funding shortfalls, inadequate infrastructure, and misdirection of limited funds. Much of the scientific potential of Armenian students is being lost due to the lack of adequate university laboratory facilities, especially in the biological sciences, that provide opportunities for hands-on research experience. The principal science-oriented universities of Armenia have shown that they can stretch resources a long way, and investment in equipping teaching laboratories would yield high benefits. Modern equipment for research laboratories is also badly needed. Future investments should be centered in the institutions that train large numbers of students. Selecting the laboratories to be upgraded will require careful evaluation of priorities, perhaps with input from objective outside experts, because modernizing all of the facilities is not possible.

Science curricula also have to be updated to bring them into line with world standards. To promote this effort, a sustained program should be initiated to bring distinguished international professors to Armenia for periods of three to twelve months or longer. A modest investment in such a program could have a multiplier

effect not only in upgrading the course content but also in improving organizational and administrative practices within universities.

Additional funds are needed to support travel by Armenian researchers, especially junior investigators, to visit U.S. and European laboratories, preferably coupled with opportunities to attend scientific conferences. The U.S. Civilian Research and Development Foundation (CRDF) and the National Foundation of Science and Advanced Technologies (NFSAT) support a limited number of exchanges, but many more Armenian graduate students and young researchers could profitably spend a year or two in foreign laboratories. Armenia is not in a position to finance such trips, but support from other countries and even from the receiving laboratories might be arranged. Mechanisms are needed to counter the significant "brain drain" afflicting Armenia. The U.S. National Institutes of Health offers reentry grants to help scientists from some countries who have spent time in the United States reestablish themselves in their home institutions, and the U.S. National Science Foundation provides similar support for U.S. researchers who have done postdoctoral research abroad. If a similar program of reentry grants were established for Armenian scientists, it could provide an attractive incentive to return home.

Increasing salaries for young and mid-level researchers to keep them in science in Armenia is a high priority. Currently, such an investment is easiest to defend in information technology and physics, areas of Armenian strength.

Biology, though weak at present, is such an important area for both health and agriculture that it is too critical for the well-being of the country to be ignored. The Academy of Agriculture, Yerevan State Medical University, and the American University of Armenia (AUA) have made promising progress toward building strength in the biological sciences, but a significant investment in equipping teaching laboratories, particularly with instruments for molecular biology and biochemical analysis, would yield high benefits. Other organizations such as the Center for Medical Genetics and the Drug and Medical Technology Agency have also developed good biological programs and can provide a limited number of jobs for university graduates.

According to senior Armenian government officials, provision of software development services by Armenian companies generated about $50 million in export revenue in 2003. The young entrepreneurs and returnees in this field have impressive links with Western companies. However, inexpensive and widely accessible international broadband connectivity is now essential to build a larger and more effective network inside Armenia. Connectivity should be a high priority for building on successes in the information technology (IT) field and extending capabilities throughout the country as well as within the academic and scientific communities.

Armenia's S&T future depends on international linkages for many reasons: for journals at more affordable prices, for identification of and cooperation with partners abroad, for marketing and sales, and for customer service. The North

Atlantic Treaty Organization (NATO) Virtual Silk Highway Project is an important regional effort in information technology. It began as a network infrastructure project for the Caucasus and Central Asia and has evolved into a broad initiative aimed at supporting national research and education organizations throughout the region. While Armenia's S&T community still faces significant problems of isolation and the Virtual Silk Highway Project has encountered problems with hardware and bandwidth availability, electronic infrastructure-building initiatives of this nature are helpful and could be encouraged.

The S&T capacity of Armenia is much greater than the current ability of the economy to absorb its output; therefore, external customers are essential if this capacity is to be sustained. Markets outside Armenia would provide important income streams for the Armenian economy. Advertising Armenia's capabilities and building customer confidence in using Armenian services require travel and connectivity as well as effective marketing. The IT sector is making good progress, and such efforts should be extended to other areas.

In addition to marketing, a new product requires specialized individuals and institutions to support its development throughout its evolution from research to commercialization. Many of the resources and institutions critical to science- and technology-based economic development—such as knowledge of marketing, finance, and intellectual property protection; access to capital; and product development skills—are missing in the Armenian economy. Development assistance to promote a specific technology should also target those institutions and economic capacities needed to move the products of that technology to market. The agricultural support programs of the U.S. Department of Agriculture (USDA) can serve as a good example of this type of holistic approach.

Most of Armenia's small S&T companies as well as its research institutes lack the contacts, knowledge, and funds required to find foreign customers. The Enterprise Incubator Foundation, a joint effort of the government of Armenia and the World Bank, addresses some of these needs among information technology firms by providing business, training, and facility services and helping to promote Armenian enterprises and increasing their competitiveness in the global marketplace. The foundation is establishing an office in the United States, which should be helpful. However, young entrepreneurs also need more training in business and marketing. The AUA can play an important role in this area, perhaps by providing continuing education opportunities.

Continued emphasis should be placed on encouraging foreign direct investment in private-sector companies in Armenia, particularly companies that could take advantage of the products of the many research institutes.[1] Greater involve-

[1]The U.S. Department of Commerce's Business Information Service for the Newly Independent States maintains a comprehensive website providing information about various sectors of the Armenian economy as well as specific Armenian firms seeking foreign investors and partners (see *http://www.bisnis.doc.gov/bisnis/country/armenia.cfm).*

ment of foreign firms should enhance both the technical and business skills of Armenian employees through opportunities for formal and on-the-job training. Ensuring that investments in S&T eventually lead to self-supporting and sustainable institutions and activities is a key issue. One aspect of sustainability relates to the long-term flow of development assistance that directly supports research activities. A broader aspect concerns how development assistance can help create or strengthen institutions or economic activities so that they become self-sustaining over time. To this end, institutions should expand ties with foreign collaborators who derive financial benefits from supporting science in Armenia and therefore become committed to long-term involvement.

AREAS OF POTENTIAL COMMERCIAL INTEREST

The following fields may offer commercial opportunities that build on existing strengths in S&T.

Information Technology, Particularly Software Development. At present, the industry is oriented primarily to performing outsourced tasks for large foreign software companies. Moving to the stage where Armenian-owned software products are marketable worldwide will require improving business and marketing skills among the management personnel at these software firms and strengthening the framework for intellectual property rights.

Semiconductors. The NAS-RA institutes have a history of work in this area. For example, one laboratory reportedly has produced up to 50-pin integrated circuits with down to 1-micron feature sizes on a laboratory basis. It is highly unlikely that a semiconductor production plant will be built in Armenia. However, Armenian specialists might be able to build on their previous work in solid-state phenomena and pursue basic research related to circuit design that would be of value to U.S., European, or Asian semiconductor companies. Such niches for specialty electronics should be explored.

Infrared Detectors. Bismuth and antimony multilayer solid-state components for detecting infrared radiation at wavelengths as long as 6 microns are under development at the NAS-RA Institute of Radiophysics and Electronics. Researchers at this institute are producing thin films of bismuth (Bi), antimony (Sb), solid solutions of bismuth and antimony, and multilayer Bi-Sb-Bi-Sb structures from elemental sources by pulsed laser deposition for optoelectronic applications. This method of sequential deposition is used for fabrication of multilayer Sb-Bi-Sb structures with quantum-confined layers of bismuth. Sensors that can detect infrared radiation at wavelengths as long as 6 microns would address large markets for analytical instruments, night vision, and other defense systems. However, such components have to be integrated into complete systems, which is currently beyond Armenia's capacity. The production and testing of prototype components and the refinement and validation of manufacturing techniques for these devices are technical-manpower intensive, which should provide a com-

petitive advantage for the development of the technology in Armenia. In order to assess and then access worldwide markets in military and nonmilitary applications, a partnership with a large international company is necessary.

Production of Large Single Crystals. Armenia was the former Soviet Union's largest producer of crystals for use in lasers. Much of this capacity still appears to exist. One company, LT-PYRKAL, a joint venture owned by the Armenian and Greek military defense agencies, offers a wide range of monocrystals of different materials for a variety of lasers. Several NAS-RA institutes and start-up companies also possess the necessary expertise for growing large single crystals that are important in laser optics and other applications. Of particular interest are crystals used in scintillation counters for detecting X-rays and gamma rays that could be used in computed tomography (CT) and positron emission tomography (PET) medical diagnostic scanning systems.

Laser Technology and Light Detection and Ranging (LIDAR). Considerable expertise in laser technology exists in Armenia that may have economic potential. Besides its work with crystals, the firm LT-PYRKAL also has the capability to produce a wide range of laser systems and laser system components, including optics, mirrors and antireflective coatings, lasers, electronic parts and blocks, mechanics, and software. There is a premium available in the market if firms can produce high-quality items of this type while meeting production schedules.

LT-PYRKAL has, for example, developed an optical parametric oscillator that operates in the middle infrared in the wavelength range of 1.4-4.2 μm. This device is an ideal light source for an enormous number of applications, including LIDAR, high-resolution spectroscopy, medical research, environmental monitoring, display technology, and precision frequency metrology. The firm has used its laser technology to develop a device for remote atmospheric sensing using infrared differential absorption LIDAR. This device can be used to measure the concentrations of trace gases in the atmosphere, which are very important for environmental monitoring, chemical process control, and biomedical applications. The reported performance specifications of this system make it a state-of-the-art instrument. The world market for this type of high-performance, high-price instrument may be only in the range of 25 to 40 instruments; however, the ability to produce this device demonstrates a capacity to build high-quality components and to integrate complicated systems. If the firm can perform similarly in commercial production, there are likely to be many markets for its laser components and systems.

Precision Electromechanical Instruments. Armenia has a capability for precision machining and equipment building, as well as the design of numerical control software. The company Mshak has produced what it claims to be the fastest machine in the world for punching holes in printed circuit boards. Similar capability exists in the NAS-RA Institute for Radiophysics and Electronics, which has built absolute angle encoders for use in space and robotics systems. The

encoders appear to exhibit high-quality design and workmanship, and the expertise of their creators in using precision machining to make electromechanical devices could be the basis for the development of advanced electromechanical components for various applications.

Analytical Services. The NAS-RA Molecular Structure Research Center currently has modern analytical instruments, including a nuclear magnetic resonance (NMR) system with a superconducting magnet, a mass spectrometer, infrared and ultraviolet spectrometers, and chromatographs. Some of this equipment is unique not only in Armenia but in the region. International analytical services based on these instruments might be expanded. The center has already fulfilled a contract for a Dutch firm. It is able to offer additional analytical services such as providing NMR and mass spectra for users as well as spectral interpretation and database services for molecular structure analysis.

Specialty Chemicals. If international customers could be found, specialty chemicals such as the range of metal hydrides and carbides currently produced at the NAS-RA Institute of Chemical Physics could be marketed readily through worldwide distributors. Important requirements for a successful business in this area include high standards of quality (purity), reproducibility, reliability of delivery, and low cost. Sales of small quantities of materials for research purposes might open the door for large-quantity sales. Such specialty chemical synthesis is highly labor intensive and requires considerable technical expertise, aspects that could provide competitive advantage for such a business in Armenia.

Specialty Materials. The NAS-RA Institute of Applied Problems of Physics has been studying the dramatic changes in properties of solid-state materials and crystals under acoustic excitation. One development with some commercial potential is a light bulb with a spectrum similar to that of sunlight. Also, the NAS-RA Institute of Mechanics has developed and is attempting to market a new material for use in brake pads.

Specialty Agricultural Products and Processing. Beyond ensuring Armenia's self-sufficiency in food, certain new products might be suitable for export. Shipping fresh fruit and vegetables has long been under way, but costs are very high due to transportation problems. Thus, processed foods such as wine and liquor, dried fruit and vegetables, preserves, fruit juice, mineral water, pasta, cheese, sausages, smoked meats, smoked and frozen fish, and herbal teas are preferable.

Nutraceuticals and Functional Foods. An interesting area in the early stages of development, as previously discussed, is functional foods, or foods that provide health benefits beyond simple nutrition. These high-added-value, easily transported products are in increasing demand worldwide and might be an excellent niche for Armenia.

Genetic Testing and Other Clinical Laboratory Services. A high-quality Center for Medical Genetics already exists in Yerevan. This center and other diagnostic clinical laboratories could be expanded to provide regional services.

Such a business might best be developed in collaboration with an international partner since success depends on a large volume of users.

Human Clinical Trials. As previously noted, clinical trials could be carried out by Armenian medical centers in collaboration with international pharmaceutical firms.

Regional Health Centers. As mentioned earlier, centers specializing in cardiology, orthopedic surgery, and gynecological services have the ability to provide regional services for paying customers.

Geological Consulting. As noted, a regional service could be provided for assessing seismic and other hazards in building and road construction.

Earthquake Engineering. Certain products associated with earthquake hazard reduction, such as building base isolation equipment, could be produced if a worldwide market were developed.

Mineral Refining. Ores of various metals such as gold, lead, zinc, and molybdenum as well as perlite and bentonite are extracted but not refined in Armenia. Refining such materials in Armenia could add value to these exports, although investment costs would be substantial.

RECOMMENDATIONS

Small Business Innovation Research Program

There appear to be unexploited opportunities for commercialization of science and technology activities in Armenia that might be competitive in worldwide markets. To encourage such commercialization activities, a small business innovation research program[2] should be considered in Armenia. Competitive proposals for the commercialization of technology could be solicited from the country's universities, research institutes, and commercial groups in fields such as those listed earlier in this section. The proposals would describe how specific technical ideas could be transformed into profitable businesses and would identify potential customers. Business plans would describe the markets for the proposed products or services, the competitive advantages of Armenia in the proposed business area, project management, and long-term financing plans.

[2]In the United States, Small Business Innovation Research (SBIR) programs provide research and development funding to early-stage companies following a rigorous process of peer review. All major U.S. agencies that fund research are required to set aside a specific percentage of their research budgets for SBIR grants. Applications are reviewed in two phases. In Phase I, grants of $50,000 to $100,000 are provided for initial studies to demonstrate the technical feasibility of a proposal. In the second phase, funding from $500,000 to $1 million can be awarded to build prototype products or services. Phase II grants usually require that the business model for the product be established and business partners be identified.

The U.S. model, by which grants are made in two phases, may be useful.[3] Perhaps Phase I, funded at a level of $10,000-20,000, would call for a prototype product or other proof of the validity of the technology. This phase would also require the identification of potential partners and approaches for the manufacturing and distribution of the proposed product. Then, Phase II, funded at perhaps $100,000-200,000, would allow for the completion of the product and demonstration of its effectiveness. Grants in both phases should be awarded based on the results of a rigorous peer review process, with the expert review panels preferably including representatives of industry and the international science community as well as Armenian scientists. Of course, decisions about the details of any program launched in Armenia would be up to its planners, but the basic model described might be a useful point of departure.

Given the size of the Armenian S&T sector and the potential impact of a program of this type, $10 million per year might eventually be an appropriate allocation for such grants. This would allow 40-50 grants to be funded in each of the two phases per year. Before launching a program of this scale, however, it is essential to have a smaller-scale exploratory grants competition to test the concept and demonstrate the quality of proposals that can be developed. The Next Steps to Market program of CRDF provides an example of a mechanism for testing the concept (see Appendix M).

Centers of Excellence

High-quality centers of excellence in research and teaching are an essential foundation for seeding new ideas in a science- and technology-based society. Such centers should be highly focused. Excellence in even a small number of areas could make a significant contribution to high-technology business development in Armenia. A program of centers of excellence grants should be established to support and strengthen the most productive and promising elements of Armenia's research and educational sector. These centers could be established in universities or in NAS-RA or ministry-run institutes or under the auspices of university-institute partnerships. Such partnerships should be especially encouraged.

Centers of excellence can be envisioned in computer science, solid-state devices, microelectromechanical systems, polymer sciences, natural product chemistry, fluid mechanics, and microfluidics. These examples are areas of cur-

[3]The National Research Council is currently conducting a study of the SBIR programs operated by the U.S. Department of Defense, the Department of Energy, the National Aeronautics and Space Administration, the National Institutes of Health, and the National Science Foundation, and the conclusions reached may be helpful to others planning similar programs. Information about the study, which is expected to be completed in the spring of 2005, may be found at *http://www7.nationalacademies.org/sbir/index.html.*

rent Armenian strength; however, the actual fields supported should be determined in large measure by the quality of the proposals received.

The selection of centers should be based on a peer review system including international researchers, representatives from industry, and other users of research products from Armenia and abroad. Pre-proposals could be required to allow the final proposals to be better developed. Grants for the centers might be for a five-year term and should allow for the purchase of research equipment as well as covering salary costs, research-related travel, and expendable supplies. Ideally, centers should have both research and educational components. An initial investment of $10 million per year would establish this program as a major force in the revitalization of Armenian S&T. Grants of up to $1 million per year per center might be appropriate, for example, with the goal of 10 new centers being established during the first five years.

National Foundation of Science and Advanced Technologies

The National Foundation of Science and Advanced Technologies is a model institution for the support of peer-reviewed research funding in Armenia and deserves a severalfold increase in its funding. Funding for new S&T programs such as those recommended in this report should be administered through NFSAT or another organization with a comparable peer review process.

Higher Education

The Armenian educational system is in need of reform. Armenian institutions of higher education should continue to modernize their organizational structures and curricula and make strong efforts to recruit young, foreign-educated faculty. A sustained program of visiting professorships would provide a useful mechanism for bringing in distinguished foreign faculty who could not only enrich curricular content but also contribute new ideas about university organizational and administrative practices. In some cases, their visits might also lead to longer-term joint research efforts and ongoing mentoring of Armenian graduate students.

Selected laboratories for use by faculty and students in the universities should also be upgraded. Improved and stable economic conditions are important in allowing educational reform to move forward, as they should provide the Armenian government with additional resources to provide the required level of support. In the meantime, philanthropic organizations will likely be the main source of funding for these efforts, although industry may also be a promising source of support if firms can be convinced of the value of strengthening the technical education of their potential future employees. As examples of both of these avenues of support, the State Engineering University of Armenia has received a fiber optics laboratory from an Armenian-American professional society and the American

University of Armenia has outfitted its motion control laboratory with equipment donated by a U.S. firm.

CANDLE

CANDLE (Center for the Advancement of Natural Discoveries using Light Emission) is an ambitious attempt to create a state-of-the-art, next-generation facility with applications in a wide range of fields, from basic physics, chemistry, and biology to applied research in drug design, medical diagnostics, and environmental remediation. It deserves to be supported through the next pre-construction phase of detailed engineering design and testing the concept of building prototype equipment in Armenia, which will require funding of up to $4 million over a two-year period.

Intellectual Property

Intellectual property is a key enabling issue for the long-term success of technology-based businesses. Entrepreneurs in Armenia need to understand the importance of timely filing of applications for patents, copyrights, or trademarks in Armenia and abroad before such filings are compromised by publications, web postings, or presentations at conferences. Without strong intellectual property positions, they may not be able to raise the financing needed for development and production activities or to compete successfully in international markets. At the same time, considerable expenses are involved in obtaining protection for intellectual property; for example, expenses in the United States often exceed $10,000 for each successful filing that provides protection only in the United States. Therefore, to receive international protection, the entrepreneur in Armenia must have substantial financial support from sources that are confident the products will be market successes.

In Armenia, both an improved understanding of the legal framework for obtaining protection of intellectual property and the financial resources necessary to obtain such protection are important. Of course, there is a natural tendency for researchers and inventors to assume that their products will sell if only they have patent protection, but the reality may be quite different.

A broad survey of the overall intellectual property rights (IPR) situation in Armenia—including the adequacy of domestic legislation and government organizations and the linkages of local IPR procedures to international IPR requirements—is urgently needed. This survey should be followed by steps that will begin to provide a framework for protecting commercially attractive innovations in Armenia. Meanwhile, Armenian institutions that have participated in activities sponsored by the International Science and Technology Center (ISTC) are eligible to apply for ISTC support in the areas identified in Appendix N. Unfortunately,

similar services have not yet been established to assist other entrepreneurs. Among the key questions are the following:

- Are the existing Armenian laws covering patents, copyrights, and trademarks adequate? If not, how should they be amended to help ensure that there is clarity as to ownership of intellectual property developed with private funds and intellectual property developed with government funds and that the procedures for applying for and obtaining certification of such ownership are appropriate?
- Should there be an office within the Armenian government that has the ability to advise entrepreneurs on how to obtain intellectual property protection within Armenia and the relationship of that protection to protection in other countries? Could such an office process applications for protection in Armenia in an efficient manner?
- How can the advisory mechanisms of ISTC, the European Union, or other external organizations be strengthened to provide entrepreneurs with guidance on applying for IPR protection in the United States, Europe, Japan, and other major worldwide markets, and how can the costs of such filings be covered for newly emerging firms?
- Is the court system in Armenia prepared to resolve disputes over infringement of intellectual property rights? What steps are necessary for it to do so?
- Is an advisory mechanism available, through ISTC, CRDF, or other organizations, that can assist entrepreneurs in their negotiations with foreign firms concerning the sharing of intellectual property rights (analogous to the services provided by these organizations in Russia)?

There may be so many weaknesses in the current system in Armenia and inadequacies in the currently available advisory groups that a new center for intellectual property rights is warranted. In any event, when considered together with the realistic potential for worldwide marketing of many Armenian products, there is clearly a need for better understanding of these issues by entrepreneurs and relevant specialists. To this end, the law schools of AUA and YSU should be encouraged to give greater attention to intellectual property rights in their curricula.

An effective initial approach would be to have a series of international workshops on various IPR issues to stimulate the Armenian government to become more involved while allowing entrepreneurs in the country to have direct access to foreign specialists who are able to clarify approaches and help answer their specific questions. In addition to ISTC and CRDF, NATO might also be able to provide a venue for such workshops.

As the extent of the need for protection of intellectual property becomes clearer, a fund to support worldwide patent filings might be considered. Of course, there will be considerable challenges in sorting out which filings should be sup-

ported, given the uncertain potential value of a specific invention and the difficulty in assessing the possibility of competing applications.

Product Certification

In addressing international markets, Armenian officials and entrepreneurs have limited understanding of important regulatory and product certification issues. These constraints are particularly important for biotechnology and pharmaceutical development. Again, as an initial step, a series of international workshops to help sensitize both the Armenian government and entrepreneurs to these issues, such as U.S. and European regulatory requirements concerning food and drugs, are in order. During these workshops, foreign experts would have an opportunity to clarify the scope of the areas of concern and recommend mechanisms for addressing these concerns on a continuing basis. Perhaps the government should increase its capabilities in the areas of interest, or perhaps a university or a nonprofit group in Yerevan should be supported to provide advisory services in this field.

Business Management Skills

Business management skills are a critical need in Armenia. Master's of business administration (M.B.A.) training programs in Armenia should be expanded, as previously discussed. Such support could include, for example, subsidizing existing M.B.A. programs at AUA and the State Engineering University of Armenia and providing funding for these programs to sponsor visiting faculty from Europe or the United States. Workshops in specific areas such as international finance, taxation, and management could be supported through a not-for-profit organization modeled after Connect San Diego or Pasadena Entretec.

Research Relevant to Interests of U.S. Department of Defense

Research related to military interests extends beyond the scope of this report. However, it could be very useful to arrange visits by U.S. military R&D organizations, such as the Office of Naval Research, the Air Force Office of Scientific Research, or the Army Research Office, to relevant Armenian institutions and firms. If an area of joint interest is found, these U.S. organizations should be in a position to provide travel grants, support research, or convene workshops as appropriate.

Science and Technology Policy

Overarching all of the foregoing recommendations is concern about the most efficient use of Armenia's scarce resources to build an S&T base that both

responds to global challenges and opportunities and is grounded in the economic realities of the country. Strong Armenian government leadership is needed, including a long-term budgetary commitment to upgrade the science and technology base. Although the Armenian government has set a reasonable target of devoting 3 percent of the total national budget to S&T, actual funding has been only about one-third of that level. This low level of support by the government has led to excessive dependence on foreign sources of funding for the nation's S&T capacity. Insistence by foreign funders on cost sharing by the Armenian government should be considered as a means of encouraging it to fulfill its budget commitments.

Improving consensus within the country on S&T priorities, institutional responsibilities, and interactions with international partners is important in optimizing the use of resources. To this end, a series of well-structured national conferences, with international participants, on selected aspects of S&T policy should be considered. International experience can provide Armenia with a range of options as the country seeks the best road to making science and technology more potent development forces. Discussion of the issues by Armenians themselves can assist the international community in understanding how its members can most effectively participate in future activities in the country.

Armenia must move toward an integration of education and research, focusing on fewer research institutions than now exist and creating centers of excellence corresponding to areas of national priority. Over time, the results of research will increasingly be applied in the local economy, when the latter improves its capacity to absorb research and researchers. Alternatively, research results may be sold abroad as part of cooperative projects. From these relationships and from the increasing marketability of students trained in these activities should emerge a condition of sustainability, meaning economic viability, and a greater contribution to the Armenian economy.

The process of moving toward a knowledge-based economy is not simple and must be supported by committed political leaders with an appreciation both of what science and technology can contribute to economic and social development and of what they cannot.

Appendixes

Appendix A

U.S. Agency for International Development (USAID) Armenia Program Overview for Fiscal Year 2005

The Development Challenge: Armenia is politically and economically isolated, with Azerbaijan and Turkey maintaining an economic blockade against it as a result of the Nagorno-Karabakh (NK) conflict. The blockade has a large negative impact on Armenia's economy and its prospects for growth, though some highway and rail traffic continues across the borders with Iran to the south and Georgia to the north and a small amount continues with Turkey through Georgia. The dominance of the executive branch of government has reduced competition in Armenia's political and economic spheres. As a result, rule of law is problematic, political parties are weak and the media is not truly independent. Corruption is undermining Armenia's economic, political and social reform process. Despite high rates of economic growth, poverty in Armenia remains persistent. Basic poverty indicators demonstrate little progress during the last few years.

U.S. Interests and Goals: Since its independence, Armenia has emerged as a strategically important country in the Caucasus. U.S. ties to Armenia are many and varied, from the cultural bond of the large Armenian-American diaspora to diverse personal connections, commercial interests, and broader political relationships. U.S. national interests in Armenia, and in the larger Caucasus region, revolve around security, conflict resolution, internal reform and energy security. Armenia's progress towards becoming a stable, Western-oriented and democratic country with a transparent, market-based economy is important to U.S. security and economic interests in the region. USAID contributes to U.S. Government policy priorities in Armenia through its support for reforms advancing democratic governance and a market economy, integrated into the community of nations.

The USAID Program: The USAID/Armenia Program covers seven strategic objectives for which USAID is requesting FY 2004 and FY 2005 funds. These seven programs concentrate on technical assistance and training to support institutional changes that support growth in small and medium enterprises (SMEs), the economic segment most likely in the near term to create jobs; companion public investment in a healthy and appropriately-trained society; a climate of governance conducive to those public and private investments; and the presence of transparent, accountable institutions that respond to the needs and demands of the Armenian society. FY 2004 funds will be used to implement ongoing programs in economic restructuring, energy sector reform, democracy and governance, primary health care, and social assistance, including earthquake zone recovery. The specific activities to be funded by FY 2004 and FY 2005 appropriations are described in more detail in the following Program Data Sheets.

Other Program Elements: The USAID Farmer-to-Farmer Program strengthens the capacity of host organizations at three levels: the firm level, agricultural support organizations, and financial institutions.

Other Donors: The United States is the largest bilateral donor in Armenia. The second largest bilateral donor is Germany (private sector, small and medium enterprise development, export promotion, infrastructure development, public administration, and education). Other bilateral donors include France (education, health sector, and culture), United Kingdom (public sector reform, civil society, and support for the national census), the Netherlands (agribusiness), Japan (private sector development and technical assistance), Sweden (social and health sectors, poverty reduction, environment, governance and civil society, and education), Switzerland (housing, social sector, health, and elections), Belgium (health) and Italy (health and culture).

The largest multilateral donor in Armenia is the World Bank (WB) (natural resource management and poverty reduction, foreign investment and export promotion, information technologies, infrastructure, education, health, social sector, agricultural reform, municipal development, transport, and judicial reform). Armenia joined the WB in 1992 and the International Development Association (IDA) in 1993. IDA lending has helped finance infrastructure rehabilitation, including support for earthquake reconstruction, irrigation, power, road maintenance, and municipal water. IDA credits supporting the social safety net and improving access to services have included operations in health, education, and a social investment fund aimed at improving basic social and economic infrastructure. WB and USAID activities complement each other's efforts in most sectors, particularly social, health, and information technology development.

Donors to Armenia have established formal mechanisms to coordinate their assistance, supplementing frequent informal consultations. Most donors participate in formal monthly donor meetings, co-chaired by the WB, United Nations Development Program (UNDP) and USAID. Theme groups meet periodically as

well, reporting critical technical and policy information to the donor coordination group.

Other multilateral donors include the European Union (energy, legal reform, environment, macroeconomic policy, governance, education, transport, SME development and information technology), the International Monetary Fund (macroeconomic policy), the United Nations network of agencies, e.g., UNDP (poverty reduction, democracy and governance, post-crisis management, infrastructure, and information technology), United Nations High Commission for Refugees (refugee support), United Nations Children's Fund (health, education, and social sector), World Food Program, World Health Organization, and the Organization for Security and Cooperation in Europe (anticorruption and elections).

Several Armenian diaspora donors are active as well, the largest of which is the Lincy Foundation (road network, Yerevan public works restoration and improvements, SME development, tourism and earthquake recovery). In addition to Armenian diaspora, private foundations such as the Open Society Institute are also active in Armenia (civil society, education, public health, culture, media, and judicial reform).

SOURCE: U.S. Agency for International Development. 2004. Fiscal Year 2005 Budget Justification to the Congress.

Appendix B

Institutions Visited by the National Research Council Committee on Science and Technology in Armenia

FEBRUARY 22-27, 2004

Armenian Government Organizations

Ministry of Agriculture
Ministry of Education and Science
Ministry of Energy
    Institute of Energy Research
Ministry of Foreign Affairs
Ministry of Health
    Drug and Medical Technology Agency
Ministry of Nature Protection
    National Survey for Seismic Protection
Ministry of Trade and Economic Development
    Yerevan Physics Institute
Ministry of Transportation and Communications
National Assembly Standing Committee on Science and Education

National Academy of Sciences of the Republic of Armenia

Presidium
Center for Ecological-Noosphere Studies
Center of Medical Genetics
Institute for Informatics and Automation Problems

Institute of Applied Problems of Physics
Institute of Biotechnology
Institute of Chemical Physics
Institute of Economics
Institute of Geological Sciences
Institute of Organic Chemistry
Institute of Mathematics
Institute of Microbiology
Institute of Molecular Biology
Institute of Radiophysics and Electronics
Molecular Structure Research Center
State Microbial Depository Center

Institutions of Higher Education

American University of Armenia
Armenian Academy of Agriculture
Institute of Health
Yerevan State Engineering University
Yerevan State Medical University
Yerevan State University
Yerevan State University of Architecture and Construction

Private Companies

H_2 ECOnomy
LT-PYRKAL
Mshak
SolarEn LLC

U.S. Government

U.S. Agency for International Development
U.S. Department of Agriculture
U.S. Embassy, Office of the Ambassador

Nongovernmental Organizations

CANDLE Project
Enterprise Incubator Foundation
National Foundation of Science and Advanced Technologies
Project Harmony
Union of Information Technology Enterprises

Appendix C

Research and Development Institutions of the National Academy of Sciences of the Republic of Armenia

Institute	Total Staff
Byurakan Astrophysical Observatory	139
Center for Ecological-Noosphere Studies	71
Center of Medical Genetics	22
Garni Geophysical Observatory	17
Institute for Informatics and Automation Problems	163
Institute for Physical Research	175
Institute of Applied Problems of Physics	245
Institute of Archaeology and Ethnography	137
Institute of Arts	67
Institute of Biochemistry	159
Institute of Botany	113
Institute of Chemical Physics	71
Institute of Economics	44
Institute of Fine Organic Chemistry	285
Institute of General and Inorganic Chemistry	149
Institute of Geological Sciences	186
Institute of Geophysics and Engineering Seismology	64
Institute of History	128
Institute of Hydroecology and Ichthyology	51
Institute of Hydroponics Problems	52
Institute of Language	69

Institute	Total Staff
Institute of Literature	67
Institute of Mathematics	59
Institute of Mechanics	136
Institute of Microbiology	68
Institute of Molecular Biology	207
Institute of Organic Chemistry	119
Institute of Oriental Studies	67
Institute of Philosophy, Sociology and Law	66
Institute of Physiology	127
Institute of Radiophysics and Electronics	143
Institute of Zoology	111
Institute/Museum of Genocide	38
Mashtots Engineering Center	30
Molecular Structure Research Center	23
Shirak Armenological Study Center	20
Special Experimental and Design Technological Institute	15
State Microbial Depository Center	59
Total	3,762

SOURCE: Provided by the National Academy of Sciences of the Republic of Armenia, February 2004.

Appendix D

Higher Educational Institutions in Armenia

PRIVATE UNIVERSITIES

Yerevan Hrachya Ajaryan University
Yerevan Gladzor Government University
Yerevan Galik University
Yerevan University of Economic Law
Yerevan MFB Financial Academy
Gyumri Imastaser Anania Shirakatzi University
Gyumri Progress University
Armenian Medical Institute of Yerevan
Yerevan Institute of Traditional Medicine
Yerevan Haybusak University
L. Kalashyan Armenian Open University of Yerevan
Yerevan Management University
Yerevan Hyusisain University
Yerevan National Academy of Fine Arts
Vanadzor Mkhitar Gosh Armenian-Russian International University
Yerevan Martig University of Foreign Economic Relations
Yerevan Azat-Veteran University of Judicial Practice and Psychology
Mkhitar Gosh International University of Yerevan
Yerevan Interlingua Linguistic University
Yerevan Anania Shirakatzi University of International Relations
Yerevan Urartu University of Practical Psychology and Sociology
Yerevan Institute of Ecology, Economics and Law

Hrazdan Humanitarian Institute
St. Theresa Charitable Sisters Medical Institute, Yerevan
Yerevan University of Government and Information Technology
Mesrop Mashtotz Pedagogical University of Yerevan
Yerevan Institute of Biotechnology
Movses Khorenatsi University of Yerevan
Grikor Zohrap University of Yerevan
Ararat Institute of Armavir

PUBLIC UNIVERSITIES

Yerevan State University
Yerevan State University, Idzevan Branch
State Engineering University of Armenia, Yerevan
State Engineering University of Armenia, Gyumri Branch
State Engineering University of Armenia, Vanadzor Branch
State Engineering University of Armenia, Goris Branch
State Engineering University of Armenia, Kapan Branch
Yerevan State University of Architecture and Construction
Yerevan State Institute of Economics
Yerevan State Institute of Economics, Gyumri Branch
Kh. Abovyan State Pedagogical University, Yerevan
V. Brusov Yerevan State Linguistic University
M. Nalbandyan State Pedagogical Institute of Gyumri
H. Toumanian State Pedagogical Institute of Vanadzor
Komitas State Conservatory of Yerevan
Yerevan State Conservatory, Gyumri Branch
Yerevan State Academy of Fine Arts
Yerevan State Academy of Fine Arts, Gyumri Branch
Yerevan State Academy of Fine Arts, Dilijan Branch
Yerevan State Institute of Theater and Cinema
Yerevan State Institute of Theater and Cinema, Gyumri Branch
M. Heratzi Yerevan State Medical University
State Institute of Physical Education, Yerevan
Armenian Agricultural Academy, Yerevan
State University of Gavar
Armenian-Russian (Slavonic) University, Yerevan
American University of Armenia, Yerevan
French University of Armenia, Yerevan

SOURCE: Provided by Armenian Embassy in Washington, D.C., May 2004.

Appendix E

Presentation of Armenian Ambassador Arman Kirakossian to the National Research Council Committee on Science and Technology in Armenia

Washington, D.C.
February 6, 2004

First, I want to thank the National Research Council and Mr. Schweitzer for extending me an opportunity to speak before you and present the Armenian government's perspective on science and technology in Armenia. I am glad to see representatives from the State Department, USAID (U.S. Agency for International Development), and CRDF (U.S. Civilian Research and Development Foundation). Armenia is fortunate to have the support of the people and the government of the United States in many areas, and your assistance in the area of science and technology is helping to preserve a bright future for Armenia.

I want to start by emphasizing that the single distinct feature of Armenian reality is the human capital of the nation. Unlike its neighbors, Armenia does not have oil, or gas, or other natural resources in significant amounts. What we have is people. Education is a priority for most if not all Armenian families. In fact, since the Armenian alphabet and literature in Armenian first appeared in the fifth century A.D., education, literary tradition, and scientific pursuit have played an important part in preservation of the national identity.

The reason it matters is this. The collapse of the Soviet Union, the 1988 earthquake, and economic blockades brought severe hardship and drastic reduction in national income. The poverty and income statistics for Armenia are not encouraging, but the presence of a strong educational and scientific capacity is an indication that the long-term development of Armenia can be assured. Yet, the maintenance and modernization of this capacity is essential if we want to

preserve the high levels of literacy, higher education, and scientific potential that Armenia enjoyed at the outset of independence in 1991 and continues to enjoy even now.

The literacy rates for Armenia are almost 100 percent, and the number of people with higher education is among the highest in the world. Secondary education is compulsory and free of charge through grade ten. The main problem, however, is the general economic conditions in the country. Similar problems continue to exist in the science sector. During Soviet times, the organizational structure was highly centralized and based on the Academy of Sciences. Some research institutions reported directly to federal agencies in Moscow and some to local Armenian ministries. The economic transition in Armenia has had a major impact on science, basic and applied research, and technological development. Armenia has more than 140 scientific institutes, centers, and other units, including major institutions like the Yerevan Physics Institute, the Byurakan Observatory, and the Microbiological Depository Center. The National Academy of Sciences [NAS-RA] coordinates fundamental and applied research in different fields. As a state scientific organization, the NAS-RA unifies scientific and research institutes and subsidiary services. In 2001, the Academy system had a total staff of about 4,600 employees, including a scientific staff of about 2,400 (116 academicians, 340 doctors of science, 1,150 candidates of science).

The story of Armenian science in the last decade was a story of survival and adaptation to new conditions. In 1998, scientific R&D expenditures in Armenia were 0.3 percent of the gross domestic product (GDP) and educational expenses were less than 2 percent of GDP. Although state funding is very low, Armenian scientists are doing excellent work in many areas, due to substantial scientific potential, recognized schools, research-oriented scientific traditions, and good equipment. The number of scientific publications was 0.8 per scientist per year in 1998, and the ratio of scientific personnel to the general population was 0.17 percent. Scientific institutions of course experienced a major problem as many scientists have emigrated. Yet, sometimes it can be beneficial as well, because the former staff members have helped to establish good contacts between their former and current institutions.

I want to speak about the problem of "brain drain" and emigration from Armenia. Armenia's census in 2002 showed that the permanent population in Armenia comprised 3 million people, implying an emigration of close to 800,000 people since 1989. Emigration has now significantly slowed down, but it is a cause of concern. The emigration of people from Armenia is the tragic result of underutilized economic potential. Neither is it an isolated phenomenon: we know from history that Ireland has suffered a similar brain drain, which is now being reversed. I have confidence that eventually, as Armenia's economic progress picks up, it will be possible to stop and reverse the migration in Armenia.

Soviet Armenia's economy, which was approximately twice the size of the current GDP, was anchored in the Soviet Union's command economy. By 1989,

Armenia had developed heavy industry, including radio electronics, defense, and chemical industries. This was a blessing in disguise, because it allowed a high level of urban employment but made Armenia completely dependent on the Soviet Union. Cities were built that depended on one huge plant to provide employment, like Hrazdan, Charentsavan, and Kapan. Pollution and social problems also arose.

Well, the Soviet Union no longer exists. Those enterprises that employed thousands of people are now idle, and the people who worked there found themselves out of a job. The problem of unemployment is especially tough for those with fewer skills. The Armenian government and the World Bank estimate that more than 50 percent of the population is vulnerable, while 23 percent live in dire poverty. The government, working together with its donors, has adopted a national strategy for poverty reduction that will stress the creation of economic opportunities, training, and targeted social work to significantly reduce poverty by 2014. Armenia's budget, which is much smaller than it was a decade ago, is also strained due to important expenditures on national defense and security, rebuilding the earthquake zone, and social welfare.

Obviously, the Armenian government is concerned about the future of science and education. There is a government activities program adopted in August 2000 that also addresses the situation in this field. The government plans to press ahead with reforms of the secondary schools, including streamlining the number of schools, increasing their academic autonomy, and introducing per-student subsidies to each school (instead of current, fixed financing from the budget, which is not flexible). This process, called "optimization," is under way in Armenia. Eventually, the government plans to introduce a six-day week for school students and an eleven-grade secondary education. An average secondary school now has ten grades, 1 through 10. In American terms, the students go through elementary, middle, and high school while attending the same secondary school.

The government plans to develop a national program for development of the education system. This program would provide for a significant increase in teachers' salaries, training, and establishment of teachers' training and continuing education centers.

As there are many private colleges operating in addition to the already established state colleges and universities, the government plans to develop a strong licensing and accreditation mechanism based on solid standards and to increase the colleges' autonomy. The government works with the U.S. State Department-sponsored program Project Harmony and other foreign donors to provide Internet connectivity for Armenia's secondary schools and state universities, to allow the students and faculty to fully utilize the modern research and high-technology tools available through the Internet.

SCIENCE

The government views the science sector, including the research institutes and laboratories, as an essential factor in the long-term economic and social development of the country. The primary objectives of the reforms in this sector should be to optimize the structure and management of the scientific institutions and to secure a steady flow of financing for them. In addition to state budget financing, the government envisages incentives for encouraging private-sector and third-party financing of R&D projects. The government has consistently increased science funding; this year's budget allocates approximately $6 million (1 percent of total government expenditures) to the scientific institutions.

A major help to the struggling scientific institutions is the existence of international foundations helping scientists in Armenia. The U.S. government has established the Civilian Research and Development Foundation (CRDF), which provides grant funding to scientists in the Newly Independent States; I know Mr. Modzelewski is going to make a presentation on CRDF later this morning. There is also the International Scientific Technical Center, a cooperative venture of the United States, the European Union, and the government of Japan, which fosters contacts between Western scientific institutions and their counterparts in Armenia. The U.S. government runs a number of other programs that benefit the Armenian scientists and educational institutions, for example, the Muskie Scholarship program, which allows dozens of Armenian graduate students to study in the United States every year. There's an organization called Armenian Engineers and Scientists of America, comprised of Armenian-American scientists as well as the scientists who have emigrated from Armenia, which has also been of great help to their Armenian colleagues. These programs have helped sustain the scientific institutions, orient them toward the needs of the private sector, and establish a culture of good cooperation and collaborative efforts with their counterparts in the United States and European countries.

I don't want to create an impression that everything is bleak in Armenian science. There are indeed many success stories. A recently published Armenian high-tech directory lists products by 38 Armenian scientific institutes and their branches. This is a testimony to their enterprising spirit and adaptation to new times. The Cosmic Ray Division of the Yerevan Institute of Physics participates in a global network of scientists involved in detecting neutrinos and other cosmic particles. New discoveries are being made by Armenian scientists in Armenia in physics, chemistry, and other areas.

As I said, many of the Armenian scientists who emigrated abroad continue to engage in research and help their colleagues back home to stay tuned to the current developments. One example, Yuri Oganessian—one of the scientists in Russia's Institute of Nuclear Reactions who together with their American colleagues recently announced the discoveries of new heavy elements—is originally from Armenia. One area where expatriates proved particularly helpful was the

information technology [IT] sector, which has become a booming industry. There are more than 20 large IT companies in Armenia that have capitalized on existing potential and the expertise of people like Ashot Hovanesian, who emigrated to the United States and established a company in Virginia called Synergy International, which supplies information management systems to the U.S. government and corporations. A significant part of the software is written by the Armenian branch of his company. Most Armenian IT companies work for U.S. and European customers.

There is another project that deserves the support of the government and the international community, namely the construction of Center for the Advancement of Natural Discoveries using Light Emission (CANDLE). This project will benefit Armenia and the larger region, because fundamental science knows no boundaries. I know that's one of the areas your team will look at in Armenia, and I certainly want that project to succeed.

Natural sciences should not be the only area that you explore, as the potential for social science is also great in Armenia. In particular, due to a rich history, literature, and culture, Armenian studies is one area where strong cooperation exists between the Armenian researchers and their colleagues in foreign universities and in the diaspora. Existence of institutional links between Armenian studies chairs and departments can help facilitate contacts between academic institutions in Armenia and the United States; it's also one area that attracts significant attention and funding from the Armenian diaspora.

As you travel to Armenia and meet with your colleagues in the academic institutions, you will discover a spirit of partnership, desire to collaborate, and willingness to consider new ideas and proposals. I say this from my personal perspective, as I have had the privilege of working in the Academy of Sciences system prior to joining the Foreign Ministry. The Armenian government and the Ministry of Education and Science will also be interested in the results of your work.

The key to the future of Armenian science is to increase government funding in this area, but also to encourage the private sector's direct participation and feedback in this process. I am sure that your study will provide concrete suggestions that will help the government, its international partners, and the scientific community. Thank you.

Appendix F

International Science and Technology Center Projects Funded in Armenia in 2003

Gas Sensing, Catalytic, and Heme-Modeling Properties of Metalloporphyrins' Sublimed Layers
Molecular Structure Research Center

Obtaining Monocrystallic Oxidic and Chalcogenidic Films by Way of Chemical Transportation of Crystallic Compounds
State Engineering University of Armenia and Yerevan State University

Investigation of Genes and Enzymes Involved in Pyruvate Metabolism in Coryneform Bacteria: Approaches to the Improvement of Amino Acid Strain Producers by Recombinant DNA Technology
Institute of Biotechnology and State Microbial Depository Center

Free Electron Laser without Inversion
Yerevan Physics Institute

Research and Development of New Polymer Materials for Treatment of Radiation/Thermal Burns
Research Center of Radiation Medicine and Burns and Yerevan Institute "Plastpolymer"

Rafaelites: Basis for Developing New Multipurpose Glass Ceramics
Scientific Industrial Enterprise of Material Science

Design and Synthesis of Compounds Possessing Antiviral (Anti-HIV) Action and/or Regulating the Activity of the Cardiovascular System
Institute of Fine Organic Chemistry

Research on Confinement Strength during a Large Break in the Primary Coolant System of an Armenian Nuclear Plant
Armenian Nuclear Regulatory Power Authority, Armenian Nuclear Power Plant, and Yerevan Physics Institute

Determination of the Incidence of Multiple Drug Resistant Tuberculosis and Tuberculosis Program Assessment to Conceive, Develop, and Implement a National Tuberculosis Reform Program, Republic of Armenia, FY 2003-2006
Armenian Centers for Disease Control and Prevention and Armenian National Institute of Health

Development of a Project on the Establishment of the Garni International Earth Science Research Center
Institute of Geological Sciences

Development of a Prototype Detector System for a Space Weather Monitoring and Forecasting Worldwide Network
Yerevan Physics Institute

SOURCE: Provided by the International Science and Technology Center.

Appendix G

U.S. Civilian Research and Development Foundation (CRDF) Grants in Armenia, 2002-2003

COOPERATIVE GRANTS PROGRAM (CGP)

2003A (Announced in August 2003)

Spectral and Kinetic Study of NO_x Reactions with Metalloporphyrins
Tigran Stepan Kurtikyan, Institute of Applied Chemistry
Peter Campbell Ford, University of California, Santa Barbara
Grant Amount: $68,000

New Technology for the Treatment of Molybdenum Sulfide Concentrates
Kliment Yenok Hakobyan, Navro, Ltd.
Hong Yong Sohn, University of Utah
Grant Amount: $80,000

Development of Multivariate Multiple Sampling Charts for Statistical Quality Control
Viktor Karoevich Ohanyan, Yerevan State University
David Weihua He, University of Illinois, Chicago
Grant Amount: $52,000

Growth and Investigation of Nonlinear Optical Crystals of L-Arginine, Its New Derivative, and L-Histidine Salts
Aram Petryosan, Yerevan State University
Mikhail Antipin, New Mexico Highlands University
Grant Amount: $55,000

Dual-Frequency Active Elements for Compact Lasers Based on Periodically Poled $LiNbO_3$:Er^{3+}- Yb^{3+} Crystals
Edvard Pier Kokonyan, Institute for Physical Research
John Gruber, San Jose State University
Grant Amount: $67,000

2003 B (Announced in February 2004)

Study of Very High Energy Cosmic Rays and Gamma Rays with the Improved GAMMA Array at Mt. Aragats
Roman Martirosov, Yerevan Physics Institute
Lawrence Jones, University of Michigan
Grant Amount: $80,000

The Design and Development of a Device for Accurately Determining Post-mortem Duration
Robert Simonyan, UNESCO Chair—Life Sciences International Educational Center I
Howard Wachtel, University of Colorado, Boulder
Grant Amount: $65,000

2002 BILATERAL GRANTS PROGRAM

Category A

Assessing the Conservation Status of Armenian Vultures: Sentinels of Environmental Change
Karen Ernest Aghababyan, Institute of Zoology, Armenian Academy of Sciences
Keith L. Bildstein, Hawk Mountain Sanctuary Association
Grant Amount: $26,850

Paleoecology and Paleo-radioecology of Lake Sevan, Armenia
Viktoria Levon Ananyan, Center for Ecological-Noosphere Studies, Armenian Academy of Sciences
William C. Burnett, Florida State University
Grant Amount: $29,300

Polarimetric, Active-Passive, Combined Measurements of Bare Soils, Wheat, and Herbaceous Vegetation at L-, C-, and X-Band Frequencies
Artashes Koryouni Arakelyan, Institute of Radiophysics and Electronics, Ashtarak, Armenian Academy of Sciences
Alexander G. Voronovich, National Oceanic and Atmospheric Administration
Grant Amount: $27,420

Armenian National Strong Motion Network Development
Valery Grigory Arzumanyan, National Survey for Seismic Protection
Roger Borcherdt, United States Geological Survey
Grant Amount: $25,600

B-Quark Decays as a Test of the Standard Model
Hrachya Manvel Asatryan, Yerevan Physics Institute
Alexander Kagan, University of Cincinnati
Grant Amount: $28,800

Electromagnetic Processes with Charged Particle Beams and Transition/ Diffraction Radiation
Hamlet Karo Avetissian, Yerevan State University
Todd I. Smith, Stanford University
Grant Amount: $28,100

Introduction of Pharmacophore Groups into Biogenic Pyridines by Pyrimidine Recyclizations
Gevorg Danagulyan, Institute of Organic Chemistry, Armenian Academy of Sciences
Alan Katritzky, University of Florida
Grant Amount: $28,150

Taxonomic Investigation of Armenian Grasses (Poaceae)
Eleonora Gabrielyan, Institute of Botany, Armenian Academy of Sciences
Mary Barkworth, Utah State University
Grant Amount: $27,400

Stochastic Implications of Combinatorial Integral Geometry
Ruben Victorovich Hambardzumyan, Institute of Mathematics, Armenian Academy of Sciences
Eric Grinberg, Temple University
Grant Amount: $26,000

Guide to Veterinary Parasitology in Armenia
Gurgen Hovnanyan, Institute of Zoology, Armenian Academy of Sciences
Dwight Bowman, Cornell University
Grant Amount: $26,640

Cold Atoms in an Optical Lattice
Artur Michael Ishkhanyan, Engineering Center, Armenian Academy of Sciences
Juha Javanainen, University of Connecticut
Grant Amount: $28,000

Intense Quasi-Monochromatic X-Ray Beams of Resonance Transition Radiation of 10-50 MeV Electrons and Their Application
Karo Asatour Ispiryan, Yerevan Physics Institute
J. Theodore Cremer, Adelphi Technology Inc.
Grant Amount: $22,120

Utility of Black Flies in Identifying Centers of Aquatic Diversity and Freshwater Impairment
Eugenie Ashotovna Kachvoryan, Institute of Molecular Biology, Armenian Academy of Sciences
Peter H. Adler, Clemson University
Grant Amount: $28,700

Study of Electrode-Induced Interface in Substrate-Electrode-$PbZr_{1-x}Ti_xO_3$ Heterostructures
Yevgenia Kafadaryan, Institute for Physical Research, Armenian Academy of Sciences
Naijuan Wu, University of Houston
Grant Amount: $28,810

Kinetics of Rapid High-Temperature Reactions in Gasless Systems: Non-isothermal Conditions
Suren Levoni Kharatyan, Institute of Chemical Physics, Armenian Academy of Sciences
Arvind Varma, University of Notre Dame
Grant Amount: $29,570

Entangled Bright Light and Distant Atomic Ensembles for Quantum Communication
Gagik Yuri Kryuchkyan, Yerevan State University
Janos A. Bergou, City University of New York, Hunter College
Grant Amount: $24,450

Jets from Young Stars: Deciphering the Fossil Record of Star Birth
Tigran Yurievich Magakian, Byurakan Astrophysical Observatory, Armenian Academy of Sciences
John Bally, University of Colorado, Boulder
Grant Amount: $28,700

Nonlinear Optics at Low-Light Level in Coherent Atomic Media
Yuri Panuiri Malakyan, Institute for Physical Research, Ashtarak
Dmitry Budker, University of California, Berkeley
Grant Amount: $25,230

Determination of the Energy Spectrum and Mass Composition of the Primary Cosmic Rays with the GAMMA Installation at Mt. Aragats, Armenia
Romen Martirosov, Yerevan Physics Institute
Lawrence W. Jones, University of Michigan
Grant Amount: $27,680

The Asymptotic Behavior of Toeplitz and Winer-Hopf Determinants with Singular Symbols and Their Applications
Levon Velikhani Mikayelyan, Yerevan State University
Estelle L. Basor, California Polytechnic State University
Grant Amount: $27,300

Chemically Activated Combustion Synthesis and Densification of Boron Nitride-Based Composite Materials
Lvoya Dadivanyan, Institute of Chemical Physics, Armenian Academy of Sciences
Jan A. Puszynski, South Dakota School of Mines and Technology
Grant Amount: $28,400

Gravitational Waves from Neutron Stars with Superfluid Component
David Mher Sedrakyan, Yerevan State University
Matthew Benacquista, Montana State University
Grant Amount: $29,200

Investigation and Development of New Effective Methods and Apparatus for Measurement of Solar Cell Parameters
Ruben Vardanyan, State Engineering University of Armenia
Richard Ahrenkiel, National Renewable Energy Laboratory
Grant Amount: $28,084

Category B (Equipment)

Comparative Studies of Influence of Interstrand Cross-Links and Strongly Stabilized Sites Caused by Metal-Based Antitumor Compounds on DNA Structure, Stability, and Thermodynamic Properties
Samvel Garnic Haroutiunian, Yerevan State University
Roger Wartell, Georgia Institute of Technology
Grant Amount: $79,500

Oxo Transfer Reactions of Metalloporphyrin Nitro Complexes
Tigran Kurtikyan, Molecular Structure Research Center, Armenian Academy of Sciences
John Goodwin, Coastal Carolina University
Grant Amount: $79,400

Novel Photonic Materials Based on Poly(arylureas)
Shiraz A. Markarian, Yerevan State University
Frederick Lewis, Northwestern University
Grant Amount: $79,300

Development and Mass Production of the Ceramic PCBs [Printed Circuit Boards] for Preshower Detector of the CMS [Compact Muon Spectrometer] Experiment at LHC [Large Hadron Collider] (CERN [European Organization for Nuclear Research])
Albert M. Sirunyan, Yerevan Physics Institute
Vasken Hagopian, Florida State University
Grant Amount: $70,700

SOURCE: Provided by CRDF, June 2004.

Appendix H

U.S. Government Assistance to Armenia, 2003

Freedom Support Act Funds Budgeted (million dollars) Agency		
U.S. Agency for International Development (USAID)		
Democratic Reform	7.73	
Energy-Sector Reform	7.70	
Environmental Management	2.60	
Parking Fine Withholding	0.00	
Private-Sector Initiatives	16.78	
Social-Sector Reform	11.36	
Cross-Cutting, Special Initiatives	7.53	
Eurasia Foundation	1.99	
Total		55.69
U.S. Department of Agriculture (USDA)		
Marketing Assistance Program	7.00	
Cochran Fellowship Program	0.10	
Total		7.10

U.S. Department of Commerce		
Business Information Service for the Newly Independent States (BISNIS)	0.10	
Special American Business Internship Training (SABIT) Program	0.20	
Total		0.30
U.S. Department of State		
Bureau of Educational and Cultural Affairs Public Diplomacy Exchanges	11.73	
EUR Bureau—Public Diplomacy Programs	0.40	
Coordinator's Office (EUR/ACE) Humanitarian Assistance, Transportation Costs, Grants	1.00	
Export Control and Related Border Security	0.50	
Bureau of International Narcotics and Law Enforcement Affairs	2.20	
International Information Programs	0.04	
Performance Funds	2.60	
Total		18.47
U.S. Department of Treasury—Technical Advisers		0.99
U.S. Department of Energy—Nuclear Reactor Safety		4.47
U.S. Nuclear Regulatory Commission—Nuclear Reactor Safety		0.80
National Science Foundation, Civilian R&D Foundation		1.59
Other Sources		
USAID—Public Law 480, Title II—Contribution to United Nations World Food Program		3.99
U.S. Department of State		
Bureau of Educational and Cultural Affairs Public Diplomacy Exchanges	0.49	
Export Control and Border Security	1.01	
Foreign Military Financing	5.00	
International Information Programs	0.02	
International Military Education and Training	0.66	

NADR Humanitarian Demining	0.75	
PRM Humanitarian Assistance	0.12	
Science Centers	1.00	
Total		9.05
U.S. Department of Defense		
International Counterproliferation	0.30	
ODHACA Humanitarian Demining Program	1.10	
Total		1.40
U.S. Department of Energy—		
Materials Protection, Control, and Accounting		0.60
Peace Corps—Volunteers		1.70
Total U.S. Government Funds Budgeted in 2003		106.16
Value of Donated Humanitarian Commodities		14.42
Total FY 2003 U.S. Government Assistance		**120.58**

NOTE: ACE = Office of the Coordinator of U.S. Assistance to Europe and Eurasia; EUR = Bureau of European and Eurasian Affairs; NADR = Nonproliferation, Antiterrorism, Demining, and Related Programs; PRM = Bureau for Population, Refugees, and Migration.

SOURCE: Provided by U.S. Department of State, June 2004.

Appendix I

Caucasus Seismic Information Network: International Science and Technology Center (ISTC) Project A-651

Title:	Caucasian Seismic Information Network for Hazard and Risk Assessment (CauSIN)
Status:	Project under way
Leading Institute:	Armenian National Survey for Seismic Protection and Seismic Hazard Assessment Complex Center, Yerevan, Armenia
Supporting Institutes	Geophysics Institute, Tbilisi, Georgia
	Armenian Association of Seismology and Physics of the Earth's Interior, Yerevan, Armenia
	Institute of Geological Sciences, Yerevan, Armenia
	Georgian Geoecological Service Center, Tbilisi, Georgia
	Georgian Geophysical Society, Tbilisi, Georgia
	Institute of Mechanics, Yerevan, Armenia
	Scientific Research Company GEORISK, Yerevan, Armenia
Collaborators:	National Observatory of Athens/ Institute of Geodynamics
	Lawrence Livermore National Laboratory
	Massachusetts Institute of Technology
	Ecole et Observatoire de Physique du Globe, Strasbourg, France
	Massachusetts Institute of Technology/Earth Resources Laboratory

Project Summary

The Caucasus is a region of numerous natural and manmade hazards and ensuing disasters. Analysis of the losses due to past disasters indicates that those most catastrophic in the region have historically been due to strong earthquakes, dating back as far as the 19th millennium B.C.

In more recent times, seismic risk in the region has reached its highest level over the entire historical period of the existence of the Caucasus countries. This is due in large part not only to the increased population and urbanization but also to the recurring cycle of high seismic activity leading to a high probability of new strong seismic events. In addition, the relatively low seismic resistance of existing buildings and structures when compared to the actual level of seismic hazard, poor preparedness of the population and government agencies, difficult economic conditions, political problems, and many other social and economic problems add to the already high seismic vulnerability of the countries in the region.

The impact of an earthquake is not only limited to direct losses, such as losses of life, building damages, and business disruptions. Earthquakes also cause indirect losses by producing supply shortages and demand reductions in various economic sectors that do not sustain direct damage. Indirect losses have a ripple effect that is transmitted throughout the regional economy and the social fabric. In a country with a fragile economy such as Armenia or Georgia, a large earthquake can actually contribute to an economic or governmental collapse.

Seismic faults and the ensuing hazards due to these fault zones have no state boundaries, and a catastrophe in the region could easily damage neighboring countries. Taking this into consideration as well as the great interest of each state in the region in protecting its own population and sustainable economic development, the problem of earthquake hazard assessment and risk reduction in the Caucasus countries is essential to all countries of the region.

The main objective of the project is to establish a basis for further seismic risk reduction studies in the Caucasus region. The main tasks of the project are:

1. Database creation
2. Seismic hazard assessment
3. Calibration for determination of sites for regional seismic stations and Comprehensive Test Ban Treaty (CTBT) monitoring
4. Tectonic studies
5. Seismic risk assessment and training

Seven institutions from Armenia and Georgia will participate in the project:

- National Survey for Seismic Protection under the Government of the Republic of Armenia
- Armenian Association of Seismology and Physics of the Earth's Interior

- National Academy of Sciences of Armenia
- Scientific Research Company GEORISK
- Institute of Geophysics, Georgian Academy of Sciences
- Georgian Geological Service Center GEOECO
- Georgian Geophysical Society

The participating institutes have rich research experience in the aforementioned fields. The main scientific and engineering potential of Armenia and Georgia in the field of earth sciences is concentrated in these institutions.

Implementation of the project will support the creation of a shared, quality-controlled regional database that will include seismological, geological, geophysical, geotechnical, and other data as well as data on critical facilities that could have significant impact in the region if damaged. During project implementation, existing scientific data will be collected and newly interpreted for input in the database. Based on the newly created database, a range of regional seismic hazard models will be formulated and seismic risk will be assessed for selected structures/facilities.

Tectonic studies and physical/mathematical modeling will be used to create regional seismotectonic and geodynamic models. Active tectonic structures will be traced and adjusted in transborder regions.

Special attention will be paid to regional calibration aimed at site selection for installation of the regional seismic network and facilitation of CTBT monitoring.

New and modern approaches to seismic risk assessment will be applied to assessing loss estimation for selected structures/facilities in the region. Training workshops and pilot training for policy makers and members of the media will be conducted.

Scientific and practical results obtained through project implementation will be transferred in a usable format as recommendations to appropriate state and private institutions, organizations, and companies interested in or responsible for managing and mitigating natural hazards.

Project implementation will facilitate establishment of a basis for further seismic risk reduction activities in the region and will promote close collaboration of scientists and policy makers in this field. The project will provide weapons scientists and engineers with opportunities to redirect their knowledge and skills to peaceful activities. In addition, it will support research and technology development in the fields of seismic hazard and risk assessment, seismic risk reduction, and environmental and population protection.

Foreign collaborators have been actively involved with the development of this project and will continue to collaborate with project participants in the following areas:

- Serving on technical advisory committees for each project area to provide input and guidance for project implementation as well as participation in regular meetings
- Exchanging data during project implementation
- Providing peer review of project results
- Participating in semi-annual project review meetings
- Commenting on technical reports being submitted to the ISTC
- Conducting joint symposia and seminars
- Collaborating on scientific exchanges in various study areas
- Taking part in complementary activity through leveraging funds from related projects funded by other agencies
- Providing opportunities for hosting project participants at Western universities and laboratories
- Disseminating as widely as possible validated results from the project and identifying other sources of support

It should be noted that colleagues from Azerbaijan participated in the development of this project. It is the intention of project participants and collaborators to include colleagues from this country to the extent possible through funding sources beyond the ISTC. In addition, discussions have been held with the North Atlantic Treaty Organization and the INTASS program to ensure that this project is well coordinated with other related projects and to pursue funding of related efforts through a coordinated approach with these other potential funding organizations.

SOURCE: *http://www.istc.ru*

Appendix J

Extracts from Testimony of Paul V. Applegarth, Chief Executive Officer, Millennium Challenge Corporation (MCC)

HOUSE COMMITTEE ON INTERNATIONAL RELATIONS

May 19, 2004

MCC completed a major milestone on May 6, 2004, when the Board of Directors selected 16 countries as eligible for funding from the Millennium Challenge Account (MCA). The eligible countries for FY 2004 are:

Armenia	Georgia	Madagascar	Nicaragua
Benin	Ghana	Mali	Senegal
Bolivia	Honduras	Mongolia	Sri Lanka
Cape Verde	Lesotho	Mozambique	Vanuatu

For several decades, many of us have worked to change the conditions in developing nations. . . . Many programs, policies and institutions are making significant changes but some, unfortunately, are not succeeding as well as we would like. Building on what has been learned in international development assistance, the MCC will take a new approach, one that combines six major concepts in an unprecedented way:

- MCC emphasizes *policy reform.*
- It *focuses exclusively on sustainable growth.*
- Its relationship with emerging countries will be characterized by a *spirit of partnership.*

- MCC will require partner countries to *incorporate the views of broad elements of their societies* as they determine their priorities.
- It *focuses on results* and establishes outcome-based standards for success up front.
- It establishes *accountability* as a key operating principle and will *monitor progress* on an on-going basis.

Previous development assistance has involved these concepts with varying degrees of emphasis and success. The fact that all of them are key structural components of MCC makes MCC truly different—and, I believe, capable of making a real difference in the lives of millions. Let me elaborate briefly on some of these core elements of MCC's approach. First, policy reform. Research has shown repeatedly that development aid produces the best results when it is targeted to countries that respect political and economic rights and freedoms, respect the rule of law, and pursue effective growth policies. Thus, MCC provides incentives for countries to adopt or maintain policies for governing wisely, investing in their own people and promoting economic freedom. Policy reforms in poor nations can provide opportunities for citizens to benefit from increased international trade and private capital flows, from the growth of their domestic economics, and from greater economic and political freedom. These reforms, in turn, can have a much greater impact than whatever MCC itself achieves.

President Bush told me personally that providing incentives for policy reform to our partner nations is a critical aspect of our new approach. MCC provides incentives for countries to change their policies, reward those that do, and assist them in achieving their development goals.

Second, MCC will promote sustained economic growth. There are many legitimate purposes of development assistance, including disaster relief, food aid, and disease prevention. But over the years, the press of short-term needs has squeezed out attention onto long-term issues. Thus, MCC's focus would include investments in agriculture, education, private sector and financial systems development, legal and regulatory reform, and enabling infrastructure. *Our exclusive mission is to focus on the long-term challenge of assisting developing countries to escape their dependency status through self-sustaining economic growth.*

Partnership is a critical third piece. This is a major change in the relationship between donors and recipient nations. Millennium Challenge Corporation will ask qualified nations: What are *your* development priorities? This positive, empowering approach gives partner nations ownership for their programs from the start, and then provides the financing they need.

Let me add that this partnership spirit should extend beyond MCC's relationship with its partner countries. MCC has an extraordinary Board. USAID [the U.S. Agency for International Development], the State and Treasury Departments, and the U.S. Trade Representatives are each represented on MCC's Board. All greatly contribute to MCC's own expertise, experience, resources and country

relationships. MCC's own staff is lean by design. We should and will take maximum advantage of what these partners, and others within the U.S. government, can contribute.

Fourth, to meet MCC criteria, each partner nation must *consult broadly* within its society to determine their priorities. This ensures the participation of non-governmental bodies, private businesses, and representatives of civil society, with all their skills, knowledge, interests and concerns.

Fifth, MCC will enter into Compacts with qualifying nations that *focus on outcomes* that outline concrete objectives, benchmarks and responsibilities for meeting development goals.

And finally, partner nations will be accountable for their performance. If a country's performance under a Compact begins to falter, MCC will attempt to find ways to support and assist it. However, if under-performance is chronic or if a country fails to live up to its commitments, MCC must be prepared to terminate funding and end a Compact.

OPERATIONAL PROCEDURES

As the first step in the partnership between the MCC and eligible countries, eligible countries will identify their priorities and the programs to achieve them, and submit proposals for assistance to the MCC. Proposal guidance is posted on our website (*www.mcc.gov*) and will also be shared directly with the 16 eligible countries.

The six core concepts that I described above—the core structural components of the MCC—will encourage partner countries to adopt and implement better policies, to develop institutions and build capacity to govern wisely, to invest in their own people and to promote economic freedom. At the same time, these core concepts also provide a clear opportunity for the USG to demonstrate international leadership in promoting economic growth that will help reduce poverty in many of our world's poorest countries. They articulate an international role for the United States that is a positive statement about our country and our values.

This year's 16 eligible countries—and others as well—are clearly eager to be partners and participants. Over the three months that the MCC has been in existence, we have heard from many of them. Indeed, countries have already begun to discuss ways to improve their performance on the indicators.

In short, the incentives inherent in the MCC's core concepts are already at work, even before the MCC has entered into a Compact or disbursed a single dollar. This is the ultimate sign of the ability of this approach to catalyze positive change.

BUDGET PRIORITIES

The Compacts between the MCC and partner countries will establish multi-year programs that involve significant up-front commitments by countries, which will commit to continued policies and actions that promote growth, and by the MCC, which will commit to deliver a significant level of financial assistance. These commitments by the MCC and partner countries will permit the countries to achieve measurable objectives that lead to economic growth and poverty reduction.

MCC allocation and funding decisions will be driven by the quality of each country's proposal rather than by the number of eligible countries that submit proposals. MCC may not finalize Compacts with all eligible countries if the programs proposed do not meet MCC standards. But where we can successfully negotiate a Compact, it is important that the MCC be able to provide substantial funding. Being among the largest providers of assistance in a country will allow the MCC to be an effective incentive, to command the attention needed for breakthrough country proposals, and to galvanize the political will essential to success.

In order to underscore this commitment, the MCC plans to fully fund multi-year Compacts at a magnitude that would make it either the largest or second largest donor on average in country. In an analysis earlier this year, the GAO [General Accounting Office] estimated that, with a funding level of $3.5 billion, the MCC could fully fund three-year Compacts in 8 to 13 countries.

Appendix K

Government of the Republic of Armenia Resolution No. 1302-N, August 15, 2002

Approved by the President
of the Republic of Armenia, R. Kocharyan,
on August 30, 2002

On Science and Technology Development Priorities in the Republic of Armenia

1. In compliance with the Law of the Republic of Armenia on Scientific and Technological Activities, the Government of the Republic of Armenia decides:

To approve the science and technology development priorities as follows:

- Armenian studies
- Basic research promoting applied research of vital importance
- Special purpose research
- Information technologies
- Advanced technologies (biotechnology, nanotechnology)
- New energy sources
- Risk factors and human health
- New materials

2. The Ministry of Education and Science, the National Academy of Sciences, and other interested ministries are prescribed to undertake adequate measures

directed to the development of priority science and technology fields and the training and retraining of skilled specialists.

A. Margaryan
Prime Minister of the Republic of Armenia

SOURCE: Provided by the National Academy of Sciences of Armenia, February 2004.

Appendix L

Proposals on Priority Areas for Science and Technology Development in the Republic of Armenia

This document briefly presents and explains the proposals of the National Academy of Sciences of Armenia (NAS-RA) regarding priority areas for science and technology development in the Republic of Armenia. It is based on Resolution No. 1302 of the government of the Republic of Armenia dated August 15, 2002, entitled "On Science and Technology Development Priorities in the Republic of Armenia." Taking into account the NAS-RA proposals on top-priority scientific and technical areas and programs for implementation in 2002-2006, this document presents fundamental principles regarding the improvement of scientific and technical endeavors as well as plans for targeted programs aimed at developing these priority fields.

LIST OF PROPOSED TARGETED PROGRAMS

Armenian Studies

- History of the Armenian people from ancient times to the present day
- The Republic of Armenia as a factor in the Transcaucasus-Middle East geopolitical region
- History of Armenian literature
- History of Armenian artistic culture
- History of Armenian philosophy
- Problems of shaping and managing the economy of the Republic of Armenia and its energy infrastructure

Information Technologies

- Creation of an information system for the state agencies of the Republic of Armenia
- Creation of a state scientific computing system

Laser Physics, Instrumentation, and Technologies

- Basic research aimed at stimulating development of the most important fields of applied research

Nanotechnology

- Nanotechnology and semiconductor nanoelectronics

Risk Factors and Human Health

- New biochemical preparations for treating a number of immunodeficiency and infectious diseases
- Identification and prevention of the impact of dangerous factors on the environment and human health
- Preservation of natural resources and improvement of water quality in Lake Sevan

Biotechnology

- Application of bioleaching for extracting copper and gold from Armenian ore deposits
- Development of hydroponic, biotechnologically valuable, rare, and endangered plants (medicinal and aromatic plants, spices, etc.) and initiation of their soil-free cultivation

New Materials

- High-temperature superconductivity
- Efforts to ensure the long-term operation of the Arpa-Sevan tunnel
- Compounds and materials with special properties based on Armenian natural raw materials

FUNDAMENTAL PRINCIPLES REGARDING THE IMPROVEMENT OF SCIENTIFIC AND TECHNICAL ENDEAVORS

The scientific infrastructure in Armenia was created in its present form in the 1930s and 1940s. This structure and the state policy of stable support for science

gave Armenian scientists the opportunity to develop research activities effectively. A number of results obtained by Armenian scientists over the past 60 years would do honor to a major scientific center in any developed country. During all of these years, the NAS-RA has justly been counted among the ranks of the leading academies.

Science in Armenia has traditionally enjoyed high prestige, and today one of the most important objectives of state and national security lies in preserving and developing the country's scientific potential and ensuring its competitiveness in the world arena.

The first task is to maintain the positions achieved by Armenian scientists in the basic sciences, inasmuch as it is more difficult to establish and develop scientific schools in these fields. They are formed and consolidated over many years. World experience has shown that in many countries, even material prosperity is insufficient to ensure the accelerated development of basic science.

The following concept expressed by Armenian president Robert Kocharyan is of indisputable importance: "We have set forth the idea of creating a consolidated state. Armenia must have science-intensive industry and must become a center of intellectual thought for the region."

The question of preserving and developing scientific potential in basic science is fundamentally important. While attaching great significance to applied scientific and technical research, it is nevertheless impossible to ignore the fact that applied research as a rule depends on basic science. The loss of accumulated potential in basic science would be an unforgivable and irreparable error. It is fundamental achievements in basic research that ensure stable scientific-technical progress. Basic research is also extremely necessary in university-based science and education; without it, the universities cannot train qualified personnel even for the applied spheres, the need for which will again be evident both for the development of domestic technologies and for the introduction of technologies developed by other countries.

This document presents basic principles for improving scientific and technical endeavors, as well as related proposals, the implementation of which could provide the appropriate foundation for preserving and further developing the current level of science and technology in Armenia.

In the aim of maintaining this level and ensuring the appropriate foundation for the development of basic science, it is essential to implement a science policy based on the following principles.

1. Unconditional implementation of principles included in laws, administrative acts, and regulatory documents of the Republic of Armenia regarding science and scientific-technical activities. Establishment of controls over the ongoing process by the appropriate agencies.

A fundamental achievement of recent years was the passage of the Law on Science and Scientific-Technical Policy, which defined the role and place of the NAS-RA in the country's scientific system. However, in violation of this law, the government of the Republic of Armenia has largely assigned the "management of science" to the Ministry of Education and Science. Cautious steps have been taken recently to increase the functional role of the Academy in this regard. This is undoubtedly insufficient. Strict observance of the law must be ensured.

The law emphasizes the primary role of the Academy system in the scientific life of the republic. In accordance with the law, the Academy is the highest scientific center of the Republic of Armenia, and it organizes and carries out basic and applied research on scientific problems and coordinates ***basic research*** conducted in scientific organizations and higher educational institutions.

The law clearly notes that the Academy is accorded special status in the areas of science policy development and implementation as well as science management in the Republic of Armenia, and in its relations with the state the Academy is to be in direct contact with the republic's Prime Minister.

The NAS-RA is the official scientific adviser of the government, and its proposals are required to be discussed by government agencies and state administrative units. Core and program-targeted financing for the activities of the Academy is included as a separate line item in the state budget.

The above-mentioned principles are still not being implemented, and neither is the important provision by which "beginning in 2002 the state allocates funds totaling at least three percent of the annual expenditure portion of the state budget to finance science and scientific-technical activities." This circumstance is having a strongly negative impact on the development of scientific activities.

Understandably, the republic's budget deficits for 2001 and 2002 (and evidently for 2003 as well) made it impossible to accomplish this objective, but with the proper attitude toward science, special mention could have been made of this point during adoption of the budget so as not to evoke scientists' mistrust of the laws. It is essential to maintain respect for the law. It is essential simply to indicate when it will be implemented. It is also essential

- First of all, to observe the norms stipulated by the law;
- To clarify the meaning of "management of science" and specify the responsibilities and rights of the Ministry of Education and Science and the NAS-RA in matters of developing and implementing science policy; and
- To submit for discussion by the government of the Republic of Armenia the question of recognizing the NAS-RA as the authorized agency of the Armenian government in the field of science, taking into account the fact that the Academy president is granted the rights, privileges, and authorities of a minister.

All of this is clearly indicated in the law, and there is no need now to pursue devious ways of making changes, especially unreasonable changes. The govern-

ment of the Republic of Armenia must simply bring the authorities of the NAS-RA in the science sphere into accordance with the law.

2. Improvement of the management system. Optimization of the systems network.

The NAS-RA has on many occasions noted the urgent need to energize the work of the Scientific and Technical Policy Council, which in actuality must become the highest entity involved in forming and implementing science policy in the Republic of Armenia. Given the existing diversity of organizations operating in the science sphere in Armenia and the insufficient utilization of resources, facilitating the work of the Council is a pressing task.

The Council should consist of the republic's leading scientists and representatives of industry. The head of the Council, the President of the Republic of Armenia, must be the guarantor for implementation of scientific and technical policy in accordance with the country's interests and needs. Following the example of the Russian Federation, the responsibilities of deputy chair of the Council will be held by the president of the NAS-RA, which ensures the expert nature of the Council's activities based on the appropriate scientific units and institutes of the Academy and utilizing the capabilities of its various problem-oriented councils. These bodies include the leading scientists of the relevant branches of science in the republic, and they are assigned these responsibilities in accordance with the charter of the NAS-RA.

It is difficult to explain the fact that over the course of several years the Russian Federation, following our example, organized an analogous Council under the auspices of the Russian President, while we in fact consigned our own Council to inactivity. Why? Numerous attempts have been made to revive the work of the Council, but without result.

We are certain that the President of the Republic will succeed in taking care of this situation.

The Council's fundamental objectives must be to guide state scientific and technical programs in the republic, establish priorities for the development of scientific and technical progress, and determine necessary funding levels and mechanisms. The Council must ensure the following:

- Adoption of the appropriate decisions on the status of science and especially on certain high technologies as well as the effectiveness of the use of state budget allocations
- Creation of productive linkages between scientific research, technological developments, and industry
- Discussion of proposals and ratification of decisions on the signing of interstate contracts on scientific and technical development, scientific and technical progress in general, the organization of efforts to sign protocols and agreements,

mechanisms for protecting intellectual property rights, and the development of programs for the education and training of particularly gifted young people abroad.

At the present stage, while in the process of negotiating the difficult path of preserving science, the NAS-RA in turn is implementing new approaches for the structural improvement of its own system, including the following:

- Eliminating unnecessary or ineffective departments from its administrative structure
- Reviewing the structures of institutes and conducting a recertification of personnel
- Consolidating research themes and unifying the efforts of groups engaged in the study of related problems
- Discussing and resolving issues concerning the more efficient economic utilization of buildings and equipment of Academy institutes and devoting the savings to the development of science
- Considering a program of creating international centers for which the necessary preconditions already exist, given the importance of regional tasks and international cooperation in the aim of involving Armenian scientific society in the productive collaborative process in the international arena.

3. Increased funding for science. Efficient use of limited resources. Improved mechanisms for acquiring funds besides those provided by the state budget.

At present, scientific activity is largely funded according to the principle of thematic financing and through international grants. Furthermore, the scientific organizations of the NAS-RA, higher educational institutions, and institutes under the auspices of government departments and ministries receive financing from the state budget. These latter non-Academy institutes were previously established with the aim of developing various industrial and agricultural sectors and introducing new, more efficient technologies in them. It should be noted that the unprecedented economic development of Soviet Armenia was facilitated thanks to the patriotic work of many of these institutes. However, in contrast to Academy research organizations, which focus mainly on basic research, the results obtained in the non-Academy institutes must find direct application in a particular branch of industry. Therefore, it is natural that these applied institutes were financed by the corresponding production associations (which included these expenses in the production costs of their products).

Both local and foreign sponsors can also contribute to the financing of science (especially to the preservation of jobs, as well as the publication of works in the field of Armenian studies), if such activity is encouraged by the state.

During a meeting with scientists at the NAS-RA, President Kocharyan noted that the government's caring approach to the field of Armenian studies is

explained not only by the importance of research in our history and culture but also by the fact that this field of science, lacking international interest as it does, likewise lacks broad possibilities for attracting grants. For effective comparison of the above-mentioned forms of financing for science, the following measures must be taken:

- The continued growth of state budget financing for preserving and developing science must be ensured, and its volume must be reviewed each year with an eye to the capacities of the state budget and of other sources not prohibited by law.
- Institutes of the NAS-RA system must be funded primarily according to the base financing principle.
- University-based science must be funded according to the thematic financing principle.
- Industrial enterprises in the relevant sectors should be attracted to fund non-Academy applied research institutes as well as applied research projects of the NAS-RA.
- In preparing and approving the budget for science, the proportion of funding provided by international scientific programs must be considered, which will also promote the growth of the science budget overall.
- Tax incentives should be provided for local entrepreneurs who make contributions to support basic science research.

4. Reform of training for scientific and technical personnel. Development and implementation of effective mechanisms for improving the skills of specialists.

Cuts in state funding for fellowships at the master's and doctoral levels and the long-standing lack of attention to state support for basic, cutting-edge, and promising fields of science in the sphere of postgraduate specialized education do not promote the building of linkages between science and education.

Training solely within the framework of local scientific schools does not ensure the appropriate level of preparation for scientific personnel and in some cases leads to the stagnation of the scientific field itself.

Tendencies toward obsolescence are being observed in the system for training scientific personnel, along with a certain randomness in the selection of scientific fields and a lack of correlation between current demands and top-priority areas. To correct this situation, the following measures are proposed:

- The demand for scientific personnel in the Republic of Armenia in the fields of management, industry, agriculture, engineering, technology, and basic science (including Armenian studies) must be clarified by specialty, regardless of the actual possibilities for their training in the republic.
- Based on an analysis of objective data collected over many years, a deter-

mination must be made of the fields in which it is possible for local scientific schools to train specialists who meet contemporary demands, taking into account the effectiveness of guidance by leading specialists working in the given field and the availability of the necessary material-technical infrastructure.

- If the necessary conditions are lacking for training the specialists that the republic needs, the appropriate training must be provided in foreign centers by concluding international agreements regarding graduate school placements for the training of personnel in specific fields in the leading scientific centers abroad. (This method is also efficient because it consequently provides Armenian scientists working abroad with informal colleagues in a given field.)
- To facilitate the further professional growth of young scientists (Ph.D.s), opportunities must be found for sending them on visits to the leading international scientific centers to improve their qualifications.

5. Provision of favorable working and social conditions for scientific personnel.

Science requires an appropriate professional environment and a continual influx of young personnel. At present, the average age of scientists is rather high, while the number of young specialists choosing science is unfortunately far from satisfactory. After receiving their Ph.D.s, the majority of young people either leave science and work in other fields or else find work in their specialties in foreign science centers. The basic reasons for this situation lie in unfavorable working and social conditions. To attract talented young people to basic science, the following measures are necessary:

- Working conditions for scientists must be improved to bring them as close as possible to modern standards (materials, equipment, professional travel, scientific literature, etc.).
- The matter of supplemental salary payments for advanced degrees and titles as stipulated in the law must be resolved in order to encourage professional growth among scientists and accelerate the process of generational turnover.

6. More effective utilization of the material-technical infrastructure of scientific organizations and units.

Over time, the instruments, equipment, and experimental base acquired by the NAS-RA or designed and built within its system have become physically worn and technologically obsolete, while the modern equipment acquired in recent years using funds from various grants is insufficient for carrying out broad-scale research. The following actions are necessary to remedy this deficiency:

- An inventory should be taken of all equipment of more or less value within the institutes of the NAS-RA system.
- Equipment unsuitable for further use or duplicate equipment should be written off, with the funds freed up to be put toward the acquisition of new equipment.
- For related institutes or laboratories, an experimental and material-technical infrastructure featuring unique equipment should be created for joint use, which in turn will stimulate further optimization of the system of institutes and their structure.

LIST OF TARGETED PROGRAMS PROPOSED BY THE NAS-RA

Armenian Studies

History of the Armenian People from Ancient Times to the Present Day

The NAS-RA Institute of History has done a great deal of work in recent years to study fundamental questions of the history of the Armenian people. This work has resulted in the publication of dozens of scientific reports, monographs, collections of articles, school textbooks, and teaching aids on the history of the Armenian people. A multitude of declassified archival documents and materials has been put into circulation, making it possible to take a new and objective look at the history of the Armenian people in recent times as well as in the Soviet period. It is no secret that many questions regarding these periods of history either have been covered in a one-sided manner, from the positions of Communist ideology, or have not been covered at all. The scientific potential of the Institute of History makes it feasible to prepare a multivolume work for publication in a short time. The final result of this project will be the publication of a multivolume comprehensive history of the Armenian people in Armenian, Russian, and English, a work that will have great significance not only scientifically but also politically. It will allow members of the Armenian diaspora, as well as foreign specialists, to obtain reliable and objective information on the history of the Armenian people. The publication of this new multivolume work will also represent a rebuff to those circles of foreign pseudospecialists who are engaged in falsifying the history of the Armenian people. (*Cost:* 47,260,500 drams over four years)

The Republic of Armenia as a Factor in the Transcaucasus-Middle East Geopolitical Region

The NAS-RA Institute of Oriental Studies carries out studies of the politics of the republic's immediate neighbors (Turkey, Iran, Georgia, and Azerbaijan), the balance of forces within the Transcaucasus-Middle East space, and the revela-

tion of Armenia's place in the system of global and regional structures. A key point lies in a factor facing all states without exception, including Armenia, namely Armenia's international weight and the role it plays and is capable of playing in modern international relations. This problem should be viewed in the framework of the Transcaucasus-Middle East political system, which is shaped by two circumstances. First, the Transcaucasus and the Middle East are the vital political-geographical space of Armenia. Second, they occupy an important place in modern international relations and lie at the center of the political and military interests of the United States, Russia, the European Union, and the North Atlantic Treaty Organization (NATO). Consequently, shedding light on the Armenian factor in a Middle East-Transcaucasus context takes on not only regional but also international significance. This project entails the organization of scientific conferences and roundtables, the preparation and publication of monographs and scientific articles, and the presentation of analytical guidance to the Armenian government. (*Cost:* 9.8 million drams over three years)

The History of Armenian Literature

An enormous amount of material on the history of Armenian literature has been accumulated in recent decades. This material must be considered in light of the new demands of literary science. On the other hand, the scientific community and readers need publications that embrace the entire history of Armenian literature and present the process of Armenian literary development from new viewpoints and on a high theoretical level. A three-volume collective monograph will be published based on the results of this research, with an abridged one-volume version in English. Overall, the work could be used as a monograph and a teaching aid for schools and universities. The materials could be computer coded and disseminated over the Internet, which would allow the publication to become an important means of publicizing and gaining international recognition for Armenian literature. (*Cost:* 8.8 million drams over three years)

The History of Armenian Artistic Culture

The basic goal of this project is to create the first-ever integrated history of Armenian artistic culture, including all forms of national art—architecture; the fine, decorative, and applied arts; music; theater; and film. The NAS-RA Institute of Arts has rich experience in creating scholarly monographs devoted to outstanding Armenian artistic figures as well as particular stages of Armenian artistic development. However, to this day, we still have no scientifically considered and generalized research on Armenian artistic culture as a whole. There is even a lack of fully developed research meeting modern standards with regard to certain types of national art. The proposed program—an urgent, completely new, and innovative scientific research project—will substantially fill this gap. It proposes

the creation of a two-volume history in Armenian and single-volume editions in Russian and English. The research will be presented chronologically. The first volume will be devoted to the ancient and middle periods in the development of Armenian artistic culture up to the eighteenth century. The second volume will cover the history of Armenian artistic culture in the later period—the nineteenth and twentieth centuries. This publication will have not only scholarly but also cultural-anthropological, educational, and sociopolitical significance. The scientific results and analysis of this research could be used in monographs and textbooks for schools and universities and could be posted on the Internet, thus becoming an important means of publicizing national culture and winning broad international recognition for it. (*Cost:* 15,262,400 drams over four years)

The History of Armenian Philosophy

The scientific research group on the history of Armenian philosophy at the NAS-RA Institute of Philosophy and Law has done a great deal of work on methodological problems of the history of Armenian philosophy as well as research on the historical-philosophical process in Armenia. This group collaborates with the republic's leading specialists in this field. The proposed project involves the creation of a factological research base and clarification of methodological principles and research reference points. The results of this research will be published in a four-volume history of Armenian philosophy, which could have not only scholarly but also educational and cultural significance. It will substantially facilitate both the integration of national spiritual and intellectual values and the formation of philosophical consciousness and thought. (*Cost:* 13,706,800 drams over four years)

Problems of Shaping and Managing the Economy of the Republic of Armenia and Its Energy Infrastructure

The NAS-RA, the Institute of Energy closed stock company, the Armenian Ministry of Energy, the State Engineering University, and a number of research and other organizations carry out work in which the most important objective centers on creating a base option for the development of the Armenian economy and its energy infrastructure. The NAS-RA Institute of Economics, the Institute of Energy, and the State Engineering University have done much work on the formation and management of the Armenian economy and its energy base. The elements of this proposed project include a modified program for forecasting the level of energy demand depending on various scenarios for the development of the Armenian economy, an imitation model for deployment of energy facilities in relation to economic development, a program for defining the level of development of the Armenian energy sector, and a program for predicting likely levels of energy conservation in Armenia. Overall, this project is aimed at establishing

fundamental results for the formation of sectors to develop the Armenian economy and its energy base and creating reliable preconditions for evaluation of financing levels and sources as well as systems for managing the Armenian economy and its energy sector. (*Cost:* 18 million drams over three years)

Information Technologies

Creation of an Information System for State Agencies of the Republic of Armenia

State agencies are carrying out information technology programs for their own needs using loans, grants, and budget resources. These programs do not take into account the possibility of fully utilizing the information space existing between various state structures. The Yerevan Scientific Research Institute of Mathematical Machines, in close cooperation with the Ministry of Social Support, the State Healthcare Agency, the State Pension Fund, and the Ministry of Justice, developed a number of information systems and worked with databases for a number of ministries and agencies (Ministry of Energy, Ministry of Communications, Ministry of Internal Affairs, Ministry of Agriculture, etc.). These projects were carried out with grants from USAID (the U.S. Agency for International Development), the World Bank, Tacis, and others. The proposed program involves the creation of a conceptual model for a unified information field for the state agencies of the Republic of Armenia as well as development and implementation of such a system. This would enable the agencies to exchange necessary information and have a unified information space without any duplication of systems. Strategic planning and analysis will be facilitated along with appropriate development of the information resources of state agencies. (*Cost:* 16 million drams plus outside grants and loans over three years and eight months)

Creation of a State Scientific Computing System

The NAS-RA, Yerevan State University, the Armenian State Engineering University, and a number of Armenian scientific, technical, and educational organizations conduct research aimed at creating a computer information network environment that would make it possible to carry out high-productivity calculations, create large-volume databases, and ensure reliable data transmission. The NAS-RA Institute of Problems of Informatics and Automation (IPIA) has done a great deal of work on creating network infrastructure. In 2002, IPIA, in cooperation with seven other scientific organizations, received a grant from the International Science and Technology Center (ISTC) to create a computer cluster in Armenia. The basic objectives of the proposed project include creating an infrastructure to support high-productivity calculation, developing applied programs and databases using this infrastructure, providing Armenian-language computer

support materials, and carrying out theoretical research. A state scientific computing system will provide the modern hardware and software that enable research institutes and state organizations of Armenia to enjoy highly productive computing resources that meet the needs of the republic and the region in the near future. (*Cost:* 18 million drams plus outside grants and loans over three years and six months)

Laser Physics, Instrumentation, and Technologies

The NAS-RA, Yerevan State University, the State Pedagogical University, the closed stock company LT-PYRKAL, and a number of other organizations are working to develop basic and applied science in the field of laser physics and technology; to create new science-intensive, high-tech-oriented, economically profitable technologies and laser equipment for broad use; and to train highly skilled specialists in this field. The proposed program involves creation of the necessary infrastructure, as well as actual conduct of scientific research. Completion of this comprehensive program will substantially promote the development of laser physics, instrumentation, and technology and, on the basis of modern scientific-technical developments, make it possible to create a new branch of science-intensive technology in the Armenian economy. Lasers and devices will be created for application in microelectronics, nanotechnology, medicine, industrial production, and scientific research. They will meet the demands of the republic and the region in the future and provide trained specialists for the utilization of existing equipment. (*Cost:* 330 million drams over five years)

Nanotechnology

Nanotechnology and Semiconductor Nanoelectronics

The first precondition for this program is development of the electronics, optoelectronics, computer, and related industries in the twenty-first century thanks to the new generation of semiconductors and nanoscale solid-state devices. Beginning in the 1970s, the Institute of Radiophysics and Electronics, the Institute of Physics, Yerevan State University, the Armenian State Engineering University, the Yerevan Physics Institute, and a number of other research and production organizations in the electronics sphere developed scientific schools studying the physics of semiconductor micro- and nanostructures and related devices. The largely preserved infrastructure and scientific-technical personnel in numerous Armenian electronics industry organizations (Pozistor, Elektron, Atom, Sin-Kristall, Astro, Mikroelektronika, Razdanmash) also represent a resource. Armenian scientists cooperate broadly with counterparts from Russia and a number of Western countries within the framework of three ISTC grants and several grants from the International Association for the Promotion of Cooperation with Scientists from

the Newly Independent States of the Former Soviet Union (INTAS). The basic objectives of work under the proposed project involve carrying out targeted theoretical and experimental research, creating a republic Nanoelectronics Center and outfitting it with the appropriate technological and metrological equipment, training young specialists in nanoelectronics, and organizing republic seminars and conferences on current problems in nanotechnology and nanoelectronics. Expected results include new scientific findings, the development and creation of new nanoelectronic and optoelectronic devices, creation of the above-mentioned center, and organization of the production of experimental models of nanoelectronic devices. (*Cost:* 1.5 billion drams over four years and eight months)

Risk Factors and Human Health

New Biochemical Preparations for the Treatment of a Number of Immunodeficiency and Infectious Diseases

The NAS-RA Institute of Biochemistry has discovered new neurohormones and brain cytokines. Physicochemical and immunochemical methods were subsequently worked out for the collective determination and identification of proline-rich polypeptides (PRPs) in brain microstructures, immunocompetent cells, and visceral organs. It has been established that one of these PRPs has antimicrobial and antiviral activity and is a powerful regulator of lymphopoiesis and myelopoiesis, which opens up real possibilities for creating new types of medicinal preparations to treat a number of immunodeficiency and infectious diseases. This project will involve the development of a method for the chemical synthesis of PRPs as well as methods for neurohormone purification, study of the influence of PRPs on the immune system along with their antitumor properties in vitro and in vivo in animal models, and study of the regulatory role of PRPs in lymphopoiesis, hematopoiesis, and myelopoiesis. The project will involve the joint efforts of the NAS-RA Institutes of Biochemistry, Physiology, Molecular Biology, and Fine Organic Chemistry; Yerevan State Medical University; the Russian Academy of Sciences Bakh Institute of Biochemistry; and the Russian Academy of Medical Sciences Institute of Human Morphology. (*Cost:* 60 million drams over three years)

Identification and Prevention of the Impact of Dangerous Factors on the Environment and Human Health

Biogeochemical research conducted in the NAS-RA Center for Ecological-Noosphere Studies in conjunction with the Ministries of Agriculture and Health provides vital data on the content of heavy metals, radioactive elements, and isotopes in soil as well as the mechanisms of migration of these substances from soil into plants. Under conditions of severe environmental pollution, a negative

impact has been noted in a number of human health indicators. For example, an increase in child mortality has been observed, along with increases in cardiovascular, oncological, neuropsychological, and allergic diseases. Joint research regarding environmental pollution and medical-biological indicators is of important scientific and practical significance and facilitates development and implementation of the necessary protective measures. This project will involve data collection, monitoring of heavy metal and radionuclide contamination, and development of appropriate countermeasures. The results expected are as follows: (1) ranking of territories by degree of pollution and determination of risk groups among the population; (2) development of soil decontamination technologies and creation of antifiltration barriers to protect underground water; and (3) ecotoxicological assessment of agricultural output from polluted areas. The results obtained will make it possible to develop measures and approaches oriented to reducing the risk to human health posed by heavy-metal pollution of the environment, which causes great harm to the country's economy in addition to its damage to the population's quality of life. For example, calculations made in cooperation with experts from the World Bank showed that lead pollution costs Armenia on the order of $34 million to $42 million annually. (*Cost:* 65 million drams over three years)

Preservation of Natural Resources and Improvement of Water Quality in Lake Sevan

The first phase of this project will entail an assessment of the impact of the surrounding watershed on Lake Sevan in order to determine ways of reducing risks presented by water inflows as a factor in the degradation of the limnosystem. In the second phase, the biogeochemical exchange of substances and the structural-functional characteristics of Lake Sevan will be studied with an eye to reducing the degree of risk regarding water quality deterioration. In the final phase, a database will be created using the results of hydroecological monitoring studies, and mathematical models will be made of the basic interrelated processes that shape the quantity and quality of the natural resources of Lake Sevan and its watershed. Completion of this program will help to determine the basic factors and mechanisms of eutrophication in Lake Sevan and of maintenance of its trophicity by reducing risk factors for worsening of the quality of the lake's natural resources. Analysis of the data obtained will make it possible to evaluate the impact of specific industries in the watershed on processes affecting the Lake Sevan limnosystem and to develop measures to counter their negative effects. A cohort analysis of fish stocks in the lake will make it possible to manage the commercial fishing industry. Creation of a mathematical model will form the basis for forecasting and managing the eutrophication process in the limnosystem. (*Cost:* 77 million drams over three years)

Biotechnology

Application of Bioleaching for the Extraction of Copper and Gold from Armenian Ore Deposits

Bacterial leaching (bioleaching) is widely used for obtaining copper, arsenic, uranium, gold, and other metals from sulfide ores. The process is used to extract metals from unconditioned ores, and this technology is also environmentally friendly. It is widely employed in many countries; however, this technology is not used in Armenia despite its great prospects in this regard. As a result of many years of work, the Republic Microbial Depository of the NAS-RA has demonstrated the possibility of applying this process in the extraction of copper and other metals from unconditioned ores and wastes, which have accumulated in huge quantities in Armenia. The main factor limiting broad introduction of this method is lack of an experimental setup for working out the technology for the process relative to specific ore deposits. This project will involve development and creation of a pilot plant for assessing the effectiveness of bacterial leaching of copper from unconditioned ores and wastes, as well as development of a technology for efficient extraction of copper from abandoned mines and waste dumps in Armenia. Effective technologies for utilizing the bioleaching of gold from ores with high arsenic and antimony content will also be studied and developed. In the final phase of the project, initial data for the broad introduction of bioleaching for copper and gold extraction in Armenia will be developed and disseminated in cooperation with the Institute of Mining and Metallurgy. Widespread implementation of bioleaching in Armenia will allow the state to effectively meet its objective of utilizing the republic's natural resources and organizing the large-volume, high-efficiency production of copper, gold, and other valuable metals while ensuring that the environment is protected. (*Cost:* 250 million drams over three years)

Development of Hydroponic, Biotechnologically Valuable, Rare, and Endangered Plants (Medicinal and Aromatic Plants, Spices, etc.) and Initiation of Their Soil-Free Cultivation

The swift growth of the world's population has posed a difficult task for farmers—achieving a stable increase in the productivity of agricultural plants. It will be easier to meet this objective if new industrial methods of intensive plant production are discovered. One way of increasing plant productivity many times over is the development of biotechnology for soil-free (hydroponic) industrial production of agricultural plants under managed-culture conditions in an artificial environment. The NAS-RA Institute of Hydroponics Problems has already developed and prepared for introduction biotechnologies for the soil-free production of a number of valuable small-volume crops (about 40) and has comprehensively studied the physical-biochemical and agrochemical foundations for

improving the productivity of certain plants useful for the extraction of medicinal compounds, essential oils, and dyes. The first stage of the project entails optimization of the conditions for hydroponic cultivation of plants, preparation of the growth medium, breeding of medicinal plants with adaptogenic properties using conjugate hydroponics, and in vitro culturing for accelerated growth. In stage two, biotechnologies for soil-free cultivation will be developed, and in stage three the technologies will be implemented and production organized. The scientific findings and biotechnologies for hydroponic production of a number of valuable, rare, and endangered plants will lay the foundation for industrial production of ecologically pure, high-quality plant raw material and will ensure the preservation of certain medicinal plants, including some listed in the Red Book of endangered species in Armenia. Soil-free production will make it possible to utilize land currently unsuitable for agricultural use, including salty, sandy, and rocky areas. (*Cost:* 155 million drams over five years)

Organization of Production of Feed, Food, and Biologically Active Preparations Based on the Microalgae Spirulina

Microalgae of the spirulina variety are widely used in many countries for the production of feed and food products and biologically active substances. The biomass yield and nutritional value of these microalgae are tens of times higher than those of traditional agricultural crops. The great prospects for the widespread introduction of spirulina in Armenia have been established in many studies conducted at the Republic Microbial Depository; however, due to the lack of the necessary funding there has been no practical implementation. The first stage of this project would involve the development and creation of an experimental production facility for cultivation of spirulina based on the mineral source in the village of Malishka. Next, effective technologies and technical documentation would be developed for the production of spirulina biomass using mineral and ground waters from Armenia's soda-containing salt marshes. Various preparations would be developed from spirulina biomass, and basic data and proposals would be created regarding the establishment of large-scale production in Armenia of spirulina biomass for food and feed purposes, particularly in salt marsh areas. The wide-scale production of spirulina biomass in ground waters from saline soils could be the most effective approach to bringing Armenia's soda-containing salt marshes under agricultural cultivation. The republic possesses significant resources in the form of carbonated mineral waters, which could be used highly economically for cultivating spirulina. Creation of the planned experimental production facility is a necessary and important condition for the successful resolution of Armenia's feed and food problems. (*Cost:* 12 million drams over two years and six months)

Development and Production of New, Highly Effective Bacterial Fertilizers

As a result of many years of research, the Institute of Microbiology has produced new, highly effective cultures for nitrogen-fixing bacteria that have been successfully used and tested as fertilizers. The institute has also established important conditions for their effectiveness with various agricultural crops. Resolutions have been adopted regarding the wide introduction of these research findings into practice, but they have not been realized due to the lack of funds for organizing a test facility for these preparations. Fundamental attention will be paid to developing and organizing production of the highly effective preparation Nitragin for bean crops. The Institute of Microbiology has laid the necessary foundations in this field of research and possesses a large store of well-studied microorganism cultures as well as the necessary personnel to handle this problem. In phase one of the project, the institute will identify, test, and select highly effective cultures of rhizobial bacteria for the production of the fertilizers Nitragin and Azotobakterin for various types of crops. Effective forms of Nitragin will be developed and produced based on local resources and then field-tested on different crops in various ecological zones of Armenia. Finally, a pilot plant will be established for the production of Nitragin and Azotobakterin. The development of new bacterial fertilizers ensuring a significant increase in crop yields is a necessary condition for successful implementation of the republic's food program. Given the limited resources that Armenia possesses in terms of arable lands, creation of a capability for producing such fertilizers is an essential condition for the development of Armenian agriculture. Establishment of the planned pilot plant and organization of experimental production will make it possible to ensure the successful development and widespread practical use of other microbiological preparations as well. (*Cost:* 13 million drams over three years)

New Materials

High-Temperature Superconductivity (HTSC)

Research in the area of HTSC by targeted program participants (Institute of Physics Research, International Science and Education Center, Institute of Radiophysics and Electronics, Yerevan Physics Institute, Yerevan State University, etc.) has been and continues to be conducted as part of more than 30 different research themes in the republic, and more than 20 international grants have been received to support these efforts. Financing is awaited on two projects under the ISTC program (A-936 and A-939). Thanks to the efforts of our scientists, a unique methodology for studying superconductivity has been created, and in combination with classical methods it makes possible with a high degree of resolution the discovery of fine characteristics of superconductivity shifts not possible with other methods.

This proposed targeted program in HTSC calls for a wide range of work including the creation of HTSC materials as well as basic research on HTSC properties aimed at discovering the nature of superconductivity in these substances and their application in new fields of science and engineering. The basic subprograms include (1) development of scientific foundations for synthesizing HTSC materials with specific properties and creation of thin-film structures for use in scientific instrument building; (2) creation of new non-disturbing methods of studying the fine properties of superconductivity and HTSC materials in the presence of various external physical factors; and (3) study of the characteristics of the superconductivity shift in HTSC materials at the start of the formation of this condition and development of theoretical aspects of superconductivity in direct proximity to the shift, with the aim of discovering the mechanism of HTSC. Funding support requirements include money for the organizational stage and infrastructure creation, establishment of a republic center for HTSC and provision of the necessary equipment for it, and ongoing operations.

Expected practical results include the development of several classes of new electronic and superconducting instruments capable of making visible the superconducting properties of thin-film HTSC materials at 1 μm resolution. Hybrid equipment based on the method created as well as on SQUID [Superconducting Quantum Interference Device] technology will be capable of discovering small displacements (<1Å) and weak magnetic fields (<1 rT), for use in medicine, geology, geophysics, military hardware, research, communications, and navigation, that will facilitate qualitative changes in many types of metrological instrumentation. We also expect to produce submillimeter and terahertz receivers for monitoring atmospheric gas content; high-resolution seismic detectors for early detection, registration, and study of weak fluctuations in the earth's crust; a deep-earth metal detector for use in civil construction work; and a new type of sensitive microphone with an expanded frequency range. (*Cost:* Approximately 710 million drams over five years)

Facilitation of the Long-Term Operation of the Arpa-Sevan Tunnel

One of the most important problems facing the republic is that of ensuring the reliable operation of the Arpa-Sevan tunnel, the use of which is constantly characterized by processes involving the destruction and restoration of its concrete facing. These phenomena are caused by complex geological, hydrogeological, and hydrochemical processes and, very importantly, by improper selection of the concrete composition (in 1963-1964). Resolving the problem of ensuring the stability of the concrete facing against the effects of aggressive natural waters is possible with correct selection of the concrete composition by taking into account the chemical and physical-chemical properties of its components. Many highly qualified specialists with many years of experience working in these and nearby areas are carrying out research projects under various international programs. In

particular, these researchers have selected special concrete compositions (1984-1985) for structures intended for use in seawater (the Far East). The project currently proposed involves the participation of specialists from the NAS-RA Institute of Geological Sciences and the Scientific Research Institute of Seismic-Resistant Construction and Structural Protection. The first stage of the project includes field work and testing of soil, water, and concrete samples in the area of the Arpa-Sevan tunnel. Next, collected samples will be comprehensively studied along with experimental-theoretical foundations for the selection of sulfate-resistant concrete compositions and their behavior in aggressive environments. Finally, technical documentation will be prepared and the developed concrete compositions will be put into practical use. This project will make it possible to ensure the uninterrupted operation of the Arpa-Sevan tunnel, the use of the data obtained in other hydrotechnical structures, and the resolution of similar problems in other regions of the world. (*Cost:* 360 million drams over three years and six months)

Compounds and Materials with Special Properties Based on Armenian Natural Raw Materials

This project calls for the creation of new materials and compounds based on new scientific principles and methods such as heterophase processes for the chemical transformation of solid-state inorganic materials and compounds under the influence of gas-phase chain reactions and the combustion synthesis of inorganic compounds and materials. Completion of this program will help consolidate Armenia's scientific potential (the NAS-RA Institutes of Chemical Physics, General and Inorganic Chemistry, and Physics Research, as well as the State Engineering University). The broad participation of young specialists and graduate students is also envisioned. The first phase of the program involves development of the methodology, theoretical analysis of the material, and initiation of experimental research. Next, processes will be developed to process natural raw materials into new materials, further work will be done on defining the scientific foundations for these technologies, and the new materials themselves will be synthesized. This project will facilitate utilization of the republic's local mineral resources—quartzites, perlites, and zeolites—to obtain concentrated raw material for the production of high-quality glasses of various types, crystals, and various inorganic materials with specific properties—catalytic, electrophysical, electromagnetic, and so forth. Another expected result is the synthesis of refractory compounds—disilicides, carbides, nitrides, and borides of various metals, metal hybrids with especially high hydrogen content, amorphous materials, nanoscale and composite materials, and laser crystals. Overall, these objectives have important significance for the economic development of Armenia. (*Cost:* 90 million drams over three years)

SOURCE: Published in Russian and Armenian by the National Academy of Sciences of the Republic of Armenia, 2003. Russian version provided to the committee in February 2004 and translated and abridged by Kelly Robbins.

Appendix M

Next Steps to Market Program of the U.S. Civilian Research and Development Foundation (CRDF)

The CRDF Next Steps to Market (NSTM) Program

- Promotes the development of new, sustainable business opportunities in science and technology in the former Soviet Union (FSU) that will bring economic benefit both to the countries of the FSU and to the United States; and
- Funds collaborative R&D projects that allow U.S. for-profit companies and FSU universities, institutes, and companies to perform market research, develop business plans, and perform the pre-commercial R&D necessary to prepare selected technologies for the commercial market.

The NSTM Project Grants Program funds advanced R&D projects with a maximum duration of two years.

NSTM grants require a cost share from the U.S. company to ensure that the company is committed to the project and to establishing a long-term partnership with the FSU researchers involved.

CRDF NSTM grants are technical assistance grants, and, as such, funds and materials provided under the award are generally exempt from taxation in the countries of the FSU.

SOURCE: *www.crdf.org.*

Appendix N

International Science and Technology Center (ISTC) Patent Advisory Service

Following is a list of services regarding intellectual property rights (IPR) matters that the ISTC Secretariat provides to institutes that are recipients of ISTC project funding:

- Training courses on basic approaches to IPR protection and management
- Advisory service on general issues (procedures, documentation, web sites, local experts, etc.) provided by Secretariat staff
- Consultancy service on specific issues (patent search, preparation of patent application, filing of patent application, etc.) provided by professional experts on recipient request approved by the Secretariat
- Advisory service on allocation of IPR with foreign partners for partner-funded projects (for regular projects, allocation is consistent with Statute and Project Agreement)
- Financial support to prepare and file patent application in Russia or under the Patent Cooperation Treaty (not abroad)
- Full-scale service (including market search, preparation and filing of patent application abroad, etc.) for technologies approved for Commercialization Support program

ISTC IPR services are available to all ISTC recipient institutes including those in Armenia.

SOURCE: Information provided by ISTC, June 2004.

Appendix O

Biographical Information on Committee Members

Dr. John D. Baldeschwieler (committee chair) (member, National Academy of Sciences) is J. Stanley Johnson Professor and professor of chemistry, emeritus, at the California Institute of Technology. Dr. Baldeschwieler joined the Caltech faculty in 1973. His research has focused on molecular assemblies for use in the delivery of pharmaceuticals, for scientific instrumentation, and particularly for development of ion cyclotron resonance spectroscopy. He also pioneered the use of nuclear magnetic resonance and double resonance spectroscopy, nuclear Overhauser effects, and perturbed angular correlation spectroscopy in chemical systems. Dr. Baldeschwieler was a member of the President's Science Advisory Committee from 1969 to 1972, serving as vice chairman from 1970 to 1972. He served as deputy director of the Office of Science and Technology from 1971 to 1973. He was a founder of Vestar Inc., which merged with NeXagen Inc. to form NeXstar Pharmaceuticals. He also served as director of NeXstar until it was acquired by Gilead Sciences, Inc. Dr. Baldeschwieler was also a founder and director of Combion, Inc. He currently serves as a managing member of the Athenaeum Fund and is a director of Drug Royalty Corporation Inc., the Huntington Medical Research Institutes, Pasadena Entretec, and several privately held companies. Dr. John Baldeschwieler is a recipient of the National Medal of Science.

Dr. Robert Anex received his Ph.D. in civil and environmental engineering from the University of California at Davis in 1995. Prior to completing his Ph.D., Dr. Anex spent eight years in industry as a systems engineer. From 1996 to 2002, he was a research fellow at the Institute for Science and Public Policy at the

University of Oklahoma and an associate professor in that university's School of Aerospace and Mechanical Engineering. He is currently an associate professor of agricultural and biosystems engineering and a research associate of the Center for Sustainable Environmental Technologies at Iowa State University. His research interests include technology assessment, industrial ecology, environmental and technology policy analysis, and risk assessment. In 1999, he was selected to participate in a two-week National Research Council (NRC) Young Investigators Program on Energy and Environment in Armenia.

Dr. Barry C. Barish (member, National Academy of Sciences) is Linde Professor of Physics and Director of the Laser Interferometer Gravitational-Wave Observatory, California Institute of Technology. A fellow of the American Physical Society, Dr. Barish is an experimental high-energy and gravitational-wave physicist. He is involved in the MINOS project, a long baseline neutrino physics experiment between Fermilab and the Soudan Mine in Minnesota, as well as other major non-accelerator experiments both in the United States and Italy. He is a former member of the 1991 Astronomy Survey Panel on Particle Astrophysics, the Briefing Panel on Scientific Frontiers and the Superconducting Super Collider for the 1986 physics survey, and the 2001 Astronomy Survey Panel on Particle, Nuclear, and Gravitational-wave Astrophysics. Dr. Barish co-chaired the U.S. Department of Energy/National Science Foundation (DOE/NSF) High Energy Physics Advisory Panel's recent subpanel on long-range planning for the U.S. high energy physics community. He is chair of the oversight committee for IceCube and a member of the agency review committee for the Sudbury Neutrino Observatory. He is also a member of the oversight council for the National Aeronautics and Space Administration's Gamma-Ray Large Area Space Telescope and the Commission on Cosmic Rays of the International Union on Pure and Applied Physics (IUPAP). Dr. Barish recently served as chair of the IUPAP Commission on Particles and Fields, as well as the DOE/NSF Scientific Assessment Group on Experimental Non-Accelerator Physics review panel. He is the chair of the international organizing committee for the NSF-sponsored workshop on neutrinos and underground science and currently chairs the NRC-administered U.S. Liaison Committee for IUPAP.

Dr. John R. Filson is a scientist emeritus with the U.S. Geological Survey (USGS). After several years at the Massachusetts Institute of Technology and the Advanced Research Projects Agency of the Department of Defense working on scientific problems related to the detection and identification of underground nuclear tests, he joined USGS in 1978 and from 1980-1988 served as the Chief of the Office of Earthquakes, Volcanoes, and Engineering. He served as Acting Chief Geologist of the USGS from November 1994 through March 1995. From April 1995 through March 1997 he worked on the technical aspects of the application of seismology to the verification of arms control agreements. From August

1997 through July 2003 Dr. Filson served as coordinator of the Earthquake Hazards, Geomagnetism, and Global Seismology programs of the USGS. He retired in August 2003 and currently holds the position of scientist emeritus at the USGS, continuing to work on issues related to earthquake safety. He has received many awards and is also a past president of the Seismological Society of America and a fellow of the American Association for the Advancement of Science.

Dr. Norman P. Neureiter is director of the Center for Science, Technology, and Security Policy at the American Association for the Advancement of Science. He retired in September 2003 from the post of Science and Technology Adviser to the Secretary of State upon the completion of his three-year term of service. Previously, he was vice president of Texas Instruments (TI) Asia. While at TI, he held a number of positions, including director of East-West business development, manager of international business development, manager of the TI Europe Division, and director of TI-Japan. During a five-year residency in Tokyo, he was an active participant in negotiation and implementation of the U.S.-Japan Semiconductor Trade Agreement. Prior to his work with private industry, Dr. Neureiter worked as an international affairs assistant in the White House Office of Science and Technology Policy during 1969-1973, reporting to the President's Science Adviser. Dr. Neureiter entered the U.S. Foreign Service in 1965, serving as Deputy Science Attaché in the U.S. Embassy in Bonn, Germany. From 1967 to 1969, he was the first U.S. Science Attaché in Eastern Europe, based at the U.S. Embassy, Warsaw, with responsibility for Hungary, Czechoslovakia, and Poland.

Dr. Abigail Salyers is a professor of microbiology at the University of Illinois. Dr. Salyers is a member of the American Academy for Microbiology and served as president of the American Society for Microbiology from 2000 to 2001. She has served as co-chair of the NRC's Committee on the Progress and Promise of Systems Biology since 2001. Dr. Salyers received her Ph.D. in physics from The George Washington University in 1969, also completing graduate study in biochemistry and anaerobic microbiology at the Virginia Polytechnic Institute and State University from 1972 to 1975. She was a research associate and then associate professor in the Anaerobe Laboratory at Virginia Tech for five years before joining the faculty of the University of Illinois as an assistant professor in 1978. She began her current role as professor in 1988. Dr. Salyers also served as co-director of the Microbial Diversity Summer Course of the Marine Biological Laboratory in Woods Hole, Massachusetts, from 1995 to 1999. Dr. Salyers' research interests include the interaction of colonic bacteria with host, molecular microbial ecology, genetics of obligate anaerobes, polysaccharide uptake and catabolism by Bacteroides, and conjugative transposons of Bacteroides.