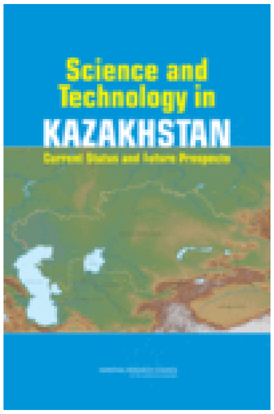

Science and Technology in Kazakhstan: Current Status and Future Prospects

Committee on Science and Technology in Kazakhstan, Office for Central Europe and Eurasia, National Research Council

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Science and Technology in KAZAKHSTAN

Current Status and Future Prospects

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Preface

In June 2006 the National Research Council (NRC) entered into a contract with the National Center for Scientific and Technical Information (NCSTI) of the Ministry of Education and Science (MES) of the government of Kazakhstan to carry out a study of the current status and the potential for future development of the science and technology (S&T) base of the country. Of particular interest to both parties were the S&T human resources of the country, the organizational and institutional structures of the public and private sectors that have S&T dimensions, the capabilities of research and education institutions, the linkages among these and other organizations that have a role in the innovation process, and the sectors of economic and social development that deserve priority for investments of government funds to support research and development (R&D) activities. This report presents the results of the study carried out by a committee of specialists selected by the NRC.

S&T-related policies, priorities, and activities are changing in Kazakhstan as the government attempts to upgrade the S&T infrastructure as rapidly as possible and as the private sector steadily increases its investments in the expanding economy. This report is based on conditions in the country as of September 2006. Many of the conclusions and recommendations in this report should be relevant for several years, though, since the technology-oriented commitment of the country's leadership to rapid economic and scientific development probably will remain until the next major political election in 2012.

SCOPE OF THE STUDY

The Statement of Task in the contract specified that the following topics would be addressed:

- Existing institutional capabilities of Kazakhstan's R&D institutions, state research centers, and other institutions of the S&T community.
- Higher education capacity and trends, with particular attention to (1) research activities and (2) the significance of national S&T policy in influencing higher education and research.
- Current and potential domestic and international customers for R&D results and S&T products.
- Funding sources for S&T.
- Shortcomings in Kazakhstan's policies that affect S&T and the principal mechanisms for implementing relevant policies.
- Factors hindering the development of Kazakhstan's S&T.
- Specific measures for maintaining and facilitating research activity that can lead to breakthroughs.
- Opportunities for regional S&T collaboration.

In addition, NCSTI asked the NRC to provide observations to the extent possible on other aspects of the S&T base that are being addressed in the government's program for the evaluation of scientific institutions, recognizing that there were time, resource, and information constraints for providing such observations. Of particular interest were the proposed Terms of Reference for the government's evaluation. These proposed Terms of Reference are set forth in Appendix A.

In subsequent discussions NCSTI officials indicated that the following topics would be of special interest:

- The legal basis for activities in the field of S&T.
- The material and technical base for scientific activities.
- Public- and private-sector funding of research activities.
- Establishment of priorities in the field of S&T.
- Relationships between public- and private-sector research and education activity.
- Commercial demand and potential domestic and international customers for the products of research.

Taken together, the overlapping interests set forth above cover almost every aspect of S&T activities in the country. Since this study was to be completed within six months in order to be most helpful within the government's planning and budget timeline, the committee members and consultants engaged to assist in this effort were not able to spend sufficient time in Kazakhstan to examine all aspects of the S&T infrastructure.

At the same time, a number of other foreign organizations were developing recommendations concerning S&T activities in the country. The Ministry of Industry and Trade (MIT) was supporting studies by international experts of industrial technology activities, with an emphasis on the role of the private sector. Further, the World Bank had completed in early 2006 the development of an analytical framework for providing support to selected research groups of excellence in the country and for promoting technology transfer activities. Also, as of September 2006 the Science Foundation of Ireland was carrying out a limited study of S&T aspects of higher education, and specialists from the Organisation for Economic Co-operation and Development in Paris, the World Bank, and MES were initiating a more detailed study of the same topic.

Well aware of these constraints and overlapping activities, the NRC committee and NCSTI agreed that it would be most helpful to MES if this report had the following characteristics:

- The study would identify fields of S&T that should be considered for increased and sustained government R&D funding and/or political support. At the time of initiation of the study, the government was considering designation of five fields of priority importance for focusing R&D efforts: space science and information technology, biotechnology, nanotechnology, nuclear and renewable energy, and hydrocarbon and mineral resources. The study was to examine these fields along with additional fields that the NRC committee thought warranted consideration for special emphasis.
- Given time and logistics constraints, the committee and NCSTI agreed that it was not feasible to examine activities in space science and the social sciences other than economics, recognizing that each of these topics deserved serious assessments through other mechanisms.
- The current and future activities of key public-sector educational and research institutions under the purview of MES would be primary focal points for the study. A limited number of institutions of MIT, the Ministry of Agriculture, the Ministry of Health, and the Ministry of Energy and Natural Resources would be considered as well. Organizations subordinate to the Ministries of Transportation, Communication, Environmental Protection, and Defense—while involved in S&T-related activities—would not be included in the study. A few private-sector institutions, including selected universities, small innovative firms, and large companies that are particularly active in S&T endeavors would be included to ensure a broad overview of S&T-related capabilities.
- The study would give special attention to the government's proposed draft of the program plan for development of science from 2007 to 2012 and provide comments on the program as appropriate. The main idea of the plan, as explained by NCSTI, is to create and develop the necessary conditions and envi-

ronment for carrying out research; for increasing the quality of research; for developing the base for cooperation between research centers, education institutions, and the private industrial sector; and for motivating young scientists to work in Kazakhstan.

- The crucial importance of development and retention of the nation's S&T human resource base would be a major consideration throughout all aspects of the study.
- The study would consider research, development, and education within the broader context of the entire innovation process—from basic research to successful use of the products of research.

AUDIENCES FOR THIS REPORT

The principal audience for this report is the government of Kazakhstan, particularly MES. President Nazarbayev, his advisers, the parliament, and other government officials and organizations should be interested in the analyses and conclusions since the report addresses some of the highest priority issues that have been debated within the government in recent years.

A second important audience is the large array of Kazakhstani organizations involved in activities that have important S&T components. Some are designers or implementers of research programs. Others are potential users of the products of research. Others train managers and specialists to carry out S&T-related activities. Still others are affected financially by decisions to allocate resources to S&T. Many more are affected in the long run by scientific endeavors that lead to changes in the technological capabilities of the country. In the words of the U.S. National Academy of Engineering, "Every business participates in technological change as an originator, user, or victim of technological invention and innovation."[1]

A third audience includes many international organizations, governments of neighboring states, providers of foreign assistance, local and foreign investors in the economy of the country, the international scientific community, and international and homegrown nongovernmental organizations that are involved in shaping the future of the country. Some members of this audience are familiar with many of the developments cited in the report, but others are not. Therefore, appropriate references are provided to assist in clarifying for a broad audience the recent developments discussed in the report.

[1] William G. Howard, Jr., and Bruce R. Guile, eds., *Profiting from Innovation*, MacMillan, New York, 1992, p. 7.

THE CHALLENGE OF KAZAKHSTAN[2]

Kazakhstan has a population of 15.2 million people spread over a vast territory. The workforce is about 8.8 million people, with 30 percent engaged in industrial activities, 20 percent in agricultural activities, and 50 percent in service activities. About 56 percent of the population lives in urban centers, and the average life expectancy is 63.4 years.[3]

Kazakhstan has a 3,500-kilometer border with Russia and also extensive borders with Uzbekistan, Kyrgyzstan, and China. Long stretches of the border are open, and control of people or goods crossing the frontier is very difficult. Much of the terrain is uninhabitable due to harsh climate, lack of water, and difficult environmental conditions for sustaining life. In some regions, mountain ranges bring cold weather to the country in the winter in sharp contrast to the high temperatures in other regions in the summer. Adding to the difficult living conditions, some regions in the south of the country are subjected to earthquakes that may cause considerable damage in urban areas. In the west the level of the Caspian Sea abutting Kazakhstan has risen and fallen up to 3 meters in 25- to 30-year cycles. Of course, the environmental and economic consequences of the contraction of the size of the Aral Sea are well known throughout the world.

Kazakhstan is a constitutional republic with a strong presidency. The prime minister, appointed by the president, serves as the head of government. There is a bicameral parliament. The country is divided into 14 regions (oblasts) and two municipal districts, namely Astana and Almaty. The capital was transferred from Almaty to Astana in 1998, and the transition process is still under way.

Exports are key to Kazakhstan's current economic success, with oil, gas, and minerals leading the way. These areas have attracted most of the almost $19 billion in foreign investment since 1993. Kazakhstan has significant deposits of coal, iron ore, copper, zinc, uranium, and gold as well as the large quantities of oil and gas. As to other commodities, Kazakhstan is the world's sixth-largest producer of grain, including wheat, barley, and rice. Wheat is a particularly important export product.

In 2002 the U.S. Department of Commerce deemed Kazakhstan to have become a market economy. This step recognized substantive reforms in the areas of currency convertibility, wage rate determination, openness to foreign investment, and government control over the means of production and allocation of resources.

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[2]This section draws on "Background Notes," U.S. Department of State, 2006, and on committee discussions in Kazakhstan.

[3]Human Development Indicators Country Fact Sheet: Kazakhstan, United National Development Programme, 2006, available at *http://hdr.undp.org/hdr2006/statistics/countries/country_fact_sheets/cty_fs_KAZ.html,* accessed September 2006.

During the Soviet era, Kazakhstan was the site of a number of major high-technology facilities. The principal testing ground for Soviet nuclear weapons was located at Semipalatinsk. Testing ceased at the site after the breakup of the USSR in the early 1990s, but several facilities near the site and elsewhere continue to support research on peaceful uses of nuclear energy. The world's first breeder nuclear reactor, which provided the energy to support an associated desalination facility, operated in Kazakhstan for many years beginning in the 1970s. It ceased operation in 1998. The Baykonur space center is located in Kazakhstan, with the Russian government currently operating the facilities under a rental agreement. Also during the Soviet era, Kazakhstan became a center for investigating the use of dangerous pathogens in biological weapons, and a number of Kazakhstani scientists became quite skilled in dealing with pathogens that have implications for human and animal health as well as for bioterrorism.

In short, for decades groups of Soviet scientists worked on the territory of Kazakhstan with unique advanced technologies, primarily related to military and space interests of the government of the USSR. During the past 15 years, many military-oriented facilities have lost some of their technological prowess as they changed their profiles to peaceful endeavors and as many key Russian specialists associated with the facilities returned to Russia. Nevertheless, a formidable array of advanced technological capabilities remains and provides the cornerstones in the government's efforts to build a broad technological base in the country.

In sharp contrast to the advanced technology dimensions of Kazakhstan, however, are the realities of impoverishment in many towns and villages. With an overall annual per capita income on the order of $2,000, conditions in many poor regions of the country contrast markedly with the relatively prosperous conditions in Almaty, Astana, and other well-developed cities. Large segments of the population do not have access to telephones and adequate medical care, and in some areas the safety of drinking water is in question. Unemployment is 8.2 percent, and 15 percent of the population lives below the poverty line.

An important Soviet legacy in the country is a well-educated population, with a literacy rate of almost 99 percent. However, since the early 1990s, educational standards at both the secondary and university levels have declined, particularly in the natural sciences and engineering. Many talented educators have left the country, whereas others have entered private business, given the low academic salaries. At the same time, general interest among young people in scientific careers has diminished, since well-paying jobs in research and in scientific services have been scarce and since the prestige of being a scientist that developed during Soviet times has steadily declined. As discussed in Chapter 3, the government is optimistic that the internal brain drain from science is slowly turning around. This is to be accomplished by providing increasing levels of resources to upgrade educational opportunities, by increasing the salaries for scientific workers in the public sector, and by encouraging greater technology-oriented investments by the private sector.

In short, the Kazakhstani government is in an increasingly favorable financial position to strengthen its S&T base, although there are many parties seeking access to the national income from the expanding oil production. Reportedly, much of this income has been set aside as a "rainy day" fund to cope with emergencies. This report is intended to assist the government in deciding how it can most effectively invest its financial resources during the next decade to revitalize a long tradition of scientific excellence that has been on the decline.

THE APPROACH IN PREPARING THIS REPORT

For a number of years, NCSTI and other Kazakhstani organizations have carried out many studies concerning the development of the nation's S&T potential. Some studies have drawn on the results of questionnaires distributed to Kazakhstani organizations. Others have been based on roundtables and other forms of direct discussions among specialists from many governmental organizations and S&T facilities. Some have drawn on the expertise of foreign specialists. The NRC committee had access to a number of these studies.[4]

A significant recent development has been the preparation of an annual report prepared by leaders of the Kazakhstani scientific community and issued by the country's National Academy of Sciences on the state of science within the country in selected fields. Observations by Kazakhstani scientists on these reports and related recommendations to the government on steps to strengthen the scientific base of the country helped inform the committee on the perspectives of important scientific leaders.

Also of importance in preparing this report have been many reports prepared by American and other foreign organizations concerning S&T developments in Kazakhstan. Hundreds of S&T-related projects have been supported by external funders, and many of these projects have resulted in reports. Due to time and resource constraints, only a few of these reports were reviewed by the committee, but an examination of the titles and the international and domestic participants provided pointers to the organizations in Kazakhstan that deserved particular attention.

Against this background, committee members, along with a number of unpaid consultants with expertise in fields of interest to the committee, visited a large number of Kazakhstani organizations and facilities during July and September 2006 to gain firsthand insights into capabilities, strategies, and activities

[4]See, for example, the following reports of NCSTI: L.A. Gurevich and E.Z. Suleimenov, *Science Through the Eyes of Scientists*, 2006; E.Z. Suleimenov, Ye. A. Galants, and N.V. Vasilyeva, *Dynamics of Science-Technology Potential of Kazakhstan for 2001-2005,* 2006; Yu. G. Kulevskaya, S.K. Kulumyetova, and G.F. Zharkova, *Conditions and Tendencies of Development of the Science-Technology Potential of Kazakhstan*, 2006.

and to learn about the impacts of externally funded projects. (The organizations that were visited are identified in Appendix B.) The NRC and NCSTI staffs worked together in preparing questionnaires that were sent to the organizations in advance of the visits, thereby leading to rich discussions. Also in preparation for the visits, NCSTI prepared considerable statistical data at the request of the committee concerning trends in the development of human resources, financial expenditures for S&T-related activities, and related activities. These datasets, together with statistical reports routinely prepared by NCSTI, provided the basis for NCSTI briefings of the committee that were quite helpful.

In summary, this report presents the conclusions drawn from reviews of important official and unofficial Kazakhstani documents; reports of other observers of developments in the country; observations and discussions involving committee members, staff, and consultants during visits to Kazakhstani institutions; and consultations with specialists from other countries who are knowledgeable about developments in Kazakhstan.

Alvin W. Trivelpiece
Chair, Committee on Science and Technology in Kazakhstan:
Current Status and Future Prospects

Glenn E. Schweitzer
Director, Office for Central Europe and Eurasia

Acknowledgments

The committee is very appreciative of the efforts of hundreds of colleagues in Kazakhstan in assisting committee members gain an appreciation of important aspects of the S&T infrastructure of the country. This study was a unique experience for the committee members, and they gained valuable insights applicable to other countries as well, including the United States.

Analyses by NCSTI staff were invaluable in enabling the committee to focus on key issues critical in setting the course for S&T development that should undergird future development of the country. NCSTI spared no effort to ensure that the committee had all information that was requested and that the logistical aspects of the visits were worked out without difficulty. Without this strong support, preparation of this report would not have been possible.

The consultants who contributed to this report are identified on page v. Their insights were invaluable in ensuring that the report is based on realistic assessments of developments in the country.

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 process.

The committee thanks the following individuals for their review of this report: Phillip Griffiths, Princeton University; John Hay, University at Buffalo;

Eugene Krentsel, Binghamton University; John Lambert, Argonne National Laboratory; Mary Leech, San Francisco State University; and Evelyn Putnam, U.S. Embassy, Tashkent.

Although the reviewers listed above 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 R. Stephen Berry. Appointed by the NRC, 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.

Contents

Summary

Kazakhstan has an ambitious program to increase its technological competitiveness in the global marketplace during the next few years. At the same time, the government has a wide variety of policies and programs in place that are intended to improve the social and economic well-being of a population of 15.2 million people dispersed over a vast geographical area. Government leaders have emphasized that achieving success both internationally and domestically will depend in large measure on the effectiveness of upgraded science and technology (S&T) capabilities—within the education system, research and development (R&D) institutions, and Kazakhstani production companies and service organizations.

S&T-related activities permeate all sectors of the economy. Given the constraints on time and financial resources available to complete the present study, the National Research Council committee that was responsible for this report focused on a limited number of S&T activities in Kazakhstan. Still, the report identifies important opportunities and limitations in achieving more effective development and use of S&T in a variety of areas. While other aspects of S&T deserve further analyses, the conclusions and recommendations of this report, together with related conclusions of analyses by the Ministry of Education and Science (MES) and other ministries, should help a number of governmental organizations with strong interests in S&T chart the future course of the country.

CONTEXT FOR THE DEVELOPMENT OF S&T CAPABILITIES

Kazakhstani officials have correctly concluded that the country's long-term economic well-being will depend in large measure on how wisely its financial resources are invested in the development of nonoil sectors of the economy and in promotion of sustainable, broad-based economic growth. The country needs to make the transition from producing and exporting primarily unprocessed raw materials to producing and exporting more knowledge-intensive, value-added goods and services, but this transition will take many years. Upgraded S&T capabilities in both the public and the private sectors are essential in moving forward in this regard. However, during the next few years, Kazakhstan has no choice but to rely heavily on foreign technologies to operate and modernize its industrial base and to serve the requirements of its population.

The government must balance the urgent need to strengthen its industrial base through the use of imported technologies with a comparable need to support the rapid development of a capability to generate its own technologies. Thus, the government should support through financial, tax, regulatory, procurement, and other mechanisms the educational and S&T infrastructures necessary for the development in Kazakhstan of technology-intensive goods and services for the Kazakhstani and world markets.

At the present time, however, few industrial companies show interest in the products of local R&D activities. Thus, the future technological needs of companies do not usually play a role in determining the focus of research programs, particularly within public-sector institutions. In the absence of the development of greater "market pull" for technological innovations, the likely success of most technology transfer programs will remain low. Governmental policies such as those noted above that encourage companies to invest in innovation, either in their own laboratories or through outsourcing tasks to R&D institutions, are essential.

MES, other ministries, and many S&T institutions have documented these and other problems that inhibit effective development and application of S&T. Of critical importance, all reports that have been available to the committee underscore the fact that the number of talented and well-trained students who pursue S&T careers in Kazakhstan following completion of their studies is inadequate. This loss of S&T-oriented talent is due in large measure to low salaries, poor laboratory facilities, and housing difficulties that inhibit mobility, along with the attractions of working abroad or entering private business in Kazakhstan. At the same time, many well-established researchers must cope with outmoded laboratory equipment and limitations on financial support that inhibit their personal growth and their contributions to national development.

Unfortunately, the coupling of research with education is often weak. For example, universities are not able to take full advantage of the research capabilities of the 25 independent research institutes that had formerly been under the management of the National Academy of Sciences of Kazakhstan. This is due to a variety of factors, including (1) the long history of organizational separation; (2) higher levels of scientific development in most of the institutes and the lack of interest of their scientists in a university environment; and (3) competition among the educational and the independent research institutions for limited government resources, which discourages early sharing of concepts.

APPROACHES TO UPGRADING S&T CAPABILITIES

Against this background the committee reached the following conclusions:

- Considerable time will be required to reach the ambitious goals of the country. Progress is dependent on many factors in addition to the availability of financial resources. In particular, the pace of financial investments should be consistent with the development of human resources that can use the investments effectively.
- The Kazakhstani government faces a continuing challenge of choosing between investments in (1) upgrading existing S&T institutions, complexes, or laboratories and (2) replacing or supplementing these institutions, complexes, or laboratories with new facilities. Each approach will have certain advantages in specific situations, and the government needs to draw on objective expertise, domestically or internationally, to identify and assess the advantages and difficulties associated with each approach.
- Intense interest by the country's leadership in the potential economic payoffs from development of "breakthrough" technologies seems to have pushed the importance of modernizing established technologies into the background. In the near term, upgrading established technologies will often have higher payoffs than attempting to introduce entirely new products and processes into uncertain domestic or international commercial markets.
- The government has ambitious plans to expand R&D activities so that new products and new processes can be developed in Kazakhstan, but comparable attention should be given to the importance of S&T services (e.g., health care, standards, geological mapping) that have been and should continue to be provided to government organizations, the private sector, and the general public by technology-oriented institutions.
- The government and R&D institutions should make special efforts to help ensure that researchers are linked to potential users of the results of research early in the R&D cycle. At the same time, the government should promote programs to educate the S&T community on recently enacted patent legislation concerning government-funded R&D that provides the researchers' institutions with ownership of the intellectual property rights.
- The government should provide incentives for young entrepreneurs to take risks in setting up small innovative firms, such as tax incentives, opportunities to lease research equipment when necessary, and access to incubators.
- While the government's commitment to taking advantage of international experience and expertise is laudable, the selection of international advisers should be made with care, assuring that they are not only experienced in their

fields of interest but also are sensitive to the realities of carrying out activities in Kazakhstan. Prior to engaging international advisers, the relevant government offices should clearly identify the tasks and scope of the results that are expected.

• Procurement offices throughout the government of Kazakhstan regularly make decisions as to whether to import products or equipment with embedded technologies or to purchase such products or equipment that are or could be produced or assembled in Kazakhstan. As Kazakhstan continues to develop its industrial base, the government should have a consistent policy as to the extent to which Kazakhstani organizations should be given special consideration in competing with foreign organizations for government contracts. This policy should recognize the importance of procurements that enable Kazakhstani institutions to use their S&T capabilities and to link these capabilities with users of the results of their research.

• Kazakhstani officials, in their presentations to political leaders, emphasize the simplicity of a linear model that depicts the movement of an idea from basic research to applied technology to design and development and then to a successful process, product, or service. But the steps are seldom discrete, and the overall process is not simple. While some key officials recognize this reality, others may not. Furthermore, the process of developing a product does not necessarily lead to a successful business, and a substantial failure rate for businesses, particularly technology-intensive businesses, should be anticipated.

The committee has several recommendations as to S&T policy:

• The committee is concerned about the intention of the Kazakhstani government to consolidate the administration of all government R&D funds under MES. Before such consolidation is implemented, careful analyses should be carried out of the possible negative impacts on the capabilities of other ministries to draw on and effectively nurture the technical expertise of the R&D institutes for which they are responsible.

• The Ministry of Energy and Natural Resources (MENR) has limited in-house capability to assess oil, gas, and mineral reserves as a basis for setting development and extraction policies and for negotiating and controlling the activities of national and international companies operating in the country. The current approach of reliance on short-term contracts, awarded on a competitive basis, to provide authoritative natural resources information is not adequate, given the large financial stakes involved. MENR needs a strong resources assessment unit within its organizational structure that can help guide the development and use of hydrocarbon and solid mineral resources in a consistent and sustained manner.

• The government should encourage foreign investors to satisfy "local content" requirements through the use of products based on local R&D activities and the use of services provided by highly skilled Kazakhstani S&T specialists rather than using only low-technology local products and low-skill services to satisfy these requirements while importing S&T-intensive goods and services.

INITIATIVES IN RESEARCH AND EDUCATION

Turning to developments within the universities and research institutes, the committee has reservations about the Kazakhstani government's plan to establish 15 applied technology centers in specialized technical fields at 15 universities of uneven quality in various regions of the country. These technology centers would be components of five central national laboratories that are planned. The importance of stronger education, applied research, and technology transfer capabilities in a number of disciplines is clear, and the committee recognizes the political appeal of the distribution of technology centers within selected universities in regional cities.

However, the committee recommends an alternative approach. This approach calls for concentrating available resources within three or four technology centers and expanding to a larger number in several years if the initial centers are successful in bridging the gap between research and commercial applications. Also, the locations of the centers should be determined on the basis of open competitions that would not be limited to applications from only universities. If geographic distribution is important, a constraint on the competitions could be a limit on the number of technology centers that could be located in any one city.

Other aspects of higher education are also of considerable importance. As the universities make the transition to the bachelor's-master's-Ph.D. degree system, the awarding of the degree of doctor of science should continue and should be widely recognized as a significant scientific achievement. Stronger integration of research and higher education activities should receive priority. In particular, the 25 research institutes that had been components of the Academy of Sciences should gradually become affiliated with the universities during the next few years in a way that avoids further disruption of important research programs. Finally, one or more new grant programs to support postdoctoral scientists at universities, research institutes, and other appropriate institutions should be established, with particular emphasis on using such programs to encourage scientists trained abroad to become researchers in Kazakhstan.

The Ministry of Health has under its jurisdiction a number of medical universities and research centers. However, the universities concentrate almost entirely on classroom education activities. Research centers that are separate from the universities are primarily interested in applied research and publish their research results primarily in Russian-language journals with limited international circulation. Also, clinics are distant from the universities. Establishment of a modern hospital as a component of one of the medical universities and located adjacent to the university, together with an expanded emphasis on basic research at the university, could serve as a model for significantly improving opportunities for students, researchers, and practitioners to participate routinely in a broad range of education, medical research, and health care activities.

As to research at the agricultural universities and institutes, linkages with international research centers are particularly important. Kazakhstan and other countries with institutions involved in international networks already benefit from the linkages to Kazakhstani institutions. The orientation of agricultural research toward highly applied activities is appropriate in the near term. In the longer term, greater emphasis should be given to basic research, particularly in the universities.

The foregoing comments highlight the significance of higher education as a critical determinant of the technology future of Kazakhstan. The country is fortunate in having a highly literate population that appreciates the value of education and that is eager to expand on the country's advanced technological achievements in the nuclear and space fields. Sound policies are of course important, and continued economic growth can provide much-needed resources. But only with competent and committed scientists, engineers, and health care professionals will Kazakhstan be able to reach the ambitious goals that have been set. The Bolashak program that provides government financial support for 3,000 students studying at leading universities abroad at any given time reflects the commitment of the government to strengthening the human resource base of the country.

S&T PRIORITIES

The Kazakhstani government should give special emphasis to several types of activities that cut across the entire range of S&T programs, particularly the following:

- Universal broadband access to the Internet by members of the S&T community.
- Appropriate modern equipment throughout the research laboratories.
- Maintaining the high level of pedagogy in mathematics, physics, biology, chemistry, and the earth and atmospheric sciences.
- Economics training and research.
- Professional scientific societies, industrial associations, and academies of science and engineering.
- Standards and quality control.
- Publication in English-language journals.
- Ethics for S&T-related activities.

Turning to specific S&T areas that deserve priority, the committee developed the following criterion for judging their importance:

Within the area of interest, Kazakhstan has or could have in the next five years the technical leaders and the human and physical resources that are necessary to carry out R&D programs and/or provide S&T services that could contribute in a major way to the social and/or economic progress of the country. Such progress could over time be measured through (1) increased profits for Kazakhstani exporters of products based on R&D achievements or for providers of S&T services for foreign clients, (2) attraction of new domestic and foreign investments in Kazakhstan that utilize the R&D results or S&T services of local organizations, and/or (3) improved well-being of the general population as a result of the R&D products or S&T services.

At the same time, expanded government support of the priority area of interest should (1) increase significantly the attractiveness of educational opportunities within the country that have the potential of leading to important S&T-oriented careers for highly talented young people and (2) enhance the prestige of Kazakhstani S&T within the country and internationally.

With this criterion in mind, the committee recommends that the government of Kazakhstan give priority to the S&T aspects of the areas listed below, with the understanding that priorities should be reviewed periodically, perhaps every three years. There may be other areas of particular importance that the committee did not have an opportunity to address, such as the following:

- Nuclear science and technology: assessment of nuclear power facilities; radioecology; uranium mining.
- Biomedical science and technology: disease surveillance and prevention; cancer therapies; natural products chemistry; orthopedic devices.
- Agricultural S&T: cereal grain production; livestock productivity; nutrition.
- Hydrocarbon resources: chemical engineering; catalysis; assessment of reserves; environmental protection.
- Minerals: metallurgy; assessment of ore deposits; environmental protection.
- Construction: seismic-resistant structures; construction materials.
- Water science and technology: irrigation systems; monitoring and assessment of water quantity and quality; protection and remediation of water quality.

Finally, hundreds of S&T-intensive programs are under way that involve specialists from Kazakhstan and neighboring countries. Given the long tradition of regional cooperation, the committee recommends expanding regional efforts in several areas that would be of economic as well as S&T benefit to Kazakhstan. Specifically, regional cooperation in the management of transnational water resources is increasingly important. Surveillance for human and animal diseases that are endemic to the region or that could enter the region is of great concern. Educational experiences for foreign students in public health education and associated research facilities in Kazakhstan could strengthen important professional ties. Finally, the new advanced-technology university in Astana offers an opportunity to attract future scientific leaders from neighboring countries where Kazakhstan hopes to have markets for its high-technology products of the future.

1

Context for Science and Technology Activities in Kazakhstan

This chapter addresses recent developments that provide a context for considering specific science and technology (S&T) issues in subsequent chapters. As discussed below, S&T permeates large segments of the economy of the country. The committee considered policies and programs that the National Center for Scientific and Technical Information (NCSTI) identified as relevant to S&T activities as well as additional policies and programs that the committee considered important. The committee did not have time to delve into the details of many policies and programs, but it nevertheless obtained an overview of directions that are being taken by the Kazakhstani government. NCSTI agreed that a comprehensive review of all relevant policy, program, and related organizational developments was beyond the scope of this report.

CONCEPT OF S&T

Too often, building S&T capacity in a developing or middle-income country is considered a distinct development challenge separate from strengthening activities in traditional development sectors such as health care, agriculture, energy, communications, construction, and water resources. The following concept reflects the importance of integrating S&T with economic development sectors and has been used by the committee in addressing the S&T capacity of Kazakhstan:

> S&T includes the natural sciences, engineering, technology, the health sciences, and the economic and social sciences. S&T activities are components or enabling elements within programs directed to achieve educational, economic, social, and political objectives. This concept recognizes the pervasive role of

> S&T in development and is somewhat broader than more traditional definitions of S&T that focus on research and on science and engineering in education. From the vantage point of developing (and middle-income) countries, S&T should involve interconnected national and international systems of activities that encourage the acquisition and generation of important knowledge and the application of this knowledge to improve the quality of life and the security of populations.[1]

Thus, S&T is integral to the capacity of the public and private sectors in Kazakhstan to:

- provide technical services that support economic and social development—such as the provision of health care, education, agriculture extension, transportation, communications, maintenance and upgrading of water and sanitation facilities, management of natural resources, and energy and environmental services;
- assess the economic and technical merits of technologies being considered for use and within that context carry out research, development, technology transfer, technology adaptation, and technology application activities;
- produce industrial goods and agricultural products based on technologies and modern management methods that are well suited to the local environment;
- prepare and evaluate implementation of economic, trade, industrial, agricultural, health, educational, environmental, and other policies that have technical dimensions or that influence the acquisition and use of technical resources;
- participate in international trade negotiations, environmental treaty discussions, and other types of policy dialogues involving technical issues of political, economic, and social importance;
- conduct programs that heighten public awareness of the potential and limitations of modern technologies to improve the well-being of the public; and
- develop an appropriate physical infrastructure, a robust human resource base, and a network of educational and training institutions to support the foregoing activities.[2]

Within this broad context, the primary focus of this report is on research, development, S&T services, and technology transfer and on the S&T dimensions of higher education.

[1]National Research Council, *The Fundamental Role of Science and Technology in International Development*, The National Academies Press, Washington, D.C., 2006, p. 18.
[2]Ibid., pp. 18-19.

THE KAZAKHSTANI LANDSCAPE FOR USING S&T

The World Bank released the following summary assessment in March 2006 of its findings in Kazakhstan:

> Kazakhstan has made commendable progress in stabilizing its economy and carrying out structural reforms over the past decade. Increasing oil revenues, spurred by a favorable conjunction of higher prices and larger production volumes, contributed to growth rates that have averaged around 11 percent since 2000, with per capita income rising above $2,000 in 2004, 65 percent higher than in 2000. Against this favorable backdrop, Kazakhstani officials have concluded that the country's long-term prosperity and economic well-being will depend on how well and wisely the country invests its oil windfall to develop the non-oil sectors of the economy and promote sustainable, broad-based, economic growth. A key conclusion flowing from this review is that the country must make the transition from producing and exporting primarily unprocessed raw materials to producing and exporting more knowledge intensive, value added goods and services.[3]

The committee generally agrees with this assessment, although as noted in the Preface, the committee understands that the "oil windfall" has been put into a "rainy day" fund and will not be used simply as a new source of investment capital. In addition, the committee concurs with the following conclusions of the World Bank:

- Kazakhstan emerged from the Soviet Union with a strong cadre of scientific leaders in high-technology fields such as atomic energy and space research and a well-educated workforce. Since the early 1990s, a number of key scientific researchers have left the country or have shifted to more lucrative business careers, the average age of the remaining scientific workforce has risen significantly, and educational standards have eroded considerably.
- Many research and educational institutions operate in isolation from each other and from domestic and foreign industry.
- Research institutes frequently set their own priorities without regard to the government's scientific priorities, the needs of the public sector, or the interests of the private market at home or abroad.
- The quality of equipment and instrumentation in research and in teaching laboratories is poor, with little equipment purchased in recent years.
- High value-added activities in the oil sector are dominated by international firms, with Kazakhstani firms supplying relatively low skill services and low value-added products.[4]

[3]World Bank, *Project Information Document, Appraisal Stage for Technology and Competitiveness Project*, March 24, 2006.

[4]Ibid.

However, the committee is unaware of efforts by the World Bank or by any Kazakhstani or other international organization to address a critical impediment to the advancement of science in Kazakhstan. Unfortunately, a hierarchal approach to the organization and management of science is omnipresent in the country. Junior and middle-level scientists and educators are often unwilling to make even minor decisions that have not been cleared with senior staff, and there is reluctance to make suggestions for new approaches, since they might upset administrative or management personnel. This problem will not be remedied until senior people retire and a new generation assumes leadership positions. Even then the problem will be overcome only if the next generation has been trained in more global approaches to management. Thus, it is essential to expose Kazakhstani scientists and educators at every level to a 21st-century approach to S&T and research and development (R&D). An important way to achieve this goal is to promote maximum contact between Kazakhstani managers and scientists and Western colleagues.

Against this overall background, the challenge for the government is to devise policies and programs that will encourage development and use of S&T more effectively for economic and social progress.

Opportunities for industrial development based on advanced technologies have received most of the recent attention of the Kazakhstani leadership when addressing the upgrading of the S&T infrastructure. The leadership is particularly interested in achievements and experiences of industrialized countries as models in its search for rapid mastery of advanced technologies. However, the committee is concerned about possible neglect of (1) the need to upgrade S&T-related services using well-established technologies that should be provided through the systems of a number of mission-oriented ministries such as the Ministry of Health and (2) the importance of using well-known techniques for improving the performance of the agriculture sector, which sustains a substantial portion of the population and contributes to export earnings through cultivation of grain, raising of livestock, and production of food-related commodities. Additional comments on these concerns are included in later chapters of this report.

Greater attention should be directed to understanding the relationships between expanding the availability of technologies, old or new, and employment creation and displacement. Continued growth of the economy should result in more jobs, particularly in the service sector, although there may be dislocations in some sectors. At the same time, there should be considerable opportunities for job creation in the construction, food, and natural resources sectors. More effective use of technologies, leading to increased investments in these and other areas, should in general expand these opportunities. At the same time, given the limited cadre of technically qualified specialists, movement of personnel should be expected. The committee recommends that the intersections of technology and employment be on the research agendas of social scientists in Kazakhstan to assist the government in considering important impacts on society of promoting specific technological achievements.

In order for the government to be able to sustain large investments in S&T, particularly investments with long-term payoffs, the positive impacts of expanded reliance on S&T on the everyday lives of the general population must be evident in the near term. Supporting advanced technology approaches in the search for "breakthrough" technologies is important in some areas, as discussed in Chapter 2. But modernization and more effective use of established technologies are essential in supporting the day-to-day activities of the entire population and in reducing poverty in many areas of the country.

VISION OF THE GOVERNMENT OF KAZAKHSTAN

The president of Kazakhstan has established the goal of Kazakhstan becoming one of the 50 most technologically competitive nations of the world by 2015.[5] According to the Ministry of Education and Science (MES), Kazakhstan ranked 56 as of September 2006.[6]

Given the steadfast commitment of the president to this goal, the parameters used by MES in measuring progress must certainly receive attention. Many Kazakhstani organizations are developing strategies and programs to help the country reach the goal as soon as possible. The committee found that articulation of the goal has served as an important catalyst for launching a number of significant S&T-related activities. At the same time, however, the committee is concerned that preoccupation with reaching the goal in the next few years could result in the neglect of some aspects of development that in the long term are critical to sustainability of economic growth and social progress (e.g., conservation of water resources, reduction of environmental pollution, improved nutrition).

As a key component of the nation's S&T approach, the Ministry of Industry and Trade (MIT) prepared a Strategy for Industrial-Innovation Development for 2003-2015 and a related Implementation Plan.[7] This effort has become entwined

[5]"Kazakhstan, Reaching for the Stars," *Foreign Affairs*, September/October 2006, special section sponsored by the government of Kazakhstan.

[6]Speech by Vice Minister A. Abdymomunov, MES conference, "Future of Science and Technology," Astana, September 25, 2006. He stated that the following criteria, which had been developed by the World Economic Forum, were used in this rating: transfer of technology, capabilities of engineers and scientists, technology index, capabilities of specialists providing scientific and technical services, technological readiness, protection of intellectual property, quality of scientific research institutes, and availability of venture capital. See also the World Economic Forum, *http://www.weforum.org/en/initiatives/gcp/Global%20Competitiveness%20Report/index.htm.*

[7]*Strategy of Industrial-Innovation Development of the Republic of Kazakhstan for 2003-2015*, Press Service of the Ministry of Industry and Trade, Astana, 2003.

with a collaborative program with the World Bank scheduled to begin in 2007, as noted in the Preface. It involves support of scientific groups of excellence; establishment of an instrumentation center open to all interested researchers; and expansion of technology transfer programs, commercialization, and advisory services. The emphasis on groups of researchers rather than laboratories or other organizational entities is intended to highlight the importance of development of individuals. Directly related topics are discussed in subsequent chapters.

Since the development of the World Bank program, a broader framework for the S&T infrastructure has emerged. This framework is encapsulated in large measure in the proposed draft of the State Program for the Development of Science in the Republic of Kazakhstan for 2007-2012. The State Program draft includes many activities that are also addressed in the aforementioned strategy on industrial innovation. However, the State Program draft is under the management of MES and therefore has an understandable emphasis on education and research.[8]

The State Program draft calls for seven areas of activity:

- Improvement of the system of state management of S&T development.
- Improvement of the mechanisms for financing scientific research, development, and design activities.
- Improvement of the integration of science and education.
- Strengthening the technical and equipment base for conducting research, development, and design activities.
- Development of a system for certification of scientific and scientific education cadres and accreditation of scientific organizations for raising the effectiveness and quality of scientific research, development, and design activities.
- Improvement in the information base for the development of science.
- Protection of intellectual property rights.[9]

Preparatory steps are to be taken during 2007-2009 for implementation of the proposed State Program. They include changes in the legal and normative basis for scientific and technical activity, modification of the system of state management of scientific and technical development, and reform of the basis for financing research, development, and design activities.

From 2007 to 2013 the proposed State Program is to be implemented with a focus on (1) integrating science and education, (2) preparing the scientific workforce, and (3) developing the scientific infrastructure to help raise the contribution of local science to production activities. Planned activities of particular

[8] *Proposed Draft of State Program for the Development of Science in the Republic of Kazakhstan for 2007-2012*, Astana, 2006, provided by NCSTI in July 2006.

[9] Ibid., Section 4.

interest for this report are (1) establishment of five national laboratories, each with a distinct program profile determined by the five areas of priority interest that are currently being identified (see Chapter 2); (2) centers of the national laboratories at 15 geographically dispersed universities where selected applied technology aspects of the national laboratories' areas of priority interest will be emphasized (see Chapter 3); and (3) establishment of business incubators at research centers and universities for commercialization of small engineering projects (see Chapter 4). An important component of the program is to be the establishment of a Science Fund, which is discussed below.

Funding for R&D (measured in local currency) should increase by 25-fold from the local currency (tenge) equivalent of $103 million during 2005. Annual inflation rates have been predicted by the government to be 7 percent and by Western experts to be 15 percent. Thus, the real increase in R&D support, even if fully funded, will be significantly less than 25-fold but nevertheless should be very substantial.

By 2012 the private sector is to provide 50 percent of national R&D expenditures compared to 7 percent in 2005. Eventually, the private sector is to fund two-thirds of the national R&D effort. It is important for the government to encourage substantial increases in private-sector funding of R&D, but the foregoing goals are excessively optimistic. A large number of private-sector companies are currently committed to minimizing expenses by continued use of outmoded equipment. Only a handful of companies have shown interest in investing resources in new processes and products, even if in the long term these investments would increase profit margins. Also, most technologies of interest to companies prepared to upgrade their activities are readily available on the international market.

Still, encouraging private support of local R&D activities, as discussed in Chapter 4, deserves high priority by the government. For example, the requirement that multinational companies operating in Kazakhstan must spend a certain portion of their investments for acquiring local content of the equipment and services being used in the country provides a mechanism to link these companies with local S&T institutions. One Western oil company is considering investing in local R&D to help perfect corrosion-resistant drilling equipment suitable for extracting offshore oil with high sulfur content.

If substantial progress is achieved in moving toward the spending targets that the government has established, particularly the targets for private-sector support of R&D, the S&T base of the country can be significantly transformed. Of special importance are increases in salaries for researchers, which can encourage the most talented scientists to pursue careers in the laboratories of Kazakhstan.

The president's goal of moving Kazakhstan up on the international competitive index is ambitious, especially as other countries also seek to move upward. The plans described above to help achieve the goal will require efforts by many institutions on a variety of fronts. The suggestions set forth in subsequent chapters of this report, if implemented, will increase the likelihood, but certainly not guarantee, that the goal will be achieved while at the same time the S&T capabilities of Kazakhstan respond to the broader needs of the population.

ORGANIZATIONAL AND FINANCIAL STRUCTURES

In the autumn of 2006 the government of Kazakhstan established the Supreme Science and Technology Commission, chaired by the prime minister. The 30 members represent the scientific community, relevant ministries and agencies, parliament, national companies, and business. However, an individual member representing a company has voting rights only if his or her company invests annually at least 1 billion tenge (about $7.5 million in 2006) in support of S&T development in Kazakhstan.

One of the commission's primary tasks is to establish national S&T priorities. In a related responsibility, it will send reports to the government every three years concerning S&T priorities and developments. Within the organizational framework of MES, an interagency science committee that reports to the commission is to provide a single focus for government approval and financing of R&D activities.

The new Science Fund will support applied R&D activities with an emphasis on projects involving matching funds from industry ranging from 25 to 75 percent of the costs of projects. The target is to have the fund eventually responsible for dispensing 25 percent of the entire R&D budget of the government. As to private-sector support of R&D through matching funds or directly, only seven enterprises provided support for R&D at their in-house laboratories and at R&D and educational institutions with up-to-date equipment capabilities in 2005. Thus, there is a question as to whether there will be enough good projects to warrant matching funds on a significant scale. Also, as industry becomes directly involved in the use of government funds, questions will undoubtedly arise as to the decision-making mechanisms for approving projects. Consideration might be given to simple grant funding by the government of feasibility studies as an initial step toward larger matching-fund projects.

The following summary of the Kazakhstani government's budgeting process highlights the many sources of public funding for S&T. There will soon be (1) competitive grant programs of the new Science Fund and (2) special governmental allocations for support of the national laboratories (e.g., $40 million during 2006 for the biotechnology center, which MES has proposed as the basis of a national laboratory for biotechnology). The government will continue to provide (3) support for the core costs of operating and modernizing the entire public-sector research infrastructure, including investments in capital upgrades and purchase of essential equipment when appropriate.

MES will administer two grant programs. These programs will provide (4) support for fundamental science activities in fields such as mathematics, mechanics, physics, earth sciences, medicine, biology, and social sciences, on a noncompetitive basis in order to ensure a broad base of science capabilities, and (5) support on a competitive basis for projects in fields of national significance such as mineral resources, mining, renewable energy, health care, agriculture, water management, seismology, ecological security, and warning and liquidation of emergency situations of natural and technical origins. Apparently, MES intends to ensure that the applied research programs that it supports are among the best in the country while preserving all basic research programs, even those of secondary quality. The committee recommends that MES distribute the majority of funding for both basic and applied research through competitive mechanisms, targeting particular fields of basic science for support as necessary to ensure a broad base of science capabilities.

Of particular importance for applied R&D are the funding mechanisms that are in various stages of introduction within MIT under the new "holding" organization named the Kazyna Fund. This fund was initially capitalized in 2006 at $1 billion. The S&T-oriented funding mechanisms under the umbrella of the fund include (6) grant programs of the National Innovation Fund, (7) loans of up to 30 years by the Development Bank of Kazakhstan, (8) venture capital of the Investment Fund, and (9) equity investments of the Small and Medium Enterprise Support Fund.

The mix of various types of publicly supported research in Kazakhstan is to change from the current division among basic research (20 percent), applied research (70 percent), and development (10 percent) to a future division of basic (15 percent), applied (35 percent), and development (50 percent). While the need for more emphasis on development seems clear, effective public financing of development at the projected level will be difficult, particularly if the private sector is expected to provide matching funds for the activities. Also, an increasing portion of government funding is to come from (10) allocations by regional (oblast) governments in addition to allocations of national governmental bodies. Finally, there will certainly be (11) special government allocations for politically attractive projects, such as support of the research infrastructure at the advanced technology university to be established in Astana.

Kazakhstan, like every country, must take into account the history and personalities of its scientific community, political realities, and governance issues in adopting its own administrative structures. Foreign models and experiences may be helpful in providing options for consideration, but they are seldom appropriate for complete adoption.

Nevertheless, the committee is concerned about the approach being considered of transferring responsibility for all government grant funding for R&D to MES, with the mission-oriented ministries no longer having control over the grant financing of R&D activities of institutions that report to them. In 2005 about 50 percent of the government's support for R&D flowed through MES.

The other 50 percent flowed through other ministries. The proposed approach of centralization is not the practice of most industrialized and middle-income countries (e.g., the United States, Russia, Israel). Presumably, the new approach is to improve coordination and to ensure that resources are focused on priority issues. But there are other mechanisms that can achieve these objectives without reducing the mission agencies' authority over research that supports their mission objectives. Of particular concern to researchers should be the requirement that all applications for R&D support would go through a single entry point that might be biased toward the interests of a single ministry. Finally, MES has limited experience in addressing many technical issues in the applied sciences, and strengthening the relevant capabilities of MES seems essential.

As previously noted, S&T services provided by R&D facilities should be fully recognized. Services with an underpinning of well-established R&D programs are particularly important in supporting the efforts of mission-oriented ministries to design and manage technology-intensive programs for which they are responsible. Thus, the committee recommends that before control of all R&D government funding becomes centralized within MES, careful analyses should be carried out by the interagency Science Committee to assess both the positive and negative impacts of such centralization on the capabilities of the institutions subordinate to the mission-oriented ministries. Particular attention should be given to past experiences of the institutions in responding to requests from the ministries for S&T support.

Another concern is confusion as to the meaning of R&D and S&T when financial decisions are considered. The government often refers to financing of R&D as financing of "science." In the Russian language the word *nauka*, which is translated as "science," is often used to encompass R&D. At other times the government uses the terminology "science, design, and development" to more precisely define R&D. As discussed at the beginning of this chapter, S&T is far broader than R&D, and incorrect terminology can give an understated level of financing of S&T. Recent attempts by the government to define "innovation," as discussed in Chapter 4, further add to the confusion. The government should be more precise when discussing S&T expenditures, R&D funding, and levels of support for innovation, recognizing that services that extend far beyond R&D are a very important S&T activity. The definitions developed by the Organisation for Economic Co-operation and Development should be helpful in this regard.[10]

INTERESTS OF THE RELEVANT MINISTRIES

While the Supreme Science and Technology Commission will be responsible for oversight of a variety of interrelated activities of various ministries, many

[10]See *www.oecd.org/topic/0,2686,en_2649_37417_1_1_1_1-37417,00.html*.

important decisions, including decisions of interest to multiple agencies, will continue to be made at the ministerial level. The five ministries that provide R&D funding of primary interest for this report are MES, MIT, the Ministry of Natural Resources and Energy, the Ministry of Agriculture, and the Ministry of Health (MOH). Other ministries provide smaller amounts of R&D funding. Each ministry has a strategy and administers state programs for promoting development in its sector. Each is responsible for a number of research institutions. MOH is responsible for medical universities, while the other higher educational institutions are under the purview of MES.

Presumably, all or almost all of the more than 200 research institutions currently under the purview of the five ministries will continue their activities. Most institutes have long histories dating back to Soviet times, some earlier. Many have recorded impressive achievements in their fields of interest and are well known to international partners. Others are less prominent but nevertheless are considered important by various ministries. Still others are largely orphan institutions with few advocates in the government ministries. Twenty-five of the most important institutes in fundamental science that had been components of the Academy of Sciences are now clustered under four administrative centers that report to MES.[11] The relationships between these four centers, which are to stimulate effective transfer of research results to paying customers, the other ministries, and the new national laboratories, have not yet been developed.

MES has the lead for establishing national science policy in consultation with the other ministries. Still, this topic is so vital to the nation that there will undoubtedly be interagency concerns as to the reach of MES authorities. In particular, MIT has broad S&T interests that overlap with the interests of MES. These interests include exports and imports of technology-laden products, stimulation of private industrial investment in Kazakhstan, and promotion of technology transfer in the country. MIT also supports a number of scientific institutions that fall within MIT's purview.

MIT's technology transfer activities are addressed primarily in Chapter 4. Nevertheless, MIT's efforts to promote technology-related industries deserve mention both in this chapter and in Chapter 2, which addresses priorities.

For example, MIT selects industrial "clusters" of activities that offer potential for economic return. Clusters are considered to be geographically proximate groups of interconnected companies and trade organizations. They should work with nearby governmental bodies and with research and education institutions to enhance their international competitiveness. However, the convergence of common interests of individual specialists and their organizations, rather than centrally determined geographic locations, should be the primary factor in determin-

[11]When the Academy structure was changed, there were more than 40 institutes that were transferred to MES. That number has steadily decreased to about 25, due to mergers and closures.

ing how and where clusters emerge and develop. As of July 2006, the selected clusters included agriculture and food processing, oil and gas machinery, cargo, construction materials, metallurgy, tourism, and textiles.

The committee did not have access to the justifications for selecting these topics. Nevertheless, the choice of textiles is questionable. Given the intense international competitiveness in this field, the uncertain quality of products that use the short-fiber local cotton, and the lack of a significant polymer industry in the country, Kazakhstani companies will probably have difficulty effectively competing on the international market or even the domestic market. Perhaps the decision was based on a political imperative of providing employment opportunities for depressed southern regions of the country, even though cotton growing with uncertain payoff would take a heavy toll on limited water resources.

The effort by MIT to select areas for investment of public funds based on economic analyses should be encouraged, recognizing that at times political intervention in the process will be inevitable.

KAZAKHSTAN'S COMMITMENTS TO USING INTERNATIONAL EXPERIENCE

The government has made a major commitment to the integration of successful practices of other countries with the realities of the Kazakhstan environment for carrying out R&D, improving education, and supporting private- and public-sector businesses. The government has sent its officials and specialists around the globe to learn from the approaches of others—to Singapore, Ireland, Germany, Chile, the United States, and many other countries. And the government has carefully studied the findings.[12]

Of course, many government officials know well the Soviet and Russian approaches. For example, a large number of Kazakhstani specialists consider their scientific degrees from Moscow State University to be equivalent to or better than scientific degrees from leading Western universities. Many graduates of this and other universities located in Russia retain their educational ties and through these linkages stay abreast of developments in Russia. At the same time, few Kazakhstani specialists have confidence in adopting Russian approaches in order to achieve technological competitiveness.

As to industrial development, in the past about 50 major Soviet enterprises sustained much of the industrial technology base of the country. Many of the enterprises had defense industry orientations. Almost all have either disappeared or been transformed into unrecognizable forms. Production equipment made in Soviet times is still being used in many enterprises, with the necessity of spare part linkages to Russia. But as the influx of Western equipment through interna-

[12]Op. cit., Proposed Draft of State Program for the Development of Science, Section 2.

tional companies and direct purchases by Kazakhstani companies continues, the industrial ties to Russia are weakening. Although trade with China as well as with Western countries is growing rapidly, Russian imports still exceed imports from China, the United States, and France combined.

As to the generation of technology in Kazakhstan, government surveys indicate that 5 percent of new products available in Kazakhstan are provided by foreign companies operating there, 3.7 percent by Kazakhstani private companies, and 0.6 percent by state-owned companies.[13] The bulk will continue to come from abroad for many years whether it be in space-oriented fields, nuclear and other energy areas, transportation and communication, construction, or other fields. Of course, an important objective for the country is to begin complementing and in some cases replacing this dependence on foreign technology with reliance on locally generated technologies.

A few Kazakhstani researchers still long for a reemergence of subsidized Soviet-style design bureaus that were the bridges between laboratories and state-owned factories. But these elderly specialists who are still active are decreasing in number. Their views seem irrelevant to current thinking in Astana and Almaty. Kazakhstani officials are increasingly looking to the West and to the East for their entry points into the global world of high technology.

International peer review is a mantra that now permeates many offices of the government of Kazakhstan. Of course, some officials and specialists are not convinced that foreign experts should be guiding the route to national development. However, these skeptics have little choice but to accept the reality of the government's effort to seek foreign advice. This report along with reports of other foreign organizations and individual specialists are clearly considered important by the government.

Several examples of peer review systems that are being established are as follows:

- At the level of providing advice on national priorities to the Supreme Science and Technology Commission, an International Expert Council, with 75 percent of the members from abroad, is to be established.
- At the level of assessing the results of R&D programs, an expert council is to be established by MES, with at least 60 percent of the scientists being from abroad.
- At the level of selection of projects to be financed by MES, an expert council with 50 percent foreign specialists is being organized.
- As to the World Bank proposal for a program to award research grants, MIT is organizing a 100 percent international expert panel to recommend recipients of grants who would establish groups of excellence.[14]

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[13]Information provided by NCSTI, September 2006.
[14]Ibid.

Impressive emphasis is being given to the importance of peer review involving foreign reviewers and the need for foreign experts to advise on policies and priorities while the size of the domestic cadre of experts grows. However, considerable attention must be given to selection of "appropriate" foreign experts who not only are well versed in their fields of S&T but also understand the power and limitations of S&T-intensive approaches in Kazakhstan and the needs of Kazakhstani users of S&T services and products. Such experts who are prepared to devote their time to working with the government may be in short supply throughout the world. Also, foreign specialists embedded in Kazakhstani committees must have adequate time and access to sufficient information to be able to express independent views and not become simply endorsers of recommendations they have not been able to adequately consider. Finally, Kazakhstani program managers need to be able to define the tasks that are to be assigned to external experts before the experts are engaged.

PRINCIPAL THRUSTS OF THE S&T POLICIES OF KAZAKHSTAN

Against this background, the committee has selected for discussion in subsequent chapters several principal thrusts of the policies of the government of Kazakhstan for supporting the development and use of S&T capabilities. According to Kazakhstani officials, the purposes of its policies are to strengthen the nation's international economic competitiveness, improve the social and economic situation for the country's population, and enhance at home and abroad the prestige of S&T practitioners and researchers who can increasingly play an important role in Kazakhstan's social and economic development. To this end, the policy thrusts can be categorized as follows:

- Encourage through economic incentives investments in Kazakhstan by domestic and foreign companies that rely on modern technologies. For many years the preponderance of such technologies will be acquired abroad.
- Encourage private-sector enterprises operating in Kazakhstan to increase their investments in R&D activities that are carried out in private- and public-sector facilities in the country, which will both serve the needs of the enterprises and enhance the technical capabilities of these R&D facilities.
- Provide financial and other types of support to Kazakhstan's educational institutions, publicly owned R&D institutions, and other organizations to carry out R&D activities and provide S&T services when market mechanisms (i.e., public-sector goods and services) are not appropriate or are simply not developed.
- Support education at all levels of talented Kazakhstani S&T students and young specialists and provide them with incentives to work in the country's S&T institutions.

- Provide the financial resources needed to elevate the level of scientific research in Kazakhstan to an internationally competitive level in selected areas of particular promise.[15]

The government recognizes that in the near term the interest of government-owned and private enterprises in the products and services of local S&T institutions will be limited. When they need such products or services, they will usually look abroad for well-proven products or services. Therefore, the government intends to select priority areas for support that will enable local S&T institutions to develop the capabilities to complement the flow of technologies from abroad with technologies that are also of interest to the enterprises that have been developed locally.

In short, the government seems to recognize the importance of taking advantage of imported technologies while building an indigenous S&T infrastructure that increasingly provides homegrown technologies. Details of how this approach is carried out are described throughout the remainder of this report.

As to basic research, which should be an essential component of the educational process and the foundation for applied activities, the situation in Kazakhstan in many fields lags behind international developments. This topic is addressed in subsequent chapters.

[15]The committee developed this characterization, which was endorsed by NCSTI.

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Science and Technology Priorities

This chapter responds to the request of the Ministry of Education and Science (MES) for the National Research Council committee to provide its views on those "areas" that encompass significant science and technology (S&T) activities that should be considered as priority areas for financial and other types of support by the Kazakhstani government.[1]

CRITICAL ELEMENTS OF THE S&T INFRASTRUCTURE

Before addressing specific S&T areas and fields that deserve priority status, the committee emphasizes that strong support is needed for the following types of activities that cut across all S&T programs.

Universal Broadband Access to the Internet by Members of the S&T Community

Science has long been based on theory and experimentation. In recent years, computational sciences have become an essential aspect of advances in many fields of science. The S&T community of Kazakhstan has an opportunity to draw on international developments in hardware and software in its efforts to stay abreast of and contribute to scientific achievements throughout the world.

[1]The information presented in this chapter is based on discussions held with Kazakhstani officials and specialists, although the conclusions reflect the views of the committee. A few references with supplemental information are identified.

The committee gave special attention to the importance of the entire S&T community having affordable broadband Internet access. Such access is essential for carrying out research programs, for having access to information sources, and for communicating within the country and internationally. Internet access is increasingly important in educational efforts, particularly in a country as vast as Kazakhstan with schools and universities distant from qualified teachers and professors in specialized fields. And it generally elevates public awareness to the importance of using modern technologies for the benefit of the entire population. Indeed, broadband Internet access has become one of the commonly accepted measures of a nation's international competitiveness.

Kazakhstan's performance in this field has been uneven. On the one hand, Kazakhstan, with the help of Russia, has launched its own communications satellite, and it has developed strong information technology (IT) capabilities in connection with its programs in space science. It has developed a fiber optic network to link educational and research institutions in Almaty. It has opened a highly publicized IT techno-park in Almaty to promote commercial and public interest in IT. And it is developing impressive long-distance educational programs at both the primary and secondary levels as well as the university level.

On the other hand, results to date have been limited. Hiring qualified staff at the universities has been very difficult. Most educational institutions have inadequate computer capabilities for researchers or students. The fiber optic network connecting three university campuses in Almaty is vastly underutilized. Modern supercomputers that can provide advanced scientific computational capabilities and connect educational and research institutions internally and to external networks are not available, although Eurasia University is in the process of acquiring a 16 teraflop computer. And national information portals are only in their early stage of development. The hundreds of private firms engaged in software development have yet to demonstrate capabilities that will lead to a strong market niche on the global scene.

Kazakhstan cannot afford to continue to lag behind in this field if its S&T capabilities are to advance at a pace that will attract and retain scientists working in forefront areas of science. Furthermore, if Kazakhstan is to benefit from the rapidly expanding global information infrastructure, which should enable it to export services and assess export markets in many fields, it needs to develop and nurture a talented and flexible workforce that can play a more active role in supporting the government's priorities within the country and internationally.

Appropriate Modern Equipment Throughout the Research Laboratories

Most of the research equipment in the universities and research institutes that committee members visited is out of date. Much is not even operating. Occasionally modern instrumentation is provided by international companies for training purposes. But surprisingly good research is nevertheless carried out in many laboratories despite equipment problems.

Clearly the government cannot reequip every laboratory in the country. However, those laboratories that are to support priority areas of research should have modern equipment as soon as possible. Purchases of new equipment should be linked to specific projects to ensure that it will be used. Also, purchases of particularly expensive equipment should be tied to commitments by the recipients of the equipment to share it with other researchers with related needs. At the same time, the reliability of the electrical supply must be assured if the equipment is to be operational.

Maintaining the High Level of Pedagogy in Mathematics, Physics, Biology, Chemistry, and the Earth and Atmospheric Sciences

The quality of university pedagogy programs in the natural sciences has historically been high throughout the system that was established by the USSR. Kazakhstan should seek to maintain that high quality, which is in danger of declining as senior faculty members retire without younger replacements in the pipeline. As discussed in Chapter 3, special efforts are needed to encourage a greater influx of young talent into the university faculties; to this end, stronger research capabilities at the universities can play an important role.

Visits by committee members to two specialized high schools indicated that at least a few young students will be well prepared for university-level science programs. Some of the students have won first place in Olympiads and other competitions. Expanding such early focused training to more students in the country is highly desirable.

Economics Training and Research

Stronger economic analysis capabilities are needed by the government of Kazakhstan, local companies, universities, and research institutes. Wise use of the oil windfall, incentives to attract investment in Kazakhstan, and decisions concerning privatization of public-sector companies and institutions are issues laden with economic considerations that should be addressed by well-trained specialists. Many other examples could be cited.

A number of specialists trained in economics are employed by the wealthiest industrial companies. Of course, their interests are oriented to the profit lines of the companies. Also, financial institutions are able to pay the salaries necessary to attract specialists who have been trained in the West or who have otherwise gained skills oriented to market economies. At the same time, the governmental organizations that are responsible for issuing approval documents for the activities of companies should have on their staffs well-trained specialists or should be supported by organizations with such specialists. But according to

Kazakhstani officials, this usually is not the case. There is simply a shortage of well-trained specialists and a lack of financial and other incentives to attract them to government service or to education and research institutions.

Several universities and research institutes offer specialized courses in economics. Their research agendas seem impressive—for example, solving poverty and related vulnerability problems, innovation in Kazakhstan in the global context, ecologically sustainable exploitation of minerals. If their conclusions concerning developments in these topical areas are helpful to government officials, they certainly deserve additional support for related research. If their conclusions are weak, the teams need to be upgraded.[2]

Professional Scientific Societies, Industrial Associations, and Academies of Sciences

A variety of nongovernmental organizations that bring together members of the S&T community with common interests can provide important resources for the government and should be encouraged. Committee members were particularly interested in the efforts of the National Academy of Sciences of Kazakhstan to prepare reports on the state of science for the government and of the National Engineering Academy of Kazakhstan to encourage the business sector to begin to participate in government-supported research projects that could have implications for development of the economy. In the future the government might request that these academies prepare reports on policy issues that require careful scientific and technical analyses. Also, the IT Association of Companies seemed to offer an important mechanism for the government to improve its understanding of how the country's IT sector can be developed in a broader and more effective manner than in the past.[3]

These nongovernmental organizations also provide important connections with foreign and international counterpart organizations. Such connections often enable participating scientists and engineers to establish linkages that enhance their personal capabilities and stature while providing important interinstitutional cooperation as well.

[2]See, for example, *Institute of Economics*, brochure, Ministry of Education and Science, September 2006, and *Almaty Academy of Economics and Statistics,* Bastau Publishing Co., Almaty, obtained September 2006.

[3]See, for example, *National Engineering Academy of the Republic of Kazakhstan, Fundamental Research, 2006-2008*, presentation slides, September 2006, and *National Report on Science for 2005*, vol. 3, National Academy of Sciences, Astana-Almaty, 2005.

Standards and Quality Assurance

Development and enforcement of national health and safety standards are important if Kazakhstani products are to be acceptable internationally. Product performance standards are essential for interchangeability of components produced or purchased by Kazakhstani organizations. Also, good laboratory practices and good manufacturing practices are essential for any country developing its technological base in any sector. More broadly, adoption of voluntary standards systems linked to international efforts is critical if Kazakhstan is to become an internationally recognized source of modern S&T products.

Publication in English-Language Journals

Kazakhstani scientists have a long tradition of publishing scientific findings in Russian-language journals. While government leaders now recognize the importance of increasing publications in English-language journals, the transition process is difficult for scientists who do not have English-language fluency. Nevertheless, this transition is essential if Kazakhstan is to play a significant role in international scientific or business circles.

The government could provide an important incentive to increasing reliance on English-language journals and databases by helping libraries increase their holdings of such journals and increase access to databases. Several approaches should be considered. The National Center for Scientific and Technical Information (NCSTI) is currently establishing an Internet portal for this purpose, and it should receive strong support. Government funds should be made available to purchase the most important journals for libraries of the universities and research institutions throughout the country. Finally, foreign colleagues should be encouraged to provide unneeded back issues of journals, which would be of interest to Kazakhstani scientists.

Ethics for S&T-Related Activities

Ethics cut across many S&T activities, such as experiments related to cloning, reporting and interpreting results of human trials for new drugs; and compliance with engineering standards in the design and construction of buildings and bridges, to name but a few examples that directly affect human lives. Ethics permeate the financial aspects of S&T activities. Ethics are important in maintaining laboratory notebooks, in calibrating instrumentation, and in selecting and rejecting data to be considered. As another dimension of ethics, objectivity is very important in presenting the results of S&T activities to decision makers at many levels—from the president to project managers.

Of particular importance is the need to ensure that scientific publications and claims of scientific discoveries are sound. Their quality influences perceptions as to whether research is being carried out in a manner that is consistent with internationally acceptable codes of research ethics. This topic is of considerable importance in Kazakhstan, which inherited from the USSR some inappropriate approaches to research and development (R&D) as well as some sound ones. Research managers often took excessive personal credit for important scientific findings that should have been attributed to team efforts rather than individual efforts. Sometimes inadequate attention was given to research methodologies in publications, thus raising questions about the reproducibility of research findings. Unfortunately, plagiarism was a widespread practice at some educational institutions.

Of special importance in ensuring the integrity of the research process are well-designed processes for reviewing articles and other manuscripts prior to their publication or release. Fortunately, the government is increasingly emphasizing such reviews. Also, lectures, seminars, and publications on ethics should become engrained in the activities of both educational and research institutions. Professional S&T societies can play an important role in raising sensitivities to the importance of scientific integrity.[4]

SIGNIFICANCE OF S&T PRIORITIES

MES has identified on a preliminary basis several priority areas (i.e., space science and information technology, nuclear and renewable energy, hydrocarbons and minerals, nanotechnology, and biotechnology). The Ministry of Industry and Trade has also identified priority industrial areas for encouraging investment, and all of these areas involve S&T (i.e., information technologies, electronics, and telecommunications; chemistry and petrochemicals; biotechnology and pharmaceuticals; machinery building and metallurgy; construction materials; and light industry, including the textile and food industries).

However, the committee had considerable freedom in developing its recommendations. It was not obliged to embrace the areas identified by the ministries as being among its priorities. The committee was not asked to organize its recommendations around the themes of the areas identified by the ministries. Indeed, the committee considered other categories of activities to be appropriate, as discussed below (e.g., Biotechnology is subsumed in Agricultural Science and Technology and in Medical Science and Technology).

The committee did not have the opportunity to review activities in all of the areas identified as priority areas by the ministries. Therefore, it is not in a position to comment on several areas identified by the ministries but not on the

[4]See, for example, Bruce Alberts and Kenneth Shine, "Scientists and the Integrity of Research," *Science*, December 9, 1994, pp. 1660-1661.

committee's priority list. For example, as previously noted, the committee was asked not to address space science due to logistical difficulties in becoming adequately informed about activities in this field. MES also requested that the committee identify specific fields of particular importance (referred to by MES as "critical technologies") within each priority area.

Technologies are critically important in enhancing economic competitiveness. But there are national objectives that can benefit from strong S&T capabilities in Kazakhstan even though the critical factors may not be technological ones (e.g., improved education curricula, land management, or urban planning). Therefore, this report does not use the term "critical technologies" in discussing priority areas or important fields within these areas.

Development of a very wide range of S&T capabilities is, of course, important for every country. The identification of specific priorities in this report does not suggest that other aspects of S&T should be ignored. However, the resources available to Kazakhstan, while generous, are limited. Thus, at this time selection of areas that offer particularly high payoff in terms of social and economic development in the not too distant future should be useful in guiding the government's near-term investments.

The government is already investing significant financial resources in each of the areas/fields the committee has identified as deserving priority. Analyses concerning the appropriate levels of support for these areas/fields were beyond the scope of this report. They should be carried out on a continuing basis by Kazakhstani specialists. However, these areas/fields deserve strong support during the next several years, and designating them as priority areas/fields should help ensure that such support is forthcoming from the government. Also, designation of these areas/fields should attract the attention of potential nongovernmental funders, including enterprises operating in Kazakhstan.

The appropriateness of the priority areas selected by the government should be reviewed periodically, perhaps every three years. Trends in both global and local demands for S&T-based goods and services in each area should be analyzed. And, of course, the progress of the country in capitalizing on the government's support of priority areas should be carefully examined. Based on these assessments, the government should be prepared to modify its priorities as appropriate, keeping in mind the long-term nature of developing strong and effective S&T capabilities in any area.

Committee members and American consultants associated with the study that led to this report visited more than 130 institutions as they became familiar with S&T achievements and capabilities in Kazakhstan. However, they did not have time to visit many other institutions involved in S&T activities. Therefore, the priority areas set forth below do not reflect an assessment of the totality of the nation's S&T strengths, and they certainly do not reflect all opportunities to obtain significant returns on S&T investments. Nevertheless, the suggestions in this chapter should help the government of Kazakhstan direct its attention and its financial resources to areas that have good possibilities of leading to positive economic and social impacts.

CRITERIA FOR SELECTING PRIORITY AREAS

MES has established preliminary criteria for selecting priority areas that embrace S&T and the associated "critical technologies" for financial and other types of support by the government. They are:

- Promise of technical activities in the area from a global perspective.
- Necessary and sufficient conditions for realization of technical achievements in Kazakhstan.
- Economic soundness of pursuing technical activities in the area.
- Patentability of S&T achievements.
- Probability that technical activities will lead to a qualitatively new level of scientific or technological development.[5]

These criteria are significant, but they are also very general. They need elaboration at the outset of the process of selecting priorities, particularly the criterion concerning the feasibility of Kazakhstani institutions being able to realize meaningful S&T achievements.

In addition to their vagueness, the criteria do not call for adequate consideration of the importance of effective use of S&T in meeting a broad range of specific societal needs of Kazakhstan, except when meeting such needs is a derivative of the general contribution of S&T to economic progress. For example, the support provided on a daily basis by the S&T community for governmental health, environmental, water conservation, and social services programs may not be eligible for consideration for priority status using the MES criteria. Such support involving S&T services is particularly important, given that the general economic category "services," which includes S&T services, accounts for more than one-half of the nation's gross domestic product.

The following criterion for selecting priority areas and "fields" within the areas is suggested:

Within the area of interest, and the fields within the area, Kazakhstan has or could have in the next five years the technical leaders and the human and physical resources necessary to carry out R&D programs and/or provide S&T services that could contribute in a major way to the country's social and/or economic progress. Such progress could be achieved through

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[5]*Proposed Draft of State Program for Development of Science in the Republic of Kazakhstan from 2007 to 2012,* Astana, 2006. Provided to the committee by MES on July 22, 2006.

(1) increased profits for Kazakhstani exporters of products based on R&D achievements or for Kazakhstani providers of S&T services for foreign clients, (2) attraction of new domestic and foreign investments in Kazakhstan that utilize the R&D results or S&T services of local organizations, and/or (3) improved well-being of the general population as a result of the R&D products or S&T services.

At the same time, expanded government support of the priority area of interest and specifically the fields within the area should (1) increase significantly the attractiveness of educational opportunities within the country that have the potential of leading to important S&T-oriented careers for highly talented young people and (2) enhance the prestige of Kazakhstani S&T within the country and internationally.

In principle, the level of governmental financial support of any S&T activity should be commensurate with the anticipated scientific, economic, and social benefits to be realized from such support, in both the near term and the long term. Such benefits from successful investments are very diffuse and cannot be predicted with a high degree of confidence. Despite this lack of predictability, the experiences of industrialized countries have shown that S&T development is essential not only to grow the economy but also to improve social conditions for local populations. In making judgments as to the levels of investments that are appropriate, the government should consider both (1) the likely interest within Kazakhstan and globally during the next decade in the anticipated products of S&T activities and (2) the likelihood that competitive products can be based on Kazakhstan's S&T capabilities.

The suggested criterion, along with the criteria developed by MES, should contribute to the national debate on how best to select S&T priorities, recognizing that criteria can only provide general guidance. Criteria cannot be rigorously applied in identifying priorities among disparate areas for this report or for determining levels of financial support for specific projects. Technical uncertainties will accompany most innovative activities. Also, there will be future political and economic measures undertaken by the international community or by Kazakhstan's leadership that will affect economic and social conditions that provide the context for the priorities to be given to S&T programs.

The national debate over the country's development strategies may well lead to the selection of priorities other than those set forth in this report. But the report should help stimulate the discussion of the important issue of selecting S&T priorities.

PRIORITY AREAS

Recommendations concerning priority areas and priority fields within these areas for governmental support follow.

Nuclear S&T

Kazakhstan has a long history in nuclear science and technology. Soviet testing of nuclear weapons began at the Semipalatinsk test site in the late 1940s. After dissolution of the USSR and the cessation of testing, the National Nuclear Center was established. It is now a well-staffed and well-equipped institution with facilities located primarily in the city of Kurchatov near the test site and in the suburbs of Almaty.[6]

The center has received dozens of international contracts and grants during the past decade. Initially, international interest was focused on quickly providing funding to encourage the redirection of nuclear talent from military to peaceful nuclear applications. In recent years, increasing emphasis by international funders has been on the quality of the research activities that are carried out. The large number of international contracts and grants provides good evidence that the research is important and worthy of support.

Nuclear science and technology should be among the priority areas supported by the government. Strong support for the following three fields is recommended.

Assessment of Nuclear Power Facilities

For many years the National Nuclear Center has conducted feasibility studies of nuclear power plants to help solve residential and industrial electricity problems, particularly in the Almaty region. The world's first breeder reactor to operate on a commercial scale was constructed by Soviet specialists in Aktau in the 1960s and was in service until 1998. As a result many Kazakhstani specialists have on-the-job training in reactor design, operations, and maintenance and in many other aspects of nuclear science and technology. In July 2006 the government reached an agreement with the Russian government to begin design and construction of the next nuclear power plant, with others to follow.[7] However, Kazakhstani officials informed the committee that there has not been a final decision on the characteristics of the initial plant or the foreign partner and that the government is considering issuing an international tender in order to receive proposals from firms in other countries. But it appears that after many years of internal discussions, the government is now determined to move forward in this area.

Why should an oil-rich country pursue nuclear power? The committee is not in a position to pass judgment on the economic and environmental merits of

[6] *National Nuclear Center, Republic of Kazakhstan,* booklet, National Nuclear Center, Kurchatov, undated. Obtained in Almaty, July 2006.

[7] "Atomstroyeksport Will Build First NPP in Kazakhstan," *www.minatom.ru*, July 26, 2006.

installing nuclear power stations in Kazakhstan. However, the committee observes that Kazakhstan is an unusual oil-rich country in view of its nuclear heritage. In addition to the anticipated contributions of nuclear power to the economy by supporting electrification of the country, nuclear power is to be an important symbol of national high-technology achievements that enhance the prestige of Kazakhstan S&T at home and abroad. Nuclear power will provide opportunities for hundreds of Kazakhstani engineers to hone their skills and become national scientific leaders and will ensure that Kazakhstan plays a significant role in international discussions of the future of nuclear power.

The importance of a strong S&T infrastructure that will enhance the nation's capability to manage the development of the nuclear power industry seems obvious. Even if the country is heavily dependent on foreign technical expertise, local specialists will be continuously called on to advise the government on policies and regulatory requirements and on the appropriateness of arrangements with foreign organizations. R&D programs, particularly those linked to international efforts, will be particularly important to ensure that nuclear specialists stay abreast of worldwide developments that affect the choices and operation of nuclear power systems. Also, Kazakhstan needs strong capabilities to ensure that the siting and engineering of nuclear power plants in a tectonically active region do not create unacceptable risks.

Radioecology/Radiation Safety

Nuclear contamination from Soviet weapons testing presents serious ecological problems not only at the Semipalatinsk site but at other sites where tests were conducted (e.g., Lira, Azgir). The extent and hazards of the testing legacy will take decades to fully determine, but there is sufficient evidence to warrant immediate measures to prevent exposure of humans and animals to certain contaminated areas. Also, land reclamation is of considerable interest in some lightly contaminated areas that remain populated, and the reclamation procedures call for high-level skills in the nuclear field. Kazakhstan has a strong cadre of specialists in radioecology who are addressing not only the testing legacy but also contamination associated with uranium mining and possible health hazards associated with other naturally occurring radionuclides throughout large regions of the country.[8]

Another issue with potential health and ecological consequences is the need for skilled collection and disposition of ionizing radiation sources that have exceeded their useful lifetimes for applications in industry, medicine, and other fields and of other still-useful sources that are no longer needed. At present, many sources that are no longer in use are being stored at the Baikal site in

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[8]Artem N. Yermilov, *Nuclear and Radiation Ecology at a Glance: Focus on Kazakhstan*, booklet, Institute of Nuclear Physics, Almaty, 2006.

Kurchatov.[9] The development and implementation of procedures for handling these sources are highly dependent on a highly skilled S&T workforce that is currently concentrated at the National Nuclear Center. While source collection and disposition activities are better described as S&T services than as R&D activities, they are very critical in Kazakhstan.

Radioecology/radiation safety is clearly a field of scientific strength for the country, with broad implications for the general public.

Uranium Mining[10]

Kazakhstan has an estimated 20 percent of the world's uranium reserves and currently provides uranium concentrate for almost 10 percent of the world markets. The government has ambitious plans to increase uranium production fourfold by 2010, with a steady growth in its share of the world markets. Directly related mining capabilities support the extraction and preparation of beryllium products for 20 percent of the world markets and tantalum products for 6 percent.

Kazakhstan has been a pioneer in developing in situ leaching of uranium that permits extraction of sandstone-bedded uranium deposits by selective transfer of natural uranium ions into solution. With the use of this process, the sand and stones of the uranium ore-body remain underground, unlike conventional mining that requires significant waste management and restoration efforts on the surface. This leaching technique is believed to be suitable for about 70 percent of the uranium reserves.

A research agenda includes enhancement of borehole construction and extraction technologies, improvement of safety measures, and development of improved waste reduction techniques. In addition, a variety of services are based on this experience, including the design of construction projects of interest to both the governments of small towns and the oil industry and development of procedures to respond to mining and other emergencies.

Given the economic importance of these activities and the long experience of Kazakhstan in this field, uranium mining deserves priority status.

Biomedical S&T

Similar to its nuclear legacy, Kazakhstan inherited from the USSR a well-developed institutional and human resource base for detecting and controlling pathogens in populated areas and in the general environment. Kazakhstan was a

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[9]Ibid.
[10]*Institute of High Technologies*, brochure, National Atomic Company, Almaty, 2006.

location for Soviet testing and production of biological agents that could be weaponized. It had an extensive network of well-developed research facilities, including unique antiplague stations that had dual-use capabilities and a system of sanitary epidemiology stations focused on clinical aspects of human health. These and other facilities were involved in both monitoring the occurrence of naturally occurring pathogens and carrying out research on methods to prevent and treat disease outbreaks. With a small amount of upgrading, these capabilities could be turned into an international asset for detection and control of infectious diseases.

Also, the country has long had extensive facilities to prevent, diagnose, and treat common ailments—from measles to cardiovascular disease. A large number of specialized medical research centers are in place, and much of the research that is under way is a continuation of efforts that began decades ago. But as international contacts with Western countries expand, there is growing interest in the adoption of new approaches to health care, particularly approaches based on medical research findings at home and abroad.

Most of the research laboratories in the fields of microbiology and virology that the committee observed are in poor condition and need to be replaced. Rebuilding laboratories from the ground up rather than attempting renovation has several advantages. Difficult-to-sterilize surfaces should be replaced. Designs to accommodate existing and new equipment as well as modern good laboratory practice support systems are needed. In addition, better laboratory layouts can often consolidate activities, provide office space for research managers and gathering rooms for staff, and in other ways improve laboratory efficiency.

Hundreds of talented but aging biological scientists are still in place, while the influx of young scientists into public-sector institutions has been very limited for almost 15 years. Nevertheless, current research capabilities are unique in Central Asia. Data banks contain a great deal of public health and germplasm information that is important to the international community. At the same time, the government is investing significant new resources into restoring lost capabilities.

Kazakhstan is a huge storehouse of important disease strains of many types that occur in different ecological settings. Intense international interest in the distribution and impact on public health of a wide variety of such strains will undoubtedly continue to increase for the indefinite future. Few countries have both the diversity of disease agents and the underutilized scientific workforce that exist in Kazakhstan.

At present, Kazakhstani interest in biotechnology is high—in recombinant DNA techniques, genomic analysis, bioinformatics, and related activities. While this section of the report concentrates on biomedical applications of S&T, biotechnology capabilities can also contribute to overcoming problems in other sectors of the economy, including mineral beneficiation, treatment of wastes, restoration of polluted areas, plant sciences, and food processing. Research laboratories that master biotechnology techniques related to human health are in a good position to expand into other areas as well.[11]

In view of the foregoing, this area deserves priority status and the following fields are recommended for focusing government resources.

Disease Surveillance and Prevention

In 2004 the Ministries of Health and Agriculture, at the initiative of the U.S. government, launched an intergovernmental program to strengthen the capabilities of existing disease surveillance networks. This program involves improving diagnostic laboratories, creating central reference laboratories with state-of-the-art equipment, and installing modern communications and information technology backbones. Mobile teams are to respond to outbreaks, and selected pathogens will be consolidated at the central reference laboratories.

Anticipated benefits from this program are manifold. Early warning of emerging health problems will be improved. Upgraded capability should strengthen local competitiveness for international research funding. Talented young scientists should be attracted to modern laboratory settings. The security of significant strain collections will be strengthened.

The Kazakhstani readiness to sustain the program after external financial support terminates is a key issue. The Ministries of Health and Agriculture should ensure from the outset that the program meets the needs of local authorities and practitioners responsible for day-to-day surveillance. They should then be able to commit to supporting the program for the indefinite future.[12]

As to prevention, the embryonic efforts of Kazakhstani scientists to employ modern biotechnology approaches in the search for effective drugs and vaccines are already showing positive research results as evidenced by continued funding of research efforts by foreign partners as well as the government of Kazakhstan. In particular, the recently established National Center for Biotechnology has strong leadership and well-conceived research projects in fields that have attracted international support, such as genetic mapping of dangerous infections. It is also engaged in the global search for vaccines for hepatitis C at the Institute of Microbiology and Virology. In a related area, diagnostic kits for detecting a variety of diseases have been produced and marketed in Central Asia for a number of years by the M. Kimbaev Kazakh Scientific Center for Quarantine and Zoonotic Infections. As the country develops its biotechnology

[11]See also *National Program on Health Sector Reform and Development in Republic of Kazakhstan for 2005-2010*, Decree of President No. 1438, September 13, 2004, Astana.

[12]Letter report of the National Academies to the U.S. Department of Defense on the Threat Agent Detection Response System (TADR) network, July 2006, Washington, D.C.

capabilities and its analytical facilities, regional markets for kits and related services should expand.

Given the importance of controlling infectious diseases—locally, regionally, and globally—this field deserves priority. Moreover, disease surveillance capabilities can be expanded to improve surveillance of a variety of health conditions as their plans for public health evolve.

Cancer Therapy

The rate of early mortality due to cancer in Kazakhstan is comparable to the rate in other former Soviet republics and is considerably higher than the averages across Europe. Lung cancer is of special concern. While breast cancer rates have been low, they have recently been on the rise. The relationships between nutrition and cancer are becoming increasingly apparent in Kazakhstan as in other countries.[13]

At the same time, Kazakhstan has unusually strong capabilities to treat cancer, particularly with well-developed radiation techniques, which are attributable in large measure to its long involvement in Soviet nuclear programs. The staff members of the national cancer program that committee members met are well qualified to prescribe and conduct radiation and related therapy programs. A number of the young scientific leaders are up-to-date on international developments.

As to the development of new chemical therapies for cancer, Kazakhstan is involved in multinational trials, although further development of its national capabilities in this field is needed. Young scientists are deployed around the country, and they are providing a valuable service in obtaining new insights into detection and treatment of cancer.

Of course, the death tolls from other diseases, such as cardiovascular disease, also are of concern and may deserve priority as well. But from the committee's observations of the country's medical system, cancer therapy stands out as an area of particular interest. Strong support by the government should enable Kazakhstan to become a leader in the not too distant future in both R&D activities of global significance and treatment technologies and services for the entire Central Asian region.

Natural Products Chemistry

For several decades, scientists at the research and production center Phytochemistry in Karaganda have analyzed about 500 plant species indigenous to Kazakhstan. About one-half have been selected for detailed studies, and 1,000

[13] *Highlights of Health in Kazakhstan*, World Health Organization, European Office, April 1999.

promising compounds have been identified from these plants. Also, chemical modifications of about two dozen plant oils have been carried out. In short, there is a very active program that has received strong support from the government.

The committee is aware of the difficulty in discovering molecules with important medicinal qualities, particularly in laboratories that do not have the latest technologies for rapid screening of plant species. Efforts in countries with sophisticated scientific capabilities, such as China and India, have not yet had high returns after many years of effort. Indeed, skeptics sometimes characterize natural product chemistry as a low-probability effort. However, the payoffs from successful discoveries can be large, and Kazakhstani scientists have demonstrated that they have the capability to contribute significantly to the international search for high-payoff medicinal products.

Kazakhstan's efforts have attracted broad international attention. The scientific leaders understand the hurdles from discovery of a new drug to market, the importance of disseminating findings through both the scientific literature and personal contacts, and the necessity of protecting discoveries through international patents. They recognize the need to work with foreign partners with better access to existing databases and potential customers. Indeed, major successes of their activities are more likely to be reflected in arrangements with foreign companies rather than in direct sales of their products.

Their best-known product to date is Arglabin, an antitumor drug. Phytochemistry has orders for 10 million ampules to be produced by 2009 for oncology clinics in Kazakhstan, several other Central Asian states, and Russia. Of the more than 770 patients who had been treated with Arglabin as of July 2006, reports indicate a 76 percent positive response rate.[14]

Other products also are being produced. They include wound-healing ointments, medicinal cosmetics, special health foods used in clinics, sweeteners, and antitoxicants. In addition, a number of products for the agricultural sector are of interest. Also, Kazakhstani researchers are just beginning to manipulate the molecular structures of naturally occurring species using modern genetic engineering techniques.

Kazakhstan has unique plant species and an inexpensive and experienced workforce. The potential payoff of success in this field is reflected in the intensive international interest in finding plant species with unusual curative powers.

Orthopedic Devices

The worldwide demand for prosthetic devices is on the rise. Maimed populations of war-torn areas will increasingly need such devices. In Kazakhstan and other countries, automobile accidents are resulting in an increase in demand.

[14]Information provided by Phytochemistry, September 2006.

Kazakhstani specialists have developed a network of international contacts who can help position the country to contribute its talents and products in response to this rising demand.

Kazakhstani researchers have been quite successful in drawing on the metallurgical capability of the country in the design and construction of prosthetic devices. The researchers are experienced in developing devices with unusual metallic properties that can be manufactured at low cost. For example, they have been particularly successful in designing artificial hips and knees and also with stapling devices to ensure the proper functioning of the prosthetic devices. Of course, greater international awareness of their capabilities is important, and the young staff members of key institutions recognize the need to reach foreign customers. At the same time, the government has been providing substantial financial support for their efforts. The enthusiasm of the research teams in response to this support is infectious.

Given the likely payoff from establishing a market niche in orthopedic devices, this field should be given priority status.

Agricultural S&T

Agriculture follows hydrocarbons and mining as the third most important economic sector of the country. Almost three-quarters of the country's extensive land area is suitable for agricultural production. Most of this area is available for livestock grazing, while about 10 percent of the total land area is arable. Cereal grains and livestock are the most important commodities. Cotton, rice, and vegetables also are important, although they require extensive irrigation.

The fertile black soils of the plains and steppes in the northern part of the country coupled with adequate rainfall are the basis for rain-fed wheat production on a large scale. Consequently, Kazakhstan is the sixth-largest producer and the sixth-leading exporter of wheat. Wheat, in particular, is likely to become more important as countries with insufficient water supplies seek to import more cereal grains.

As to livestock, many rural dwellers, who represent a disproportionately large share of the country's poor, are engaged in livestock production. In many cases, this is one of the few economic activities available to them.[15]

Turning to broader issues, many senior researchers will soon be retiring. There is only a limited cadre of midcareer scientists to take their places and an inadequate number of younger scientists in the pipeline. For maintaining their scientific strengths, the best institutions clearly depend on good ties with international groups, including the Consultative Group on International Agricultural

[15]For additional information, see *Analysis of the Tendencies in the Development of Agrarian Science in the World, Conditions and Perspectives for Its Development in Kazakhstan*, Kazakhstan National Academy of Sciences, Department of Agrarian Science, Almaty, 2005.

Research, United Nations agencies, and universities and research institutes in a number of countries. Most research is of a highly applied nature, and greater attention should be given in the years ahead to a stronger basic research agenda. The newly established National Center for Biotechnology is leading the effort in this regard, but its existing facilities need substantial renovation—both at the headquarters in Astana and elsewhere. It also needs upgraded laboratory equipment and higher salary levels to attract high-quality talent.

Priority status for agriculture is important to ensure that the required talent will be attracted to the field and that both exports and food products available for local consumption will continue to rise in quality and availability.

Cereal Grains

Kazakhstan has unique patterns of precipitation, drought, temperatures, and soil moisture conditions. Therefore, extensive research has long been under way to assess new varieties in test plots by examining both production and environmental variables. Committee members observed a number of test plots where varieties from many regions, extending from Siberia to Canada, had been crossed in the search for the most productive wheat varieties. Among the related research topics of interest are rotation schemes, fertilization approaches, plant protection methods, implications of minimum till, and soil restoration techniques. Researchers are pleased with their interactions with international research centers in all of these areas, and they correctly believe that the centers contribute a great deal to international science.

Laboratories are reasonably well equipped, although as previously noted there is an obvious absence of young talent working in the institutions. The National Center for Biotechnology is playing an important role in genetic engineering of different varieties of grains. This focus on basic science is a welcome complement to the applied nature of most research activities.

The income potential of grain exports and the importance of these crops to ensuring the livelihood of large segments of the population are strong reasons why the national research effort should continue to emphasize this field of activity.

Livestock Productivity

The livestock sector in Kazakhstan has several important advantages for increased income, more rapid growth, and expanded exports. They include underutilized pasture land, well-developed and inexpensive small farm production capacity, and inexpensive feed. Among the steps needed to develop the sector should be an emphasis on ensuring that the animals are healthy and that their meat and dairy products are of high quality. Diseases such as tuberculosis, brucellosis, and foot and mouth disease must be controlled, particularly if the export market is to develop. Also, factories that produce feed at international quality levels are needed. Greater attention to maintenance and improvement of pasturelands, including rotational grazing, and to breeding of strains of cattle and other livestock that are best suited to the pastureland are also research challenges.[16]

Kazakhstani research institutions have over many years developed a variety of diagnostic tests, vaccines, and drugs for use with livestock. For example, committee members observed significant work on antibody-based diagnostic assays (ELISA) for animal pathogens at the Agriculture University in Astana. Such research activities should continue, but they should be coupled with affordable veterinary services, particularly for the small private farmers who are increasingly important in this sector. Such services include field observations, laboratory testing, and recommendations as to vaccines and drugs that should be administered or developed.

Two arguments for improving livestock production—export potential and a direct linkage to alleviating poverty in rural areas—are strong. When coupled with the existing cadre of experienced specialists in the field of animal science, they call for priority status for this field.

Nutrition

Throughout the former Soviet Union, increases in cases of infectious and noninfectious diseases have been clearly linked to deterioration in the quality of nutrition. The linkages of these nutritional deficiencies to morbidity and mortality in Kazakhstan seem clear. For example, two-thirds of the population has a high risk of iodine deficiency, and the frequency of registered cases of endemic goiter in some regions of the country has reached levels between 60 and 90 percent. Almost one-half of women suffer from iron-deficiency anemia, and Kazakhstani epidemiologists have conducted many studies documenting the linkages between cancer and poor nutrition. Much of the attention over diets focuses on the health of children. Lack of vitamin A, particularly in the countryside, is a major concern.[17]

In addressing these issues, scientists support and facilitate breast feeding. They encourage dietary diversification. And they participate in public education programs. Nutritionists are particularly effective in engaging highly qualified medical personnel in their programs and advocacy efforts.

For several decades, improved nutrition has been high on the research agen-

[16] *Livestock of Kazakhstan, Joint Program of Government of Kazakhstan and World Bank*, June 2004, Washington, D.C., provided by World Bank, July 2006. Also, *Scientific Developments*, Scientific-Production Center of Livestock and Veterinary Sciences, Almaty, 2006.

[17] See, for example, *Kazakh Academy of Nutrition,* booklet, Kazakh Academy of Nutrition, Almaty, undated, obtained September 2006.

da in Kazakhstan. A strong staff capability was inherited from the USSR, and capable researchers are carrying out well-conceived research tasks. Often, these tasks are coordinated with the United Nations Children's Fund and the World Health Organization, and the research programs seem to be consistent with global priorities set by these organizations.

The importance of improved nutrition is clear, and the eating habits of the country's population, particularly the youth, need considerable improvement. Researchers have had significant impact in working with mothers and infants, for which they have received many well-deserved commendations. Now the challenge is the broader population. Fortunately, Kazakhstan has the capability to continue to make research contributions of international scientific significance and of importance to the general population of the country.

Hydrocarbon Resources

According to Kazakhstani officials, investments in oil extraction in Kazakhstan since the mid-1990s are expected to exceed $80 billion within a decade. Opportunities to connect local S&T programs and the development of the human resource base of Kazakhstan with business activities that enable the country to become more economically competitive clearly exist in the hydrocarbon sector. These opportunities range from the assessment of reserves to the production of value-added products.

For example, due to its limited petrochemical capabilities, Kazakhstan imports gasoline, and the country has little capability to add value to its oil exports. The three operating refineries are reported to be "outdated and inefficient,"[18] although modernization of at least one refinery is under way. Given the nation's large hydrocarbon reserves, expansion of refining capabilities deserves much greater emphasis. Also, there are no facilities to transform hydrocarbon fractions into higher-value, lower-volume products close to the source of the oil reserves; this too is an area for emphasis. While upgrading and expanding the petrochemical infrastructure of the country will continue to involve international companies, local specialists and entrepreneurs can play an increasingly important role in the country's efforts to guide the industry in directions that are consistent with national objectives.

As to other challenges, huge quantities of natural gas remain untouched in the ground. Large amounts are being flared at oil extraction sites. If this resource could be recovered in an economically feasible way, the payoff could be substantial.

The geological service of the country was disbanded during the 1990s, and

[18]*Oil and Gas Journal*, July 10, 2006, p. 32.

the government has very limited scientific capability to manage the nation's hydrocarbon supplies. All detailed assessments are now in the hands of the international companies and government contractors that are engaged only for short-term projects (see recommendation for resource assessment unit on page 100).

The economic stakes are so large, the interests of Kazakhstan in effectively managing and participating in the development of its most valuable resources so important, and the S&T challenges so daunting that the development of hydrocarbon resources clearly deserves priority status.

Chemical Engineering

Stronger capabilities in chemical engineering are a key to increasing the value of the country's oil and gas resources. An important opportunity is to modernize and expand oil refining capacity for gasoline, diesel, and fuel oil to meet domestic needs and for export, perhaps initially to other Central Asian countries. The existing chemical engineering courses at the universities should be upgraded to provide technical specialists for the industry and to develop strong R&D programs that in the long term can be of importance in addressing unique problems of the country. Hard-core chemical engineering (e.g., process design and unit operations) should be considered as an area of specialization at one or more selected universities.

Gas reserves that are not being utilized may present a special opportunity. The gas can be dehydrogenated to ethylene, which is the starting point for many plastics. Western chemical companies are already partnering with Middle East producers of vinyl chloride, polyethylene, and other products, and they would probably be interested in new opportunities in Kazakhstan, where raw material prices are low. Also, most natural gas is methane, which can be converted to methanol and higher molecular weight products through a gas-to-liquid process. Exports of these products to India and China might be feasible since pipeline initiatives are being considered in Kazakhstan. Of course, the quality of the available workforce and the related educational institutions as well as the reliability of existing analytical laboratories are significant determinants as to whether international companies will invest in Kazakhstan or in any country.

In view of the importance of the oil and gas sector and the near total reliance of Kazakhstan at present on imported technologies to develop and utilize petroleum resources, this field clearly deserves priority status.

Catalysis

A key to the yield and specificity of gas to liquid and of polymer processes is chemical catalysis. Research programs at the Institute of Catalysis, the Institute of Chemical Synthesis, and perhaps other institutions are relevant to these processes. Improving the instrumentation at these institutes (e.g., high-field nuclear magnetic resonance, mass spectrometry) and providing incentives for students to pursue studies in catalysis, synthetic organic chemistry, and polymer science are important. In this regard, new technology for large-scale combinatorial testing of catalytic formulations that is being promoted by at least one U.S. firm is directly related to a focus on catalysis.

The petroleum industry would not be the only beneficiary of an emphasis on catalysis. Kazakhstan's embryonic interests in nanotechnology could be linked to catalysis research efforts. The efficiency and specificity of some catalysts, for example, are strongly dependent on the catalyst's particle size, morphology, and interaction with the support structure. For some processes, optimum sizes may be in the range of 100 nm. Nanoinstrumentation and methods could be used in catalysis applications. Also, improved catalyst formulations could be high-value, high-technology export products.

Catalysis has long been a strength of the Kazakhstani research community and deserves new impetus as the oil and gas sector continues to expand.

Assessments of Reserves

The importance of strong government scientific capabilities to assess the extent and quality of Kazakhstan's hydrocarbon resources is increasing as new fields are opened and developed. While the government will not have the capabilities of the oil and gas companies in this regard, it needs to have internal capabilities to be able to confirm the reliability of data provided to it by the companies and to assess the significance of the data. The research agenda of the government should include the following topics: estimates of reserves of oil, gas, gas condensate, and associated components; seismic data interpretation and modeling; logging data interpretation; analysis of lithological and stratigraphical thickness formations and of local structures and fields; and geochemical analysis and characterization of oil and natural gas.[19]

The geological maps and related data produced by the academic and research institutions are useful, and their efforts should continue. But such products are not sufficiently detailed to help ensure the soundness of the government's daily decisions concerning management of the nation's most valuable natural resources. The priority that should be given to this field seems obvious.

Environmental Protection

Even a casual visitor to the Caspian region of the country quickly becomes aware of the ever-expanding environmental problems associated with the rapidly growing industrial activities linked to extraction and processing of oil and gas

[19]*Kaznigra,* brochure, Kazakhstan Scientific Research Geological Survey Oil Institute, Atyrau, no date, obtained September 2006.

resources. Not only is the contamination directly attributable to the hydrocarbon processes, but large-scale construction projects and rapid urbanization are having significant side effects. The booming hydrocarbon and associated service companies have the financial resources to use modern technologies and environmentally sensitive approaches that will limit environmental damage. Kazakhstan has an opportunity to demonstrate to the world in a highly visible manner that it will not jeopardize its human and biological resources in a quest for greater national income.

Of course, capping the discharge of pollutants must be at the top of the list, and sophisticated technologies are needed in the assessment and reduction of effluents from construction, drilling, and processing activities. Already there are severe air pollution problems involving heavy metals; radionuclides; nitrogen, carbon, and sulfur oxides; and paraffin and unsaturated hydrocarbons. There are contamination threats of organic pollutants and heavy metals to ground and surface water, and heavy metals are being spread over large segments of the soil.

On a broader basis, detailed environmental impact assessments are needed to ensure that future investments do not cause serious problems. Disposal of waste products appears to be a serious problem. The possibilities for productive use of more than 10 million tons of sulfur that has accumulated from oil extraction activities is currently under active investigation.

According to Kazakhstani officials, appropriate environmental pollution standards have been established. But these officials readily admit that effective enforcement is lacking. According to local environmental officials, fines are levied when appropriate. However, as in many countries, it may be cheaper for companies to pay the fines than to take corrective actions. Also, committee members were informed that there are very limited laboratory capabilities, particularly in various regions of the country, to analyze the severity of pollution.

The importance of balanced and sustainable development of oil-rich regions of the country and of areas where the petrochemical industry is emerging are clear. The S&T community must play a central role in helping to ensure such responsible development. There are comparable environmental concerns in other areas as well, as discussed in the following section on minerals.

Minerals

Minerals have long been at the backbone of the economy. Copper, lead, and zinc have been important for many years; more recently aluminum, titanium, and manganese have emerged as important commodities. Unprocessed minerals currently account for 40 percent of the country's exports (including uranium and related minerals discussed above). Seven percent of the nation's industrial output is based on ferrous metallurgy and 13 percent on nonferrous metallurgy.

Coal and lignite account for 2 percent of industrial production, and they serve as the backbone of the electricity-generating sector.[20]

A large number of research and educational institutions have long been in place to support the minerals industry. During Soviet times, they were reportedly very tightly linked to the state manufacturing enterprises. In recent years these linkages have weakened, but nevertheless there seems to be considerable synergy among the education, research, and production activities. At the same time, many of the production facilities are old, and the interests of scientists in developing advanced processes often do not match well with manufacturing realities.

Modernization of the minerals sector seems essential. As such efforts are undertaken, the S&T community should be in a position to contribute in a variety of ways.

Metallurgy

There are interesting aspects of the metallurgical complex in Kazakhstan. First, the country is a world leader in the analysis of new metals and alloys from rare-earth metals. Also, Kazakhstan manufactures very heavy duty metals and alloys. New kinds of hardware designs are of interest. Recycling and industrial processing of waste products are important.

Committee members visited several research laboratories that were engaged in both research and testing of materials and quality control activities for industry. Some of these services are provided to the state-owned companies free of charge, continuing the tradition that developed during the Soviet era.

Among the many research areas of interest are the following:

- Ore beneficiation: gravity methods, ecologically clean flotation, magnetic separation.
- Hydrometallurgy: leaching, ionic exchange, electrolysis, hydrothermal deposition.
- Vacuum processes: pyro-selection, distillation, crystallography, continuous process equipment design.
- Pyrometallurgy: chlorination, magnesium reduction, titanium alloys, agglomeration of materials, and magnetic separation.[21]

Assessment of Ore Deposits

Analogous to the discussion in a previous section on assessment of hydrocarbon reserves, the government of Kazakhstan should have strong internal ca-

[20]Information provided by Kazakh National Technical University, September 2006.

[21]For additional details, see *The Institute of Metallurgy and Beneficiation*, brochure, undated, Almaty, obtained July 2006.

pabilities to assess the nation's mineral ore deposits as a basis for developing policies concerning permissions for private companies to carry out exploration and extraction activities. These resources are important to the economy, and their wise development is a central issue for the government. Regrettably, the government does not have an internal capability to carry out detailed investigations of ore reserves or to confirm the findings of the private-sector companies. Also of critical importance is the ecological dimension of mining activities, and expertise on this topic should be readily available within the government.

Skills in carrying out gravity, magnetic, and electrical prospecting are essential components of geophysical investigations. The use of hydrogeology methods and reliance on nuclear geophysics are also important. In short, a strong institutional S&T capability that is always available to advise the government on its development policies is needed. This field deserves a new priority within the government of Kazakhstan.

Environmental Protection

The belching smoke from a metallurgical complex near Karaganda highlighted for committee members a pressing need to protect the health of the residents of areas of the country where mining and metallurgical activities are concentrated. Stringent enforcement of environmental regulations is needed in order to control activities throughout the process of extracting ore deposits and manufacturing metallic products. This need was a constant topic of conversation during the visit to Karaganda on a day when air pollution was high. According to Kazkhstani colleagues, a Soviet legacy of outmoded and heavy polluting production facilities has been compounded by construction of new large facilities since 2005 that also add to environmental problems.

Of special concern are the 8 billion tons of toxic industrial waste and secondary products that have accumulated over many decades from ore mining and processing activities. While the government contends that environmental management has become a national priority and that cleanup efforts are under way, the effects of this policy will take many years to substantially reduce the environmental hazards. Still, the S&T community should play an important role in helping to reduce the problems as quickly as possible. Among the areas where S&T efforts are essential are the following:

- Water: purification, decontamination, remote monitoring and control of pollutant discharges, improved filters and pumps, and sludge control.
- Air: reduction of air emissions (including particulates, SO_x, NO_x, and heavy metals), waste gas treatment and disposal, and protection of respiratory tracts.
- Soil: treatment, rehabilitation, and reclamation.

- Waste: storage, sorting, and disposal technologies; processing and purification; and waste utilization.
- Recycling: waste oil regeneration and waste as alternative energy sources.[22]

The problems are so severe that limiting them and cleaning up the problems of the past clearly deserve priority. As discussed in the section on environmental protection in the hydrocarbon sector, environmental protection is an urgent imperative for the country.

Water S&T

Adequate water—for human consumption, for household use, and for agricultural and industrial activities—is a critical commodity throughout the country. Four rivers flow into the country from Russia, and they provide much of the available water. In some areas, snow and rain fill important reservoirs, and groundwater is present in some regions.

Of course, the Aral Sea symbolizes how ecological catastrophes can result from poor water management programs. Lake Balkash is also receding. Unfortunately, the committee did not have the opportunity to investigate these two developments. However, many other organizations have documented the problems that are attendant to these ecological tragedies and have provided many recommendations to the government and international organizations concerning remedial actions.

Eighty percent of water consumption is devoted to irrigation. The major irrigated crops are fodder (primarily alfalfa), cereals, cotton, and sugar beets. Seventeen percent is devoted to industry and only 2 percent to household usage. About 85 percent of the water that is used is from surface water and 15 percent is from groundwater. A minor amount is from reuse. There are both regional and seasonal freshwater deficits that are often very serious. At the same time, the quality of water for consumption is highly questionable in some areas of the country, and an estimated 50 percent of the population uses drinking water that does not meet international standards of salinity and hardness. At times the population consumes water that does not meet bacteriological standards.[23]

There is no national research agenda for the development, conservation, and protection of water resources nor are there regional agendas. Many ministries are

[22]For additional details, see *Ecotech*, *www.ecotech.kz/en/2005/desc/#2*, accessed September 20, 2006.

[23]Kazakhstan: Antoine Blua, *U.N. Report Highlights Poor State of Water Resources, www.refrl.org/featuresarticle/2004/01/710469a0, 8/16/2006*, accessed September 3, 2006.

involved, and many research organizations have their own agendas, which are often influenced by the availability of international funding. This lack of effective integration of research activities limits the effectiveness of the findings of individual projects. Indeed, international projects may be pointing in different directions from national projects. Of particular concern, the use of groundwater and the use of surface water are often considered separate problems even when they service the same areas, and little attention is given to conjunctive use of these resources.

The relationships among water, agricultural, and environmental issues are manifold. Thus, appropriate use of S&T in the assessment and management of water resources can have broad impacts on many sectors of the economy, and this area deserves priority status.

Irrigation Systems

Irrigated acreage is concentrated in several basins, particularly the Syr-Darya Basin. Seventy percent of the water available for irrigation is from transboundary water sources. Possible diversion of water by upstream users is understandably a constant concern. The origins of irrigation water are primarily river diversion, reservoir sources, and pumping from rivers. Small amounts of irrigation water come from drainage water and groundwater, although groundwater resources are usually too deep or too saline. There is no fully private irrigation, with various levels of government involved in the irrigation schemes depending on the size of the irrigation project.

During the past several decades, Kazakhstani specialists have developed a wide array of irrigation systems designed to reduce excessive water usage while improving water quality through reducing salt levels and cleansing out harmful pollutants. Among the technologies that have been developed and introduced into practice are finely dispersed overhead sprinkling equipment, low-pressure drip irrigation devices, hydro-automated water distribution systems, furrow hatchways, and water-lifting devices using hydro power. Management of water and salt content of soils is an area of interest. Also of interest are integrated water management approaches that involve such technologies as purification of water from suspended salt, flushing of mountain water intake units, and computer-based systems for water distribution on the basis of GIS (geographic information system) capabilities.[24]

Given the heavy population concentrations in areas where the people have become dependent on irrigation as the basis for their livelihoods, improvement of the efficiency of irrigation systems deserves high priority. Water is a com-

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[24]*Scientific Research Institute for Water Resources*, booklet, Taraz, 2006, *www.kazIWR.isd.kz,* accessed September 20, 2006.

modity of ever-increasing importance, and it needs careful management and control.

Monitoring and Assessments of Water Quantity and Quality

Kazakhstani specialists are increasingly frustrated by the absence of reliable information on the state of the nation's water resources. As the country continues to develop economically and as neighboring countries such as China require increasing amounts of water for their own consumption, it is essential that the government have improved information on the trends and future prospects for meeting the water needs of the population. The drinking water needs are of critical concern along with household, agricultural, and industrial needs.

Given the large size of the country, monitoring the conditions of the many sources of water is not an easy task. However, the scientific community recognizes the importance of GPS (global positioning system) and remote sensing technologies to assist in monitoring snowmelt, river levels, flooding conditions, and other parameters that are important in water quantity estimates. As to water quality in urban, industrial, and agricultural areas, a wide variety of measuring strategies are needed. Of course, the difficulty of assessing groundwater resources must be addressed. They are not subject to the whims of neighboring countries that seek a greater share of surface water resources, and this resource needs to be protected and used appropriately.

Good assessments of water quantity and quality are fundamental to management of one of the nation's most important assets. The government needs an internal scientific capability to carry out such assessments. It simply cannot afford to rely on limited and disconnected projects of various research organizations to perform a task that requires continuous attention and close coupling to governmental decisions at all levels.

Protection and Remediation of Water Quality

The quality of water in many areas of Kazakhstan is on the decline. In some urban areas, the aging drinking water systems are becoming infiltrated with contaminants from sewage systems and other sources, and bottled water has become a best-selling item. The heavy use of fertilizers and pesticides has saturated large agricultural areas with runoff into groundwater resources and seepage into the groundwater. Industrial discharges and mine runoff have not been regulated as strictly as needed, with attendant pollution in streams and rivers.

In all of these areas, modern technologies can play a role in maintaining water purification and distribution systems that have been installed to ensure the quality of water and to prevent incursions of undesirable materials into water supplies. The starting point is water quality standards, and officials have stated that such standards are in place. Enforcement is, of course, critical if the standards are to be meaningful.

Past investments in water systems have been substantial. Maintaining and improving those systems deserve priority. While reducing environmental problems often seems to be of secondary importance to the rapid development of Kazakhstan's technological capabilities, highly visible steps to ensure the safety of drinking water can be a stimulus for giving more attention to environmental problems that directly affect human lives.

Construction

The construction industry accounts for 6 percent of national income, and the industry's growth rate has been over 20 percent in recent years. Thus, the importance of activities in this sector is clear. Most of these activities are dependent on S&T—a project's design, the materials used, construction techniques, establishment of building codes, and quality control of the construction activities.

Construction takes many forms—buildings, houses, highways, tunnels, mines, power stations, dams, production complexes. It involves many materials—wood, metal, plastics, glass, and concrete, for example. In many areas there are opportunities for innovation to cut costs and improve performance. In short, Kazakhstan's architects and engineers have an unprecedented opportunity to contribute to rapid development of the country while local investors and builders have the challenge of weighing the costs and benefits of using local goods and services in competition with or in conjunction with imported goods and services.

Given the importance of this sector and the opportunities to use local S&T capabilities more extensively, construction deserves priority status.

Seismic-Resistant Structures

About 1.5 million people live in the Almaty area. The city is a hub for most business activities in the country and for many governmental activities. Key institutions of all types are located in the area. Yet this city is in a highly seismic-active region. If a large earthquake were to occur, the death toll could be substantial and the disruption massive. Predictions indicate that earthquakes will continue to take place in and near the city.

The danger of seismic activity exists in other regions as well, particularly southwest of Almaty, where a serious earthquake occurred in 2003, killing several dozen residents and seriously damaging structures in rural areas. In short, the likelihood of major earthquake damage in the future is high.[25] While build-

[25]See, for example, *Lessons from Lugovsky Earthquake of May 2003, for Kazakhstan,* United Nations Development Programme, Almaty, 2004.

ing codes have been developed and seismic-resistant designs are being introduced as new structures are built, the problems of retrofitting existing facilities to reduce earthquake damage are particularly daunting.

Among the S&T challenges are the following:

- Evaluations of earthquake-resistant capabilities of existing buildings in urban areas, including strength and lifetimes of materials, joining of beams and pilings, adequacy of anchor bolting, and stairwell designs.
- Strengthening transportation facilities, including bridges and overpasses.
- Analysis of soil and foundation conditions and adapting designs of new buildings accordingly.
- Upgrading earthquake resistance of schools, hospitals, government buildings, and low-cost housing in rural areas, particularly unreinforced masonry structures.
- Assessing the capabilities of buildings to support roofing material in earthquake conditions.
- Construction in regions where mining activities have penetrated foundation areas.
- Protection of lifelines that are important in the aftermath of earthquakes, including power, communication, and water systems as well as fire suppression and other first-responder facilities.

An impressive national seismic network is in place that provides important information on earthquake trends and past episodes. The seismic data that have been collected have been used to prepare vulnerability maps in regions throughout the country and in microregions in urban areas, particularly Almaty. In the event of an earthquake in a populated region, real-time seismic data will be important in anticipating aftershocks and in identifying affected areas of particular concern. Thus, seismic research and monitoring capability remains important, but a new emphasis is needed on seismic-resistant engineering activities.

Given the threat to life and property involving more than 10 percent of the nation's population and the opportunities for Kazakhstani specialists to be important participants in worldwide efforts to reduce damage from earthquakes, priority support should be given to the S&T community, which is responsible for upgrading the capabilities of the nation to reduce damages from future earthquakes.

Construction Materials

At present a large percentage of construction material is imported. One estimate is that less than one-half of needed materials are available locally. This orientation toward foreign suppliers has been particularly important in the oil and gas sectors where enormous construction works have been under way.

Often local materials are not considered to be up to international standards. Thus, many materials have been imported from China, Turkey, and Germany. Even as the government presses for import substitution, there is frequently a reluctance to rely on the quality of local products.

At the same time, there are significant stocks of raw materials available locally for manufacture of building materials. For example, concrete, high-quality cement, brick, and slate can readily be obtained from local raw materials. Many types of woods and metals are available locally. Polymer materials must still be imported, but there are opportunities for processing these materials locally in ways that meet the needs of the building industry. Thus, it is not surprising that new products are emerging, such as fiberglass insulation material, roofing and waterproofing products, energy-efficient glass, aluminum extrusion, and engineering equipment. In a sense, imports have greatly contributed to stimulation of the domestic construction industry.[26]

Upgrading of a broad range of civil engineering activities is warranted. Of particular importance are research and design programs targeted on growth areas in the construction field, such as transportation systems, development of management and contracting skills, exploration of innovative approaches to foundation engineering, and application of new techniques for mining construction. Quality is key. Scientists and engineers are essential in raising the quality of products.

AREAS THAT DESERVE MORE DETAILED ASSESSMENTS

The committee had the opportunity to visit a few energy-related research facilities and to discuss with colleagues a variety of approaches to improve the application of S&T resources in addressing important energy issues. Four S&T-related areas stood out as deserving more detailed attention. Successful applications of S&T in these areas should facilitate economic progress and improve the health and safety of the general population.

1. The engineering research community seems to have good linkages with the power generation companies, and a number of investigations at the universities and research institutes are under way to improve the *efficiency of the electrical power system*. For example, university-based chemistry studies of corrosion of boilers and development of methods to combat corrosion seem important. Also, studies of the advantages and costs of installing higher voltage electrification grids build on the extensive experience of the USSR in this area. Given the increasing demands for electricity-generating and distribution capabilities and the apparent technological stagnation in this sector during the past 15 years, the

[26]"Architecture/Construction/Engineering Services," U.S. Commercial Service, Kazakhstan, 2005, *www.butusa/kazakhstan/en/architecture.html*, accessed September 30, 2006.

payoff from expanded R&D efforts in these and other fields should be carefully considered.

2. Committee members were in Karaganda the day following a deep underground methane explosion that killed about 50 coal miners near the city. This accident was a tragic reminder of the importance of using the latest technologies to ensure the safety of miners in a country that is heavily dependent on coal to fuel its power plants. The committee is unaware of the specific technologies that are currently used in the coal mines of Kazakhstan. But given the dangers associated with coal mining and the economic importance of coal, *coal mining safety* should be carefully evaluated to determine whether sufficient priority is being given to ensuring that available technologies and well-demonstrated methods are being adequately used to reduce the likelihood of accidents. These approaches include not only technologies directly linked to the mining process (e.g., limestone dusting of walls, spraying of mine faces to reduce coal dust) but also techniques to ensure continuous and sufficient airflow, clearly marked and available exit routes, and the availability of safety equipment underground.

3. From the geographical and meteorological points of view, Kazakhstan seems to be an appropriate country to develop *wind power* in some regions. Wind power cannot compete economically with power from coal that feeds into large electrical grids, even though there would be environmental advantages. In some circumstances wind power may have economic advantages in serving small local markets. Kazakhstani specialists have proposed that former defense-oriented machine plants in the country that are no longer being used to capacity may be able to produce components of wind turbines, perhaps in cooperation with Western companies, at relatively low cost. A few Kazakhstani specialists and their international partners that are currently supported through the World Bank's Global Environmental Facility have ambitious plans to develop wind power. The costs and technical feasibility of their plans should be carefully examined. A few economic success stories could certainly increase interest in wind energy—in Kazakhstan and elsewhere.[27]

4. *Energy conservation* apparently has not been high on the government's agenda. However, as has been shown in the United States and elsewhere, easy-to-implement steps—whether required by regulation or adopted by consumers simply to save money—might have significant impacts in reducing energy usage. On the technological front, improved insulation in buildings, standards that require efficient heating and air-conditioning systems, and glass that transmits light but reduces transmission of heat are examples of energy-saving approaches that are proving effective. While the relevant financial, organizational, and social conditions are undoubtedly unique in Kazakhstan, this topic deserves greater attention by both the policy and technical communities.

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[27]Project document: *Kazakhstan Windpower Market Development Initiative*, United Nations Development Programme and Global Environmental Facility, KAZ/02, 2003-2006, obtained from the World Bank, July 2006.

3

The Human Resource Base

This chapter emphasizes the role of the higher education system and related research activities in Kazakhstan in preparing science and technology (S&T) specialists for the nation's workforce. It only briefly mentions the importance of adequate secondary school preparation, although a strong primary and secondary school system is essential for providing well-qualified applicants to higher education institutions and for promoting general scientific literacy of the general population. These important aspects were beyond the scope of the study.

The National Center for Scientific and Technical Information (NCSTI) has carried out a number of studies of the S&T human resource base of the country. About 13,200 scientists and engineers are involved in research and development (R&D) activities. Supporting personnel, including technicians, number about 5,700. In general, these studies have been quite critical of efforts during the past decade to improve higher education. One report, for example, has concluded that "the growth rate in higher education coverage will not result in rapid economic growth but will be reflected in the loss of public funds and in expectations of the youth that have not come true."[1] Still, such reports exude confidence that the problems impeding rapid progress can be overcome through better strategies, focused priorities, and more effective programs. The Ministry of Education and Science (MES) correctly believes that a talented, motivated, and well-prepared scientific workforce will be an indispensable key for national development.

[1] *Concept Note for Joint Work Program of MES and the World Bank*, provided to the committee by NCSTI, July 2006.

Turning to the international community for advice, MES called on the World Bank and the Organisation for Economic Co-operation and Development (OECD) in early 2006 for assistance in reviewing the S&T aspects of the higher education system. A report by World Bank, OECD, and MES specialists, working as a team, was to be completed during the fall of 2006. The review was to be carried out in accordance with a comprehensive methodology that the OECD had used in other countries. Meanwhile, the Ministry of Industry and Trade had contracted with the Science Foundation of Ireland to undertake yet another study of higher education, and this effort was under way during the fall of 2006. The study involved distributing questionnaires to dozens of higher education institutions and then carrying out analyses of the responses as background for subsequent visits to selected institutions by two experts and for preparation of their report.

The information-gathering component of the study that led to this report was completed in September 2006. Therefore, the committee did not have an opportunity to review the findings of the other international study efforts. Informal conversations with the specialists involved in these efforts indicated that there will be considerable overlap in the coverage of their reports and the coverage of this report.

The committee was able to make brief visits to only a limited number of educational institutions and to consult with but a few of the many Kazakhstani specialists with responsibilities for improving the education system. NCSTI selected most of the universities and secondary schools that were visited, and these institutions were probably among the best in the country. Consequently, the committee was not in a position to address some aspects of the education system, particularly at the regional and local levels.

At the outset, this chapter presents relevant data and general observations prepared largely by NCSTI about the education system in order to provide a context for discussions that follow in this chapter and in later chapters.[2] The on-site observations of committee members and comments to them by a number of Kazakhstani specialists were consistent with the information presented in NCSTI reports and set forth in this chapter. The chapter then raises a few issues concerning the evolution of higher education institutions, the integration of education and research, the special challenges of engineering and medical education, and the importance of international educational opportunities.

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[2]See, for example*, State Program for the Development of Education in Kazakhstan 2005-2010,* Decree of the President of Kazakhstan, October 11, 2004, No. 1459, and *Report on the National Policy in the Area of Higher Education of the Republic of Kazakhstan,* undated, provided to the committee by NCSTI in July 2006.

THE CHANGING CHARACTERISTICS OF HIGHER EDUCATION[3]

The number of government higher education institutions increased from 40 in 1992 to 72 in 1994-1995. The number decreased to 56 in 2004-2005 as the result of (1) government efforts to ensure that the quality of all institutions was satisfactory and (2) financial difficulties at some institutions. Nine universities currently have the status of national universities, and 18 serve as regional universities. Five of the higher education institutions are pedagogical institutes. In addition, there are 13 security-related higher education institutions established by the government (*negrazhdanski vuzi* in Russian) and 80 affiliates of higher education institutions in geographical areas distant from the parent organizations. Five of the affiliates are extensions of higher education institutions in Russia.

Beginning in 1997, private higher education institutions became popular. By 2005, 109 nongovernmental institutions were functioning. All private as well as public institutions have been accredited by the government as discussed below.

In 2004-2005 about 400,000 students were enrolled in government higher education institutions and 344,000 in nongovernmental institutions. About 47 percent of the students were day students. About 53 percent were correspondence students (*zaochni* in Russian), who spend most of their time off campus but take examinations at the institutions. A very small percentage were evening students. The percentage of day students was significantly higher in governmental institutions than in nongovernmental institutions. As to the language of instruction, nearly 59 percent of the courses were taught in Russian and 40 percent in Kazakh. About 5,700 students studied in English and 3,500 in Uzbek.

In 2004-2005 the teaching staffs of the institutions numbered about 42,000, including 2,700 doctors of science (a degree based largely on a compilation of important research achievements of midlevel and senior scientists) and 12,400 *kandidats* of science (a degree often equated to a Ph.D. but for which the requirements vary depending on the granting institution). The ratio of students to professors and lecturers is somewhat higher in the nongovernmental institutions.

As to students studying for advanced degrees during this period, 48 governmental higher education institutions, five nongovernmental institutions, and 66 scientific research institutions, not affiliated with higher education institutions, accepted graduate students who were working toward the *kandidat* degree. For the doctor of science degree, 15 government universities and 23 scientific research organizations accepted scientists who were seeking to expand their education credentials. But as of 2004-2005, only 18 percent of graduate students ever succeeded in obtaining their *kandidat* degrees, reflecting at least in part

[3]This section is based on information provided by NCSTI on September 20, 2006, as well as on observations of a number of facilities in Kazakhstan.

shortcomings in undergraduate preparation together with lack of motivation by the students.

The distribution of students among the eight disciplines used by the government for statistical purposes was roughly even following an upsurge in enrollment in humanitarian, economic, and juridical studies and a decline in enrollment in agricultural and technical studies in recent years. The disciplines are as follows: humanitarian, economic, juridical, agricultural, technical, medical, pedagogical, and scientific.

The criteria used by MES in accrediting higher education institutions and the weight given to each criterion are as follows:

- General aspects of the educational program: 11
- Technical and sociocultural base for pedagogy: 11
- Preparation and qualifications of the faculty: 9
- Level of knowledge of the students during the educational process: 13
- Scientific capabilities of the institution: 25
- Financial condition of the institution: 10.5
- Reputation of the institution: 14.5
- Student success in national and international competitions: 6

MES officials are concerned about weaknesses in the accreditation process and are attempting to improve both the criteria and the procedures.

Among the weaknesses in the education system that MES has singled out are the following:

- Absence of a system for evaluation of higher education activities and lack of qualitative information.
- Large exodus of young instructors into the business community.
- Aging of professors and senior researchers at higher education institutions.
- Poor preparation of teachers for secondary schools.
- Lack of responsiveness of education to the needs of the country.
- Poor utilization of information technology.
- No material means for stimulating quality of institutions or quality of individual faculty members.
- Poor quality of advanced technical education.
- Too great a dependence on correspondence students.

Many recommendations have been set forth by national and international experts for raising higher education to an international level and for integrating the system with international approaches. Among the most significant recommendations that are being implemented are the following:

- Transition from the past system of granting a diploma after about five years of successful higher education and then a *kandidat* degree after three or more years to a system of bachelor's-master's-Ph.D. degrees with times for attaining each degree comparable to times in the United States and Europe, in keeping with the Bologna process of educational harmonization.
- Transition from the past system of MES awarding all degrees to a system whereby approved higher education institutions award degrees. In addition, several administrative centers that oversee the independent research institutes are scheduled to have authority to grant the master's and Ph.D. degrees for work carried out at these institutes.
- Transition from financing higher education based solely on funding provided from either the state's appropriated budget for education or by the students themselves to increased reliance on research-education grants (particularly at the master's and Ph.D. levels).
- Support of a core of strong universities, as reflected in the relatively high level of resources provided to the nine national universities and also in the initiative for an advanced-technology university in Astana (discussed below).
- Providing a clear and strengthened vocational track for students who complete 10 years of schooling and who desire to acquire skills that will lead to employment within two to four years.

Finally, with regard to financial support for universities, MES encourages higher education institutions to find innovative ways to increase their incomes. Though funding from the state budget is the primary source of support for state institutions, these as well as the private universities increasingly rely on fees from students who are required to pay their own way, including fees for enrollment in continuing education programs. Also of importance are the renting and leasing of property and equipment belonging to the institutions. In addition, investments by the institutions in stocks and venture funds are identified as a new and important possibility. While the policy of encouraging self-financing holds promise, adequate attention should be given by the government to the implementation of such a policy to help ensure that legitimate financing schemes are developed and carried out while government financing continues to provide for core requirements. Finally, as noted in Chapter 1, government-industry matching grants, perhaps encouraged by tax incentives, also should be considered in strengthening university research capabilities.

Clearly, the foregoing discussion does not touch on several aspects of higher education that will probably be addressed by other international teams. For example, financial aspects of higher education, such as the overhead associated with grant funds, are particularly complicated and controversial. Also, many facilities are in poor condition, and salary levels are generally low. Highlighting the challenge of upgrading education is one report by MES that a large percentage of students in the higher education system admit to giving bribes in exchange for favorable grades.

RESEARCH-EDUCATION LINKAGES

During Soviet times, most of the fundamental research throughout the USSR, including research in the former Soviet republic of Kazakhstan, was concentrated in the research institutes of the academies of sciences, medical sciences, and agricultural sciences. Applied R&D was carried out in large measure in applied research institutes (previously referred to as industrial branch institutes) and in design bureaus that were subordinate to various ministries and enterprises.

Now the academy structures have been changed in Kazakhstan, and the academies that are currently in place do not manage research institutes. Most of the applied research institutes and design bureaus have been closed. However, there remains a legacy of separation of the universities from many important research activities supported by the government.

Based on the observations of committee members, the research programs at the universities are not as strong as some research programs in the same fields at the independent institutes that formerly were components of the Academy of Sciences. At the same time, the government devotes 20 percent of its R&D budget to higher education institutions. These funds support a large number of research institutes and laboratories embedded in the major universities. Even though these institutes and laboratories are components of the universities, the coupling of their research and education activities does not always seem to be strong. In this regard the universities seldom use their core funding to support research. Since funding is in short supply, the university-based research institutes must respond to government tenders with fundable proposals that may or may not be related to the curricula of the universities.

Sixty percent of the government's total R&D budget is provided to independent scientific research institutions, including the institutes that had been affiliated with the Academy of Sciences. While many scientists from these institutes give lectures at the universities, these scientists are at times motivated simply by opportunities to supplement their incomes and not by commitments to link education and research. A limited number of graduate students conduct research in these independent institutes, but overall the gap between the universities and the independent institutes is significant.

Committee members visited several research centers of Al Faraby Kazakh National University and K.I. Satpaev Kazakh National Technical University that are reportedly among the most extensive research facilities in the country's higher education community. Altogether these centers employ hundreds of researchers and cover many disciplines. In these settings, graduate students often play a prominent role as participants in research activities. For these students the integration of research and education seems good, but they appear to be the exceptions.

While most of the research facilities at public-sector universities that were visited are in poor condition and the equipment is old, the senior researchers whom committee members met nevertheless seemed to be carrying out important research of international interest. Within the institutes of Kazakh National University, publication of research findings is a top priority. At Kazakh National Technical University, applied efforts to improve the performance of engineering and other industrial systems are prominently on display. At both universities the researchers reported considerable success in obtaining research grants from MES and other ministries, although the size of the grants that were reported was small—usually on the order of tens of thousands of dollars with little funding provided for new research equipment.[4]

At these and other universities, great respect is shown for past recipients of the doctor of science degree; they usually lead both academic and research programs. While the universities are making the transition to the bachelor's-master's-Ph.D. model (as noted above), which could eliminate the doctor of science degree, the committee believes that continuing to award this degree is important, even though it is not commonly awarded in the United States or other industrialized countries. The respect for this degree, which had great prestige in the Soviet education system, is understandable and probably well justified. If the degree provides an incentive for senior scientists to document and analyze their accomplishments in their fields of specialization, there is strong justification for the government to continue to recognize it as an important achievement.

Committee members visited the Kazakh-British University, which has impressive research capabilities that have been equipped by a number of private companies. Also, two Kazakhstani companies have their research laboratories on the premises of the university. The Industrial University and the adjacent Metallurgical Institute near Karaganda have an obsolete experimental machinery facility, but there is a newly equipped metallurgy laboratory. The university is strongly oriented toward support of Kazakhstani metal processing enterprises, providing technical support to the plants without charge. The Eurasia University in Astana has an impressive new nuclear accelerator for investigating heavy ions; it should attract the interest of both faculty and students. Each of these examples reflects the importance of modern laboratory facilities as a bridge between education and research, with opportunities to connect with enterprises as well.

Clearly, strengthening the research capabilities of universities throughout Kazakhstan is an essential component of improving higher education in science,

[4] *Kazakh National Technical University named after K.I. Satpaev,* TOO Yevero, Almaty, obtained July 2006; *Biology Faculty*, Kazakh National University named after Al Farabi, Almaty, 2004.

engineering, and medicine. Faculty research activities enrich the environment for the training of students and provide opportunities for hands-on participation by students in research work. Up-to-date equipment and modern research facilities are important, but they are not the only requirements for meaningful research programs. Expanded staffs to handle both pedagogical and research responsibilities are needed. Financial incentives—salary increases, opportunities to travel to international meetings, and in some cases access to housing—are important to attract researchers who can design and lead competitive programs. Also, provision of sufficient copies of basic and advanced textbooks for use by both faculty and students is essential. Easy access to research papers that are published in international journals, facilitated by continuous access to broadband Internet connections, is also a clear requirement for both education and research.

A major challenge facing Kazakhstan is how best to upgrade the research capabilities of its university system given (1) the limitations on qualified faculty members who are currently available and those who may be in the pipeline and (2) financial constraints. As discussed below, the government plans to follow several directions to deploy scientific talent and financial resources that can build on the current array of university research capabilities while also establishing new facilities that attract highly talented Kazakhstani scientists, engineers, and medical professionals. The dual effort of modernizing existing universities and establishing new education-research complexes will be expensive and will take many years to accomplish in a manner that significantly strengthens the nation's international competitiveness.

At the same time, the deadline set by Kazakhstan's leadership for the country to enter the ranks of the world's top 50 most competitive countries is less than 10 years away. The young scientists who will receive their Ph.D. degrees in 2015 are already in secondary school. This short timeline will require quick and decisive changes to upgrade the training of young scientists by preserving and enhancing the country's research activities.

The government will be confronted with many choices as to education priorities. Clearly, high priority must be given to scientifically sound approaches that are appealing to talented Kazakhstani specialists and to students. Yet balancing the interests of the different generations of specialists will not be easy. Many well-known and highly respected scientists have spent their entire careers developing the older institutions of the country, and their priorities may well be to expand the activities they are currently pursuing. The new generation has far fewer institutional or personal allegiances to past approaches, and new efforts with greater opportunities for professional advancement in the near term may be the enticement that outweighs opportunities to work abroad. All the while, it will be necessary to address the lack of affordable housing near new workplaces, particularly in Almaty and Astana.

Turning to an immediate and highly relevant issue, a proposal heard by the committee several times in Kazakhstan is to bring together the former research institutes of the Kazakhstan National Academy of Sciences and the universities. These institutes obtained independent status just a few years ago. MES is still trying to find an appropriate administrative structure to manage the affairs and provide for the budgets of the institutes.

The proposal for a merger suggests to many scientists that each institute would become subordinate to a selected university. Few, if any, scientists in these institutes think this is a good idea. Each institute that committee members visited has an impressive history. The scientists at the institutes believe that the capabilities developed during these histories would be degraded if the institutes were combined with universities where the research capabilities are, in their view, often of a lower quality and stature. Of course, they are concerned about degradations in their professional status as well if their institutes are subsumed by the universities.

Most scientists, within and outside the universities, seem to favor close cooperation between the independent research institutes and the universities. Many recognize that an undervalued asset is continued exposure to research in fields that are tangential to but important for their own projects, an opportunity that often characterizes university environments. However, there is now head-to-head competition for research grants. This competition at times discourages transparency in research programs since such transparency might reveal likely themes of future competitive proposals. Indeed, a frequent complaint of researchers who had worked within the Academy of Sciences structure is that now they must share with university researchers government funds that in the past had been earmarked exclusively for the Academy.

The committee recommends that during the next several years the institutes gradually become affiliated with the universities in a way that avoids further disruption of important research activities. The form that this affiliation takes should be worked out by MES in consultation with both the universities and the institutes. But there clearly is a need to bring the research capabilities closer together and to link research more closely with educational programs. As part of the transition, degree-granting authority should become the exclusive purview of universities even when the research leading to a degree is carried out in independent research institutes. However, standards for the degrees should be carefully developed, taking into account that the independent research institutes often impose higher demands than many universities.

At the same time, the government should continue its efforts to encourage through financial incentives the establishment of joint teams involving scientists from the universities and the independent scientific institutes to undertake important research problems, as has already become a tradition for a number of groups. Also, additional teaching opportunities with appropriate financial rewards should be afforded to specialists from the independent institutes. Financial incentives are a strong motivator in this regard. As groups from the two communities become more accustomed to close cooperation in both education and research endeavors, an organizational affiliation might become more desirable and less disruptive in the future.

In summary, the research-education link is crucial if strong S&T capabilities are to be developed. The absence of positive research experience for students undoubtedly contributes to a lack of enthusiasm for S&T careers. While foreign experts can provide advice on how to improve the integration of research and education, visits by Kazakhstani university administrators to Western universities that have successfully addressed this issue would be helpful in promoting changes to the science culture.

Applied Sciences at the Universities

Three initiatives are addressed in this section: (1) the Kazakhstani government's initiative to establish a new "world-class" technology-oriented university in Astana, (2) the government's plan to establish 15 technology-specific applied research centers at 15 universities throughout the country, and (3) a committee recommendation to establish a university hospital adjacent to one of the medical universities that will help demonstrate the importance of integrated and improved education, research, and clinical services. A number of other applied science initiatives also are under way at a variety of universities (e.g., establishment of incubators and techno-parks; see Chapter 4), but in considering educational opportunities the committee concentrated on the foregoing three initiatives.

A World-Class University in Astana

The proposed university in Astana is to be constructed during the next several years with instruction beginning by 2010. The university is to offer both undergraduate and graduate programs. The emphasis is to be on education in four high-technology fields, with extensive research facilities embedded in the university to support activities in each field. Two fields being considered are biotechnology and nanotechnology; there apparently is still some uncertainty as to the other fields. Research priorities that may be relevant to the orientation of the university are discussed in Chapter 2.

Recognizing the importance of attracting experienced faculty and staff to lead the administration of the university, to establish high-quality academic programs, and to design cutting-edge research programs, the government plans to select one-half of the professors from the faculties of foreign universities. They will move to Astana for periods of two to three years, or longer. Short-term visiting faculty will also be invited to Astana. For each of the four fields, one or more international partner universities will help guide the design and implementation of both the educational curriculum and the research program.

This initiative of the president of Kazakhstan is an innovative way to provide an important focal point for rapidly developing advanced technological capabilities. There are many advantages of a new start that is strongly supported by the political leadership of the country. They include (1) the ability to attract faculty members to Astana, including Kazakhstani citizens living abroad, by offering them appropriate salaries and scientific leadership positions; (2) the opportunity for faculty members to design new programs that reflect modern approaches to education and research; and (3) the excitement of students who are participants in frontier research involving respected scientists from abroad working in modern facilities. Taiwan, Japan, and Singapore, for example, have successfully used the prestige of international scientists to inspire local students to become engaged in cutting-edge research.

Of course, there are pitfalls as well. Myriad administrative, pedagogical, and research challenges are entwined within the concept of the new university. The key to success will be the quality and integrity of the faculty and students who are attracted to Astana. The government should maintain very high academic standards for all appointments, beginning with the president of the university, and should not lower these standards in a rush to launch the institution. The government should be patient in arranging for appropriate collaborating international institutions. It should also ensure that the university's leaders are selected on the basis of educational and research credentials and that students demonstrate outstanding capabilities during acceptance procedures and throughout the educational process. It should insist that both faculty and students abide by an internationally acceptable code of ethical conduct. In short, the university should be corruption-free—academically, administratively, and financially.

The return on this investment will come many years in the future. At least a billion dollars, probably much more, will be needed to build, equip, maintain, and operate the university during the first decade if it is to acquire international recognition as a promising young university. Detailed cost estimates are presumably being carried out by the government, based on both the estimated size and composition of the student body and the research capabilities that are needed to prepare students for appropriate positions in society during the next several decades. It seems clear that extensive computational facilities and large stocks of both large and small research equipment and instrumentation will be essential, and they will constitute a substantial portion of the total cost of establishing and operating the university. These investments will need to be supplemented every few years.

Of course, it is difficult to estimate the actual initial investment costs in research facilities until the leaders of the various laboratories have been selected. These leaders undoubtedly will have their own ideas of how best to equip the laboratories for which they are responsible. After their requirements are accommodated, the final cost estimates for research facilities may significantly exceed the estimates of planners who will not have responsibility for operating the laboratories.

Fifteen Technology Research Centers

The Kazakhstani government plans to establish applied research centers in yet-to-be-selected priority fields at 15 yet-to-be-selected universities. The government describes these centers as "engineering" centers, to be geographically distributed throughout the country. Preliminary selections of the universities and fields of concentration have apparently been carried out by the government, but the committee is unaware of firm commitments to any universities in this regard. Locating the centers in different regions (oblasts) will have considerable political appeal among the leaders of the chosen regions. However, the likely impact on the economy of dividing such a major investment among 15 recipients with untested technological capabilities may not be as great as other approaches.

This concept is part of the proposed reform of the nation's research system that is intended to focus innovative efforts on specific technologies. These centers are to upgrade the workforce through graduate-level studies and research while also providing strong technology transfer capabilities in fields with significant economic potential. However, upgrading technical education at the graduate level and developing an associated research base with strong linkages to the private sector will be a complicated, expensive, and time-consuming process. Building an effective research base at a large number of universities of uneven quality will simply not be possible in the near term. There are too many administrative, financial, personnel, and technical issues that must be addressed—all subject to questioning by the universities that were not selected.

Illustrating the problem of selecting an appropriate university, Kazakhstan National Technical University was part of the Soviet system of polytechnical universities that were important in developing the technological strength of the USSR. The university continues to attract and graduate well-qualified students who find significant positions in many sectors of the economy. But its staff is aging, its facilities are in poor condition, and its research achievements command less and less attention from the industrial sector. Still, this is probably the best engineering university in the country.

At the same time, the importance of stronger technical capabilities within the university and research systems cannot be underestimated. Committee members heard from many sources about the need for more and better-trained engineers and the opportunities for saving energy, improving food production, developing water resources, and reducing construction costs through better engineering practices. Pricing of major construction works, ensuring the quality of engineering projects, and reducing contamination from industrial processes were among the common comments the committee members encountered. All of these observations point to a need for better technical capabilities.

The government apparently is determined to move forward with the establishment of the new centers. However, there is a need for stronger education and applied research capabilities in a variety of science-based areas, such as the biomedical, agricultural, and geological sciences as well as in engineering fields. The term "engineering" center seems too restrictive in developing the concept and might be replaced with the term "technology" center.

Even assuming that the concept of engineering centers is broadened to technology centers, the committee is not able to endorse the concept of establishing in the near term 15 new centers at 15 universities to develop advanced technologies. Alternatively, it recommends that the Kazakhstani government focus its major resources on establishing or strengthening three or four centers at particularly strong universities. This initiative would overlap but not duplicate the university initiative in Astana discussed above where the emphasis is to be almost entirely on "breakthrough" technologies. The selected universities would stress the importance of modernizing current approaches to traditional S&T subjects, particularly the systematic use of computational sciences in addressing engineering and other technical challenges. Electrical, mechanical, chemical, and civil engineering would be among the disciplines at the forefront of concerns. Strong involvement by the international community in upgrading both educational and research activities would be very important. Also, the centers should not necessarily be single technology-oriented facilities but in some cases should be able to select several important technologies as focal points for their activities.

Second, the centers should be selected on the basis of a competition open to research institutes as well as universities. In some areas, such as nuclear technology, it is difficult to identify universities which could supply technologies for applications that would be of interest to the leaders in the field. The competition should clarify the extent to which the centers are expected to enhance the international competitiveness of Kazakhstan's S&T, and criteria should be developed for judging the responsiveness of the applications to this requirement. If there is a compelling need for geographic distribution, the competition could limit the number of centers to be located in any one city.

The foregoing recommendation raises doubts about the overall plan for the five national laboratories that are to be based on the five areas of priority interest that will be determined by the government, with the laboratories providing the umbrellas for the 15 technology centers. This plan should be reconsidered. The national laboratories can still have strong outreach programs to universities throughout the country. But the likelihood seems low of a significant number of regional universities being able to develop strong applied technology programs that would provide new processes or products for businesses in Kazakhstan and internationally in the near future. It is essential to begin on a small scale, striving for excellence; if the initial centers are successful, the plan for 15 centers might be fully implemented over the next decade.

Finally, as suggested above, economics training for engineers and other technical personnel, together with management training that links economics and engineering considerations, is important and should be a key component of the proposed centers. The country will continue to make large investments in engineering systems in the years ahead. Capabilities to help ensure the selection of the most cost-effective technical choices by both the government and the private sector can have significant economic impacts.

A Model Medical Education Complex

The future role of the medical universities is of particular interest in addressing the integration of education, research, and clinical services. The Ministry of Health (MOH) is responsible for medical education, medical research, and health care services.[5]

Six medical universities and 20 medical scientific centers are key components of the infrastructure of the public health sector. In the aggregate these institutions cover almost all medical and public health disciplines. In addition, several medical colleges prepare a range of professional and technical specialists, including nurses, dental assistants, laboratory diagnosticians, and optometrists.

The near-term educational goals of MOH include the following:

- Creation of an education system that provides clear career paths for entry into medical universities after 12 years of schooling and entry into technical training after 10 or 12 years as appropriate.
- Improvement of procedures and requirements for admission of students into higher education with better linkages between admission and (1) education policies and (2) the health needs of the nation.
- Restoration of the practical and technical bases of medical higher education institutions, with an emphasis on providing opportunities for training of students in clinical settings through establishment of clinical teaching centers.
- Introducing a system for managing the quality of education, including accreditation of medical education organizations in accordance with international standards and with the assistance of international experts.
- Introducing a system of independent control of the quality of medical activities, including licensing of all specialists and their recertification every five years.
- Strengthening the capabilities to use information technologies and expanding education in foreign languages to better integrate the health care system with international networks.[6]

Based on committee visits to two medical universities, observations at several clinics, and consultations with MOH officials, achievement of these goals

[5]For an overview of medical education, see *Conception of Reform of Medical and Pharmacy Education,* Ministry of Health, Astana, November 2005, provided to the committee by MOH in September 2006.

[6]Ibid.

seems very important but at the same time very challenging. The universities that were visited in Almaty and Astana have good staffs, but they do not have the basic research strengths that are commonplace in well-developed medical schools in many countries. Further, they suffer from a lack of access to English-language journals, and the researchers have little tradition of publishing in English-language journals. Thus, they have difficulty staying abreast of developments in the rapidly moving international mainstream of medical science.

The universities have expressed strong interest in having their own hospitals rather than relying on clinics distant from the educational campuses as locations for student experiences and faculty medical services. It is becoming increasingly difficult for both doctors and students to travel through traffic jams to take advantage of health care facilities distant from the campuses. Consideration should be given to building a new modern hospital adjacent to the campus of one of the strong universities. Such a hospital would not only help improve the current unsatisfactory situation of providing care for the population but would also significantly increase the opportunities for training experiences for students, interns, and residents. And it would generally improve the integration of education, research, and clinical practice. If this kind of teaching hospital were to be as successful as anticipated, a model could be developed from it to eventually be expanded to other universities as well. In time the science-oriented nonmedical universities should also become important components of medical complexes. An important model for such a complex is the recently established King Abdullah University Hospital in Irbid, Jordan, which is on the same campus as a medical school and other departments of the Jordan University of Technology and Science. This approach brings technology to medicine and medicine to technology.

Higher Education Abroad for Kazakhstani Students

According to NCSTI, in early 2006, 21,000 students from Kazakhstan were studying abroad. About 16,000 were enrolled in Russian institutions. These international students were studying many subjects, with business and economics among the most popular. Also, many students apparently were enrolled in science-oriented programs, but detailed statistics were not available to the committee.

The most highly publicized Kazakhstani program for supporting such international studies is the Bolashak (meaning *future* in Kazakh) program, which began about five years ago. Under this "Presidential" program, the government covers all expenses associated with the higher education of 3,000 students who are abroad at any one time. Thus, as students complete their international studies, perhaps 1,000 per year, they are replaced by new selectees. The participants are enrolled in programs at all levels (bachelor's, master's, Ph.D.) at leading universities in many countries. They are selected on a competitive basis, and the universities of choice must be judged by the government to be leading universities.

Following completion of their studies, participants are required to return to Kazakhstan to work for five years. They are not required to work in their fields of study, and indeed many of the science-oriented students apparently find more attractive positions in business upon return home. For some of these positions, S&T training is undoubtedly useful, but others may have little relevance to S&T backgrounds. To reduce the likelihood of an international brain drain, each student's family must provide the government with collateral, such as a lien on property, to ensure that the five-year commitment is fulfilled.

Recently, the government decided to give more emphasis to science-related studies in the Bolashak program, and the number of participants in such studies is on the rise. But it is too early to ascertain whether the program will have a significant effect on upgrading the nation's S&T infrastructure. In principle, it certainly should. However, the reentry conditions must be conducive to encouraging participants to work in S&T fields upon their return to the country.

A less publicized program supports research assignments abroad for about 250 of the most talented young university instructors each year. They too have the freedom of choosing their foreign destinations for postdoctoral studies. Of course, they are expected to return to their university positions in Kazakhstan. The only criticism of this program that committee members heard was the observation that researchers outside the university system could not participate. But a program targeted at university development seems appropriate.

The issue of appropriate employment of students upon their return from studies abroad is a challenge that needs serious attention. Salaries, research facilities where they can use their training, and housing are among the key determinants of whether talented young scientists will remain in science in Kazakhstan wherever they have been trained. One of the major attractions of the advanced technology university to be established in Astana is the opportunity for rapid professional advancement, and government authorities are considering whether housing incentives can be offered. While success of this university is important, the problem of placement of talented young scientists extends across the country.

The committee supports the establishment of postdoctoral grant programs. Grants should be sufficiently generous for students trained abroad to have adequate salaries and appropriate laboratory equipment. Initially, the programs might concentrate resources on returnees from the Bolashak program who have completed their Ph.D. degrees. Then as more government resources become available, the program might be opened to other recent recipients of Ph.D. degrees in Kazakhstan and abroad while creating new junior faculty positions that will help establish viable career paths.

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The effectiveness of the Kazakhstani higher education system will continue to be a critical determinant of the country's future. Kazakhstan is fortunate to have a highly literate population that appreciates the value of education and is proud of the country's high-technology achievements in the nuclear and space fields. The prospect of benefiting from the increased resources available to the government has been a strong incentive for many Kazakhstani specialists to search for their niches in private business with or without the benefits of higher education. As the economy continues to improve, new professional opportunities for the nation's children are important motivators for many families, and public support for education at all levels is therefore widespread. According to colleagues in Kazakhstan, interest in S&T education is on the rise.

The government has been establishing a variety of mechanisms to improve the integration of education and research (e.g., upgrading student laboratories, creating programs for students to spend more time in research settings) and to transfer technologies from universities to commercial enterprises (e.g., student internships in companies, university technology transfer offices, incubators). But these mechanisms, however well designed, will be useful only if significant research activities are integrated into the education system and if competitive technologies are developed that are of interest to the commercial sector. Only the human resources that are available in Kazakhstan can ensure that R&D activities are meaningful and that competitive S&T products flow through the system.

4

Technology Transfer

This chapter addresses the efforts of Kazakhstani science and technology (S&T) specialists to develop new and improved goods and services that are of interest to private businesses, government enterprises and service organizations, and consumers, primarily in Kazakhstan but increasingly in other countries as well. The emphasis in this discussion is on the process of transferring technologies from the research and development (R&D) stage to their successful introduction into practice. Chapter 2 identified a number of research areas that offer particular promise for providing R&D results that should be of interest to organizations that can effectively take the results to the public- or private-sector marketplaces.

Transforming the results of R&D into practice is, of course, only one route for enhancing the technological capabilities of Kazakhstan-based organizations. In the near term the importing of foreign technologies and the modernization of technologies that are already in place in the country will undoubtedly be the dominant mechanisms in upgrading the nation's capabilities. But commercialization and public-sector utilization of R&D results are gradually increasing their importance as routes to improving economic and social conditions.

While improving technological capabilities is a significant aspect of enhancing the economic competitiveness of Kazakhstan, other factors are also important. In particular, improved productivity using both old and new technologies is a key dimension. Also, sound marketing strategies are critical determinants of whether Kazakhstani products will penetrate global markets and command a greater share of local markets.

INNOVATION IN KAZAKHSTAN

Innovation encompasses R&D, but it is a broader concept, as discussed later in this chapter. In industrialized countries most technological innovations take place in the companies that produce goods and provide services. In continuing efforts to improve the competitiveness of their products, innovative companies usually make many small changes in their manufacturing processes and products, with the introduction of entirely new processes and products an infrequent occurrence. Similarly, the contributions of researchers and research laboratories to technological advancement also usually lead to modest improvements of products and services, although on occasion major R&D breakthroughs result in new processes and products.

In Kazakhstan, innovative companies are few in number. In other settings in the country, particularly in local research laboratories external to the companies, most successful innovation efforts will probably be modest in scope. Technological breakthroughs will be rare in Kazakhstan as in most countries.

A large portion of the R&D specialists in Kazakhstan carry out their activities at education and research organizations. A limited number work in the R&D or production departments of a few medium and large companies. Still others are entrepreneurs who have set up their own businesses to develop and market their ideas to other businesses, to government organizations, or directly to individual consumers. Many of these Kazakhstani specialists are competing against or cooperating with international providers of goods and services that are also seeking a share of the Kazakhstani and global markets for their technologies.

The process of technology transfer in Kazakhstan is often described as a linear process involving the following steps: basic research, applied technology, design and development, and production. During Soviet times, different organizations were responsible for different steps. Resources to carry out each step were usually provided, and the customers for the results of each stage were well known. Seldom was there serious competition among different entities as the evolving technology was passed from organization to organization.

Many Kazakhstani officials and specialists are now well aware that new approaches are needed to bring products to market from their origins in research laboratories or elsewhere. However, there is still a tendency to think of the process in terms of a linear model. Frequently, not enough attention is given to the essential personal interactions and to the related feedback among the participants involved in the entire chain of events if a new or improved process or product is to become a commercial success. In short, the Soviet government's "requirement" that participants work together throughout the process has disappeared. Now, success depends on collaborative efforts that rest largely on personal confidence and trust among participants to overcome organizational barriers as well as technical problems.

INCREASING THE DEMAND FOR PRODUCTS OF R&D

Transfer of technology is successful only if there is demand by specific paying customers for the technological innovation available. Demand may be for a new, better, safer, or cheaper process or product. Demand may exist before research or adaptation begins. Demand may evolve in parallel with R&D activity, or demand may emerge after a product is available for viewing, testing, or sale.

Some Kazakhstani researchers contend that a latent demand for their products is reflected in global trends that indicate clear needs for their products. They believe that if their products have performance or cost attributes that are superior to the products of competitors, there will automatically be a global market. Therefore, they seek financial support from government or private-sector investors for their R&D efforts even though they have no indication of interest in their ideas by specific customers who would purchase their products. Clearly, an important aspect of marketing research is analysis of trends in the likely markets for products. But without linking research to the interests of specific customers, the likelihood of successful commercialization is not high.

The government of Kazakhstan gives high priority to stimulating greater demand for innovative technologies by companies in Kazakhstan. Presumably, this increased demand is to be reflected in company investments in specific R&D activities at the beginning of, or at least early in, the R&D process. As previously mentioned, the government has set a goal of private-sector financing of 50 percent of the nation's R&D budget by 2012, in comparison with 7 percent in 2005. A related goal calls for the private sector's share of the R&D budget to increase eventually to 67 percent.

This "market pull" approach contrasts with the "technology push" approach that is currently emphasized by most R&D organizations in Kazakhstan. Committee members observed numerous examples of technologies that have been developed by inventors which are sitting on shelves. Their achievements are awaiting paying clients to become interested in them; according to the inventors that the committee members met, this has seldom happened. Nevertheless, both "technology push" that engages potential customers as the R&D effort moves forward and "market pull" are important approaches in Kazakhstan. In both cases, customer involvement early in the R&D cycle is critical.

As to public-sector markets for the products of R&D, various ministries are, of course, interested in high-quality and low-cost goods and services based on R&D efforts at home or abroad. Such goods and services can respond to public needs in many areas. Examples of areas include (1) upgrading governmental health care services, (2) assessing and cleaning up environmental problems, and (3) improving national communication systems.

The recent record of the S&T community in meeting the needs of public-sector markets in Kazakhstan with local goods and services, in competition with imported products, appears inconsistent despite the legacy of successful Soviet efforts to use local scientific achievements to support government activities. Public-sector procurement officials usually prefer to use well-proven international products rather than rely on lesser-known local products when advanced technologies are involved. As one official stated, his ministry does not want Kazakhstan to become a testing ground for untested technologies.

Thus, the role of foreign firms in transferring technology to Kazakhstan currently dominates efforts to acquire advanced technologies. Also, foreign assistance donors and other international partners usually rely on foreign rather than local expertise in designing projects that involve S&T. This use of foreign experts may introduce a bias toward selection of imported technologies in carrying out cooperative programs.

To interest potential customers in the products of local R&D efforts, the quality of the R&D must be perceived to be high, particularly in comparison with foreign competitors. Chapters 2 and 3 of this report discuss steps to improve the quality of R&D efforts that are to be wellsprings of technologies to be transferred.

Against this background, the government of Kazakhstan has developed a variety of new mechanisms to increase demand for R&D products that will lead to goods and services that can be commercialized. The commercialization "agents" include (1) Kazakhstani companies, (2) international companies that compensate Kazakhstani researchers for acquisition of their know-how, and (3) individual Kazakhstani entrepreneurs who market their own products either within the country or abroad. The funding mechanisms designed to support these efforts include the following:

- Kazakhstan Development Bank, which provides loans with payback periods of up to 30 years.
- Fund for support of small and medium enterprises, which provides grants to nurture promising technologies.
- Investment fund, which mobilizes venture funds both in Kazakhstan and abroad for promising approaches.
- Innovation fund, which supports entrepreneurs with particularly interesting ideas.

Also, as discussed below, the government is promoting incubators, technoparks in tax-free zones, technology transfer offices, government/industry matching grants for researchers, engineering centers, training programs concerning protection of intellectual property rights, and other approaches. But technological commercialization is a complicated process, particularly in a country with little history of market economics as the framework for commercial activity. According to Kazakhstani officials, the success of technological commercialization of new products has yet to be demonstrated on a significant scale in the country.

SEARCHING FOR MARKETS

Nevertheless, many Kazakhstani officials have a vision of a vibrant international market for high-technology products developed in the research laboratories of the country. However, only one to two international patents per 15,000 Kazakhstani scientists are filed annually. In the near term the domestic market will probably offer more realistic business opportunities for Kazakhstani organizations. When it comes to marketing S&T-intensive products internationally, Kazakhstani businesses that develop markets for their S&T-intensive products at home should be in a stronger position than those businesses operating internationally that do not have steady revenues from domestic sales.

Markets in Russia, China, and other Central Asian countries will probably be more promising in the near term than markets in more distant lands. Kazakhstan is well known and respected in the region for its nuclear and space achievements. Kazakhstani companies enjoy close geographic proximity to these countries, and there are many educational and professional ties to possible customers. For some Kazakhstani companies, the Central Asian markets may provide a stepping stone to clients in Europe, Asia, and the western hemisphere.

Some Kazakhstani businesses recognize the advantages of joining with foreign companies that have strong technical capabilities and well-developed international connections. At the same time, organizations from abroad may hesitate to invest in technology-intensive activities in Kazakhstan that are dependent on the use of local expertise and local connections. Some international companies may enter into contracts with Kazakhstani organizations in order to obtain components or technical services that support the operations of the international companies in the country or abroad, while satisfying local officials that they are doing their best to increase local content in their activities. The growing presence of oil companies offers significant potential in this area. In any event, Kazakhstani companies should stay abreast of the interests of foreign companies that have access to large S&T resources since these companies may become competitors or partners.

BARRIERS TO TECHNOLOGY TRANSFER

In 2004, at the request of the Ministry of Industry and Trade, the University of Texas at Austin carried out an assessment of the commercial potential of 35 technologies that had been developed by researchers in Kazakhstan. (Given the proprietary nature of these technologies, they are not itemized herein.) These technologies presumably reflect some of the country's most promising research results. The findings of the assessment were mixed. A few of the technologies seemed worth pursuing, and efforts are under way to identify companies that would be interested in embracing the technologies in their manufacturing activities. But still ahead are the financial, organizational, production, and other realities of bringing technologies to market.

Why have these and many other technologies been sitting on the shelf, as noted above? More broadly, why has the success rate of commercialization activities in Kazakhstan been low? Kazakhstani officials told the committee that in their view there are four problems: (1) lack of technologies with market potential, (2) lack of skilled entrepreneurs, (3) lack of methodologies for moving products from the laboratory to the marketplace, and (4) disinterest in modern technologies by businesses that profit by using low-cost labor and old technologies. The usual success rate of investments in still-to-be-proven technologies in the United States and other industrialized nations is also low, perhaps for other reasons. In Kazakhstan a higher success rate would probably emerge if the list of problems set forth below and in other sections of this chapter could be effectively addressed.

- Many research institutions perceive their missions as primarily supporting academic research that leads to scientific publications. Very few give priority to attracting customers for using the results of their research.
- There is a lack of strategic planning within research institutions and university-sponsored technology centers for effective use of core competencies not only to pursue research that leads to scientific publications but also to support activities that can succeed in the local and global markets.
- Applied research activities at some research institutes are distributed across a diverse range of topics, resulting in an absence of the critical mass that is essential for achievement of technological leadership in a specific field.
- For many years government support for R&D had been tied to defense needs, with a resulting mismatch of competencies of researchers and interests of potential commercial customers when defense orders terminated. At the same time, in Western countries space- and defense-related R&D has yielded numerous commercial technologies and products that are widely used for civilian purposes.
- There is a lack of technology transfer managers with experience working in a market economy.
- It is difficult for research institutes to persuade companies to outsource work to them when the companies have more highly qualified specialists than do the institutes in view of the higher pay levels of the companies.

Returning to the theme of market pull, Kazakhstani researchers are oriented toward what they know best—research of interest to them—not toward addressing problems of interest to potential customers. It will take a major reorientation of activities and considerable time to develop many of the research competencies of interest to potential customers. At the same time, the research leadership in Kazakhstan has limited experience in marketing the products of research and seldom has a realistic strategic vision of how research efforts can respond to customer needs in a sustainable fashion.

Approaches Advocated by the Ministry of Industry and Trade

Recognizing the foregoing and other shortcomings in Kazakhstani capabilities to carry out effective technology transfer activities, the World Bank and the Ministry of Industry and Trade (MIT) have been developing the following approaches:

- Coaching entrepreneurs in how to talk to investors.
- Teaching university and scientific institute managers how to commercialize technology, protect intellectual property, negotiate joint ventures, and look for strategic partners.
- Conducting technology audits to identify technologies that have the potential for commercial success.
- Providing business and technology commercialization expertise to the entrepreneurs in the techno-parks and incubators that have been established.
- Assisting firms in developing commercialization strategies—licensing, joint ventures, and strategic partnerships, for example.
- Marketing technologies at international fairs and helping to strengthen linkages between research institutes and (1) private companies and (2) international research institutes.[1]

The committee supports these activities. However, as previously noted, considerable attention should also be given to linking researchers with potential users early in the R&D cycle. This approach should reduce the difficulty in finding markets for products that have been developed by researchers.

In addition, the National Innovation Fund of MIT plans to implement the following grant programs to address some of the problems cited above:

- A precommercialization program to determine the commercial feasibility of ideas.
- A program to support joint research by research institutions and industry with industrial partners providing in-kind contributions.
- A program to support joint research between Kazakhstani research institutions and international research centers with the centers supporting their share of the activities.

[1] *Project Information Document, Technology and Competitiveness Project,* Report #AB2105, World Bank, March 24, 2006, provided by the World Bank to the committee, July 2006.

- A program to defray the costs of patenting inventions with commercial potential in North America, Europe, and Asia.
- A program to help Kazakhstani scientists obtain on-the-job experience in converting research into new products and services by working in foreign companies' research laboratories.[2]

These approaches are all quite appropriate and should enhance the capabilities of the participants while also establishing models to be emulated by others. Again, the committee emphasizes the importance of researchers knowing the specific needs of the customer for research results—including technical specifications and cost constraints—early in the R&D cycle. Therefore, the committee suggests a program whereby researchers work closely with companies in Kazakhstan to help both the companies and the researchers understand whether and how the researchers can respond to the needs of the companies. Such an approach is under way to a limited extent in the minerals and electrical generation industries, according to scientists in Almaty.

TECHNO-PARKS, INCUBATORS, AND TECHNOLOGY TRANSFER OFFICES

The Center for Engineering and Transfer of Technology of MIT has plans to establish 12 incubators, seven regional techno-parks, and six national techno-parks in the near future. Each incubator is to be housed on the premises of a university and is to provide for up to three years a variety of consulting services to new companies with an emphasis on financial, marketing, and legal advice. Meanwhile, techno-parks will provide physical infrastructure and consulting services for companies of any age. National techno-parks are to be dedicated to specified branches of industrial development (e.g., information technology). The residents of national techno-parks will have a variety of services and economic benefits.

Committee members visited the recently opened Alatau Information Technology Park in a special economic zone near Almaty. According to the director, the park had quickly committed 80 percent of its available space to a variety of companies, including Microsoft, Hewlett Packard, Siemens, Cisco Systems, and Kazakhtelecom. The park offers manufacturing, exhibition, and residential space as well as communication and security services. The tax benefits include exemptions from corporate tax, customs duties on imports and exports, value-added tax, and land and property taxes. Also, firms with 100 percent foreign ownership are welcome, and there are no restrictions on capital investments.

While the enthusiasm and plans of the director are impressive, government officials have reportedly been disappointed that to date there have been no manufacturing activities at the site. The resident companies apparently are using the

[2] *National Innovation Fund*, brochure, 2005, Almaty.

park for warehouse storage space, thereby taking advantage of the economic incentives while contributing little to economic development of the country. Given the Kazakhstani government's disappointment, it seems likely that steps will be taken to encourage the resident companies to broaden their activities if they are to receive economic benefits. This experience underscores the importance of offering carefully designed tax incentives that result in increased R&D activity and do not simply provide opportunities for companies to reduce costs without investments in R&D.

The committee visited a second techno-park in Karaganda. This is an impressive new facility with considerable office space and office equipment. Companies are just beginning to move into the facility, and it is too early to assess the likelihood of success. The leadership of the techno-park is well versed in the problems of bringing new technologies to the market, and local support for its activities is strong.

A number of universities and research centers seem to be aware of the need to have well-trained technology transfer specialists. Yet the committee did not encounter such specialists during its visits to many universities and centers. The role of such specialists is repeatedly mentioned in government documents. The committee considers such specialists to be particularly important as the research centers and universities struggle to relate to market needs and to navigate the many legal, financial, and other issues that arise in moving technologies toward commercialization. As a starting point, brief training in technology transfer coupled with visits to technology transfer offices in Europe or the United States by aspiring Kazakhstani technology transfer officers should be easy to organize and are recommended, provided the participants in these visits have been clearly designated to assume important technology transfer positions in their home institutions. Technology transfer is a complicated process, and continuing education and experience are necessary if specialists are to be effective.

PROTECTION OF INTELLECTUAL PROPERTY RIGHTS

The government of Kazakhstan has made considerable progress in modernizing the legal basis for patents, copyrights, and trademarks. The system that is now in place seems to have satisfied the requirements for entry into the World Trade Organization. A variety of training programs are conducted on a regular basis to familiarize specialists from a variety of organizations with the procedures for protecting intellectual property. Of course, the patent system is in an early stage of development, with only a limited number of active patents; development of the system will be an important aspect of efforts to improve the technological competitiveness of the country.

Of particular interest is the recent enactment of legislation that provides a new basis for allocating property rights for products developed using funds provided by the government. This legislation has some similarities to the Bayh-Dole legislation in the United States. The rights for commercial purposes now belong to the performing organizations, which in turn compensate inventors, with the government entitled to use the rights at no cost for its own noncommercial purposes. Also, the government has "march-in" authority to revoke the ownership of a patent if the patented technology is not exploited during a five-year period.

There are still several aspects of this approach that deserve attention. They include:

- Retroactivity—ownership of technologies developed with government funding in years preceding enactment of the new legislation.
- Awareness—educational efforts to inform potential inventors and research institutions of the new legislation.
- Enforcement—ensuring the effectiveness of administrative and judicial procedures to resolve disputes over ownership in infringement cases.[3]

INNOVATING FOR PROFIT

The foregoing discussion of technology transfer mechanisms and programs reflects key elements of the innovation system that should help the private sector become a more important engine of economic growth for the country by achieving a number of key goals of the government. These interrelated goals should include (1) to increase the share of GDP (gross domestic product) attributable to industrial activities; (2) to increase the export of value-added commodities based on the nation's natural resources; (3) to maximize fulfillment of domestic market needs with items produced in Kazakhstan; (4) to increase employment opportunities; and (5) to utilize labor, materials, and capital more efficiently as the result of technological achievements.

While the government's many programs to address the challenges of innovating for profit are admirable, some approaches deserve greater attention. For example, an increasing number of small and medium-size firms should play key roles in advancing technologies. But current laws and programs do not provide incentives for innovating firms; they are treated the same as noninnovators. Also, the transfer of technology and technology-intensive components from small and medium-size firms to large enterprises warrants greater attention. Modernization of traditional industries should not be neglected in the quest for high-technology approaches. A program to support leasing of production equipment by small and medium firms in their early stages of formation should be considered. Finally, providing incentives for young scientists and engineers to become risk-taking entrepreneurs can be important.

All elements of the process of innovation should be considered, and the government has made a good start in this regard. More active engagement of the

[3]For an overview of the patent and trademark system that is evolving, see *Annual Report 2005*, National Institute for Intellectual Property, Ministry of Justice, Astana, 2006.

government in the activities of the Organisation for Economic Co-operation and Development should help key officials understand the experience of industrialized countries in this area. Various types of statistical data that are advocated by that organization can be helpful in providing overviews of progress.

For example, it is important to understand why companies become interested in innovating. Some of the traditional reasons are as follows:

- To replace products that are being phased out.
- To extend product range.
- To maintain traditional market share.
- To create new markets.
- To reduce labor costs.
- To reduce material costs.
- To reduce energy costs.
- To improve working conditions.
- To accelerate production rates.
- To improve product quality.
- To reduce environmental damage.
- To improve customer service.

The steps that companies may take to support innovation include the following:

- R&D.
- Acquisition of patent rights and licenses.
- Acquisition of nonpatent licenses.
- Industrial design.
- Trial production and testing.
- Training of personnel.
- Market research.
- Acquisition of machinery and equipment.
- Partnering to develop precompetitive technology.
- Joint ventures to acquire technological knowledge.

The response of the private sector to these and other issues should be analyzed regularly by the Kazakhstani government in its efforts to promote innovation throughout the entire industrial base of the country. The government has defined innovation as "the result of scientific and technical activity involving intellectual property whose introduction into different spheres of production and management of society improves economic effectiveness and/or has social or ecological significance."[4] Now the challenge is to maximize such results.

[4]State Support of Innovation Activities, Law #135-III ZRK, Chapter 1, March 23, 2006.

THE HUMAN DIMENSION

In summary, technology transfer takes place between two or more organizations with the common goal of developing a useful product or service that can be sold in the public or private marketplace. At the same time, however, the interactions involve individuals who may be in vastly different institutional settings, and their perspectives on the challenge of commercialization may be significantly different. Thus, it is imperative that they develop a strong relationship that enables them to focus their energies on achieving a positive outcome. Collaboration is most effective when it is carried out on a continuing basis covering a variety of products.

As noted above, the linear model that depicts the movement of an idea from basic research to a successful product or service is often used in theoretical discussions to emphasize the different steps in the process of commercializing a product or service, but the steps are not usually discrete and the overall process is not so simple. Many deviations from the model, often linked to the human dimension of innovating for profit, are characteristic of successful endeavors. Furthermore, the process of developing a product does not necessarily lead to a successful business, and the failure rate of new businesses is substantial.

There are many examples in Western countries and Japan of successful technology transfer of ideas into commercial products that began in universities and research laboratories. Kazakhstani research managers and technology transfer specialists could benefit significantly from familiarization with the histories of a variety of examples of successful technology transfer and also with the reasons that other efforts failed. Of particular interest are steps that were taken to cope with unplanned developments in the innovation cycle and measures that reduced problems when it was necessary to deviate from planned activities.

International experts could, of course, visit Kazakhstan and recount the details of a variety of efforts that illustrate many of the pitfalls and responses in the commercialization process. This type of training would be of particular value if it were a long-term process wherein the foreign experts would become very familiar with local conditions. Also of value would be visits by key Kazakhstani specialists to laboratories and technology transfer centers abroad that have particularly good track records in bringing their products to market. They should also visit organizations that have successfully assisted government agencies in incorporating new goods and services into their public-sector programs. Such visits should include time in different geographic regions since successes or failures in many cases are a result of local circumstances.

The human dimension is key. The talent needed to successfully bring about technology transfer is in short supply, particularly in Kazakhstan, which has little modern experience in this area.

5

International and Regional Activities

For decades, science and technology (S&T) specialists from Kazakhstan have participated in a wide variety of activities at institutions outside the current borders of the country. At the same time, hundreds of foreign specialists have been working for many years in the scientific and educational institutions of the country, on short- and long-term programs. As the government emphasizes recruitment of foreign professors for positions in Kazakhstan and increases support for students traveling abroad for higher education, the extent of international programs will surely expand during the next decade. This international orientation will continue to be an important aspect of Kazakhstan's progress in improving its technological competitiveness.

During the Soviet era, Kazakhstani organizations participated in activities that were usually approved in Moscow, which meant primarily activities with other states of the former USSR and to a much lesser extent with countries of eastern Europe. Many Kazakhstani specialists received their higher education degrees in Russia, and those that attended the best Russian universities are justifiably proud of the quality of their training. Hundreds of Russian specialists moved to Kazakhstan to lead development of the scientific and educational base of the republic, particularly in areas with relevance to military defense. While some have returned to Russia, many remain. Occasionally, Kazakhstani linkages were developed with counterparts in Europe and the United States, although such relationships were usually sponsored by the Soviet government and were quite limited in scope.

After the USSR splintered into 15 independent states, S&T collaboration between institutions in Kazakhstan and those in Europe and the United States increased significantly. Some continue to grow, while others have reached a relatively even level of activity. Others have come to an end. Initially there was a serious language barrier to effective collaboration with Western countries, and limitations still exist. But young Kazakhstani specialists are increasingly mastering English, and some have mastered French or German.

Many new S&T linkages are being developed in commercial sectors, particularly with regard to development of oil and gas resources. For example, the petrochemical complexes in the country involve foreign investors and foreign management. Also, a variety of Western information technology companies have become interested in establishing a presence in Kazakhstan, and they are actively pursuing investment opportunities. Their presence is very visible in Almaty.

Some cooperative activities are undertaken pursuant to formal agreements between the government of Kazakhstan and other governments. Some of these agreements are considered “foreign assistance” agreements. Others are “S&T cooperation” agreements that specify areas of common interest. Others are simply open-ended agreements to cooperate in mutually beneficial fields that could involve S&T cooperation. A few agreements call for regional cooperation involving one or more other countries from Central Asia. But much of the international cooperation takes places on an informal basis between specialists and institutions with common scientific or economic interests.

As discussed below, important dimensions of cooperative activities with significant S&T components are programs financed by the international development banks (i.e., World Bank, European Bank for Reconstruction and Development, Asian Development Bank). Also, many United Nations agencies and international scientific organizations have been active. A favorite theme of these organizations is environmental protection, including restoration of the Aral Sea, protecting biodiversity, limiting desertification, and conserving water resources.

In April 2006 the U.S. Department of State reported that international and foreign organizations were contributing more than $1.5 billion to *active* cooperative projects directed to science, technology, health care, and environmental protection. These projects ranged from small exchange activities costing less than $50,000 to large loans for tens of millions of dollars. Of course, such estimates are far from precise since S&T is often entwined in other activities, and separating the S&T expenditures is not routinely done. Nevertheless, it is clear that many organizations in the country and abroad are involved in a large number of cooperative programs that have direct relevance to the S&T capacity of Kazakhstan.

This chapter briefly discusses a few bilateral and international programs that are particularly important for enhancing the S&T infrastructure of the country. Since Russian and U.S. institutions are the most active foreign partners, a few comments on their activities are presented. Additional international programs and projects involving Kazakhstan are then noted. As to the other Central Asian republics, the ties between some Kazakhstani institutions and their counterparts in neighboring countries have long histories, although financial constraints usually limit joint research activities at present. Building on this history, additional opportunities for regional cooperation are suggested.

Unfortunately, the committee had only limited information concerning the relationships between S&T organizations in Kazakhstan and counterpart institutions in China. Comments by Kazakhstani specialists to the committee during visits to Almaty and Astana suggested that a wide variety of linkages with China that have S&T dimensions exist.

COOPERATION WITH RUSSIA

As noted, cooperative programs involving Kazakhstan and Russian organizations are extensive. In the highly visible fields of space research and nuclear research, the ties are particularly strong. While Western countries, particularly the United States, have also supported cooperation in these two fields, Russian organizations are usually the collaborators of choice. This collaboration, as well as collaboration in other fields, is based on a variety of considerations, such as the following:

- History of sharing sensitive information.
- Russian as a common language.
- Geographical proximity of the countries to each other.
- Relatively easy access by Kazakhstani specialists to Star City (space research) and Dubna (nuclear research) near Moscow.
- Relatively easy access by Russian specialists to Baykonur (space research) and Semipalatinsk (nuclear research).
- Important educational and professional ties that date back many years.
- Kazakhstani reliance on equipment made in Russia.

Russia-Kazakhstan cooperation touches almost all aspects of S&T. Informal inquiries in Moscow and Astana indicate that almost every ministry in the two countries supports bilateral cooperative programs involving some aspect of S&T. All leading research and educational institutions in Kazakhstan have at least informal ties with Russian counterpart institutions. Many institutes of the Russian Academy of Sciences, Academy of Medical Sciences, and Academy of Agricultural Sciences have long carried out joint research activities with counterparts in Kazakhstan. As mentioned in Chapter 3, at present more than 16,000 Kazakhstani students are enrolled in higher education institutions in Russia, with many pursuing studies in technical fields.

COOPERATION WITH THE UNITED STATES

Beginning in 1992, the United States has become the largest investor in the S&T future of Kazakhstan of all countries with the possible exception of Russia.

The largest U.S.-Kazakhstan government programs have been for dismantlement of high-technology facilities that supported the Soviet military program and for conversion of the facilities and associated personnel to peaceful endeavors. These bilateral programs have involved expenditures of tens of millions of dollars by the United States and participation by hundreds of Kazakhstani specialists. A number of programs for nonproliferation of nuclear and biological materials and expertise have been under way for years, and some are currently active.

In addition, the U.S. foreign assistance program has supported cooperation in energy, health care, water management, and environmental protection. One high-profile program involves support of the Eurasian University in Astana in the field of environmental protection. Of course, efforts continue to be directed toward restoration of at least portions of the Aral Sea.

However, S&T-related programs, other than security programs, have occupied but a small portion of the U.S. assistance portfolio, which has expended about $1.3 billion during more than a decade of activity. Far greater emphasis has been given to supporting privatization, market reform, democratic governance, rule of law, development of nongovernmental organizations, and other efforts with very little technical content but in some cases long-term implications for both business and research institutions in Kazakhstan.

As to other U.S. government-funded programs, the U.S. Civilian Research and Development Foundation emphasizes small grants to local researchers and encouragement of U.S.-Kazakhstan partnerships. A U.S. Department of Energy program has helped link U.S. private companies with research institutes. Finally, the Department of Defense's nonproliferation program is designed to help strengthen local capacity to conduct surveillance of infectious diseases, and the field station in Almaty of the U.S. Centers for Disease Control and Prevention is a component of a global network for disease surveillance.

In 2004, 40 percent of foreign direct investment in Kazakhstan was by American companies. Between 1993 and 2005 they had invested more than $6 billion in the country. The companies are concentrated in the oil and gas, business services, telecommunications, and electrical energy sectors. In related activities, bilateral trade exceeded $850 million in 2004, a more than 50 percent increase over 2003.

Private foundations such as the Gates Foundation (HIV/AIDS) and the Soros Open Society (social sciences education) are active in Kazakhstan. A number of other privately funded projects, including projects in the renewable energy and environmental fields, are in place.

In summary, while American S&T achievements are highly respected in Kazakhstan and American universities are the first choice for many students traveling abroad for education in S&T fields, the U.S. government has shown only limited interest in programs for strengthening Kazakhstan's S&T capabilities, except those with direct security implications. At the same time, American companies and private organizations recognize the growing importance of working closely with the local S&T community. Thus, they are having positive, though modest, impacts that should benefit the evolution of a stronger S&T infrastructure while also rewarding the companies with profits in the years ahead.

COLLABORATIVE PROJECTS TO ENHANCE S&T CAPABILITIES IN KAZAKHSTAN

This section highlights a few other international programs and projects designed at least in part to enhance the S&T infrastructure of Kazakhstan. Much of the information has been provided by the Department of State's Environment, Science, Technology, and Health Hub for Central Asia, located at the U.S. Embassy in Tashkent, Uzbekistan, until the fall of 2006. That information has been supplemented by additional information obtained during consultations in Kazakhstan.

The Asian Development Bank has invested more than $500 million in Kazakhstan during the past 15 years, with the following distribution of resources: agriculture and natural resources (28 percent); transport and communications (20 percent); finance (20 percent); education (13 percent); multisector (12 percent); and water supply, sanitation, and waste management (7 percent; see *http://www.adb.org/kazakhstan/projects.asp*).

The European Bank for Reconstruction and Development currently emphasizes enterprise development, infrastructure modernization, and an improved investment climate. Investments since 1991 have exceeded $1.6 billion (see *http://www.ebrd.org/country/countrykaza/sign.pdf*).

The World Bank has invested more than $2 billion through 24 loans since 1992. Its active portfolio as of July 2006 included the following projects: Uzen Oil Field Rehabilitation, Road Transport Restructuring, Electricity Rehabilitation, North-South Electricity Transmission, Agricultural Post-privatization, Agricultural Competitiveness, Syr-Daria and North Aral Sea, Nura River Clean-up, Forest Protection and Reforestation (see *http://www.worldbank.org.kz*).

The Islamic Development Bank funds water supply and sanitation projects (see *http://www.isdb.org*).

The Global Environmental Fund is contributing $37.7 million to activities in the following areas: biodiversity, climate change, ozone-depleting substances, forest protection, dry-lands management, and persistent pollutants (see *http://www.gefonline.org/home.cfm*).

The Global Fund to Fight AIDS, Tuberculosis, and Malaria is financing an HIV/AIDS program to prevent HIV infection among sex workers and IV drug users and to expand care for those living with HIV (see *http://www.theglobalfund.org/*).

The International Science and Technology Center (Moscow) funded 60 projects, often at a level of about $100,000 per year for three years, during 2006. The projects cover many areas of science and technology, with considerable emphasis on nuclear and biological topics (see *http://www.istc.ru*).

The Canadian International Development Agency has provided about $16 million since 1992 to support activities directed in large measure at strengthening technical and vocational education and building small and medium enterprise capacity (see *http://www.dfait-maeci.gc.ca/*).

The German Society of Technical Cooperation supports S&T projects for implementing the United Nations Convention to Combat Desertification and to stabilizing the dried-up seabed of the Aral Sea (see *http://www.gtz.de/en/weltweit/*).

The Japanese International Cooperation Agency sends experts to Kazakhstan to cooperate on topics such as biological diversity and health and medical challenges, particularly in the Semipalatinsk region (see *http://www.jica.go.jp/*).

The Swiss Agency for Development and Cooperation and the **Swiss Secretariat for Economic Affairs** support limited efforts in the management of natural resources, health care, and private-sector development (see *http://www.swisscoop.uz*).

The United Kingdom's Department for International Development has supported projects in the health care sector and has provided extensive support for water and environmental management efforts (see *http://www.dfid.gov.uk/*).

The European Union's Technical Aid to the Commonwealth of Independent States (TACIS) Program has provided more than $200 million since 1991 in a wide variety of fields. The related **International Association for Promotion of Cooperation with Scientists from the New Independent States of the Former Soviet Union (INTAS) Program** is charged with linking scientific organizations in the country with counterpart institutions in Europe (see *http://www.delkaz.cec.eu.int*).

The foregoing organizations are among the largest external contributors to Kazakhstani S&T activities that have the potential of supporting economic and social development. Many other external organizations provide smaller levels of technical and financial resources to the effort.

According to Kazakhstani colleagues, in some cases external support was crucial to the survival of S&T institutions during the 1990s when the economy was in shambles. Frequently mentioned in this regard are the programs of the International Science and Technology Center, which has distributed more than $50 million to local scientists since 1995. Since 2000 these programs, as well as other international efforts, have continued to be important in supporting high-quality research, but they are not now as critical for institutional survival as the economy recovers and state programs provide increased funding to the S&T community.

REGIONAL PROGRAMS

As requested by the National Center for Scientific and Technical Information (NCSTI), the committee focused its primary attention on opportunities for new regional programs, without carrying out detailed assessments of the merits of the currently active international programs. The committee is aware of several important regional programs that involve the participation of Kazakhstani scientific organizations. They include the following:

- **Regional HIV/AIDS projects** sponsored by the World Bank, the Joint United Nations Programme on HIV/AIDS (UNAIDS), the U.S. Agency for International Development, and others are of considerable importance, given predictions that HIV/AIDS could infect 1 million people in Central Asia by 2030. At-risk populations of primary concern are prisoners, prostitutes, and intravenous drug users. In view of the increased trafficking in narcotics and the relative ease of travel in the region, the HIV/AIDS issue clearly deserves continuing attention.
- **The Caspian Environmental Program** coordinates the activities of organizations from the five littoral states (Russia, Azerbaijan, Iran, Turkmenistan, and Kazakhstan), which collectively address the following issues: decline in fish stocks, particularly from poaching of sturgeon; increased oil pollution; degradation of coastal landscapes and habitats; threats to biodiversity; damage to coastal infrastructures and amenities due to pollution and sea-level rise and fall; threats from introduced species; and decline in general environmental conditions and human health. Coordinated national monitoring programs, exchanges of research data, and joint expeditions are among the many activities that are carried out. Selected institutions located in the five countries have been designated as lead organizations for specific scientific activities of common interest.[1]
- **The Aral Sea** legacy is the focal point for a large number of regional projects that involve primarily Uzbekistani and Kazakhstani institutions. Sometimes other Central Asian countries that depend on water from the tributaries are involved. Many programs are supported by the Global Environmental Fund. Other external organizations have been involved. This high level of activity will probably continue for the indefinite future.[2]
- **Geological Investigations throughout Eurasia.** A number of cooperative geological investigations are currently under way involving Chinese, Mongolian, Russian, and Kazakhstani institutes.

[1]See, for example, *Science and Technology, Book 4, 2006*, Association of Universities of PreCaspian States, Atyrau, 2006.

[2]See, for example, I. Seversky et al., *Aral Sea, GOWA Regional Assessment 24*, United Nations Environmental Program, University of Kalmatr, Sweden, 2005.

• **Seismic Investigations in Central Asia and Beyond.** Several seismic networks are in place to monitor earthquake-related phenomena in the region. Presumably some of the stations were converted from Soviet stations designed to monitor nuclear testing activity. In any event, they are important given the earthquake potential in southern Kazakhstan and elsewhere.

This list of regional programs is a small sampling of the many projects that involve Kazakhstani scientists working on a regional basis.

Against this background of a long tradition of regional collaboration, the committee offers the following suggestions for initiating or expanding regional cooperation that should be of special interest to Kazakhstan:

• **Management of Water Resources:** Regional programs to conserve water resources in the arid areas of Central Asia date back many decades. The Soviet government designated a water research institute in Tashkent to serve as the lead institute for regional cooperation in this field, although the regional activities of the institute have dwindled in importance as Uzbekistan has increasingly looked inward to address development problems. Kazakhstan should not hesitate to assume a new leadership role in water management given its dependence on four rivers flowing south from Russia into the country, its water flows across the border with China, and its shared water resources in the southern part of the country. Perhaps a regional approach will be best defined by an aggregation of bilateral arrangements since the issues vary considerably in different border areas and in the tributaries that flow into these areas.

• **Disease Surveillance:** As discussed in Chapter 3, the U.S. government recently initiated a program in Kazakhstan to upgrade local capabilities to detect, diagnose, and report disease agents and syndromic episodes that threaten human health, with particular attention to zoonotic diseases. Related efforts are under way in Uzbekistan. These networks should significantly improve the capabilities of not only local scientists but also external organizations (e.g., Centers for Disease Control and Prevention, World Health Organization) to detect promptly disease outbreaks of regional and global importance, such as SARS and avian flu. The committee supports this activity and urges that consideration be given to building on the experiences in Kazakhstan to address related problems and opportunities in Kyrgyzstan.

• **Medical Education:** The medical universities and medical research facilities in Kazahkstan are well developed. As the linkages among education, research, and clinical practice become stronger in the education complexes, the quality of the preparation of health care practitioners, particularly doctors, should increase accordingly. This development should open attractive new opportunities for talented students from other Central Asian countries to attend universities in Kazakhstan.

- **Educational Complex in Astana:** Plans for a new high-technology university in Astana (discussed in Chapter 3) envision a large Western presence in terms of faculty and researchers. A special effort should be made to attract talented students from neighboring countries as well. Since markets in Central Asia for technology-intensive products should be an important component of Kazakhstan's development plans, attendance at the university by future scientific leaders from these countries should in the long run pay off in terms of ties among colleagues with common interests and with influence in their countries.

6

General Observations, Conclusions, and Recommendations

CONCERNS OF KAZAKHSTANI PUBLIC-SECTOR SCIENCE AND TECHNOLOGY SPECIALISTS

At a roundtable session in Almaty in July 2006, more than 50 science and technology (S&T) specialists from 20 public-sector education and research institutions emphasized to committee members the problems and solutions set forth below. The committee's observations are consistent with these views, which should be carefully considered in debates about the future of S&T in the country.

Human Resources

• Inadequate numbers of young specialists are entering the science and engineering professions because of low salaries, poor laboratory facilities, and housing difficulties that inhibit mobility. The attractions of working abroad or entering private business in Kazakhstan are much more appealing to many young professionals than S&T careers in Kazakhstan.

• Reliance on short-term appointments for leadership positions in the science and engineering community has introduced considerable instability into some public-sector institutions. Deans, department heads, institute directors, and other senior managers are appointed for only two years, and some of these leaders are searching for more personal security in the private sector or abroad.

• The quality and breadth of university education could be improved through (1) greater reliance on foreign professors, (2) introduction of courses in technology management, (3) improved accreditation procedures, and (4) guidelines concerning the requirements for master's and Ph.D. degrees.

Research and Development

• Insufficient laboratory equipment and limitations on financial support for research and development (R&D) from the government inhibit realization of the full potential of the existing R&D workforce. In addition, customs duties often inhibit imports of modern laboratory equipment.

• Limited access to the Internet, limited availability of international journals, and lack of opportunities to participate in international conferences prevent researchers from taking advantage of many international S&T achievements.

• Improved evaluations of past research results and future plans should serve as the basis for decisions on research grant proposals.

Technology Transfer

• Existing legislation does not provide an adequate basis for transforming research results into commercial products. For example, it does not (1) provide tax exemptions to motivate entrepreneurs to invest in the development of new technologies, (2) limit through taxation imports of technologies even if the same technologies could be developed in Kazakhstan, or (3) provide financial incentives for commercial enterprises to use the results of R&D carried out in the country.

• The commercial sector has little interest in the activities of research institutions due to poor marketing capabilities on the part of the institutions and lack of information in the commercial sector regarding the institutions' achievements. Marketing departments and technology transfer centers at the institutions would help.

• Governmental mechanisms are needed to link public-sector research institutes with public-sector enterprises that are heavily dependent on effective technologies.

GENERAL OBSERVATIONS OF THE COMMITTEE

As noted throughout this report, Kazakhstan has an unusual opportunity to develop and use S&T for increasing its global economic competitiveness while enhancing the economic and social well-being of its population. The strong commitment of the nation's leaders to rapid development of S&T capabilities and the increasing availability of financial resources to support the S&T infrastructure are strong pillars for the ambitious programs that have been developed.

However, the views of the representatives of the education and research communities noted above and comments by other S&T leaders of the country have underscored many of the impediments to rapid progress. High on the list is the limited interest of local and international companies and service organizations in investing their resources in R&D activities with uncertain payoffs. Most industrial and service organizations are accustomed to relying on well-tested imported technologies and expertise when they initiate a new program or have a need to upgrade their activities. In addition to this weak "demand" for Kazakhstani technologies and expertise are weaknesses in the infrastructure that "supplies" technologies and nurtures local expertise.

In short, greater demand—"market pull"—for local technologies is essential. In order for the demand to increase, however, the S&T establishment needs to demonstrate that it has the wherewithal to supply S&T-based goods and related consulting services that are competitive in quality and cost with comparable goods and services that can be imported. Developing this supply capability is the major interest of the Ministry of Education and Science and therefore the principal focus of this report.

The committee is concerned that some officials may become impatient with the slower-than-desired rate of progress in upgrading the S&T infrastructure and with the limited number of examples of homegrown S&T achievements that affect economic development. In an effort to accelerate progress, they may be tempted to make financial investments that are beyond the capacity of the available human resources to use effectively. The determination of the government to have a modern infrastructure that serves as the basis for providing internationally competitive goods and services is admirable. The setting of timelines to achieve specific goals is stimulating important activities in Astana, Almaty, and other cities. But it will take many years to put in place the S&T teams and facilities necessary to achieve the laudable goals that have been established. The competition for international markets will be strong. In particular, competing with Chinese exporters for market share in nearby countries, indeed in Kazakhstan itself, will be challenging. The availability of investment capital is essential, but the capabilities of the S&T workforce will be the critical factor. Thus, the pace of financial investments should be consistent with the pace of human resource development.

SIGNIFICANT CONCLUSIONS

This section consolidates a number of significant conclusions that have been identified in previous chapters and offers suggestions for addressing relevant issues.

1. The government of Kazakhstan faces a continuing challenge of choosing between investments in existing institutions and using available resources to establish new institutions. Each approach may have certain advantages. For example, the research capabilities of the Kazakh National University are formidable. With greater support they can become more effective in enriching the educational process and in opening new research areas that should be of importance to the country. Many independent research institutes have strong capabilities, and

they too could benefit from new investments. On the other hand, the Kazakh-British Technical University, which has been supported by both the government and the private sector, is an example of how a new institution can quickly become a bridge that links education, research, and commercial interests. Also, the planned advanced-technology university in Astana should offer attractive educational and research opportunities for highly talented students and young faculty members, although success will depend on development and implementation of sound and detailed plans. In the fields of public health and engineering, the near-term advantages of upgrading existing facilities must be weighed against the longer-term payoffs from establishing new scientific or educational complexes.

2. The intense interest of the leadership of the country in economic payoffs from development of "breakthrough" technologies seems to have pushed the importance of more effective use of established technologies into the background. During the next decade, established technologies in their current or upgraded forms will undoubtedly continue to undergird many aspects of the economy, and steps by the S&T community to help ensure that they are used effectively will probably have far greater economic impact than introduction of new technologies. This is not to say that capabilities to develop and use advanced technologies are not important. But the significance of maintaining and modernizing established technologies should be fully recognized.

3. The government has ambitious plans to expand R&D activities so that new products and new processes can be developed, but less attention is being given to the importance of S&T services that have been and should continue to be provided by S&T-oriented institutions. These services can take the form of advice to government agencies on their investments and their regulatory and managerial responsibilities, services to assist the public in selecting goods and services based on S&T achievements that affect daily lives such as pharmaceutical and food products, and reimbursable support for international firms that establish facilities and programs in the country. These and related responsibilities of S&T organizations should be fully recognized in the government's planning and budgeting processes.

4. While the government's commitment to taking advantage of international experience and expertise is laudable, the selection of international experts should be made with care to ensure that they are not only experienced in their fields of interest but are also sensitive to the realities of operating in Kazakhstan. Similarly, Kazakhstani specialists who work with international experts should have the capability both to appreciate the importance of the views of the experts and to assess the likely impact of incorporating those views into policies and programs. Also, they should be able to carefully define the tasks that are to be addressed by experts.

5. Procurement offices throughout the government regularly make decisions on whether to import products or equipment with embedded technologies or to purchase such products or equipment that are or could be produced or assembled

in Kazakhstan. Often, when there is a choice between commodities produced abroad and those produced locally, the difference in price or quality is relatively clear. But as Kazakhstan develops its industrial base in the years ahead and becomes more competitive, the choices may not be as clear. The government should have a consistent policy that recognizes the importance of procurements that enable Kazakhstani institutions to develop markets for their S&T products. The key issue is the extent to which Kazakhstani organizations should have an advantage in competing for government contracts. The economic arguments for using government procurement as a mechanism for encouraging development of local advanced-technology capabilities (e.g., the long-term consequences of technological protectionism) are complicated, and the government should be prepared to address these considerations.

6. The government and research institutions should make special efforts to help ensure that researchers are linked to potential users of the results of research early in the R&D cycle since the likelihood of successful transfer of technology is then much higher than when researchers search for users only after they are well along in the cycle. One technique might be programs for researchers to spend "familiarization" time in companies. Another approach is internships for postgraduate students at industrial facilities which include continuing contact with their educational mentors.

7. The government should provide incentives for young entrepreneurs to take risks in setting up small innovative firms, including providing tax incentives and opportunities to lease research equipment when necessary. Incubators may provide an important environment for new entrepreneurs.

8. Kazakhstani officials, in their presentations to government leaders, emphasize the simplicity of a linear model that depicts the movement of an idea from basic research to applied technology to design and development and then leads to a successful process, product, or service. Many deviations from the model, often linked to the importance of feedback and consultations between different participants in the entire cycle, are characteristic of successful endeavors. Furthermore, the process of developing a product does not necessarily lead to a successful business, and the failure rate for businesses, particularly technology-intensive businesses, is substantial. Also of importance is Western experience which shows that successful commercialization of R&D usually leads to small improvements in existing processes and products and that only the exceptions lead to entirely new processes and products.

9. During the next few years, Kazakhstan has no choice but to rely heavily on foreign technologies to operate and modernize its industrial base and to serve the consumer needs of the population. There are a host of near-term challenges in making the transition from this dependence on foreign technologies to greater reliance on local technologies. For example, the government should help ensure that state-controlled organizations choose wisely and use effectively imported goods and services that are laden with modern technologies. If comparable tech-

nologies are available or could become available locally, the costs and benefits of using such technologies should be carefully analyzed. Also, the government should use financial, tax, regulatory, procurement, and other mechanisms to encourage greater interest by private-sector organizations in using products that are developed in Kazakhstan.

Related to the foregoing challenges are the government's goals that call for state-owned and private companies to dramatically increase their investments in R&D during the next few years. It seems likely that much of the increase in funding will be devoted to technology transfer from public-sector institutions to the companies and for adaptation of foreign technologies. To help stimulate technology transfer both to companies and directly to consumers, the government has initiated a broad-ranging program in support of entrepreneurs, including not only financial inducements in the form of venture capital and long-term loans but also techno-parks, incubators, economic free zones, improved patent legislation, and technology advisory services. This "technology push" approach is important, but it must be balanced with greater emphasis on the "market pull" approach.

MAJOR COMMITTEE RECOMMENDATIONS

This section summarizes the major recommendations of the committee that are set forth in earlier chapters. As the government considers these recommendations along with those of other international and Kazakhstani specialists, it should develop a road map that is regularly updated regarding implementation of the recommendations it intends to pursue. The well-developed strategies of many ministries also encompass S&T programs, and they too should contribute to developing the response to recommendations and the implementation of recommendations that are accepted.

S&T Policy Issues

- *Centralization of R&D funding.* Before control of all R&D resources is transferred to the Ministry of Education and Science, careful analyses should be carried out of possible negative impacts on the capabilities of other ministries to draw on the technical expertise of the R&D institutes for which they are responsible.
- *Applied technology centers.* The government should reconsider its plan to establish 15 applied-technology centers at 15 universities of uneven quality in various regions of the country as components of the five national laboratories being planned. As an alternative, consideration should be given to concentrating available resources at three or four technology centers and then expanding the program to a larger number at a later date if the initial investments are successful

in bridging the gap between research and commercial applications. Also, the location of the centers should be determined on the basis of an open competition that would not be limited to applications from only universities. If geographic distribution is important, a constraint on the competition could be a limit on the number of technology centers that could be located in any one city, such as Almaty.

- *Resource assessment unit*. The Ministry of Energy and Natural Resources should establish a strong resource assessment unit within its organizational structure that can help guide the assessment, development, and extraction of hydrocarbon and mineral resources. This unit should carry out surveys of hydrocarbon and mineral reserves, provide advice on negotiations with international companies, and monitor implementation of exploration and production agreements.
- *Employment creation and displacement*. The likely impacts of expanded availability of old and new technologies on employment creation and displacement should be carefully analyzed. This issue is particularly important in provincial areas that could benefit from new income-generating S&T complexes or that could receive economic setbacks if existing talent moves to other areas that are the beneficiaries of new industrial or agricultural activities.
- *Local content.* The government should encourage foreign companies to satisfy "local content" requirements for their investments by using products based on the results of local R&D activities and services.

Human Resources Development

- *Integration of research and education activities*. The 25 research institutes that had formerly been components of the Kazakhstani National Academy of Sciences should gradually become affiliated with the universities during the next few years in a manner that avoids further disruption of important research programs.
- *Postdoctoral grants.* One or more new grant programs to support postdoctoral scientists at universities, research institutes, and other appropriate institutions should be established, with particular emphasis on encouraging scientists trained abroad to become researchers in Kazakhstan.
- *Model medical complex.* The Ministry of Health should establish a modern hospital as a component of one of the medical universities. The hospital should be located adjacent to the university. The complex should give new emphasis to basic research and should serve as a model to significantly improve opportunities for students, researchers, and practitioners to participate routinely in a broad range of education, medical, and health care activities.
- *Doctor of science.* Even after the nation makes the transition to the bachelor's-master's-Ph.D. degree model, the awarding of the degree of doctor of

science should continue, and the degree should be widely recognized as a significant scientific achievement.

- *Patent legislation.* The government should promote programs to educate the S&T community on recently enacted patent legislation concerning government-funded research that provides the researchers' institutions with ownership of the intellectual property.
- *Management training.* Kazakhstani research managers should visit Western laboratories and technology transfer offices that have been successful in transferring technology to industrial clients and that have emphasized the use of their technologies in the public sector.

Activities

The government should give special emphasis to several types of activities that cut across the entire range of S&T programs. They are:

- Universal broadband access to the Internet by members of the S&T community.
- Appropriate modern equipment throughout the nation's research laboratories.
- Maintaining a high level of pedagogy in mathematics, physics, biology, chemistry, and the earth and atmospheric sciences while strengthening the associated research activities.
- Expanded economics training and research.
- Greater recognition of the importance of professional scientific societies, industrial associations, and academies of science and engineering.
- Strong support for standards and quality control.
- Encouragement of publication in English-language journals.
- New emphasis on ethics for S&T-related activities.

S&T Priorities

The committee identified the following areas as deserving priority for government support, including financial support for R&D activities and S&T services, with the recommendation that the priorities selected by the government be regularly reviewed and modified as appropriate, perhaps every three years:

- *Nuclear science and technology*: assessment of nuclear power facilities, radioecology, and mining of uranium.
- *Biomedical science and technology*: disease surveillance and prevention, cancer therapy, natural products chemistry, and orthopedic devices.
- *Agricultural science and technology*: cereal grain production, livestock productivity, and nutrition.

• *Hydrocarbon resources*: chemical engineering, catalysis, assessment of reserves, and environmental protection.

• *Minerals*: metallurgy, assessment of ore deposits, and environmental protection.

• *Construction*: seismic-resistant engineering and construction materials.

• *Water science and technology*: irrigation systems, monitoring and assessments of water quantity and quality, and protection and remediation of water quality.

Regional Programs

Hundreds of S&T-intensive programs are under way that involve Kazakhstani specialists and specialists from neighboring countries. Given this long tradition of regional cooperation, the committee recommends expanding efforts in the following areas:

• *Management of water resources*. Most of Kazakhstan's surface water resources are international sources of water—flowing from or into another country or the Caspian Sea.

• *Disease surveillance*. Many human and animal diseases are endemic throughout Central Asia, and Kazakhstan is in a good position to assume regional leadership in this area.

• *Medical education*. Kazakhstan can offer high-quality medical education opportunities at several levels for students and practitioners from Central Asian countries.

• *Educational complex at Astana*. A strong regional presence at the planned advanced-technology university will help establish educational and professional ties that should be increasingly important as Kazakhstan seeks Central Asian export markets for its technology-intensive products in the years ahead.

HUMAN RESOURCES AS THE KEY TO KAZAKHSTAN'S FUTURE

The effectiveness of the education system, particularly the higher education institutions, will be a critical determinant of the future of Kazakhstan. The country is fortunate in having a highly literate population that appreciates the value of education and is eager to build on the country's advanced-technology achievements in the nuclear and space fields. Sound policies are important. Appropriate mechanisms for integrating education, research, and commercial activities are needed. The growth in national income can provide much-needed resources. But only with competent and committed scientists, engineers, and health care professionals operating in organizations that can use the products of research and that can develop competitive products will Kazakhstan be able to reach the ambitious goals that have been set.

Fortunately, in this regard, the government recognizes the importance of higher education, as exemplified by the Bolashak and related programs to support studies by talented Kazakhstani students and researchers abroad.

This report is intended to assist the government in capitalizing on its commitment to education and science as it seeks to develop the nation's S&T infrastructure, which is essential to improve the technological competitiveness of the country while also serving the day-to-day needs of the Kazakhstani population.

Appendix A

Terms of Reference

1. Development of a unified system of evaluation (peer review) of quality and impact of research programs; valuation and development of the disciplines; and development of recommendations on improving the research system;
2. Development of effective management of the operational environment of research; ensuring the diversity of scientific research;
3. Promotion of international cooperation as well as cooperation among research funding agencies to improve quality standards of scientific research; concentration and strategic distribution of resources (open competition for talented researchers, etc.);
4. Development and introduction of principles and measures for assurance of quality;
5. Development and introduction of science development indicators; promoting researcher mobility;
6. Determination and development of measures for promoting research fields of national importance;
7. Development of proposals and recommendations for a system of effective and results-aimed research programs; analyses of fields of science and factors concerning the entire research system;
8. Introduction and implementation of systematic researcher training programs;
9. Development of proposals and plans for scientific research activity;
10. Identification and introduction of methods and approaches for increasing the relevance of scientific research programs (regional, society, economic, technology, culture, environment);

11. Determination of main priorities of high-level basic research to generate new knowledge;
12. Measures and recommendations to promote open competition in R&D funding;
13. Recommendations on diversification of scientific information infrastructure (modernization of information services, networks of scientific and technical libraries);
14. Recommendations on elimination of obstacles to the transfer of knowledge and technology;
15. Development and introduction of a human resources management system in science;
16. Identification and evaluation of unique scientific capabilities and infrastructures that are in short supply regionally or globally; and
17. Recommendations on how development assistance can best be sustained in the science sector so that Kazakhstan can benefit.

Appendix B

Institutions Visited by the Committee

City of Almaty

Universities

Academy of Economics and Statistics
Al-Faraby Kazakhstan National University
- Economics Faculty
- Educational Computing Center
- Institute of Chemical Technology and Materials
- Institute of Experimental and Theoretical Physics

Almaty Technological University
British-Kazakh University
- Economics/Finance Department
- Faculty of Energy and Oil and Gas Production

Kazakhstan Main Academy of Architecture and Construction
S. Asfendiyarov Kazakhstan State Medical University
Satpaev Kazakhstan National Agrarian University
Satpaev Kazakhstan National Technical University
- Institute of Information Technology

Government Ministries/Agencies

Center for Information Systems for the City of Almaty
City Scientific Research Center for New Technologies in Education
City Water and Sewer System

Department of Public Health of the City of Almaty
Local (Oblast) Ecological Management Agency
National Innovation Fund

Research Centers

Center for Astrophysics Research
Center for Biological Research
Center for Chemical and Technological Research
Center for Geological and Geographical Research
Center for Information Technologies in Medicine
Center for Physical and Mathematical Research

Research Institutes

Aithozhin Institute for Molecular Biology and Biochemistry
Almaty Branch of the National Center for Biotechnology
Almaty Branch of the National Center for State Standards in Education and Testing
Bekturov Institute for Chemical Science
Institute for Atomic Physics
Institute for Energy and Communications
Institute for Metallurgy and Enrichment
Institute for Problems in Computer Science and Management
Institute for Scientific and Technical Information
Institute of Archaeology
Institute of Biological and Biotechnological Problems
Institute of Economics
Institute of Economic Research Under the Ministry of Economics and Budgetary Planning
Institute of Economics Under the Ministry of Education and Science
Institute of Geography
Institute of High Technologies of the National Atomic Company Kazatomprom
Institute of Mathematics
Institute of Microbiology and Virology
Institute of Seismology
Institute of the Problems of Comprehensive Utilization of Mineral Resources
Institute of the Problems of the Complex Development of Mines
Kazakhstan Academy of Nutrition
Kazakhstan Institute for Mineral Resources
Kazakhstan Institute of Information Technology and Management
Kazakhstan Scientific Research and Experimental Design Institute of Earthquake-Resistant Construction and Architecture

Kazakhstan Scientific Research Institute for Oncology and Radiology
Kazakhstan Scientific Research Institute for Power Engineering
M. Aikimbaev Kazakhstan Scientific Center for Quarantine and Zoonotic Infections
National Center for Comprehensive Processing of Mineral Resources
National Center for Hygiene and Occupational Health
National Center for Monitoring, Reference, Laboratory Diagnostics, and Methodology in the Veterinary Sciences
National Center for Problems of Tuberculosis in the Republic of Kazakhstan
National Center for Scientific and Technical Information
National Institute of Intellectual Property
National Nuclear Center
National Scientific Methodological Center for Information Technology Education
Oil Scientific Engineering Center
Physical and Technical Institute
Satpaev Geological Prospecting Institute
Satpaev Institute for Geological Science
Scientific Center for Medical and Economic Problems of Public Health
Scientific Center for Pediatrics and Pediatric Surgery
Scientific Engineering Computing Center
Scientific Research Institute for Cardiology and Internal Medicine
Scientific Research Institute for Eye Diseases
Scientific Research Institute for Problems in Ecology
Scientific Research Institute of Building Materials (NII Stromproekt)
Scientific Research Institute of Construction Materials
Sokolski Institute for Organic Catalysis and Electrochemistry
Syzganov Scientific Center of Surgery
U. Akhmedsafin Institute of Hydrogeology and Hydrophysics
Uspanov Scientific Research Institute for Soil Sciences
Zh. Abishev Chemical-Metallurgical Institute

Private Firms

Energy Institute
Business-Inform
Hydrogeoecological Scientific Production Company KazGIDEK
Inside Company
Kazakhstan Institute of Oil and Gas
Rescona Group
Tamos Development Limited
VAN Company

Other

Alatay Information Technology Park
Central City Clinical Hospital
Kazakhstan Association of IT Companies
National Academy of Sciences of the Republic of Kazakhstan
National Engineering Academy of the Republic of Kazakhstan
National Specialized Physics and Mathematics Boarding School
Polyclinic of City Clinical Hospital No. 5
Polyclinic of the Scientific Research Institute of Cardiology and Internal Medicine
Private School "Dostar"

City of Astana

Universities

Agrarian University
Gumilev Eurasian University
Kazakhstan State Medical Academy

Government Ministries/Agencies

Ministry of Agriculture
Ministry of Economics and Finance
Ministry of Education and Science
Ministry of Energy and Mineral Resources
Ministry of Environment Protection
Ministry of Foreign Affairs
Ministry of Industry and Trade
    Center for Engineering and Technology Transfer
Ministry of Public Health
Office of the Prime Minister

Research Institutes

Baraev National Grain Center
National Biotechnology Center
Scientific Production Center for Animal Husbandry and Veterinary Medicine
Scientific Research Institute of Trauma Surgery and Orthopedics

Private Firms

Exxon-Mobil

Other

Asian Development Bank
Roundtable of Good Laboratory Practices
Roundtable on Science and Technology Priorities
World Bank

City of Atyrau

Universities

Kh. Dosmukhamdov Atyrau State University

Research Institutes

Atyrau Institute of Oil and Gas
Atyrau Scientific Research Institute of Fisheries
Kazakhstan Scientific Research Geological Prospecting and Oil Institute
Munaigaz Scientific Research Institute of the Caspian

Private Firms

Tengizchevroil

Other

Atyrau City Environmental Laboratory

City of Karaganda

Universities

Karaganda Economics University
Karaganda State Industrial University (Temirtau)
Karaganda State Medical Academy
Karaganda State Technical University
    Economics/Finance Department
Karaganda State University

Research Institutes

Institute of Metallurgy (Temirtau)
Karaganda Institute for Plant Sciences and Selection (Phytochemistry)
Karaganda Institute of Plant Growing and Selection (Tsentralnoe)

Private Firms

Kazchermetavtomatika
Phytochemistry

Other

Karaganda Regional Techno-park

Other Cities

Institute of Water Management, Taraz

Appendix C

Strategic Concepts[1]

The national objective for Kazakhstan is sustainable and balanced societal and economic development. High employment, productivity, and competitiveness should be key factors.

The government, decision-makers, and blue-chip players need to realize that focused measures to step up research and technological development and the utilization of the results of these activities must play a significant role in achieving the national objective. These activities also have an important place in efforts to respond to the challenges facing cultural development and environment protection.

If decision-makers and executors of government policies do not realize the need for structural development of the research system, research will not support achievement of the national objective in a constantly changing international environment.

At the systems level, at the level of decision making, and within research and higher education institutions, the following considerations are important.

A) The research and scientific system should be developed with a view to continuous improvement of the quality and relevance of research and development.

[1]Provided by the National Center for Scientific and Technical Information to the committee, August 2006.

The ministries should realize that measures are needed to improve the setting of priorities of activities and to enhance the national and international reputations of research organizations. It is very important that at the government level and at the level of the Higher Scientific and Technical Commission the decision-makers and other participants realize that a crucial challenge for Kazakhstan is to develop world-class R&D in fields most relevant to the national economy, to societal development, and to the well-being of citizens. Also, the effectiveness of implementation of measures to promote national development must always be assessed fairly.

B) State and public research funding organizations need to expand collaboration among themselves and with private and foreign funders in order to develop, strengthen, and then increase knowledge clusters of the highest standard. It is important that the Ministry of Education and Science, funding organizations, development institutions and mission-oriented ministries realize that the core funding of research organizations and competitive funding should complement each other in a balanced way. Further, it is quite important that measures be developed and implemented to increase the number of joint projects of higher education institutions, research institutes, and companies and to expand other forms of cooperation with a view to improving operation of the research system and promoting research-based social and technological innovation.

C) The Ministry of Education and Science (together with other ministries) needs to pay greater attention to the internationalization of education, research, and innovation as a central development goal for the research system as a whole. International communication about cooperation opportunities associated with domestic science and technology achievements should be significantly improved. Internationalization of activities involving Kazakhstan also should be promoted by legislative means. In particular, mechanisms should be established to enhance the capabilities of all participants in the research system to receive foreign researchers and other specialists.

D) The links between advice on science, technology, and innovation policy and political decision-making within the government must be strengthened significantly. In particular, the role of science, technology, and innovation policy should be significantly strengthened in the Ministry of Education and Science and the Ministry of Trade and Industry, especially with a view to developing cooperation within and between the ministries concerning administrative matters.

E) Development institutions and funding organizations need to be proactive in developing their joint financing and other forms of cooperation in order to improve the impact of R&D and innovation financing and to support establishment of operational entities larger than the current ones. Development institutions and funding organizations need to review on a continuing basis existing procedures and financing instruments and, when necessary, develop new approaches, particularly with a view to promoting inter-disciplinary and inter-technological research and attracting foreign world-class experts to Kazakhstan.

F) Research institutes should seek more external research funding in order to increase its share in supporting their research and development activities. The ministries and the research institutes must improve the management of their research funding and the standardization of cost calculations in order to ensure that the real costs of their activities can be appropriately monitored and accurately calculated in assessing financial needs.

G) Universities need to improve their international competitiveness by improving the focus of their activities and by investing in improving the quality of research, expanding inter-disciplinary activities, and recruiting research personnel who can perform at an international level.

The Committee on Science within the Ministry of Education and Science has recently been established.

Appendix D

Committee Member Biographies

Dr. Alvin W. Trivelpiece (NAE) (*Chair*) was formerly director of Oak Ridge National Laboratory (ORNL; January 1989-March 2000). Since May 2000 Dr. Trivelpiece has been a consultant to Sandia National Laboratories. In January 1996 he was appointed president of Lockheed Martin Energy Research Corporation, the managing and operating contractor for ORNL. Dr. Trivelpiece served as executive officer of the American Association for the Advancement of Science (AAAS) from April 1987 to January 1989. He went to AAAS from the U.S. Department of Energy, where he served as director of the Office of Energy Research from 1981 to 1987. Dr. Trivelpiece was head of the 1986 U.S. Delegation on Peaceful Uses of Atomic Energy to the USSR. While on leave from the University of Maryland (1973-1975), where he was a professor of physics, he served with the U.S. Atomic Energy Commission as assistant director for research in the Division of Controlled Thermonuclear Research. A native Californian, he received his B.S. degree from California Polytechnic State University in 1953 and his M.S. (in 1955) and Ph.D. degrees (in 1958) from the California Institute of Technology. He was a member of the Board of Directors of Bausch & Lomb from 1989 to 2001 and of Charles River Laboratories from 1992 to 1999. He was elected to the National Academy of Engineering in 1993. He served on the National Academies Review of Technical Issues Related to Ratification of the Comprehensive Test Ban Treaty (July 1, 2000-October 31, 2001). He also served on the National Academies Committee on Science and Technology Policy Aspects of Selected Social and Economic Issues in Russia (November 1, 1999-November 10, 2000) and other National Academies committees. His research has focused on plasma physics, controlled thermonuclear research, and particle accelerators. He was granted several patents on accelerators and microwave devices and is the author or coauthor of two books and many papers. He also serves as an adviser to various government agencies. In addition to involvement in several other scientific organizations, he is a fellow of the American Physical Society, the Institute of Electrical and Electronics Engineers, and the AAAS and is a member of the American Nuclear Society.

Dr. Clifford Gaddy holds a Ph.D. in economics from Duke University. He has previously been a visiting professor of economics at Johns Hopkins University and an adjunct professor in the Department of Economics and the Center for Eurasian, Russian, and East European Studies at Georgetown University. In 1996-1997 he served as an adviser on issues of fiscal federalism for the U.S. government's Tax Reform Oversight Project for Russia. Dr. Gaddy is coauthor (with Barry W. Ickes, Pennsylvania State University) of a forthcoming Brookings Institution book, *Russia's Virtual Economy*, which analyzes the nature and evolution of the postcommunist economic system in Russia. An earlier book, *The Price of the Past: Russia's Struggle with the Legacy of a Militarized Economy* (Brookings Institution, 1996), was awarded the 1997 prize of the American Association for the Advancement of Slavic Studies as the year's best book on the political economy of the former Soviet Union and eastern Europe.

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 Asia. While there 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 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 during 1969-1973, reporting to the president's science adviser. Dr. Neureiter entered the U.S. Foreign Service in 1965, serving as deputy science attache with the U.S. embassy in Bonn, Germany. From 1967 to 1969, he was the first U.S. science attache in eastern Europe, based at the U.S. embassy in Warsaw, with responsibility for Hungary, Czechoslovakia, and Poland.

Dr. Marilyn L. Pifer is senior program manager and senior technical advisor at the U.S. Civilian Research & Development Foundation. Since 2001 she has served as senior manager of the Basic Research and Higher Education Program. Prior to joining the foundation, Dr. Pifer served twice in the U.S. Department of State's Bureau of Oceans and International Environmental and Scientific Affairs, with responsibility for science cooperation in Russia and in South Asia and the Middle East. She has also done research as a fellow with the University of Manchester's Programme on Policy Research in Engineering, Science and Technology and through a National Academy of Sciences exchange at the Institute of Molecular Biology, Moscow. Dr. Pifer holds B.S. and M.S. degrees in biology from Stanford University and a Ph.D. in molecular biology and genetics from the Johns Hopkins University Medical School. She speaks Russian, Ukrainian, and German.