RESEARCH AND DEVELOPMENT MANAGEMENT IN THE TRANSITION TO A MARKET ECONOMY

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Foreword

Today, there is no more denying the significance attributed to research and development (R&D) as a component of modern economic growth. Though a neglected topic of economic study in the first half of this century, the increasing rapidity of technological change swayed the attention of both academics and policy-makers towards the role of R&D in enhancing social and economic welfare. In a market system, the externalities characteristic of R&D make its support more difficult than most goods in which the contrasting of private benefits with private costs approximates the well-being of society at large. Thus, the organization of R&D becomes a key issue in a transition to a market system, particularly for the Russian Federation, which has inherited the majority of the scientific and technological resources after the demise of the Soviet Union.

Members of the International Institute for Applied Systems Analysis (IIASA) and, more specifically, the Economic Transition and Integration (ETI) Project recognized the importance of this matter and welcomed the proposal of then USSR Deputy Prime Minister Laverov to initiate collaborative work with the USSR State Committee for Science and Technology and the USSR Academy of Sciences on the topic of Research and Development Management in the Transition to a Market Economy. Due to its relevance, this activity has persevered and endured all the political changes since its inception in late 1990. In fact, our ties have become more direct to top-level decision-makers and scholars as numerous conference and project participants and colleagues now hold high offices in the Russian Ministry for Science, Higher Education, and Technical Policy, the Ministry for Foreign Economic Relations, the Committee for the Management of State Property, the Russian Academy of Sciences, and influential academic institutes. Several of them are represented in this volume with valuable contributions.

This collaborative paper (CP) is a collection of some of the most revealing, interesting, instructive, and insightful contributions of authors who participated in the three conferences of this ETI Activity held between November 1990 and March 1992. In the words of then co-leader of this IIASA activity, Prof. Richard Levin from Yale University (USA), this volume contains papers by Russians that present the boldest and most virtuous statements regarding reform of post-Soviet R&D management yet to be publicized in the West (not to mention the dispersion of these ideas among Russian colleagues). In addition, the CP contains studies revealing previously unpublished non-official data (i.e., not provided by Goskomstat), results of Russian research documenting a general willingness of R&D managers to accept a more market oriented style of operation, the most accurate accounts of the first stages of changes in Russian science administration policy reported anywhere, accounts of renown Western science policy experts of market economic experiences with R&D management and possible lessons for the evolving systems in the post-Soviet region, and much more.

Considerable careful effort has gone into the selection and revision of the papers in order to produce a volume rich in quantity and quality of information regarding the R&D sector in transition from a planned to a market economic system. In fact, much of the material as well as the style and openness with which it is discussed will be new to readers, particularly those in the West. Thus, this CP acquires great significance as useful background information for future study concerning this field of activity at IIASA and elsewhere.

These papers draw our attention to several principles basic to the development and preservation of R&D in the transition to a market economy in Russia.

1. Basic scientific research will need continued support by the State, both in the transition period and beyond.
2. Most applied research and development should eventually be financed by the private sector, with the exception of specific programs that correspond to national purposes.
3. The lack of adequate demand for all forms of research is a major problem of the transition. During this period, there are serious risks with respect to the potential destruction of the R&D sector while enterprises still search for its true value. Consequently, there may well be a need for transitional subsidies.

With respect to basic research, the source of financing is not a transitional issue. While organizational changes in the structure of Russian research are needed, a major change in the source of funding (i.e., the government) is not. In the case of applied R&D, care must be taken that transitional subsidies do not distort the choice of organizational form.

4. International experience has shown that a diversity of organizational forms is desirable. The market will provide adequate guidance concerning the organizational forms that make the most sense. Experience in market economies reveal that a variety of such forms can co-exist (i.e., State laboratories, free-standing contract private research laboratories, in-house proprietary laboratories). The predominant organizational form, the one most important to hamper, is the in-house, proprietary form done within large corporations. Nevertheless, this is no reason to maintain the enormous R&D groups and laboratories of the former Soviet science community. The spin-off of scientists to private industry should be encouraged, not discouraged.
5. Finally, there is a fundamental dependence of science and technology reform on the success of the overall legal and economic reform. As for the overall economic transition, one can only reemphasize the crucial importance of free, equilibrium prices for evaluating the profitability and usefulness of various alternative research and development projects and technologies. This means, of course, that demonopolization is required in order to have competition drive R&D investment (though mobility of factor inputs such as labor, capital, and material resources is a prerequisite). This will result in an increase of absolute R&D spending and will stimulate the market selection process to work more smoothly and efficiently.

The Russian Federation faces a long road ahead in the attempt to achieve the optimal organization of R&D management in the transition to a market economy and beyond. Despite the wealth of resources or possibly because of them, the conversion of the system inherited from the Soviet Union will not be easy or inexpensive. Nevertheless, it should be remembered that R&D systems in Western market economies were not born overnight and that, in fact, they are subject to continual modifications depending on the corresponding economic situation. In this sense, Western economies and their science policies are also in transition.

The ETI R&D Activity is dedicated to working closely with its international collaborators in search for sensible alternatives that can be of use to relevant policy-makers and simultaneously make a contribution to academic research. This collaborative paper is evidence of the possibility of such a constructive partnership.

P. de Jánosi *V.A. Mikhailov*

Introduction

The adjustment of R&D management to the new economic situation has become one of the key problems for the former centrally planned countries in their attempt at a successful transition to a market economy. Scientific and technical development is an instrumental key source of modern economic growth. The destruction of the accumulated R&D resources during the transition process can undermine secure economic growth and recovery in these countries. This fact is especially significant for Russia with its enormous scientific and technical potential which was indispensable in order to maintain the military strategic parity during the cold war and which still maintains a leading role in some high technological fields of the world economy.

Now, during the transition to the market economy, the R&D sector in Russia undergoes a radical transformation. This transformation is mostly spontaneous and creates not only the growth of market forms of R&D activity, but also the spontaneous deterioration of viable research structures and scientific schools.

In order to set up a proper scenario of R&D reorganization in Russia, to create market institutions of innovation activity, and to construct a long-range orientation, state support of fundamental and applied research can not be carried out based only on a simple imitation of Western experience. A successful solution to this urgent practical problem demands a complex of interdisciplinary and international research to be conducted by specialists from different countries. The necessity of such a research program is urged on by the difficulties of R&D transformation, as well as by the unintelligibility of many theoretical questions. The organization of R&D management and the combination of the state and private forms in this process are still neglected issues of economic theory.

Hence, on the initiative of the USSR State Committee for Science and Technology (now the Ministry of Science, Higher Education and Technology Policy of the Russian Federation), the Russian Academy of Sciences, the

International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria, together with the Central Economic and Mathematical Institute (CEMI) and the International Center for Research into Economic Transformation (ICRET), an international research Project under the title "R&D Management in the Transition to a Market Economy" was created in 1991.

The main goals of the Project include the study of international experiences of R&D management and elaboration of proposals on the reorganization of science and technology development management in the former centrally planned countries, and primarily in Russia. The proposed research can be divided according to three main themes:

- to study conditions, tendencies and problems of the reorganization of the scientific and industrial complex in the state and private sector during the economic transition period;
- to study international experience of industrial R&D management during the transition to a market economy;
- to carry out scenarios of R&D reorganization and restructuring in Russia and other post-communist countries.

During the first year of the Project, several studies have been completed. The most important of them were dealing with intellectual property rights issues; elaboration of proposals on the reorganization process; research institutes and laboratories behavior under the conditions of economic reform.

By now, the Project organized two international conferences: *Research and Development Management in the Transition to a Market Economy,* Moscow, July 1991; and *Industrial R&D Management in the Transition to a Market Economy,* Laxenburg, Austria, March 1992; as well as a Workshop on Patent Legislation and Protection of Intellectual Property, New Haven, USA, February 1992.

This book includes papers, presented at these three meetings, which summarize the results of studies carried out within the Project. The authors deserve much credit for their efforts to describe the rapidly changing events that constitute the transition to a market economy in the former Soviet Union. Their analysis reveals that practices and policies are often incomplete, contradictory, or insufficient. All the more reason to appreciate their ability to formulate and present the situation in a manner that significantly enhances our existing knowledge and provides valuable insight for the *rhyme and reason* behind Soviet and now Russian R&D policy.

In addition to the authors, a large number of individuals from the collaborating institutions deserve our gratitude for their administrative and technical support. With respect to the completion of this volume, we especially appreciate the excellent secretarial assistance of Sabine Malek from the Economic Transition and Integration Project at IIASA, who tirelessly and accurately converted our illegible editorial revisions into a worthy product. Of course, all these organizations and the individuals who helped us are not responsible for the views expressed here, which are solely those of the authors.

The editors thank all those who have made our work possible.

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Part I

R&D and Technology Policy

Soviet R&D Resources: Basic Characteristics

L. Gokhberg[1] *and L. Mindely*[2]

Introduction

The management of research and development (R&D) cannot be reorganized as part of the transition from a centrally planned economy to a market economy without a comprehensive evaluation of the resources allocated for research and development activities. Until recently, only a very limited set of R&D indicators were in use. In 1989, these official statistics revealed that 4.2 million people were employed in the *"Science and scientific services"* sector, including 1.5 million of scientific and tutorial staff; and that R&D expenditures were 43.6 million rubles.

However, such data neither characterize the real situation regarding the true extent, structure and quality of resources invested in Soviet science, nor do they permit a comparison of scientific performance with the leading industrially developed nations. Thus, radical restructuring of statistics related to scientific research and development becomes a crucial component in reforming the management of R&D.

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Statistics for Science in the USSR: Past Situation and Future Prospects

Collection and analysis of statistics representing scientific resources and performance was one of the youngest branches of Soviet socio-economic study to emerge in the last years. Initially, it developed in accordance with the existing administrative-bureaucratic practice of science management, planning and funding, and was mostly based on gross indicators oriented towards information support for the decision-making bodies. However, these statistics were ill-suited for analytical studies. No comprehensive set of indicators concerning R&D resources was developed; therefore, the data was incompatible because of the methodological differences in the calculation of indicators and the methods of data collection and processing in different economic sectors.

In the late 1980s and early 1990s, statistics for science in the USSR underwent serious transformations. New methodology for data collection and a new set of indicators were to be implemented. Re-shaping the institutional structure of science management in connection with the changes in the composition of ministries and departments, the formation of new, horizontal structures (interindustry state-owned amalgamations, corporations, associations, consortia etc.), and the growing independence of the union republics required a transfer from the departmental (ministry-oriented) profile of the statistical information to sector and territorial profiles.

During 1989 and 1990, considerable work was done in the restructuring the methodology and practices governing R&D statistics. Indicators widely-used in the industrially developed countries such as the number of specialists employed in the R&D, the proportion of expenditures for science in the gross national product, and others were introduced into the Soviet statistical practice. Starting in 1989, annual statistical information regarding R&D resources was collected in accordance with the standard reporting form submitted by all the country's organizations and enterprises where R&D were being performed.

Labor Resources of Science and Research

For some time already, the published official statistics revealed that one fourth of all the scientists in the world worked in the USSR. However, this data seems unrealistic. For instance, from 1975 to 1985 the number of scientists and engineers employed in the field of R&D in the USA increased by 85%, while in the USSR the number of scientific and scientific-tutorial personnel grew by only 22%. Misrepresentation of the numbers of Soviet R&D staff was caused by the methodology of statistical data recording.

The number of people employed in the sector *"Science and scientific services"* was only recorded for scientific organizations with a separate financial balance. It excludes research, design, and experimental divisions of industrial enterprises (so-called *"factory"* sector of science), as well as a number of higher education institutions and other organizations. According to our calculations, this sector actually accounted for 71% of the overall number of employees in scientific organizations, 74% of the total volume of work which they did independently, and 79% of the value of fixed assets in the scientific sector in 1989. Thus, one fourth of Soviet scientific potential is concentrated outside of this sector (1, p. 116); namely, in the formal *science and scientific services* sector.

The category of scientific workers (on the basis of a scientific degree, place of employment, etc.) formally included all scientific-tutorial personnel of higher education institutions notwithstanding their actual participation in scientific research, and persons with a degree but not directly engaged in R&D (administrative and management personnel of industry, agriculture and other sectors; art workers teaching at the higher education institutions). Yet, post-graduates and specialists employed in a considerable part of the design organizations and industrial enterprises were left out.

In 1989, all the various forms of scientific organizations employed almost 3.3 million people. According to the authors' estimates, approximately 2.1 million (63.5%) were engaged in R&D activities (Table 1). The highest degree of qualification was in academic sector: while its share of the total number of researchers and technicians was only 12%, almost 52% had an advanced (Ph.D.) degree (Table 2). The industrial sector employed 76.8% of all researchers with higher education, 47% of which had doctor and candidate of science degrees and, 88.7% of all technicians. The proportion of the latter is almost ten times the level in the academic science.

Estimates (see References M.L. Gokhberg (1990), Gokhberg, Maslennikov, and Mindely (1990)) reveal that the numerical superiority of the USSR over the USA in terms of absolute numbers of specialists engaged in R&D, which existed in the early 1980s, was replaced by the parity between the two countries by the mid-1980s (Table 3). Furthermore by 1988/1989, the rapid increase of employment in US science resulted in the number of R&D specialists in the USA to be 1.2 times more than that in the USSR. If we include American scientists and engineers engaged in consulting, this gap grows to 1.4 times.

During the second half of the 1980s, Soviet growth in scientific personnel practically stopped: from 1985 to 1988 the increase was only 3.5%. During this period the number of the specialists engaged in R&D increased by only 0.3%, while it decreased by 6.1% in the designing organizations. The expansion of scientific employment primarily occurred at the industrial enterprises and research divisions of higher education institutions. So, by 1990, each ten thousand people employed in the Soviet national economy included 128 specialists engaged in R&D versus 152 in the USA.

The higher education sector exhibited declining growth in the 1980s. In 1985, there were 894 higher education institutions in the USSR: in comparison, the USA had 2,029. Even though the Soviet number climbed to 904 in 1990, the gap essentially remained unchanged. The training of specialists in the leading capitalist countries is secured with considerable financial support of the state, local authorities, and corporations. Average expenses for one student in the USA amount to US$ 3,800 annually, while expenditures per student in the Soviet Union amount to approximately one thousand rubles or US$ 1,800 at the present official exchange rate (1, p. 193–194). This affects the level of technical support of the educational process and scientific research at the higher education institutions, especially the remuneration of professors and teachers, quality of training, and qualification level of graduates.

In 1985, there were 184 undergraduate students and 3 post-graduate students in the USSR per 10,000 residents, while the American higher education system featured a ratio of 322 to 10 respectively. The last two decades, in general, were characterized by the absolute decrease of the number of post-graduate students in the USSR. Between 1970 and 1989 this has decreased by 4.1%, the annual number of those completing post-graduate declining further.[3]

Irrespective of the fact that the number of post-graduate students has remained practically unchanged (95–100 thousand). During this period, the number of scientists has increased more than 1.6 times and the number of those with a candidate's degree 2.2 times. The number of post-graduates annually finishing their studies in 1970 was equivalent to 2.8% of the total number of scientific workers and 11.5% of those with a candidate's degree.

[3]For comparison, it is interesting to note that the number of post-graduate students in the USA in 1980–1988 has increased by 16.9%.

In 1988, these figures were 1.6% and 5.0% respectively. The falling absolute number of post-graduate students was accompanied by a set of negative changes in post-graduate education (such as insufficient relevance, lack of novelty and practical usefulness of dissertations, duplication of subjects, and so on).

The quantitative decrease of R&D staff was accompanied by a deterioration in quality; particularly with the progression in the age structure (see Table 4). Among the scholars with scientific degrees in the USSR senior persons predominate: over 51 years of age among the Ph.Ds, 41 to 60 years among the candidates of science, and both their proportions continued to increase. In comparison, the majority of American Ph.Ds was in the 36–50 years age group, though the proportion of those older than 50 increased somewhat between 1981 and 1985. Still, the proportion of persons less than 40 years old among the American Ph.Ds was higher than among Soviet candidates and doctors of science by 8.1 and 31.1 points respectively in 1985.

The structure of the scientific personnel (SP) changed very slowly and did not satisfy the requirements of technological change (Table 5). Contrary to world-wide trends, the share of specialists in the field of mathematics, computer science, and physics has decreased during 1976–1986 in the USSR.

In sharp contrast, these branches of science exhibited the highest growth rates of employment in the USA during some time interval. A clear illustration of this trend is revealed by the numbers of scientists in the fields of computer and mathematical sciences; both increased 4.7 and 2.7 times respectively. In spite of a certain decrease in the share of the life sciences in the USA, the absolute numbers of biologists, medical scientists, and agronomists almost doubled while their growth rate has slowed significantly in the USSR. A particularly large gap exists in psychological sciences: 1976 statistics show that the proportion of scientific personnel in this filed (as a percentage of the total SP employed) is 16 times higher in the USA than the corresponding figure in the Soviet Union. In fact, the absolute number of psychological scientists in the USSR was 38 times smaller than in USA. In 1986, these gaps increased to 18 and 58 times respectively. In the United States, as opposed to the USSR, the share of technical sciences has diminished somewhat, while their structure has changed in favor of aeronautics, chemical technologies, electronics, and material-studying science.

Material and Technical Resources

In the USSR, the material and technical resources utilized for R&D purposes include buildings, facilities, machinery, equipment, materials, reagents, and so forth. Inferior standards of R&D equipment, insufficient supply of advanced instruments, lack of premises, and lack of experimental base hinder the development of fundamental research, and the creation of radically new technology and equipment.

Only during the last years did the material and technical base of the scientific sector become the subject of a comprehensive and systematic study. Indicators for statistical reporting provided only the most general characteristics of scientific organizations' fixed assets and did not describe, to any precise detail, the movement, structure, condition and utilization of technical means and their quality.

A 1989 survey concerning the resources of research, designing, project-designing, and technological organizations, and higher education institutions finally provided some statistical data. The survey encompassed 5,400 research and designing organizations and higher education institutions. The amount of fixed assets of the research (designing) activity as of 1 June 1989, exceeded 36.5 billion rubles which, according to our calculations, was about 90% of the value of the total fixed assets for science (together with those owned by industrial enterprises). About 60% of these were concentrated in the industrial science organizations, 22% in the academic sector, and 18% in the higher education institutions. A considerable part of the fixed assets of industrial science was concentrated in the scientific organizations of the machine-building, chemical and forestry, agroindustrial, and energy and fuel complexes. The analysis regarding the distribution of the fixed assets by branch of science demonstrated that half were the property of the technical sciences, almost 20% belonged to the natural sciences, the agricultural and medical sciences account for 4%, and the social and humanitarian sciences for only 2%.

The overall value of machinery and equipment in the scientific sector was 22.3 billion rubles; together with the experimental bases (factories, plants, units) of the scientific organizations it increased to 24 billion rubles. Machinery and equipment dominated the fixed assets of science within the technological structure (refer to Table 6).

The analysis of the latter also demonstrated the deficiencies regarding the equipment in scientific organizations with special requirements for research machinery. Namely, the share of instruments and laboratory equipment accounted for only one fifth of the total value of fixed assets. In the branch and higher education sectors it is even lower. Furthermore, in experimental production the general purpose production equipment accounted for 69% of total fixed asset value, while the proportion of specialized equipment for experimentation constituted only 12%.

In order to successfully perform standard research and even more so in priority areas is the availability of usually expensive, sophisticated scientific instruments and equipment (electronic microscopes, spectrometers, chromatographs, X-ray machines, ultra-centrifuges etc.) crucial. However, their average share in the total value of machinery and equipment of scientific organizations was 7.5%; the academic sector privileged at 10.4%, while higher education and branch sectors were forced to make do with 6,5% and 6.7% respectively. The absolute majority of such equipment (93%) was concentrated in the fields of technical, natural, and medical sciences. However, even there, the proportion in the total value of machinery and equipment was not too impressive: just 5.7%, 12.8% and 18.5%, respectively. In addition, the level of specialization of computing equipment used in scientific organizations was rather low. On average, 46% of the total value of computing equipment were accounted for by computing centers and computers based on general-purpose processors. A very similar situation exists in the natural (48.8%) and technical (45.6%) sciences, while the situation in the field of medicine is somewhat better (33.9%).

The aggregate characteristics regarding the viability and potential of a scientific organization are usually described using indicators such as capital-labor ratio and equipment-labor ratio. The former is calculated as a ratio between the volume of fixed assets of science and the number of scientific employees and the latter as a ratio between the value of machinery and equipment and the number of employees engaged in the R&D. From the point of view of analysis, the supply of instruments and computers available to scientists is of special interest.

According to our calculations, the capital-labor ratio in Soviet science amounted to 12,800 rubles in 1989 (Table 7); 1.75 times lower than in the industrial sector.

The supply of technical means for fundamental research on a priority basis caused such indicators as capital-labor ratios or other ratios involving specific types of assets for the academic science to be twice as high on average as in other sectors. The capital-labor ratio in scientific organizations under the jurisdiction of the mining industry is about 7,000 to 9,000 rubles; in the ministries of the machine-building complex the figure lies between 7,000 and

11,000 rubles, which is still somewhat lower than the average. Equipment-labor ratio in the scientific experimental base was only 5,500 rubles (3 times lower than that in industry). Obviously, such a situation did not promote the quality of developments, samples of new technology, and industrial products and, consequently, affected the condition of the material and technical base of the whole national economy.

The instruments-labor ratio and computer-labor ratio are 3 times lower than the capital-labor ratio in science. The highest instrument-labor ratio was registered in natural (9,900 rubles) and medical (8,200 rubles) sciences. This indicator was recorded to have the values of 3,200 and 2,900 rubles in the agricultural and technical sciences respectively. It reached a minimum in the field of humanitarian and social sciences, and information and information systems (700 to 1,200 rubles). However, this is influenced, to a certain degree, by the unique feature of the latter research areas. In the field of informatics, the computer-labor ratio (9,800 rubles) was 2.4 times higher than the average across all sectors; it's level is lower in the social (5,400 rubles), natural (5,100), and technical (4,100) sciences. Among the less-computerized branches of research are the medical (2,000), humanitarian (1,700), and agricultural (1,100) sciences. Our estimates indicate that, on average, there were no more than 20 personal computers (PCs) per 1000 Soviet scientists. In certain ministries and departments this figure was actually even less than 5. All these determinants demonstrated a cross inconsistency between the technological structure of fixed assets and the true needs of modern science.

An ineffective replacement policy with respect to scientific fixed assets resulted in the accumulation of a vast amount of physically and technically obsolete equipment in the scientific organizations. As shown in Table 8, 20.8% of the machinery and equipment in scientific organizations were more than 10 years old including one fourth of them older than 20 years. The proportion of scientific instruments and equipment less than five years old amounted to 44.2% of the total volume of machinery and equipment in general, while the proportion over 10 years of.age accounts for 25.1%. The age characteristics of the machinery and equipment belonging to independent experimental bases are even worse: in 1989, 32% of the equipment was older than 10 years. According to our calculations, the proportion of the most modern equipment (up to 2 years of age) in the Soviet science was 1.5 to 2 times lower than in the USA (1, p. 205).

The system of providing resources for scientific activity did not stimulate rapid breakthroughs in the priority directions of development. Thus, in the case of biotechnology, 50% of the R&D institutes did not have experimental facilities, and 35% did not even have their own. The volume of fixed assets and current capital of these organizations were, on average, 1.5 and 1.3 times lower than those of the research institutions specializing in natural sciences in general. It is significant that 20% of the equipment in biotechnological research institutions were more than 10 years old and that half of the high-cost equipment exhibited a technical level which was lower than the best international standards. Overall, only a small percentage of such biotechnological equipment (0.4%) is more advanced than the best world standards. The proportion of Soviet high-cost machinery and equipment (as a percentage of the total value) above or equal to that of the best world technical standards varied depending on the research field as follows: only 14% in biotechnology, 21% in machine-building related research, management processes and mechanics, and 24% in general physics and astronomy, informatics, computers and automatization. This indicator was highest in the field of biochemistry, biophysics, general and technical problems of power engineering (35%), physical chemistry and technology of non-organic materials (41%); yet, even these levels were clearly insufficient in order to achieve advanced scientific results. According to the existing estimates, the overall demand for scientific instruments in the USSR is only 20–25% satisfied; for a number of important groups a mere 10% of demand is covered.

This has been a very brief review, of the survey results concerning the Soviet material and technical base of science in 1989. In future, such surveys should take place more often and at regular intervals. A systematic approach to the statistical analysis of scientific resources additionally envisages a comprehensive system of regularly conducted, subject-specific surveys of the following issues: level of computerization in scientific activity, experimental and pilot facilities, production and social infrastructure, material and technical supply of different R&D sectors, and orientation of scientific research.

Financial Resources for R&D

The overall amount of science related expenditures in the USSR was calculated as the sum of current expenses and capital investments in the construction of facilities connected with the development of science.[4] The former

[4]Capital construction performed by the scientific organizations did not include housing, cultural and consumer service installations, and other structures that were not connected with the scientific activity as such.

includes volume of work performed by independent scientific organizations as well as by divisions of enterprises, scientific-production and production associations, higher education institutions and other business entities. The latter refers to scientific organizations, their experimental and production bases, independent laboratories, meteorological service installations, botanical and experimental gardens, wild-life preserves, and so forth.

In the calculations performed in order to determine R&D expenditures the work fulfilled on a contractual basis for enterprises and organizations was recorded in both the executing agencies category (which place orders) and the research contractors category. The result was a duplication in the calculation of costs. The proportion of such double count reached almost one third of the overall value of R&D expenditures by our estimates. In addition, allocations for science included certain types of expenditures which are generally not included into the scientific budget of most major R&D nations (expenditures of museums, libraries, etc.). At the same time such calculations tended to omit certain types of expenses. These included investments in scientific divisions of industrial enterprises and higher education institutions, and depreciation payments for the renovation of their fixed assets; costs of maintenance of research and experimental facilities; costs of R&D done by the faculty of higher education institutions; training and upgrading the qualification level of the scientific personnel of these institutions financed from the state budget item "Education;" and, volume of work conducted by scientific and technological cooperatives. Nevertheless, even the most conservative estimates indicate that the amount of duplicated costs was more than twice the total amount of expenses omitted.

Our calculations permitted us to adjust the official statistical data on science expenditures by eliminating double-counted expenses (Table 9). In 1989, total expenditures on science (including that performed by the scientific and technological cooperatives) amounted to approximately 35 billion rubles. In contrast, R&D expenditures between 1987 and 1989 in the USA (including investments into science, costs of research in humanitarian sciences and at the foreign branches of American companies which the US statistics do not take into account) increased from US$ 135.1 billion to US$ 151.2 billion (1, p. 202). The 1988 science expenditures to national income ratio in the USSR was 4.2% as compared to 6.2% in the USA.

Throughout the past decades in the Soviet Union, the so-called "residual" principle was predominant as the method to allocate funds for the development of science. In regard to the structure of expenditures in the state budget of the USSR, science expenditures traditionally held one of the last places: in 1970–1989 their share was consistently between 3.4% and 4.5%. In the United States, as in a number of other leading capitalist countries, the state expenditures for science are growing more rapidly in comparison with the total budget allocations. In 1989, 7.9% of the US federal budget funds were allocated for scientific R&D. This proportion was expected to be increased to 8,6% in 1991 (7, p. 5).

As part of the overall R&D budget, the costs of defense-oriented R&D accounted for a considerable part of the total science expenditures in both nations. In 1989, the Soviets spent 15.3 billion rubles for these purposes, while the Americans spent US$ 37.5 billion or, 71% and 62%, respectively, of state allocations for science. In our country the share of science in the military expenditures amount to almost 20%; in the USA the share is 13%.[5]

Considering the gap in the absolute level of funding between the two super powers, it becomes evident that the Soviet state spent at least 4.5 times less than the American for civilian science (2, p. 55). World experience demonstrates that countries with relatively low levels of military R&D expenditures (in particular the former FRG and Japan), undergo more rapid scientific and technological development, achieve stable economic growth and improve their competitiveness in the world market. As implied by this example, it is necessary to speed up the conversion of the defense complex organizations in the Soviet Union, and more fully utilize their potential for solutions of the problems facing the national economy. However, the share of budget allocations for civilian science as a percentage of total R&D expenditures has been decreasing over time: from 54.7% in 1970 to 44.8% in 1988. In 1989 it dropped by half to 23.2%. In the USA, this value amounted to 46.7% in 1989.

The growing decentralization of the science funding, characteristic for its development during the late 1980s in the USSR, together with continually worsening state budge deficit may bring about the further serious deterioration of resource provision for fundamental science and the priority fields of scientific research.

The share of fundamental research in general science expenditure of the Soviet Union was lower than in the leading capitalist countries. It amounted to only 7.2%, while in Great Britain it was 12%, Japan had 13%, the USA equaled 14%, the former FRG share was 18%, and France boasted a high of 20%.

[5]Source: (1, p. 203). Calculated on the basis of the data of: (6,8,9).

The main part of the Soviet fundamental research (about 61.5% of total volume) was done in the academic sector. Here, the proportion of such studies in the structure of R&D expenditures was highest in comparison with the other sectors of science (Table 10). In the factory and industrial branch science sectors development was predominant, and the share of fundamental research was extremely low. The higher education institutions accounted for only one-seventh of the total volume of R&D. In conjunction with the insufficient level of development of fundamental research in the branch and even higher education sectors, it became difficult to justify the high aggregate percentage of applied research and development in the academic science (62.5%). The situation with respect to very low share of fundamental research (based on R&D expenditures) in the fields of technical sciences and informatics 5% and 9% respectively was particularly disturbing.

A comparative analysis of the distribution of R&D expenditures in the USSR and the USA (Table 11) demonstrates the disproportions in the disciplinary structure of Soviet science due to its strong technocratic orientation. The technical sciences in the USSR accounted for 75% of the total amount of R&D expenditures and the shares of other branches of science were lower than in USA. The gap in the field of medical and natural science research was especially large despite the fact that these very branches could provide effective solutions to health-care and environmental problems, for the utilization of natural riches, and for the creation of equipment, technology, and materials which are capable of revolutionizing production.

Development of market relationships began to assist in the formation of the non-state (cooperative-public) R&D sector and promoted the gradual increase of its role in the financing of R&D. In its early stages during the 1980s, this sector was comprised of mostly various small organizations. Their activities included R&D, implementation of innovations, information and computing, consulting, intermediary and other services, and copying of product and process developments. These activities were (and continue to be) organized on contractual basis. The specialists from the academic, branch science, and higher education institutions are invited to fulfill certain work based on the orders from enterprises and organizations.

In 1989, there were approximately 4,500 research and designing organizations, 528 scientific and production associations in industry, 23 intersectoral scientific and technological complexes, and 904 higher education institutions in the USSR. R&D was also performed by 720 enterprises and production associations, more than one thousand designing organizations in the field of construction, and other institutions. Since 1987 new forms of R&D institutions were established. These essentially constituted the emerging and growing non-state R&D sector. The various forms included about 500 economically independent youth centers for scientific and technological activity (YCSTA) and numerous innovation small enterprises (centers). The latter were established within the USSR Academy of Sciences, branch institutes, industrial enterprises within the system of the Union of the Scientific and Engineering Societies (USES) of the USSR, and under the auspices of the All-Union Society of Inventors and Rationalizers (ASIR).

The volume of the scientific and technological products of the non-state scientific sector continuously expanded: while it accounted for less than one tenth of one per cent of the total (gross) amount of Soviet science expenditures in 1987, this value rose to 3.2% in 1988 and to almost 11% in 1989 (Table 12).

The highest growth rate was registered by the scientific and technological (S&T) cooperatives.[6] Their number has reached 2,100 by the end of 1988 and grew five times during 1989. By the beginning of 1990, they employed 321,500 people, their volume of products (services) sold exceeded 3.15 billion rubles (Table 13). According to our estimates, the number of employees per scientific and technological cooperative is about 10, while approximately 20 more work there part-time.

High flexibility, shorter completion time for projects, and the desire to satisfy clients' requirements to a maximum degree made the S&T cooperatives increasingly competitive relative to the state organizations, further eroding the monopolization of individual fields of the R&D. A considerable portion of their activity consisted of software development (40%), information services, consulting and economic research (22%), project preparation (13%), and search and repair of equipment (10%). The orientation of S&T cooperatives activities primarily towards labor-intensive services, and many from fundamental research and science-intensive production are, to a large degree, explained by the difficulties with investments, material and technical supplies, rigid taxation, and the desire to avoid the high business risks associated with the conditions of an unstable economic situation.

Joint ventures with foreign companies became a new institutional form of development, production, and dissemination of advanced types of equipment and technology. Their establishment facilitated the implementation of so-

[6]In the statistics, scientific and technological cooperatives include research, designing, innovation-implementing, cooperatives as well as software developing and information service cooperatives.

phisticated foreign scientific products, Western management experience, and material and financial resources for the development of the science-intensive production in the Soviet Union. However, out of 1274 joint ventures registered in the USSR as of 1 January 1990, only 307 were actually operational. Only 22 (7%) of these were active in the R&D sector. The economic and practical risks made the majority of the foreign investors cautious and inclined to avoid large long-term investments. The average amount of a foreign partner's contribution between 1987 and 1989 decreased from 2,4 million to less than 1 million rubles.

In order to generate reliable and valuable statistical information concerning the USSR's R&D resources price deflation is necessary. In 1989, future inflation in this sector was to reach 40–50%.

Conclusion

The analysis undertaken in this paper only touched upon the most general issues related to the evaluation of resources in Soviet science. Proposals drafted regarding the reorganization of science and technology management under the conditions of a transition to a market economy, which is the main objective of the present international project, should be based upon comprehensive statistical information characterizing all aspects of the development of science in the USSR. For this purpose, it would be advisable to create a working group within the framework of this project that specializes in the reorganization of scientific statistics in the USSR. These should adhere more closely to the international standards, and be more frequently presented in intercountry comparisons. The above mentioned group could coordinate efforts connected with the improvement of the methodological and practical basis of the scientific statistics, the organization of special statistical surveys, expert evaluation of the reliability of statistical data, and its analysis.

Table 1. The structure of Soviet scientific personnel by level of qualification, 1989 (%).[a]

	R&D producing All Sectors	Academic Sector	Higher Education Sector	Branch Sector[b]
Persons employed in scientific organizations	100.0	100.0	100.0	100.0
of which:				
Supporting personnel	22.0	22.0	15.0	22.7
Specialists engaged in R&D	63.5	63.4	75.4	62.4
of which:				
degree holders	11.9	31.7	27.9	7.1
with:				
higher education	81.8	89.1	91.7	79.6
special secondary education	18.2	10.9	8.3	20.4

[a]Source: (1, p. 135).

[b]Including research and design divisions of industrial enterprises and designing organization in the field of construction.

Table 2. Distribution of Soviet scientific personnel by branches of industry, 1989 (%).[a]

	R&D producing All Sectors	Academic Sector	Higher Education Sector	Industrial Sector[b]
Total Persons employed in scientific organizations	100.0	12.0	7.6	80.4
of which:				
Supporting personnel	100.0	12.0	5.2	82.8
Specialists engaged in R&D	100.0	12.0	9.1	79.0
of which:				
degree holders	100.0	31.8	21.2	47.0
with:				
higher education	100.0	13.0	10.2	76.8
special secondary education	100.0	7.2	4.1	88.7

[a]Source: (1,p. 136).

[b]Including research and design divisions of industrial enterprises and designing organizations in the field of construction.

Table 3. Number of specialists engaged in R&D in the Soviet Union and the United States (thousands).

	1981		1986		1989	
	USSR	USA	USSR	USA	USSR	USA[a]
Specialists engaged in R&D	1434.2	1258.7	1599.4	1725.5 1977.6[b]	1654.6	2026.9 2318.4[b]

[a]1988.
[b]Including consulting personnel.

Table 4. Age structure of scientific workers with highest qualifications in the USSR and the USA (as of year's beginning, %).[a]

	USSR				USA	
	Doctors of science		Candidates of science		Ph.D's	
	1983	1988	1983	1988	1981	1985
Total	100.0	100.0	100.0	100.0	100.0	100.0
up to 35			10.0	10.0	17.3	13.6
36-40	2.0	2.0	13.0	15.0	32.4	19.5
41-50	23.0	20.0	47.0	40.0	32.5	37.2
51-60	42.0	41.0	23.0	27.0	19.3	19.5
61 and above	33.0	37.0	7.0	8.0	8.5	10.2

[a]Compiled from: (3, p. 22; 4, p. 86; 5, p. 76)

Table 5. Distribution of scientific personnel by branch of science, USSR and USA (as of year's beginning, %).

	USSR[a]		USA[b]	
	1976	1986	1976	1986
Total	100.0	100.0	100.0	100.0
Mathematical, computer, and physical sciences	15.0	14.6	15.3	21.2
Life sciences	12.9	12.9	9.2	8.9
Environmental sciences	2.8	2.7	2.4	2.4
Technical sciences	48.7	49.5	58.8	52.7
Psychology	0.3	0.3	4.8	5.5
Social and humanitarian sciences	20.3	20.2	9.5	9.3

[a]Scientific and scientific-pedagogical personnel employed in the economy.
[b]Scientists and engineers employed in the national economy.

Table 6. Technological structure of fixed assets utilized for scientific purposes (%).

		Sectors of Science		
	Total	Academic	Branch	Higher Education
Fixed Assets of scientific organizations	100.0	100.0	100.0	100.0
including:				
Machinery & equipment	61.1	62.8	62.9	53.3
including:				
Instruments & laboratory equipment	20.5	26.2	18.7	19.7
Computers	21.1	15.6	24.0	18.3

Source: (1, p. 150.)

Table 7. Capital-labor ratio in science (thousand rubles/unit labor).

	Sectors				
	Total	Academic	Branch	Higher Education	Factory
Capital-Labor Ratio in the main line of activity	12.8	22.3	11.3	12.8	12.2
Equipment-Labor Ratio (per specialists engaged in R&D)	11.5	21.0	10.3	9.6	10.6
Instrument-Labor Ratio (per scientist)	4.0	8.4	3.0	5.3	-
Computer-Labor Ratio (per scientist)	4.1	5.0	3.9	4.9	-

Source: (1,p. 151).

Table 8. Age structure of machinery and equipment in scientific organizations (%).

	1–2 years	3–5 years	6–10 years	11–20 years	over 20 years
Machinery and equipment of scientific organizations	21.9	28.1	29.2	15.7	5.1
including:					
Instruments and laboratory equipment	18.1	26.1	30.7	19.4	5.7
Computers	30.0	32.7	27.7	8.5	1.1
Machinery and equipment of independent experimental bases	16.1	23.9	28.0	23.3	8.7

Source: (1, p. 157).

Table 9. Science expenditures in the USSR.

	Estimates			USSR State Committee on Statistics' data		
	1987	1988	1989	1987	1988	1989
Bln. Rbls.	24	26	32	32.8	37.8	43.6
Percentage of						
National income	4.1	4.2	4.9	5.5	6.0	6.6
Gross National Product	2.9	3.0	3.5	4.0	4.3	4.7

Sources: (1, p. 164) and (6, p. 290).

Table 10. Structure of R&D expenditures by sector and type, 1989 (%).

	Total	Fundamental Research	Applied Research	Development
R&D expenditures	100	7.2	33.2	59.6
Sectors of science:				
academic	100	37.5	37.6	24.9
branch	100	2.5	31.7	65.8
higher education	100	13.7	60.4	25.9
factory	100	0.7	20.7	78.6

Source: (1, p. 167).

Table 11. Distribution of scientific research expenditures in the USSR and the USA by branch of science, 1988 (%).

	USSR	USA
Total	100.0	100.0
including the following branches:		
natural	16.0	29.7
social and humanitarian	4.1	6.0
agricultural	2.4	3.9
medical	2.2	10.2
technical	75.3	50.2

Source: (1, p. 205).

Table 12. Volume of scientific and technological products sold by alternative institutional forms of R&D (billion rubles).

	1987	1988	1989
Volume of the scientific and technological products sold	0.03	1.2	4.7
including:			
by the YCSTA	0.022	0.85	1.1
by temporary creative teams with the ASIR councils	-	0.07	0.1
be temporary creative teams with the USES	-	0.12	0.35
by scientific and technological cooperatives	0.008	0.17	3.15

Table 13. Main indicators of scientific and technological cooperatives (as of year's end).

	1988	1989
Number of operating cooperatives	2,100	10,400
Number of workers	55,000	321,500
Volume of products (work, services) sold, mln.rbls.	167.1	3151.3

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Transformation of Basic Structures and Operating Mechanisms of Soviet Science

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The 1990/91 stage in the socio-economic evolution of the Soviet Union is unique in many ways, but predominantly in terms of extraordinarily low stability of the social system. Most traditional stabilization mechanisms were faltering. As a result, the number of possible states to which the system could deviate under the impact of relatively weak disturbances grew tremendously. Soviet science was a most conservative social institution, and due to its comparatively small size and strong dependence on the condition of political and economic structures it was destined to experience the same changes as the economy: therefore, stable structures and ties collapsed, and old operating mechanisms dramatically changed. In order to have a proper insight into the painful transformation processes one must return to the principles and traditions that constituted the cornerstone of the powerful, though mythological, system that Soviet science was.

The structure and dynamics of scientific potential for an individual country are essentially determined by some basic features of the social system. The most important among these features are: political and economic targets, historic and regional peculiarities, and ethnic traditions.

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The type of centralized state that was historically formed in the USSR with its long-term traditions of authoritarian power could not help but establish similar structures in science. Moreover, combined with such factors as the vast territory and long period of socio-economic backwardness of Russia's outlying districts, this created a marked differentiation in scientific potential with a bias toward the "center-provinces." On the other hand, political goals, and invariable centrally-determined priorities (frequently to the detriment of economic ends) caused the evolution of *regional science* to be frequently determined by factors of national prestige rather than by the real needs of economy and society at large.

A prolonged period of international isolation, even antagonism, caused Soviet, national security interests to enjoy highest priority. Consequently, a significant portion of resources was concentrated in military-oriented R&D. The post World War II tensions of the Cold War saw this type of scientific potential even more strongly encouraged. Historically inherited autarchy of the USSR and its weak involvement in international economic cooperation stimulated the evolution of a *continuous research front* in Soviet science.

Still, the factor that played the decisive role in forming the basic structures of Soviet science and created procedures and operating mechanisms inherent only to this science was the administrative-command system (ACS).

Branchdom, a socio-economic phenomenon, referred to the partitioning of the economy into rather isolated sectors operating in the monopoly mode and completely managed and controlled by special integrated power structures (government-party-business). By the end of the 1930s, when the basic features of the ACS had already been established, all production decisions including R&D and long-term construction issues were taken from the authority of industrial enterprises and transferred to higher management levels (ministries and agencies). It is in this way that the branch-type or ministry-type science system was established in the Soviet Union. *Branchdom* eventually became the principal way of organizing productive forces in the ACS.

Due to the chief emphasis on production criteria for national economic development, the organizational structure, planning techniques, and management methods of Soviet science were essentially completely borrowed from material production planning . Accordingly, all relations between the subjects producing new knowledge and the remainder of the national economy were also regulated by the command-administrative type of management mechanism. The basic features of this mechanism included: branch-type organization of R&D; absolute dominance of power in management and control; planning and management of scientific activities in terms of formal indicators; and (rationed) allocation of material inputs. Furthermore, this mechanism also accounted for cost-based pricing of R&D products and a subordinate (essentially, accounting) role for financial indicators. Although consisting of a seemingly wide variety of forms the system of science financing was actually designed in order to allocate funds to support slowly evolving research institutions.

No matter how paradoxical it may appear, efficient ways and means for implementing an integrated government-science policy were never achieved in the overcentralized ACS management system. Part of the problem lay in the fact that *branch property rights* for science as a production input were only gradually established by legislation, while problems of its use and development were practically wholly the responsibility of the branch (ministry) apparatus, including the bureaucratic apparatus of the scientific community itself.

This management style made it impossible for the scientific community and customers of R&D products to participate in the assessment of research efforts by R&D institutions. There was no opportunity to influence selection of priority areas and the amount of funding for particular research topics. Conditions of economic protection were created for branch R&D institutions, allowing a branch (agency) to support its *own* science irrespective of quality.

Such organization generated *branch patriotism,* distorted objective criteria and logic of science development, and led to the disruption of the natural structure of science communities that are formed on the principle of common research problems in market economies. The final consequence was a separation of Soviet scientific potential into isolated branch dominated groups.

During recent decades, the resulting particular structure of Soviet scientific potential was molded under the strong influence of individual priorities assigned by various branches and agencies in the overall hierarchy of economic subjects.[3] In turn, these priorities reflected the ranking of government goals: first, military, then space research, then some fields of basic science, heavy industry, and, lastly came social goals.

In this respect, the commonly established tradition of dividing Soviet science into three sectors: branch (ministry/industry), academy (Academy of Sciences), and higher education (and sometimes, quite reasonably, the

[3]It should be stressed that historically generated differentiation of regional science from the pole "Center–West" to the pole "South–East" was superimposed on branch (agency) priorities.

fourth *factory* science sector is also specified) seemed rather ineffectual. In fact, the various scientific fields that exhibit common systemic features were evidently not organized according to some formal principles but, rather, according to the influential power of a particular agency on the ranking of government priorities.

The most important and impressive R&D sector incorporated high-priority, science-intensive engineering institutions in conjunction with well-developed material-laboratory facilities; the sector was characterized by stable growth rates and investment ratios. This was so-called defense science. By the end of 1980s, R&D institutions in this sector allocated about half of the total expenditures on R&D exclusively for military research; this amounted to 75% of the state budget allocations for R&D. Since a considerable portion of work conducted in this sector is concerned with the national economy at large, its share in the total expenditure on science was even higher.

A set of factors were at work in this sector that ensured the maintenance of scientific potential at an adequate level. These factors included reactively independent management, coordination, communication, logistic, and long-term construction systems that were more or less separated from similar systems in the remainder of the national economy.

The same features were characteristic with regard to higher education establishment. Consequently, several dozen educational institutions should conceptually also be included in the branch sector. They are distinguished by an exceptionally high quality of graduates who dealt primarily with R&D topics important to the branch sector. In addition, the materials-engineering base of these educational institutions, including their research and experimental units, were of considerably higher quality than the average. Part of the reasoning lay in the various economic and non-economic measures implemented to maintain and promote the levels of skilled personnel in this group of industries such as higher wage rates, inhouse system of direct allocation of social benefits, and many more.

Fundamental research was more fully developed in this area of *industrial* science than in other fields. There were broad work and business contacts between this sector and the institutions of the USSR Academy of Sciences that might have secured a higher potential level. International competition served as an efficient incentive to constantly search for new solutions in the respective fields of science and engineering fostered at establishments of the defense complex.

The second ranked R&D sector, which could be arbitrarily called *Big Academy,* involved the scientific complex of the USSR Academy of Sciences and also a number of research institutions of the republican Academies (primarily from the Ukrainian, Belarus and the Baltics) where the level of R&D, and the quality of materials base and personnel were generally similar to those of the national Academy. Some universities and educational institutions that trained specialists for the sector and maintained close contacts with academic institutions also fell in this category. Characteristic features of this sector were a relatively high share of basic research and a significant ranking of the respective agencies in the economic hierarchy of the country or of an individual republic.

A relatively high qualification of scientific personnel was achieved in the academy sector due to in-depth general education, considerable number of distinguished scientific schools, inter disciplinary and inter-branch approaches to the solution of research and engineering problems, and comparatively close ties with international science. A higher degree of openness and democracy traditionally inherent to the academic sector was also of major importance.

The third leading R&D sector consisted of research and engineering establishments belonging to the majority of civilian ministries and agencies and constituted *civilian* branch science.

Despite the rather sophisticated inner structure of this sector, specific important features were common to the majority of its institutions. First, these institutions were typically plagued by a low-level of resource support, including obsolete and disintegrated instrumentation, material and experimental facilities. Second, the scientific personnel in the sector was recruited from graduates with narrow, specialized engineering backgrounds from a weaker group of educational institutes belonging to the *non-metropolitan* section of higher education. Thus, the resulting R&D was specialized and restricted to its own scientific-engineering connections and had almost no relations with basic and international science (*Big Academy* included).

The fourth level in rank of Soviet R&D comprised institutions of *provincial science.* It was regarded as the most backward portion of branch science under the auspices of low-priority ministries and agencies, local R&D establishments and academic and educational institutions located in some relatively underdeveloped regions of the country. Typical features of the sector included: very low qualifications of R&D personnel, low quality material inputs, and strong orientation to applied problems of specifically regional nature.

The logistical system of the R&D sector, based on standards borrowed from the production sector, played an important role in strengthening deep differentiation in science. This situation was accentuated under the conditions of a shortage economy in which the distribution of instruments, materials and services were predominantly based on the system of branch priorities. Therefore, the four-tier Soviet science system was in fact finally partitioned into two large spheres: *big* and *small*. These two groupings operated under dramatically different conditions of resource support. On the one hand, *big* science was represented by the defense industries' and a part of academia's institutions; while, on the other hand, *small* science was embodied in low-priority branches that had practically no access to modern instruments, materials, and equipment.

By the mid-1980s, Soviet scientific potential, in particular with respect to R&D personnel but also the knowledge base, instrumentation, and technologies, was differentiated to such an extent that an evidently impenetrable barrier was created between the upper and lower levels of the scientific hierarchy. The science and technology sector, as also other sectors of the national economy, had very limited possibilities to substitute specific quality resources with generally available ones. Even the ten-fold increase in the number of *rank-and-file* researchers could not substitute a single really brilliant scientist.

Branchdom combined with an ACS did not offer an opportunity to fully implement even a theoretical advantage of this pattern: namely, the possibility to mobilize large-scale structural resource rechannelling in the centralized manner in favor of the most challenging research areas. In practice, the priorities of branches and agencies were a more dominant factor. Consequently, the possibility to develop most relevant and urgent study areas was dependent on resources allocated to an individual ministry (agency). In other words, branch priorities sort of *dissolved* government or public ones.

In addition, each level of the national economy production structure, specifically in all the various branches was subordinate to the priority of the so-called *leading ink* either explicitly or implicitly. This mechanism was not influential when focussed on the growth of the main parameter (be it an individual machine, a production process, etc.) in a particular economic sector. As a result, a specific type of technological progress inherent only to Soviet economic management emerged. This type of progress might be referred to as *gross-like* technological progress. Its distinguishing feature was to strive for the improvement of technological efficiency almost exclusively by increasing unit capacities of existing equipment types and production volumes, frequently beyond economically (and ecologically) justified limits.

The *gross-like* type of technological progress distorted the structure of scientific potential. As a result, inter-branch R&D was poorly developed and studies at the *cross-roads* of various fields of science were inadequate. At the same time, these factors are now of major importance in terms of consumer characteristics and efficiency of integrated technologies and machine systems. Also, back-logs in the development of resource-saving technologies (that were unprofitable under the then existing management mechanism) were rather meager. Conversely, back-logs in the traditional fields of science and technology are relatively hypertrophied. A similar situation is observed in the branches of the economy engaged in the production of the *leading ink* of integrated systems (for example, tractors in agricultural machine-building, earth-moving machinery as a part of construction equipment, and main-frames in information processing systems).

The science management system was contaminated with the formal attributes, standards, values, and aims borrowed from the ACS. Therefore, the domination of *gross-like* categories in the entire planning system biased the criteria for assessing the results of scientific activities towards the purely utilitarian sphere. In fact, applied research designed to be implemented in various branches of the national economy was recognized as most important and useful. This direction caused the level and prestige of basic research to decline. In selecting projects, scholars chose those that guaranteed some form of practical application, no matter how far-fetched they may have been at such an early stage.

Branchdom in science cultivated monopoly — the main source of low technological progress standards in the Soviet national economy. It stimulated the development of a "natural science economy" within agencies and individual institutions. This led the most common form of R&D organization to be a multi-purpose research institution that combined all creative scientific functions with services. Such a pattern prevented functional specialization in science and eventually lowered the total efficiency of science-technology potential.

Within such an organizational setting, the cognitive potential could only be enhanced by the establishment of new laboratories and R&D institutions that were designed to cope with new fields of knowledge. Soviet science was exemplary for this style of development in the 1960s. Over a period of some 10 years (from 1960 through 1972), the number of research institutions increased by more than a thousand units (from 4,196 to 5,307). Strict restrictions were imposed on the process of establishing new R&D institutions when the government suddenly perceived a real danger of loosing control over the development of the R&D network.

However, significant growth in the numbers of R&D personnel persisted. Although the structure of the network was stabilized,[4] the average size of an R&D institution (based on employment) increased by more than 25% in the period between 1975 and 1985.[5] Eventually, the ACS had produced a structure of scientific potential in which only large-scale or, rather, giant R&D organizations (numbering several thousand and sometimes dozens of thousand persons) were viable. A *small-size* R&D institution became synonymous to a *weak* or a *poor* one.

Hence, the over-centralized allocation type economy had created a very peculiar and permanently self-reproducing structure of scientific potential by the early 1980s. The most typical features of this structure were:

- unusually high monopolization level officially promoted by the branch-type management and organization of the economy;
- stable differentiation in the quality of R&D resources (and, consequently, in the results) among various fields of science and regions of the country;
- extremely low flexibility and mobility, i.e., the capability to respond to new requirements of society and science itself.

Despite periodic demonstrations of achievements, Soviet science was experiencing ever worsening stagnation by the mid-1980s.[6] The gap between the rate of *intellectual production* in the industrialized countries and that in the Soviet Union was permanently widening.

The situation finally became so critical that a radical change utilizing traditional measures involving organizational transformations, and introduction or cancellation of customary measures would have proven impossible. The entire management paradigm had to be changed both in science and in the national economy at large.

With the beginning of perestroika (actually, from 1987), a radically new stage of organizational-economic transformations in Soviet science was initiated. Hierarchical relations of subordination between the R&D subjects

[4]Their total number of R&D institutions practically did not change over the last 20 years, reaching 5,111 units in 1989.

[5]According to our estimates, an average staff of an R&D institution was 280–300 persons in the mid-1980s.

[6]In the 1980s the rate of growth in the number of R&D personnel frequently dropped below 1% a year, whereas 3–5% growth would have been necessary to secure consistent production of the scientific community and development of new research areas.

and management structures were to be gradually replaced by the relations of legislative and economic independence and equality. The principle of self-organization was more or less implemented: scientists and engineers were given an opportunity to set up provisional research groups and to unite into associations, unions, R&D cooperatives, etc. The price setting mechanism for R&D products ceased to be the domain of the state and their prices became a matter of agreement between the researcher and the client. The control of government agencies over the network of R&D institutions was considerably weakened (though not completely lifted). A portion of control functions of the administrative bodies was delegated *downwards;* for instance, to the leading R&D institutions or councils responsible for the development of individual programs. And, lastly, almost all limits on the size of personal income in the realm of R&D activities were abandoned, including limitations on combining jobs.

The results of these decisions turned out to be very important but controversial. As could have been expected, the process of *denationalization* (or, more exactly, *semi-legal privatization*) of R&D set in, creating a rapidly expanding new sector in this sphere referred to as the cooperative sector. By early 1990, R&D cooperatives (NTK) employed more than 320,000 persons who, in 1989, performed work and supplied services to the value of more than 3 billion rubles. Provisional teams of researchers and engineers operating under the auspices of various unions, associations, and cost-accounting centers performed work valued at another 2 billion rubles over the same period. So, the total amount of work performed by the new sector and reimbursed by customers amounted to some 5 billion rubles.

Small, flexible groups in this sector quickly seized the as yet unrealized opportunities for R&D, engineering and broker activities that were beyond the reach of the government. The spirit of competition revealed itself both in lower prices for studies and services offered by NTK and provisional research teams, and in much shorter periods for project completion as compared to those in the government sector. During 1988 and 1989 a sharp increase in the number of non-government R&D institutions was recorded. The consequence was a drastic reduction in the size of *commission* (from 40% to 10% and less) charged by cost-accounting institutions for their services.[7] This market soon became increasingly *tight.*

In 1988 and 1989, dramatic changes took place in the wage dynamics for those employed in Soviet R&D activities everywhere, not only in the

[7]Frequently, merely for an opportunity to pay in *cash*.

cooperative sector. For the first time in recent decades, wage growth rates in R&D were highest compared to those in other sectors of the national economy. The wage level of personnel employed in research institutions and design bureaus rose as much as 40% only in 1989. Due to the sharp wage increases, the benefits of a purely administrative career in science diminished and the former status credentials of scholars simultaneously more or less lost their previous value.

Concurrent shifts in the structure and quality of R&D activities failed to keep pace with the scale of this *Financial Revolution*. One of the reasons for these developments lay in the fact that reforms in science often preceded necessary changes in the national economy. On the one hand, market relations had been introduced in the realm of science. Consequently the transition of the national economy had not yet set the framework for or initiated demonopolization, conditions stimulating demand for highly efficient and science-intensive technologies had not been created, and a new comprehensive legislation regulating current relations among the subjects of R&D activities had not been introduced.

On the other hand, the transformations that had been effected did not always take account of the specific nature of R&D. Informative by definition, the results of Soviet R&D facilitated very cheap, or practically free, duplication. Due to the uniqueness and risk often associated with a good portion of scientific work, the concept of average prices was non-existent in this sector in the USSR and there is ample opportunity for almost arbitrary "costing." Hence, legal prospects for making superprofits emerge after commodity-money relations were established in the R&D sector. During the late 1980s, the phenomena immediately led to a sharp rise in personal income.

Under contract prices, the increase in R&D institution and design bureau revenues could have been curtailed due to limited funds of customers, essentially enterprises or government. But it is exactly during this period that the amount of "money supply" for science increased significantly. First, government expenditures on basic research were considerably increased. Second, a large amount of money was accumulated by development funds of industrial enterprises and this money could not be spent for procuring equipment and materials due to the shortage of such paraphernalia. Science became one of the safest and useful ways to get rid of *excess* money. The strong growth in the amount of R&D work in 1988–1989 is mainly explained by the price hike.

The relative *easy money* of clients prevented the natural selection of potentially most efficient research teams and institutions since these could afford to pay all their staff including the *ballast*. Funds continued to be wasted on worthless, antiquated studies directed by their privileged, "distinguished" leaders. Unfortunately, despite a considerable increase in R&D allocations, all these factors prevented fundamental changes to occur in the quality of Soviet R&D.

The *ballast* was also preserved due to the fact that labor relations and hiring methods remained unchanged. Hope was still placed on material incentives to stimulate productivity growth in science, whereas the main feature of a market (i.e., efficient economy), as is well-known, is the existence of labor market.

Regional science labor markets sprouted rapidly in a number of large cities of the USSR in the late 1980s. However, as a rule, they were *second employment* markets. These markets consisted of hundreds of thousands researchers and engineers working on a contract basis for the organizations of the non-government sector where the customer exercised *control by the ruble* and the performer had his reputation at stake. Here one could order a specific job from a single or several specialists instead of hiring a whole institution. At the same time, most actors in this sector bore no risks since they were permanently employed elsewhere.

As time passed, we witnessed the emergence of *second* or *black* science, or to be more exact, an entirely new innovation sector. Due to a lack of essential legislation, operating time, materials, equipment and, of course, final products began to be abused. The latter as a result of the problem of property rights for R&D products, which was not even close to being solved in the Soviet Union at that time.

In 1990 and 1991 the consumer market, business relations, and confidence in the ability and influence of institutions were practically completely disrupted. As sociologists put it: "the peak of *social disintegration* was reached; the situation in Soviet science was markedly changed for the worse."

Demand for R&D products on the part of industrial and agricultural enterprises dropped considerably, budget financing opportunities for R&D were curtailed (both on the national and republican levels), and a process of disintegration of a number of R&D institutions set in. Unemployment in science become a stark reality and at the same time the influx of young researchers simultaneously declined considerably. The *brain drain* process gained in strength. The persistence of these trends were sure to damage scientific potential in the USSR and may have had irreversible effects since scientific institutions and teams disintegrated rather quickly, while their establishment would take much time and effort.

What was needed at this time was a radical change in the goals and criteria of science policy. The then existing economic and political situation should have been reoriented from the past focus on the transfer ambitious large-scale projects from the U.S., European, and Japanese to Soviet soil to a realization that the main issue on hand was the need to support the survival of those structures in Soviet science that were still capable of asserting themselves. The main difficulty of this time and beyond was the search for realistic survival mechanisms that need not require multibillion ruble investments, since these were simply not available.

Restructuring processes observed in Soviet science generated severe social problems and contradictions.[8] Unless efficiently resolved, and as long as the priorities in science policy remain based on the past technocratic ideology, the system could not survive.

Suggestions for Reorganization of Science and Research in the Transition to a Market Economy

During the transition to a new system as is happening today, a considerable portion of R&D resources should be allocated to create the so-called buffer systems capable of alleviating the conflicts that are yet in their initial stage. The personnel dismissed from R&D institutions and design bureaus should not become unemployed. It is necessary to invent *generators* of new jobs that are to be designed in accordance with the dynamics of the situation or to organize a planned *evacuation* of some Soviet specialists abroad. Their resettlement and employment in foreign countries through a government supported system of international cooperation is completely different from individual emigration and employment.

A system of small-scale science-intensive ventures may become the most efficient solution to the problem of providing jobs for skilled researchers inside the country. This is a specific social-production system which has to be created as soon as possible. Another priority issue for new science policy is to ensure rapid design and implementation of a program for establishing *incubators* of small-scale ventures for R&D personnel.

In our opinion, the major difficulty which explains the failures of all previous reasonable attempted changes in Soviet science was a strong belief

[8]Here we use some ideas suggested by S.G. Kara-Murza.

in and adherence to a certain unified mechanism suitable for the entire R&D sphere. However, two basically different sectors of science emerged in the latter stages of the Soviet Union: the non-profit (conventionally basic) sector, functioning for public benefit at large, and the commercial sector, where the key incentives are individual profits. These blocks of science were not arranged as some specific organizational structures. They became radically different in terms of operating criteria, the labor motivation, value system, and even the standards of economic behavior.

Therefore, although the general concept of perestroika (freedom, democracy, and competitive markets for producers and consumers) is quite acceptable for the entire R&D sphere, specific methods of organizing, managing, and financing must account for individual features of each type of R&D institution. Operating mechanisms of the new non-government sector should be designed on a pattern completely different from that for the traditional branch, military and academic sectors. The regional aspect is also very important: the same problems for an R&D institution in Moscow should be handled in a different way for an institution of a similar type in, say, Riga.

The fall of the curtain that protected Soviet science from the necessity to compare its results with the levels attained by the international scientific community has revealed abominable gaps in the seemingly continuous front of domestic R&D. A particularly dangerous situation is observed in the civilian branch sector of science. Neither the available results, nor the quality of science potential in this sector allow production of new products and development of new technologies that can be competitive in the world market. In this respect, the Asian way of developing science and technology seems to be most effective and rational. An example would be the purchase of complete, modern enterprises and technologies on the turn-key basis with subsequent adaptation of soviet R&D and economic environment to the necessary level.

A rational conversion of the military sector should become an efficient way of preserving its scientific potential. This could simultaneously solve the problem of employment for scientists and engineers working at R&D institutions and design bureaus in this sector where demand for military products has dropped drastically. In order to develop an efficient conversion mechanism, current and potential scientific and engineering capabilities of military R&D must be thoroughly analyzed in addition to the level and types of technologies achieved in the rest of the world and used in the civilian sector. The demand perspective and other factors should also be evaluated. Next, interface areas are to be determined, amounts of investments defined, and operating mechanisms for project implementation designed. A critical prerequisite for efficient conversion should be mutual interests of all the parties involved (R&D institutions, design bureaus, industrial enterprises, brokers, trade agencies, etc., including the government). Indeed, many defense sector establishments are very close to the model of a modern diversified science-intensive company which interacts with a network of independent or semi-independent ventures. However, the organization and management scheme operating in this sector is not suitable for market conditions. It is not capable to adequately respond to the changes in demand structure, to make instant decisions on the necessary revisions of research agenda, customer and subcontractors, and so forth. We believe that to solve the problem of elaborating an efficient conversion alternative it should be necessary to gradually relieve scientific and engineering institutions of the defense sector from ministerial control, to denationalize and demonopolize this sector.

At present, it is hardly possible to develop the concept of science policy for the transition period separately from the concept of transforming the higher education system. One may easily forecast that close integration of science with the higher education system during the transition period is becoming a necessary condition for the Soviet science community to survive in its new polito-economic environment. Perhaps, new hybrid organizational forms will have to be established and supported that will possess enhanced stability during hard times even if pure scientific efficiency is to be sacrificed.

Finally, of greatest importance today is the large-scale effort in disseminating modern economic and social knowledge with the purpose of creating a new economic culture in the successor states of the Soviet Union. The changing attitudes to private property, to the role of government in the economy and social sphere, to the rights and responsibilities of an individual and many other new factors in the post-communist regions cause the existing value system to disintegrate and radically change the standards and rules of economic behavior. At the same time, rapid transition to the use of formal market attributes lacking necessary traditions and inner culture frequently puts new obstacles in the way of solving old problems. In particular, science experiences strong commercial pressure nowadays. There is a serious danger to lose all values that have been accumulated by the Russian and Soviet science genotype over many decades in the whirlwind of transition to the market economy. It is the duty of the new government and international science community to prevent this.

Responsiveness of the Soviet Economy to Scientific and Technical Innovations: Comparison with World Experience

A.I. Ageev[1] *and D.V. Kouzin*[2]

Why was the economic and political system established in the USSR so unresponsive to innovations? The answer to this question apparently involves two aspects: firstly, the existence of a glaring discrepancy between management and regulation by administrative means and innovation processes, particularly in modern, extremely dynamic and changing conditions; and, secondly, consideration of a number of economic, ideological, and sociocultural peculiarities of Soviet development.

As far as the first aspect is concerned, it has been basically proven that creative, exploratory, and science-intensive management is incompatible with order-giving methods, strict regulation and directive planning. It is no coincidence that virtually all major inter-state surveys in the 1980s distinctly refer to factors of red tape and ineffective state regulation as chief obstacles to innovation.[3]

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[3]Piater A., **Barriers to Innovation**, I, 1984, p. 176, 697.

The second aspect concerning the unresponsiveness of the command system is much more ambiguous and complicated. At this point, it is necessary to consider several key characteristics of the command system and its innovation ability, to compare a whole range of factors with similar ones acting in capitalist economies in order to reveal common trends, and also to suggest remedies. In this paper, we consider five groups of such factors which seem to be most important.

State Control and Militarization

The command system essentially led to total **state control** of economic life, rigid central planning, and decision-making in all spheres of activity, including science and technology.

Firstly, the control over science was unprecedented; the established planning mechanism made the very substance of scientific work subject to control. Academic freedom gave way to state discipline. A measure of success was the fulfillment of plan assignments and not the making of discoveries. Moreover, science came to be controlled by an administrative apparatus ignorant to the substance of research.

Secondly, the investment, research and technical polices were essentially dependent on the state budget. The independence of enterprises and associations has been hitherto limited as regards to their financing and directions of scientific and technological progress. All major decisions in this field were to be agreed at many levels, which consumed considerable amounts of time—one of the most important and difficult-to-compensate resources in implementation of innovation processes.

Thirdly, a prolonged period of prevalence for short-term interests (fulfillment of the plan) over long-term interests in no way contributed to the formation of a "future investment" culture at the level of enterprises. As a result, there was only stable demand for RDT&E (research, development, testing and evaluation) programs that generated innovations facilitating resource saving within the framework of existing technologies.

Conversely, in developed capitalist countries many scientific and technical decisions were and are made directly by firms. In the 1980s, U.S. firms financed 48% and performed 73% of all RDT&E programs,[4] while respective

[4] **Science and Technology Data Book,** NSF, Washington, 1988, p. 2.

figures in Japan were 70 % and 73% .[5] It should be noted that Japanese firms financed 98% of industrial RDT&E programs, which constituted about 2% of the GNP (gross national product). In leading capitalist countries, RDT&E expenses of firms constituted 4% to 10% of their sales during this period.

As far as the state is concerned, its relative role in financing RDT&E programs decreased from 57% to 48% in the USA and from 33% to 21% in Japan in the seventies and eighties. Of course, this did not indicate any decrease in absolute expenditure. Quite the opposite, it increased on average by 6% in the USA and by 3% in Japan in the 1980s.[6]

Recent evidence would seem to imply that the state's strategic and stimulating role, not to mention its innovation, research and technology policy, have been crucial in procuring scientific and technological progress. However, such a role of the state in developed capitalist countries has been fundamentally different from total state control and rigid planning regarding both scientific and technological progress and operation of its basic associated entities which were the enterprises and associations in the former USSR. The following have been primary functions of the state in capitalist countries;

- formation of integrated research infrastructure;
- partial financing of RDT&E programs and education from the state budget. (Absolute sums seem to be fairly large in the late 1980s: 9 billion dollars spent on fundamental science alone in the USA as compared with 1.5 to 2 billion rubles spent for similar purposes in the USSR);
- performance of a share of research activities in state-owned laboratories and transfer of relevant data to firms for commercialization;
- elaboration of a research and technological policy and top-priority programs (goal-oriented program financing);
- control over contract activities;
- creation of an innovation climate (in the form of privileges, sanctions, certain control measures) in the country as whole and in certain regions, zones, research parks, etc., to secure, among other things, participation of firms in the implementation of the chosen programs.

It should be stressed that the role of the state in inducing scientific and technological progress has increased with its military-space orientation. Specifically in the USA, France, and Great Britain, the proportion of state

[5] **The Science and Technology Resources of Japan: A Comparison with the United States**, NSF, Washington, 1988, p. 9.

[6] Ibid.

financing of RDT&E has been substantially higher than, for example, in Japan (state expenditure on RDT&E was about 80% in the USA in 1986, military research accounting for 90% of the growth of state financing; corresponding figures were 31% in France, 52% in Great Britain and 4% in Japan).[7] Scientific and technological progress has been characterized by a three-way orientation: military purposes, creating more national economic competition, and developing the consumer sector. Japan and Finland have been convincing examples of the effectiveness of the second and third variants. It is only natural that, according to different studies in the mid-1980s, militarization of the economy and scientific and technical progress was one of the reasons for a relative fall in competitive power of American industry.[8]

The basic arguments were as follows.[9] First, the development and marketing of new commercial products were stimulated primarily by competition. On this issue, the approaches of the Japanese Ministry of Foreign Trade and Industry and the U.S. Ministry of Defense were fundamentally different. The Japanese set up industry specific regulations to maintain and change in a flexible manner the character of cooperation between firms and their competition. Between 1981 and 1984, a period noted for a drastic rise in military spending, five leading contractors of the Pentagon increased their share in contracts from 18% to 22%. In 1985 there was no rivalry for 65% of the value of all military contracts.

Second, the creation of new products and the introduction of innovations generally required considerable time and resources. Therefore, many projects led by the Japanese Ministry of Foreign Trade and Industry took years, but their implementation was very purposeful and consistent, while U.S. military programs were strongly dependent on the political situation. Their rapid build-up created certain shortages, even in the American economy. According to **Data Resources**, a 20% increase in military orders resulted in a shortage of 30,000 skilled workers in the manufacturing industry in 1984–1985 alone. These and other limitations caused commercial considerations to be pushed into the background.

Third, technological competitiveness necessitated transfer of innovations from the military to the civil sphere with comparatively low expenses. Such a diffusion of innovations was the responsibility of the Ministry of Foreign Trade and Industry. However, intricate technology, say of the SDI (Strategic

[7]"ME&MO." 1988, No. 4, p. 53 (in Russian).

[8]**America's Competitive Crisis. Confronting the New Reality.** Washington, 1987.

[9]R. Reich, **Tales of a New America**, N.Y., 1987, pp. 70–73.

Defense Initiative) program, could not be easily transferred to the civil sphere for commercialization (at least by comparison with the technology of the 1950s). Purely military technology oriented scientists and engineers to other goals that were remote from a commercial system of values.

Fourth, new technology was commercially advantageous and meaningful only when it made the production cheaper. Cost reduction was at least as important and difficult as the development stage. The U.S. Ministry of Defense was, however, concerned with the obtained results and not with expenses incurred. In the case of contractors, therefore, incentives (profits) were directly dependent on the growth of resources and expenditure, while price formation was generally expenditure-dependent in much the same manner as in the USSR.

Fifth, a commercial success was supposed to do more than simply satisfy the conditions of competition; namely, satisfy consumer demand. However, the Pentagon always safeguarded U.S. companies against the risk of global competition. In its attempts to prevent foreign supplies, the Pentagon at all times gave preference to domestic producers, who often applied for governmental protection under the pretext of a threat to national security when under commercial pressure from foreign competitors.

In the USSR, scientific and technological progress had a pronounced military-space orientation (with all the ensuing consequences such as customer's monopoly, distorted price formation, secrecy, and the like), was characterized by limited relation to economic growth issues (without regard for national competitiveness), and exhibited almost total neglect of the consumer sector. Such a situation not only imposed a burden on the national economy but, in many respects, undermined its viability. There is every reason to believe that militarization of scientific and technological progress in the USSR created even greater problems for the R&D sector than, for example, in the USA. In comparison with the USA, the USSR had, firstly, significantly weaker channels for transmitting advanced technology to civil branches due to various economic barriers and, secondly, much more rigid directive management of enterprises in this field; a factor noticeably narrowing the scope of scientific and technological progress and substantially restricting the range of their choice.

Waste and Shortage Economy

The command-and-administer system established and promoted an expenditure-oriented economy which became a *"shortage economy"* in the long run. Such a system essentially had little interest in scientific and technological progress for stabilization purposes. Indeed, functions therein suppressed creativity, innovation, and development. Part of the establishment (primarily bureaucrats) was particularly interested in curbing innovations. "Easy" sales conditions in no way stimulated enterprises to improve their products beyond limits allowing "objective" substantiation of a price rise. This stemmed from the departmental form of organization of productive forces. As centers of their own economic subsystems, departments were primarily interested in steadily amassing resources and power and they had no interest in scientific and technological progress which eventually could have led to material, labor, and financial savings, and new economic ties and structures. This created a need for freedom and decentralization.

As regards to huge shortages characterizing the Soviet economy, their presence was in itself a direct hindrance to scientific and technological progress. Firstly, such supply impasses imposed restrictions on the scope of research operations. Secondly, such a situation revealed a shift in political and ideological priorities towards the financial side of the Soviet Union's economic problems and away from research and technical (i.e., long-term) tasks without which there would be virtually no progress at all. Thirdly, the scarcity of necessities appreciably distracted people's energy and attention from creative activity.

A significant feature of Soviet economy, which influenced its expenditure orientation and deficiency, was its **anti-innovation branch structure.** This structure was utterly incapable of providing a steady flow of innovations, effective transfer of technologies, and their rapid introduction. The structure was exceedingly bulky and archaic in character when compared with branch structures of the leading countries of the OECD (Organization for Economic Cooperation and Development). Data obtained in the mid-1980s for leading industrial countries showed that high-technology industries accounted for 51% of RDT&E, 11% of production and 16% of export; corresponding figures were 32%, 32% 44% for medium-technology and 17%, 57%, 40% for low-technology industries.[10]

[10]OECD, **Science and Technology Indicators**, 1986, No. 2, p. 61.

The main problem that made the Soviet Union distinct from developed capitalist countries was the absence of restructuring in the 1970s and 1980s in order to become more science-intensive. Furthermore, spheres of various services were still not sufficiently developed, a factor preventing effective growth of vanguard industries, and a sizable part of the country's production machinery was obsolete and generally worn-out with a very insignificant proportion meeting top world standards. So, the Soviet national economy was characterized by deep structural and technological imbalances. Figuratively speaking, the economy was a combination of *black holes* formed by a multitude of *discrepancies* and a wide gap between out-of-date and advanced production practices. The range of technologically lagging industries with unacceptable levels of inefficiency and was to by present-day standards not only required huge production resources (for example, annual repairs cost over 40 billion rubles in engineering industry, which is one of the highest figures in the world), but also employed tens of millions of workers in the style reminiscent of the thirties or even, uncertain instances, of past centuries. According to data supplied by the All-Union Central Council of Trade Unions and the USSR State Committee for Standards, only 8% of the models of machines and mechanisms batch-produced (to say nothing of the previously installed equipment) by enterprises of 12 engineering industries met labor safety requirements and human adaptation conditions. In the USA there was one "human factor" expert per 300 specialists developing new equipment, as compared with one such expert per 30,000 development engineers in the USSR.

The situation progressively worsened due to the missed opportunities to *leap-frog* in few industries for the general advancement of the national economy. It became more and more difficult to clearly separate the leading branches of economy from the economic laggards. Progress in high technology was impossible or ruinously expensive without an harmonious upsurge in all spheres of life of the modern society, ranging from education and nourishment to freedom of speech and conscience. P. Drucker, a prominent American economist, justly remarked: "In economy there can be no isolated viable sector of high technology as there can not be sound mind in a dead body."[11] Generally, the Soviet economic system in the last years of communist rule was not found in a neglected state but lacked any prospects in the event of a further drop in production efficiency and innovation, degradation of the environment, and aggregation of socio-economic problems.

[11] Drucker P., **Innovation and Entrepreneurship**, N.Y., 1985, p. 265.

Monopoly and Monotonous Organization of Innovations

Monopoly power was a great hindrance to scientific and technological progress in the former USSR. This type of monopoly was largely of artificial, administrative origin.

Apart from the afore-mentioned factors (absence of any interest in scientific and technological progress, preservation of the old branch structure, expenditure orientation, sole rights to inventions, etc.), a direct consequence of the departmental monopoly was the creation of rigid vertical economic barriers. However, modern technology, knowledge, and information were of an inter-branch character. Under these conditions, the existing ministerial branch management was not merely an anachronism but a direct hindrance to scientific and technological progress.

In fact, this structural development was contrary to the global trend of that time. World experience in the organization of economic management showed a common trend in favor of the expansion of horizontal economic ties. This including the establishment and further development of multi-branch corporations (the largest of them in capitalist countries having enterprises in dozens of industries), joint ventures, associations or large-scale inter-company partnerships (often international), which, as a rule, were created to provide joint ownership of advanced technology and have a strategic character.

The consequences of a producer monopoly, or monopsony as in the USSR, were degradation of product quality, lack of competition as the basic stimulus to scientific and technological progress, and infringement on consumers' rights to choice.

Experience of inter-company ties abroad, revealed that about 80% of such ties were established within the framework of supply agreements and contracts. In most Western industries, particularly in such science-intensive ones as electronic engineering, machine-tool industry and the like, consumer influence was crucial in the development of ideas from the very start of a research-and-production cycle, which naturally yielded better development results and oriented the supplier to the consumer. This was an example of a demand driven system. In some science-intensive industries in the USA of the 1980s 60% to 80% of innovations were introduced in response to customers' direct participation.[12] Under Soviet conditions, however, producer monopoly and the absence of consumer choice inevitably led to the preservation of old products or to only slight modifications, subsequently imposing poor-quality components on the manufacture of final products, naturally impairing quality as well. Essentially, this let the producer free of any real incentives.

Competition in the world arena acquired new features in the 1980s. It became world-wide and more fierce, particularly in fields with a prime emphasis on the scientific and technological sphere. Large leading firms were competing in all directions on a vast number of items. Some estimates revealed that over 70% of U.S. industrial output met with competition in other countries. Thus, the following conclusions could be drawn:

(a) market relations were of a dynamic character;
(b) large firms resorting to different strategies of vertical and horizontal integration and diversification sought an optimal "branch bag" which, as a rule, included base technologies mastered by a given firm;
(c) "global branches" possessed an oligopolistic structure (i.e., one with few leading producers of similar goods).

An illustration for the aforesaid has been the level of concentration of industrial RDT&E programs. Five leading RDT&E companies in the USA accounted for 23% of all industrial RDT&E programs; the corresponding figure in Japan was 18%. This level was fairly high in certain industries; for example, 78% in the steel industry and 69% in the automobile industry in Japan, 96% in the automobile industry and 70% in the chemical industry in the USA. However, the most science-intensive industries were not simultaneously the most monopolized ones. For example, the five leading companies in pharmaceutical, electronic and instrument-making industries in Japan carried out less than 60% of all RDT&E programs in these industries. In the USA the corresponding figure was less than 65%.

The monopolization of Soviet science by ministries and departments, its orientation to serving departmental interests, and unequal relations resulted in a situation when over 70% of science expenditure and two-thirds of the nation's scientists were concentrated in corresponding industries, while over 80% of all innovations were used at only one or two enterprises, as some surveys showed.[13] Such a situation virtually deprived science of its essential

[12] "Control of innovation process in capitalist form," Moscow, IMEMO under the USSR Academy of Sciences, 1985, p. 109 (in Russian).

[13] **Innovation Process Structure**, Moscow, VNIISI, 1981, p. 16 (in Russian).

rights, blocked channels of technology exchange, limited the mass spread of novelties, and generally hindered scientific and technological progress. The realization of scientific and technological achievements was further hindered by the fact that enterprises had very loose links with branch science. Disparities in sources of financing, planning and interests of branch science and industry gave rise to the notorious problems of implementing results of RDT&E.

Major firms in capitalist countries were undisputed leaders of scientific and technological progress. The organization of RDT&E in these firms was, however, fundamentally different both in form and content from that of enterprises in the Soviet Union. The former had access to a multi-link RDT&E organization serving both their long-term objectives, diversification strategy, and mastery of new products in numerous branches. Provided for this purpose were: RDT&E head laboratories and centers engaged in functional research; centers rendering services in key directions of the activity of corporations; and, laboratories engaged in applied research and development in branches oriented to manufacture particular kinds of products. Thus, everyday activity of large firms was separated from their long-term operation.

As regards the introduction of innovations, an additional distinguishing feature of large capitalist firms in their multi-branch character, permitted:

(a) making full use of the advantages of the scientific, technological and production experience gained in the main sphere of activity with a corresponding transfer to cooperating spheres;
(b) making a complex "branch bag" of products with an inter-firm transfer of capital, labor, specialists, technology, and knowledge and financing of new directions of activity due to mature, developed production yielding steady profits;
(c) breaking into highly profitable science-intensive industries and the service sector to modernize obsolete basic production capacities.

Large companies have undoubtedly been the prime movers of scientific and technological progress. At the same time, the role of small firms in innovation considerably increased, especially in the 1980s. In the mid-1980s in the USA, over 15,000 firms were engaged in various kinds of research and technical activity; moreover, their number was constantly growing. In spite of substantially smaller proportions of RDT&E funds in small firms (in the early 1980s capital outlays per scientist or engineer were on the average about 60,000 dollars in firms having less than 1,000 employees and 117,000 dollars in larger companies), the efficiency of their research and technical activity was often higher than in large corporations. Small firms produced twice as many innovations per employee as large firms. Over the whole post-war period, small businesses produced about half of all American industrial novelties and a predominant part of radical inventions. In many instances, small firms had certain advantages due to their mobility, special management culture, creative psychological climate, and a flexible RDT&E expenditure structure.

The role of small businesses in the realization of scientific and technological achievements should not, however, be overestimated. It is important that, in close cooperation with big business, small business enabled rational distribution of resources, scientific and technical potential, creation of an optimal economic structure for RDT&E conditions, and took a substantial share of the risk inherent in any innovation activity. It is also meaningful that only a reasonable combination of small cooperating firms such as engineering and consulting, broker (intermediary), leasing, venture, and other firms may yield a stable economic effect. For example, in the U.S. manufacturing industry, large enterprises constituted 7% and small enterprises 92% of the total number.[14]

Global experience in the organization of branch science and its production links has also revealed the presence of different mechanisms and organizational forms. First, a substantial portion of applied science has been concentrated in large companies, as stated above. Second, about 15% of state RDT&E expenditure (for example, in the USA) were distributed through research centers, institutions and laboratories of ministries and departments engaged, as a rule, in fundamental research and subsequently transferring their development results to firms for commercialization. Third, institutions under large industrial associations of producers focus on certain research operations. Fourth, universities (for example, drawing two-thirds of their financial resources from the state in the USA) played a major role in industrial research. Universities performed over 50% of fundamental science investigations directly affecting innovations in American companies.[15] As a matter of fact, universities often became "incubators" of new high-technology firms, centers of inter-company partnerships and research parks (in 1987 there were 39 of them in the USA and 36 in Great Britain) uniting the efforts of many firms. In Western Europe alone, the number of these centers and parts in-

[14] **Scientific and Technological Progress: Problems and Solutions**, No. 3, 1988, pp. 4-5 (in Russian).

[15] **America's Competitive Crisis. Confronting the New Reality.**, Washington, 1987, p. 38.

creased five-fold in the 1980s.[16] Relations between business and universities were also characterized by the fact that industrial research is financed not from the state budget but by interested firms in numerous nations. Access to university science became a matter causing fairly strong competition between firms.

These points illustrated the very dynamic and flexible economic structure of the leading companies in the capitalist world, and also the great variety of organizational forms and economic mechanisms facilitating a sufficiently effective exchange of ideas, knowledge, experience and technologies. It was in sharp contrast to the structure in the former Soviet Union.

The absence of market conditions in the Soviet economy together with the obsolete branch and industrial structure unresponsive to innovations, led to another principal drawback: more specifically, immobility of production and resource factors. International experience showed that this particular issue became one of the key conditions inhibiting new innovations and scientific and technological achievements.

Let us consider three key factors—capital, labor (primarily highly skilled scientists and specialists), and information.

In the Soviet Union, the problems associated with the absence of a functioning capital market, including venture capital, was only timidly put forward by a number of reform economists. In the West, however, the venture capital market was rapidly expanding in the 1980s (increasing dozens of times to exceed 25 billion dollars in the USA alone). It became a key instrument for innovation-type growth. For the past 10 years, about 10 million venture dollars were on the average allocated for each small innovating firm in the USA. In addition, a great variety of sources of funds was especially typical of the American system of financing new science-intensive firms. These sources were combined at specific stages of the operating cycle of a new science-intensive firm. They included personal savings of businessmen, different funds and informal investors, private investment and insurance companies, and assets of innovation banks. It was of fundamental importance that all these sources were readily accessible. At the same time, competition was taking place in the financing sphere as well. If one financier was unwilling to render aid, the innovator could apply for support from another financier. For example, active investors in the USA included 100,000 people annually in the 1980s; participating in venture financing as informal investors were about 150,000 well-to-do American families and about 550 leading venture

[16] S. Woods, **Western Europe: Technology and Future**, London, 1987, p. 51.

capital firms. In other capitalist countries these figures are not so great due to specific conditions and traditions of forming a venture capital market. Nevertheless, there was a constant increase in the 1980s elsewhere as well. The importance of venture capital for expediting scientific and technological progress and increasing competitiveness was more understandable considering the desire of Western Europe to set up a common capital market and to establish large international venture funds. Specifically high mobility of capital and a sound credit and financial system guaranteed rapid and effective combination of innovators with new ideas and sponsors with money.

A capitalist economy demonstrated higher mobility of labor, particularly skilled scientists and specialists, as compared with the Soviet planned economy. For example, in the USA, research centers and many high-technology firms annually rotated 15–20% of their personnel and some 2% or 3% of specialists moved from universities to industry and back.

A significant aspect of the process of internationalization of modern science and engineering was increasingly wide international cooperation in the field of research and exchange of scientists. With a view to promoting such cooperation, the Japanese government, for example, adopted a special law back in 1986 "on governmental exchange of researchers" which substantially increased the inflow of foreign scientists to Japan.

Personnel policy in Soviet RDT&E, based on the principles of hierarchy, secrecy and autocracy, not only gave rise to many problems connected with the stimulation of creative work, scientific growth and democratization of the scientific sector, but also created conditions in which many skilled persons were not attracted by the sphere of scientific and technological progress. Of course, the very fact that many creative persons left science for new types of organizations was even considered a positive development if taken separately. Such a situation fully conformed to world-wide tendencies. Another factor important here, namely, the fact that the existing Soviet organizations in this sphere failed to provide sufficient incentives for creative persons hindered the realization of their ideas and did not allow talents to be revealed to a full measure. However, these particular organizations continued as "fashion-setters" and chief performers of research and technical work in the last years of the USSR.

A paramount feature of the Soviet command system was mass secrecy under which great limitations were imposed on the mobility of skilled personnel and transfer of information and technology, particularly from the military to the civil sphere. Conversely, wide discussions on the problems of secrecy in the USA led to a conclusion that unjustified adoption of tougher measures would slow continuous modernization of the American economy and inflict more harm than even a few spies.

Indeed, under modern conditions not merely the transfer of information, technology, or know-how mattered, but also regular discussions of novelties, value of business involvement, elaboration of a common concept of utilization of new technology, and manufacture of new products or their improvement. This was essentially a mutual training process. Secrecy and bans undermined this vital aspect of cooperation. Countries which stood to gain most were those where in determining key technological directions and subsequent development and realization of solutions a minimum number of secrecy regulations allowed extensive dialogue and an exchange of opinions between industrial and trading firms, research institutions and state analysts, both nationally and internationally.

Referring specifically to computer-aided data transmission, the creation of nation-wide and local networks would expedite research-and-production processes, make accessible reliable information for decision-making, and help those interested in their rivals' deeds follow advanced scientific and technical ideas. According to Soviet estimates, there were over 3,000 public data and knowledge bases in the USA available in the 1980s.[17] In the USSR, there were only departmental and special-purpose data and knowledge bases.

The functioning of a developed information market necessitated a wide network of information services for the public, including everyday, educational and special information. The library of Harvard University was known to receive 106,000 periodicals. The premier Soviet library concerned with natural sciences and serving 250 institutes under the USSR Academy of Sciences received merely 4,000 scientific periodicals in an equivalent period.[18] A mandatory condition for supplying information to the public was computer-aided transmission of scientific and educational information and development of openness, including the sphere in which vital state decisions are made. Computerization was naturally essential for dissemination of information. Unfortunately, these were neglected topics under central planning, and subject to the influence of only an elite few.

[17]ME & MO No. 3, 1989, p. 48 (in Russian).

[18]**Scientific and Technological Progress: Problems and Solutions**, No. 24, 1988, p. 4 (in Russian).

Economic Culture

The extended domination of the command-and-administer system led to the formation of a special Soviet economic culture characterized by high dependence on ideology and politics, low innovative capacity, poorly developed values regulating transformation activity in the sphere of economy such as creative work, success, risk, and so forth. However, the system simultaneously promoted seemingly converse values such as stability, balance, uniformity, subordinated position of science with respect to production, etc.; the latter values being cultivated by a substantial part of state and economic machinery, and also by many heads of research and technical institutions in the USSR. Only the consideration of the cultural factors would permit adequate explanation of the deceleration or acceleration effects in an analysis of the Soviet economic system and illuminate reasons for the unresponsiveness of the Soviet economy to innovations.

One of the distinguished features of the Soviet economic culture directly influencing scientific and technological progress was the destruction of the enterprising and innovating spirit and the blocking of its revival. To begin with, the command-and-administer system distorted ideologically and politically the very notion of entrepreneurship, linking it with exploitation, class parasitism, and profit hunting in the West and with criminal and immoral activities in the USSR.

Notwithstanding, entrepreneurship has been a form of organizational and economically creative activity undertaken not only by bourgeois but predominantly by a fairly wide strata of working people, managers and specialists in Western nations. In the USA, about 10% of the labor force were entrepreneurs, i.e. conducted business independently; in the late 1980s the corresponding figure was as high as 40% for specialists in science-intensive spheres. Entrepreneurship as economic management meant: first, an entrepreneur's considerable freedom regarding the choice of economic activity, its planning, organization and control, i.e. administrative independence; second, ownership rights concerning products and returns, including profit; third, capitalization of returns, i.e. use (in part or in full) for investment purposes; fourth, the possibility of choosing administrative and economic solutions, protection against monopoly dictate. Stated differently, entrepreneurship was a common feature of all progressing economic systems. The role of self-governing management was greater in more developed economic systems.

The domination of the command system in the USSR caused tremendous damage to the country's creative enterprising potential and to the "motivating" factor of its growth. Special emphasis was placed on four directions of undermining enterprising, moral and civil principles by the command-and-administer system.

First, the Soviet system was responsible for physical, moral and social "weeding" of the bulk of the most enterprising managers and specialists as a result of repressions, the established system of selection and placing of personnel and evaluation of their activity, criminal cultivation of class orientation and principles, creation of a socio-psychological atmosphere of obedience, intolerance and fear. Second, the command-and-administer system not only eliminated the entrepreneur but blocked the broad masses of working people from engaging in entrepreneurial activity through total regulation of "everything in the world" using initially the "top has it" principle and then the "be as it is" principle. Over and over again, the command-and-administer system was described as organically alien to independent economic and other quests, unplanned initiative, unpredicted creative efforts, and the freedom needed for all this. Third, the inability to amass absolute control of all the economic processes, caused the command-and-administer system to designate their delegalization through an extensive instruction network, thus contributing to rapid growth of a "shadow" economy. According to estimates of the research institute of the Ministry of Internal Affairs of the USSR and NIZI of the State Planning Committee of the USSR, over 20 million people were active in the "shadow" economy illegally manufacturing products worth tens of billions of rubles in the late 1980s. Finally, the use of ideological regulators of economic development and the existing system of planning and evaluation of the results of scientific and technological progress led to unprecedented "paper" entrepreneurship in the form of upward distortion of results achieved, fancy projects, craving for "demonstration effects," and so on. Moreover, the life of the nomenclatura became a prestigious arena for applying enterprising abilities.

Therefore, there was every reason to assert that the enterprising spirit of Soviet economy was generally degraded as the available enterprising initiative took a wrong course.

All this created an exceedingly unfavorable social background for scientific and technological progress in the USSR. There would be no innovations without enthusiasts and entrepreneurs. Negative factors increased disproportionately, such as low general standards of workmen (9 years of training as compared with 13–14 years in leading capitalist countries), poor discipline and low responsibility, high common apathy and indifference, and a public atmosphere of inadequacy. Numerous sociological studies showed that only

25% to 33% of employees worked as hard as their potential. Incidentally, the pessimism factor turned out to be one of the major obstacles to innovations in the USSR along with red tape and inefficient state regulation. The nation additionally suffered at the hands of distorted communist educational traditions that were not intended to raise creative personalities and continued to waste the country's cultural heritage.

At the same time, leading capitalist countries turned their primary attention to such "metaeconomic" factors as increasing entrepreneurship and innovation and integrating this theme in education. The results swayed mass consciousness towards attractive images of an active, healthy and enterprising personality, creation of an optimistic public atmosphere, enrichment of the motivation and economic environment by restoring national culture, and more. For example, up to 180 billion dollars were, on average, spent on education in the mid-1980s in the USA each year. In the USSR, the corresponding figure was less than 40 billion rubles even considering propaganda expenses and utterly different material and technical supply system.

Technological Incompatibility

The command system caused grave technological incompatibility of the Soviet economy with technological standards of the leading capitalist countries. International research-and-production cooperation had become a necessary condition for technological progress in any country. Decades of "socialist construction" resulted in serious economic, technological, political and cultural barriers which became increasingly difficult to overcome on the way to such progress. A short-sighted, poorly coordinated and vulnerable strategy was chosen regarding participation in world scientific and technological progress.

On the one hand, there was orientation to technical and economic autarchy. On the other hand, foreign novelties were borrowed intensively in an open or secret way disregarding the fact that, firstly, some of them were not advanced and lacked compatibility even with each other and, secondly, their introduction took place in conditions of the aforementioned unresponsiveness of the Soviet economy to such innovations, which eventually did not increase efficiency. On the contrary, there was sheer waste of means and resources in certain instances. Neither of the above factors stimulated the use of domestic innovations. So, autarchic tendencies coupled with monopoly of the foreign economic department limited scientific and technical contacts of enterprises with foreign business and hindered the inflow of new technology, information, and ideas. Moreover, primarily due to political and ideological considerations preference was given to cooperation with the countries of the COMECON (Council for Mutual Economic Assistance), which could not provide the necessary inflow of technology to the USSR at a desirable quality level. Special emphasis should have been placed on resolving the functional unpreparedness of many officials participating in external contacts (lack of computer knowledge, language barriers, poor knowledge of ethics, international business etiquette, etc.).

Conclusions

The Soviet Union needed a well elaborated, deeply thought-out and scientifically substantiated strategy of increasing national competitiveness and providing economic security. Its key element should have been the creation of conditions for stimulating scientific and technological progress and increasing its effect in the national economy. A swift wide-scale technological breakthrough was hardly to be expected in the grave economic situation when the nation was facing an increasing burden of food and financial problems. However, it was a must at that time to lay a foundation for those transformations which would eventually put the country out of the then existing technological and economic crisis.

There could have been a number of apparent key directions:

1. A gradual change from a monopoly market to a market characterized by high internal and external competition. The following was necessary to ensure internal competition:

(a) a lesser degree of monopolization of the economy, legislative steps to stop excessive concentration of production and centralization of functions, introduction of anti-monopoly measures, abolition of the existing branch ministries but preservation of economic ties established for decades between enterprises.
(b) forms of different types and size should have been at the focus of decision-making center in the sphere of economic management and scientific and technological progress. They should have had actual economic independence and equal starting conditions as well as freedoms to dispose of available resources, to set up their own research base, to conclude agreements and contracts, and to set up amalgamations, partnerships and associations. The largest of them should have been established as

multi-branch diversified corporations. They should have competed with other rival structures (a multitude of small and medium firms, their associations and foreign corporations);

(c) transition to a full-value market was impossible without: sale and purchase of production factors; formation of capital, technology, ideas, securities and other markets; mobility of labor, particularly skilled personnel;

(d) close attention should have been paid to the problem or reorganizing Soviet science, increasing its independence and diversifying sources of its financing and ties with industry. Certain aspects of foreign experience mentioned above would have been of use here, particularly those regarding branch science and its deregulation, contractual relations, and self-organization of research teams.

The following was necessary to ensure external competition:

(a) it was essential to stimulate the creation of a system enabling firms to monitor the world technological level of manufactured products and to know the position and strategies of principal competitors, including the assortment and quality of their goods. All firms should have mastered the methods and techniques of business reconnaissance, counter-reconnaissance, and marketing, without which it remained impossible to attain a leading position in technology;

(b) no hopes could be pinned on a major breakthrough to the external market under conditions of very fierce global competition in the sphere of advanced technology. Therefore, it would have been expedient to carefully work out a strategy of filling in certain market gaps (more specifically, by forming transitional structures and joint ventures, including those abroad) regarding technologies in which the USSR had leading positions. In this case, one of the key issues would have been the protection of intellectual property. Much importance is attached to this question in developed countries in conditions of simultaneously increasing international competition and cooperation;

(c) joint ventures and foreign enterprises on Soviet territory should have been used both as a channel of obtaining advanced technology, experience and capital from the West and as a means of exerting pressure on domestic producers;

(d) there was a need for a much more extensive program of training specialists, beginning with students, in marketing, modern competition, international business and finance, and control over innovations abroad; and,

(e) strategic partnerships with foreign firms were desirable to fill in certain technological and product gaps on the world market.

2. The functions of an economic management center should have been drastically changed.

First of all, it was necessary to drastically change the entire system of planning and economic regulation, which had weak ties with scientific and technological progress, was tough and inflexible, separated science from industry, and limited the rights of economic entities to creative work, initiative and choice, without which competitiveness, scientific and technological progress were impossible.

Thus, the center of the planning process at the macro level should have incorporated the vision of a future economic structure, scientific and technical priority, and creation of differential regulation conditions for different industries depending on their strategic character, potential, stage of operating cycle, foreign economic orientation, etc., with a view to attaining structural balance for different parameters. Two further key components of centralized planning should have been complex programs and state orders (contracts), which were not formal and distorted ones, but free, effective and stimulating all partners.

Indeed, the center of scientific and technical planning in industry should have been the firms themselves. They would choose, according to their interests, the structure and sources of RDT&E and financing, participate in state programs and contracts, and cooperate between each other and with state bodies. The state apparatus would regulate the relation between competitiveness and cooperation, creating tax and other privileges for firms actively engaged in RDT&E.

These suggestions were made at a time when the Soviet Union and its scientific and technological (S&T) community still existed as a whole. The modifications of political borders over the last years make the need for restructuring the R&D sector no less important. In fact, the importance and potential value of the inherited share of the former Soviet S&T sector gives the recommendations made here new significance for the successor Republics; first and foremost, Russia itself.

Technological Assessment Problems in the Transition to a Market Economy

G.Mikerin[1] *and O. Kozlova*[2]

Under conditions characteristic of the Soviet centrally-managed system, economic evaluation was practically non-existent until the mid-1970s. Profitability rates or simple rate of return calculations were occasionally applied in measuring the efficiency of capital investments, but these indicators were not integrated in the decision-making process and were merely relegated to appear in different reports. Decisions were essentially made on only the basis of physical and technical characteristics of projects. Thus, the lack of financial and economic criteria of efficiency resulted in the situation when decisions whether a project should be implemented or not were biased due to the focus on political and ideological considerations.

Subsequently, project resources were determined on the basis of estimated costs. In most cases these figures defined at the preliminary stage were to be only a small proportion of the actual amount spent during the implementation of the project. Techniques to determine comparative efficiency were chiefly utilized in choosing the technical options for implementation of the project.

With the introduction of economic incentives in business activity (end of 1960s–beginning 1970s) a need for feasibility studies for each project became apparent. However, economic independence of enterprises was limited. The economic accountability principle, in fact, served the main system of man-

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agement based on the planning indicators that were prescribed in the centralized manner. The rigidly centralized pricing system using expenditure-based methodology also survived. Under such conditions, the economic effect of technological changes (i.e., introduction of new technology) could not be adequately demonstrated by changing values of the indicators reflecting enterprises' business activity.

In order to measure such effects, a single state methodology was introduced in 1977. Thus, an additional system of economic indicators responsive to the *introduction of new technology* was created. These indicators were used not only for feasibility studies, but also for providing material incentives (bonuses) to creators and manufacturers of new technology.

In addition, a supplementary system of economic indicators was oriented towards a more global approach (i.e., at the national level) which made it closer to the principles of the optimal functioning of the economy. However, it was the very supplementary nature of this system that did not permit it to overcome its differences with the main system of economic indicators of the centralized plan. Deeply-rooted deformations in all major ratios of the main system could not be overcome by any calculations, no matter how highly-skilled they may have been. Only transformation of the economic system itself, into an efficient market economy could have facilitated a change in evaluating new technology so as to ensure objective results.

In the USSR, the state strategy for scientific and technological development has been aimed at achieving international superiority in a number of spheres of human knowledge and has been basically determined by non-economic reasons. Therefore, more attention was paid to financial support of large-scale technological programmes, but not to creating a favorable economic climate for innovations and technological changes.

The reorientation of Soviet economic policy towards real market relations presuppose introducing methods of technological assessment.

The globally most common system of investment project assessment and selection is based upon financial analysis of investment alternatives with the help of formalized methods of comparing results and expenditures. The discounting methodology is widely implemented to analyze such problems. It appears to be connected with a growing tendency for companies to introduce large-scale innovations in which the technological change directly and indirectly influences profitability in ways not always adequatley revealed in simple models concerning resource saving.

In the late 1980s in the USSR, up-to-date methods of assessment and selection of technological progress were already in use.[3] However, the objectification of such assessments, as well as stimulation of the process of mastering and realizing innovations remained problematic. The development of innovation for commercialization were impeded due to the lack of a *real* innovation policy, that would finally make production and manufacturing receptive to different kinds of scientific and technological innovations.

In order to solve this problem it was undoubtedly tempting to use the experience of well-developed countries and instruct a system of tax and amortization benefits, loans and credits, and subsidies. Such factors should have induced independent enterprises to create, master and use innovations in the priority areas designated by the state.

Nevertheless, before implementing this approach, it was necessary to analyze whether such a system would function under the existing Soviet economic structure, price level, wage level, and level of taxation. The applicability of such an approach was dependent on institutional base for objective assessment of technology effectiveness for the national economy on the level of each particular self-supporting enterprise.

When using the method of discounted cash flow for assessment of new technology effectiveness, many local examples showed that the results of the assessments contradicted actual world tendencies regarding technological development. That, however, did not prove the method to be defective, but resulted in distorting all cost correlations. In order to analyze this phenomenon we studied the results concerning the "Industry" branch (see

[3]These were the recommended methods for complex assessment of effectiveness of actions aimed at speeding up technological progress adopted by the State Committee of Science and Technology and the Presidium of the USSR Academy of Sciences.

The assessment basis was discounted to a present value of future financial means of the enterprise, aimed at forming different funds and also dividend payments that were to be obtained as a result of business activities using technological advantages of the particular enterprise in question.

When assessing investment in state property, the national economic approach was to be followed. That meant the use of unified principles to determine the discount rate, the use of national economic norms for natural resources payment, and also other norms and standards under the existing legislation, including profit tax from enterprises for state and local budgets.

Hereinafter, the amount of enterprise financial means allocated to create different funds, and also dividend payments will be called financial results of the enterprise activities for a year, shown by the sum left on bank accounts after investment operations, achieved profits, amortization, tax collection, fulfillment of financial obligations, that correspond to the customary term used in Western methodology named cash flow.

Table 1. Basic data to assess the economic effect of traditional technology on "Industry" branch performance.

	Item	Unit	Traditional technology
1.	Result based on cost evaluation (volume of gross output in real prices of enterprises plus balance of sales tax)	bln.rbl.	862.5
2.	Expenditures:		
	2.1. One-time expenditures (average yearly cost of assets (total))	bln.rbl.	972.9
	including:		
	average yearly cost of fixed assets	bln.rbl.	778.3
	2.2. Current expenses	bln.rbl.	698.6
	including:		
	• material expenses (considering amortization for capitalized repairs)	bln.rbl.	585.5
	• wages (including payment for social insurance and labor resources)	bln.rbl.	113.1
3.	Period of calculation - 20 years		
4.	Rate of return - 0,1175		

Table 1). Statistics from 1986 are taken as the basis. The economic effect of technology use was calculated under the conditions that the present fixed assets of the branch served for 20 years, which is the average amortization norm, and that the results and current expenses did not change during the calcuation period. Followingly, we calculated the economic effect of the "Industry" branch fixed assets over their useful life under the conditions of technological and economic stability.

The result was a positive economic effect of 337.2 billion rubles, with a pay-back period equal to approximately 10 years. In each year of the calculated period, the "Industry" branch contributed approximately 122.7 billion rubles as sales tax, profit deductions (including fixed assets), income tax, allocations to social insurance and payment for labor resources to the state budget, plus 141.6 billion rubles of amortization deductions of enterprises.

One of the most important trends of scientific and technological development has been the automation of production. According to statistics, it can double labor productivity, while simultaneously reducing the productivity of fixed capital 1.6 times. The calculated economic effect based on the altered technological and economic data (see Table 2), while accommodating the new conditions and assuming constant gross output for the "Industry" branch, was 1.8 times less that when using traditional technology. Annual transfers to central management bodies declined, and the branch profits did not compensate for lost central investments.

Based on these calculations, the use of new technology (in this particular case—automation) was not profitable both from the local and global points of view. The use of economic stimuli (tax, preferences, subsidies, rate of interest, etc.) would, under the prevailing conditions, not improve the situation. Enterprise managers would be inclined to be more risk averse due to the comparative non-profitability of this kind of technology, leading to adverse selection (in favor of traditional technology) and further losses to the state budget. In addition, the innovation potential would decline throughout the national economy as a whole.

Therefore, in order to create an economy receptive to technological progress a primary step would focus on the necessity to reform the basic cost correlations in public (state) production.[4] That would naturally result in changing economic figures for all branches of national economy, including the cost structure.

We would like to show how this affects our assessment of "Industry" branch performance. For this purpose we require new basic data (see Table 3), from which we subsequently determine the extent of the economic effect depending on first traditional technology, and second on technology based on automation.

As a result, the financial indicators of industrial performance for the 20 year period, not considering the time factor (even after 10% property tax introduced for enterprises), will be 1.5 times higher with automation than with continued use of traditional technology. Under the old price, wage and tax systems, new technology appeared to be 3 times worse than the traditional one. Calculations revealed that changes in price structure and level, and wages structure and level would cause an increase in the economic effect in industry utilizing traditional technology 1.5 times; while automation would result in three-fold growth. Consequently, new technology is predicted to be 1.4 times more effective than the traditional. This result, in addition to the introduction of new regulations for relations of enterprises with local and state budgets, and non-deduction of amortization payments from the

[4]We used the doubling of prices for fuel and power, and in food industry doubling of wages fund with 14% deductions to the social insurance fund; enterprise income will be subject to sales tax and amortization deductions for renovation, and a property tax corresponding to 25% of company income tax.

Table 2. Basic data to assess the economic effect of automated production on "Industry" branch performance.

	Item	Unit	Technology based on automation
1.	Result based on cost evaluation (volume of gross output in real prices of enterprises)	bln.rbl.	862.5
2.	Expenditures:		
	2.1. One-time expenditures (average yearly cost of assets (total))	bln.rbl.	1510 (778.3 × 1.6+265)
	including:		
	average yearly cost of fixed assets	bln.rbl.	1245.0
	2.2. Current expenses	bln.rbl.	657.2
	including:		
	•material expenses (considering amortization for capitalized repairs)	bln.rbl.	600.6
	•wages (including payment for social insurance and labor resources)	bln.rbl.	56.6
3.	Period of calculation - 20 years		
4.	Rate of return - 0,1175		

enterprise balance considerably improves self-financing conditions for their performance and makes new technology more profitable than the traditional one (see Table 4).

As previously mentioned, discounted cash flow is the indicator customarily used in international practice to assess large scale projects. Our calculations showed that under the existing Soviet-type economic conditions using either traditional techology or technology based on automation was non-profitable for the "Industry" branch. However, new (altered) economic indices regarding public (state) production would cause the discounted financial stream to be positive for both variants based on branch performance. Its level was estimated at 1.5 times higher when automation used in favor of traditional technology.

A certain key measure had been taken by the Soviet Government to reform cost correlations. It consisted of a changed price structure and level, tax system with stable wages, and a special system of compensation allowance. However, as our calculations revealed, such changes did not facili-

Table 3. Basic data to calculate the economic effect from "Industry" branch performance accounting for changes in cost correlations of public production.

	Item	Unit	Traditional technology	Technology based on automation
1.	Result based on cost evaluation (vol. of gross output in real prices of enterprises equal to industrial prices)	bln.rbl.	1080	1080
2.	Expenditures:			
	2.1. One-time expenditures (average yearly cost of assets (total))	bln.rbl.	972.9	1510
	including:			
	average yearly cost of fixed assets	bln.rbl.	778.0	1225
	2.2. Current expenses	bln.rbl.	904.0	817.5
	including:			
	• material expenses (considering amortization for capitalized repairs)	bln.rbl.	701.0	716.0
	•wages (including payment for social insurance)	bln.rbl.	203.0	101.5
3.	Period of calculation - 20 years			
4.	Rate of return - 0,1175			

tate a solution to the problem of making the economy receptive to technological progress.

The economic effect of automation in the "Industry" branch was 1.2 times less under the assumed conditions, compared to traditional technology, and they both (with due regard for time factor) do not meet the demands to secure branch performance (see Table 5). This indicates that the internal rate of effectiveness for traditional and new technology was lower than the rate of effectiveness in the national economy, and, correspondingly, could not provide concordance between self-financing and national economy interests. Furthermore, the results showed that industrial enterprises on the whole could not meet the interest payments at the assumed rate of interest for middle- and long-term loans. However, doubling wages combined with a 25% reduction in the profits tax would have improved repayment ability.

So, under the Soviet structure of costs it was impossible to make self-supporting enterprises receptive to those technological progress achievements ("new technologies") that were profitable for any foreign company. Due

Table 4. Self-financing indices for "Industry" branch performance (billion rubles).

Indices	ignoring cost correlations in public production		regarding cost correlations in public production	
	trad. tech.	tech. auto.	trad. tech.	tech. auto.
1. Taxable Profit	112.3	119.0	133.3	202.1
2. Profit deductions with due regard for fixed assets (company income tax)	62.0	65.0	33.0	50.5
3. Payment for labor resources	10.7	5.4	-	-
4. Property tax				
4.1 5% of fixed assets	-	-	38.9	62.0
4.2 10% of main fixed assets	-	-	77.8	124.0
5. After-tax profit (net profit)				
5.1 [(1)-(2)-(3)-(4.1)]	39.6	48.6	61.1	89.6
5.2 [(1)-(2)-(3)-(4.2)]	39.6	48.6	22.2	27.6
6. Enterprise deductions for creating different funds:				
6.1 (5.1) + amortization share for renovation, non-deductible	58.6	78.8	98.9	150.0
6.2 (5.2) + amortization for renovation, non-deductible	58.6	78.8	60.0	88.0
7. Financial results of industrial performance for 20 years (ignoring the time factor)				
7.1 (6.1) × 20 as one-time expenses	199.1	66.0	100.5	149.0
7.2 (6.2) × 20 as one-time expenses	199.1	66.0	227.0	250.0
8. Financial results of industrial performance for 20 years (with due regard for time factor) [{(6)+(4)+ funds payments}/ rate of return-one-time expenses]	-337.2	-619.8	199.9	294.3

Note: trad. tech. = traditional technology
tech. auto. = technology based on automation

Table 5. Results of "Industry" branch performance in realizing the Soviet Government Program (billion rubles).

Indices	with Government Program		with Alternative Program[a]	
	trad. tech.	tech. auto.	trad. tech.	tech. auto.
1. Taxable Profit	204.9	227.6	149.6	213.3
2. Company income tax	112.5	125.2	37.4	53.3
3. Property tax	71.7	79.7	-	-
3.1 10% of fixed assets	-	-	77.8	124.0
3.2 5% of fixed assets	-	-	38.9	63.0
4. After-tax profit (net profit)				
4.1 [(1)-(2)-(3)-(4.1)]	133.0	147.9	34.4	39.0
4.2 [(1)-(2)-(3)-(4.2)]	133.0	147.9	73.3	98.0
5. Price raise compensation	20.5	10.3	-	-
6. Enterprise deductions to create different funds (*)				
6.1 {(4.1) + amortization share for renovation, non-deductible} (5)	142.9	186.2	72.4	100.0
6.2 {(4.2) + amortization for renovation, non-deductible} (5)	142.9	186.2	111.3	158.8
7. Financial results of industrial performance for 20 years (ignoring the time factor) [{(6)+(3)}/rate of return-one-time expenses]	0	-303.0	57.0	-8.0

[a]With due regard for price changes in line with the Program, doubling wages, 25% growth in profit tax, and introduction of a property tax.
* Payment for natural and labor resources not included.
Note: trad. tech. = traditional technology
tech. auto. = technology based on automation

to the then existing cost correlations, new technology became entirely ineffective for self-supporting enterprises; in fact, the new technology resulted in profits reduction, not growth. This was the reasoning behind the long endured practice of "forcing" new, *unprofitable* technology, on the enterprises, whereas foreign companies searched for the most desireable innovations. In the Soviet Union, the basic grounds for introducing new technology were mostly technological (including military) priorities, which were not the object of this study.

What were the basic distortions in cost correlations resulting in the contradictory situation present in the USSR?

Firstly, economic results achieved by using any technology was finally reflected by changes in the general consumption fund. For a number of years, retail prices for consumer goods were kept artificially low. In addition, prices for production factors were changed from time to time (always positively) and were themselves quasi-arbitrarily increased, also on the pretense of new technology introduction. This resulted in price distortions, that may be ex-post interpreted as minimally lowering prices for consumer goods relative to prices for factors of production.

Secondly, new technology efficiency was determined by the economic potential that could have been achieved relative to the actual production, primarily on a labor-saving basis. Namely, labor-saving technological progress. Comparatively high prices for new technology (compared to final results) and extremely low wages for labor that could be substituted by this technology, made its purchase appear non-profitable by enterprise managers. Only with wages doubling (compared to fixed capital prices), would new technology have proven to be profitable in Soviet enterprises. A similar situation existed in resource-saving (especially for energy-saving technologies). That is, only if prices for fuel and power (oil, gas, coal, power) would have increased two-fold would the economic policy of Soviet self-supporting enterprises have gradually corresponded to world standards.

Thirdly, international practice has shown that the price of new technology declines with time due to increasingly rapid diffusion and wide-spread application. This phenomena has facilitated production to remain profitable although profit margins continued to be narrowed. For example, the mass spread of personal computers over the last ten years has seen the technological level grow 3 times, while the market prices dropped 10 times. The distorted price system and the underdeveloped market in the USSR caused prices for such products to be 30 and more times higher than world market prices. Yet, despite this *additional* (excess) profit, none was re-invested into the promotion and development of such a profitable business, but rather diverted into the state budget. Even after limits to the super-profit were introduced, the magnitude of the deductions were to continue, not directly but indirectly.

These have been the most vivid elements of the Soviet economic system that created obstacles for economy to be receptive to technological progress, and additionally to newly organized enterprises that could have improved the results of public production. The fact that the economy was ineffective and unreceptive to innovations could have been explained by the general institutional structure of economy. Considerable time is needed to improve it.

It is not enough to carry out formalized privatization of enterprises and adopt legislative acts on demonopolization, freedom of enterprising, creation of joint stock companies, or restructuring credit and the banking system. Non-stop operation of various markets has become a necessity: these might include a stock market, bond market, labor market, capital market, and still others.

National Innovation Systems: A Retrospective on a Study

Richard R. Nelson[1]

What is the Study About?

In this essay I will describe a large comparative study of national innovation systems that has just been completed, tell something of what motivated the study and how it was organized and undertaken, and highlight some of the more interesting findings. This is a difficult task, for the project was not only large but also complex.

The heart of the project consisted of studies of 15 countries, including all of the prominent large market oriented industrialized ones, several smaller high income countries, and a number of newly industrializing states. The studies were carefully designed, developed, and written to illuminate the institutions and mechanisms supporting technical innovation in the various countries, the similarities and differences across countries and how these came to be, and to permit at least preliminary discussion of how the differences seemed to matter. No other project has come remotely close to treating the range of countries considered here. Moreover, many of the individual studies stand as major contributions in their own right to the understanding of the innovation systems of particular countries, going far beyond anything written on those countries before. To describe and summarize in compact

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form what came out of the project simply is impossible. I must pick and choose and hint.

The project was undertaken to try to throw some light on a very complicated and important set of issues. The slowdown of growth since the early 1970s in all of the advanced industrial nations, the rise of Japan as a major economic and technological power, the relative decline of the United States, and widespread concerns in Europe about being behind both, has led to a rash of writing and new policy departures concerned with supporting the technical innovative powers of national firms. At the same time the enhanced technical sophistication of Korea, Taiwan, and other newly industrialized countries (NICs) has broadened the range of nations whose firms are competitive players in fields which used to be the preserve of only a few, and led other nations who today have a weak manufacturing sector to wonder how they might emulate the performance of the successful NICs. There clearly is a new spirit of what might be called "techno-nationalism" in the air, combining a strong belief that the technological capabilities of a nation's firms are a key source of their competitive performance, with the belief that these capabilities are in a sense national, and can be built by national action.

It is this climate that has given rise to the current strong interest in national innovation systems, their similarities and differences, and in the extent and manner that these differences explain variation in national economic performance. There now may be more awareness and research about such national differences than on any other area where comparative institutional analysis would seem interesting and illuminating.

The project on which I report here was born of this intellectual climate, and came out of a belief on the part of the participants that much of the writing and argument were somewhat hyped, and rather haphazard. More, many of the allegedly comparative studies in fact had concentrated on one country—in recent times usually Japan—with the comparison with other countries largely implicit. The actual comparative studies tended to be of two or a very small group of countries. This limitation struck the project participants as particularly serious in view of the absence of a well articulated and verified analytic framework linking institutional arrangements to technological and economic performance. In the absence of such a framework there were (and are) only weak constraints on the inclinations of analysts to draw possibly spurious causal links between differences in institutional structures that clearly are there, and differences in performance which clearly are there also. Different authors have focused on different things and made different kinds of arguments about why this feature or that was an important factor behind strong or weak performance. A broadening of a set of countries considered simultaneously seemed to us an important way to tighten these constraints by enlarging the number of "points" that a causal theory had to "fit."

The way I have been putting the matter clearly signals that the orientation of this project has been to carefully describe and compare, and try to understand, rather than to theorize first and then attempt to prove or calibrate the theory. However, a comparative study like this requires, at the least, some agreement on basic terms and concepts.

There is, first of all, the concept of a national innovation system itself. Each of the terms can be interpreted in a variety of ways, and there is the question of whether, in a world where technology and business are increasingly transnational, the concept as a whole makes much sense.

Consider the term "innovation." In this study we, the participants, interpret the term rather broadly, to encompass the processes by which firms master and get into practice product designs and manufacturing processes that are new to them, whether or not they are new to the universe, or even to the nation. We do so for several reasons. First, the activities, and investments associated with becoming the leader in the introduction of a new product or process, and those associated with staying near the head of the pack, or catching up, are much less sharply distinguishable than commonly is presumed. Second, much of the interest in innovative capability is tied to concern about economic performance, and here it is certainly the broader concept rather than the narrower one (the determinants of being first) that matters. This means that our orientation is not limited to the behavior of firms at the world's technology forefront, or to institutions doing the most advanced scientific research, although in some countries the focus is here, but is more broadly on the factors influencing national technological capabilities.

Then there is the term "system." While to some the word connotes something that is consciously designed and built, this is far from the orientation here. Rather the concept here is of a set of institutions whose interactions determine the innovative performance, in the sense above, of national firms. There is no presumption that the system was, in some sense, consciously designed, or even that the set of institutions involved works together smoothly and coherently. Rather, the "systems" concept is that of a set of institutional actors that, together, play the major role in influencing innovative performance. The broad concept of innovation that we have adopted has forced us to consider much more than simply the actors doing research and development. Indeed, a problem with the broader definition of innovation is that it provides no sharp guide to just what should be included in the innovation system, and what can be left out. More on this later.

Finally, there is the concept of "national" system. On the one hand, the concept may be too broad. The system of institutions supporting technical innovation in one field, say pharmaceuticals, may have very little overlap with the system of institutions supporting innovations in another field, say aircraft. On the other hand, in many fields of technology, including both pharmaceuticals and aircraft, a number of the institutions are or act transnational. Indeed, for many of the participants in this study, one of the key interests was in exploring whether, and if so in what ways, the concept of a "national" system made any sense nowadays. National governments act as if it did. However, that presumption, and the reality, may not be aligned.

The studies in this project are unified by at least broad agreement on the definitional and conceptual issues discussed above. They also were guided by certain common understandings of the way technical advance proceeds, and the key processes and institutional actors involved, that are now widely shared among scholars of technical advance. In a way these understandings do provide a common analytic framework, not wide enough to encompass all of the variables and relationships that likely are important, not sharp enough to tightly guide empirical work, but broad enough and pointed enough to provide a common structure in which one can have some confidence.

In particular, our inquiry was strongly shaped by our shared understandings about the complex intertwining of science and technology that marks the modern world. In the first place, we take the position that technology at any time needs to be recognized as consisting of both a set of specific designs and practices, and a body of generic knowledge that surrounds these and provides understanding of how things work, key variables affecting performance, the nature of how things work, the nature of currently binding constraints, and promising approaches to pushing these back. In most fields of technology a considerable portion of generic understanding stems from operating and design experience with products and machines and their components, and generalizations reflecting on these. Thus consider a mechanic's guide, or the general knowledge of potters, or steel makers.

However, over the last century science has played an increasing role in the understandings related to technology. Indeed most modern fields of technology today have associated with them formal scientific or engineering disciplines like metallurgy, computer science, and chemical engineering. These kinds of disciplines are basically about technological understanding, and reflect attempts to make that understanding more scientific. An important consequence has been that, nowadays, formal academic training in the various applied sciences and engineering disciplines has become virtually a prerequisite for understanding a technology.

The intertwining of science and technology which began to occur a century ago led to the rise of the industrial research laboratory as the dominant locus of technological innovation, first in the chemical and electrical industries, and then more broadly. These facilities, dedicated to advancing technology, and staffed by academically trained scientists and engineers, were closely tied to individual business enterprises.

It is important to understand that not all of the activities and investments made by firms in innovating are conducted in R&D laboratories, or get counted as R&D . The extent to which they do varies from industry to industry. Where firms are small, or where firms are engaged in designing products to order for individual customers, much of the innovative work may not be counted as R&D. Nonetheless, while not always counted as R&D, and while often drawing extensively on external sources like universities and government laboratories, in most industries the lion's share of innovative effort is made by the firms themselves.

There are several reasons. First, after technology has been around for a period of time, in order to orient innovative work fruitfully one needs detailed knowledge of its strengths and weaknesses and areas where improvements would yield high payoffs, and this knowledge tends to reside with those who use the technology, generally firms and their customers and suppliers. Second, profiting from innovation in many cases requires the coordination of R&D, production, and marketing, which tends to proceed much more effectively within an organization that itself does all of these. These arguments hold whether one defines the innovation concept narrowly, as the introduction of a product or process that is truly new, or whether one defines it broadly as we do in the study, as the introduction of something that is new to the firm. Thus, all of the country studies paid a considerable amount of attention to the activities and investments being undertaken by firms.

The other two institutional actors with which all of the country studies were concerned are universities (and scientific and technical educational structures more generally), and governments and their policies as these influence industrial innovation. University and kindred institutions play two different kinds of roles in modern industrial innovation systems. They are the place where scientists and engineers who go into industry get their formal training. And in most (but not all) countries they are the locus of a considerable amount of research in the disciplines that are associated with particular technologies. To a much greater extent than commonly realized, university research programs are not undifferentiated parts of a national innovation system broadly defined, but rather are keyed into particularly technologies and particular industries. University training, and research, that supports technical innovation in farming and the food processing industries simply is very different than university teaching and research that supports the electronic industries. Thus, a major question in this study was how the research and teaching orientation of a nation's universities reflected, or molded, the industries where technological innovation was important in the nation.

And, of course, the individual country studies looked closely at the range of government programs and policies bearing on industrial innovation. As is the case with the activities of universities, many government programs are focussed specifically on particular technologies or industries, and these obviously were of central interest. However, as noted in my earlier discussion of the meaning of an "innovation system," given the broad way we are using the term innovation, innovative performance can not be cleanly separated from economic performance and competitiveness more broadly. Thus, in many cases the examination of government policies bearing on industrial innovation had to get into things like monetary and trade policies.

In designing the study the participants faced a quandary. From the discussion above it is obvious that a very wide range of factors influence the innovative performance of a nation's industries. The desire for comparability across the studies seemed to call for a rather elaborate list of things all country studies would cover. Yet it was apparent that the most interesting features of a country's innovation system varied significantly across countries, and we wanted to illuminate these. Limits on resources and space foreclosed doing both. Our compromise involved two strategic decisions. First, we agreed on the limited list of features all country studies were to cover, e.g., the allocation of R&D activity and the sources of its funding, the characteristics of firms and the important industries, the roles of universities, and the government policies expressly aimed to spur and mold industrial innovation. Beyond these the authors were encouraged to pick out and highlight what they thought were the most important and interesting characteristics of their country. But second, considerable effort was put into identifying the kinds of comparisons—similarities or differences—that seemed most interesting and important to make. In general these did not involve comparisons across all countries, but rather among a small group where for various reasons comparison was apt.

The overall project covered three sets of countries where we thought in-group comparisons would be most interesting. The first group consisted of six large high income countries—the U.S., Japan, Germany, France, Italy, and the United Kingdom. The second group consisted of four small high income countries, with a strong agricultural or resources base—Denmark, Sweden, Canada, and Australia. Finally, included in the set were five lower income countries—Korea, Taiwan, Argentina, Brazil, and Israel. While we were interested in the similarities and differences across groups, a considerable amount of thought and effort went into laying out within group comparisons.

As I said at the offset, it is impossible to summarize what came out of this study; I can only give some highlights and a flavor. In the following section I highlight some of the key similarities and differences across countries, and our assessments about what lies behind the differences. Then I report our tentative judgements on what distinguishes systems where firms are strong and innovative from systems where they are not; most of us believe that this has somewhat less to do with aggressive "technology policies" than current fashion might have one believe. Indeed, many of us believe that the current focus of discussion "high tech" industries may exaggerate the importance to a nation of having strong national firms in those fields. An important reason is that firms in these industries are increasingly going transnational, which brings me to my next topic: what remains of national systems in a world where business and technology are increasingly transnational? I conclude by reflecting on the acrimonious aspects of national technology policies.

Country Differences and What Lies Behind Them

To compare means to identify similarities as well as differences. Certainly the broad view of technical innovation which I laid out above and which guided this study implies certain commonalities. That view applies to economies in which profit oriented firms are the principal providers of goods and services, and where central planning and control is weak. These conditions hold in all of the countries in our set, although in some a certain portion of industry is nationalized, and in some governments do try to mold the shape of industrial development in at least a few economic sectors. In all of the countries in our set, the bulk of education, including university education, is conducted in public institutions. In all, the government is presumed to have major responsibility for the funding of basic research, although there are major differences across countries regarding how much of that they do, and where basic research is mostly carried out. From one point of view, what is most striking about the country comparisons is the amount of basic similarity. Had the old Soviet Union been included in the set, or China, or Nigeria, the matter would have been different. But, as it is, the differences across our set of countries must be understood as differences of individuals of the same species.

Within our group of countries, it would appear that to a considerable extent the differences in the innovation systems reflect differences in economic and political circumstances and priorities. First of all, size and the degree of affluence matter a lot. Countries with large affluent populations can provide a market for a wide range of manufacturing industries and may engage in other activities that "small" countries cannot pursue, at least with any chance of success, and their innovation systems will reflect this. Low income countries tend to differ from high income ones in the kinds of economic activities in which they can have comparative advantage, and in internal demand patterns, and these differences profoundly shape the nature of technical innovation that is relevant.

The threefold division of our countries into large high income industrial nations, small high income countries, and low income countries thus turned out to be a useful first cut analytic separation. By and large the economies in the first group had a significantly larger fraction of their economies in R and D intensive industry, like aerospace, electronics, and chemical products, which require large sales to be economic, than economies in the second and third groups. There are some anomalies, at the surface at least. Thus Sweden in the second group and Israel and Korea in the third have higher R&D to GNP ratios than several of the countries in the first group. Some of the mystery disappears when Israel's ambitious military R&D is recognized, and Sweden's and Korea's strong presence in several R&D and intensive industries that live largely through export. Both of the latter two countries also have strong defense programs this also undoubtedly affected their R&D intensities. There are certain interesting similarities of countries in different groups—Japan and Korea for example. However, by and large there were strong intra-group similarities, and strong inter-group differences. Thus the U.S. and Japan look much less different than advertised, once one brings Australia and Israel into the comparison set. And much of the U.S.–Japan difference can be seen to reside in differences in their resource bases and defence policies.

Whether or not a country had rich natural resources or ample farming land clearly is another important variable influencing the shape of its innovation system. It turns out that all our "small" high income countries also were well endowed in this respect. Among the large high income countries the U.S. was far and away the best endowed here. Countries that possess resources and good farm land face a different set of opportunities and constraints than countries without these assets.

Countries that lack them must import resources and farm products, which forces their economies towards export-oriented manufacturing, and an innovation system that supports this. One sees this strikingly in the cases of Germany, Japan, and Korea. On the other hand, countries with a rich resource base can support relatively high living standards with farm products and resources and the affiliated industries providing exports to pay for imported manufactured goods. The countries that have been able to do this—Denmark, Canada, and Australia stand out in our set—have developed significant publicly supported R&D programs to back these industries. So also has the United States. While effective agriculture and resource exploitation does require R&D, compared with "high tech" industry the R&D intensity here is low.

The discussion above suggests that, to some extent at least, a nation's innovation system is shaped by factors like size and resource endowments that affect comparative advantage at a basic level. But it also is true that a nation's innovation system tends to reflect conscious decisions to develop and sustain economic strength in certain areas, that is, it builds and shapes comparative advantage.

Some of the project members were surprised to find in how many of our countries national security concerns had been important in shaping innovation systems.

In the first place, among high income countries defense R&D accounts for the lion's share of the differences among the countries in government funding of industrial R&D, and the presence of large military programs thus explains why government industrial R&D spending in the U.S., and the U.K. and France, is so much greater than in Japan and Germany. In the second place, the industries from which the military procures tend to be R&D intensive, whether the firms are selling to the military or to civilians. The study of Japan shows clearly that the present industrial structure was largely put in place during an era when national security concerns were strong. This structure, now oriented to civilian products, is one of the reasons for Japan's high R&D intensity. It is possible that, to some extent, this argument also holds for Germany.

Interestingly, every one of the low income countries in our study has been influenced by national security concerns, or a military government, or both. Thus much of high tech industry in Israel is largely oriented towards the military. The broad economic policies, industrial structures, and innovation systems of Korea and Taiwan were molded in good part by their felt need to have a capable military establishment. The pockets of "high tech" atop the basically backward Brazilian and Argentine economies clearly reflect the ambitions of their military elites.

As noted, all of the countries in our set are, basically, ones in which firms are mostly expected to fend for themselves in markets that are, to a considerable extent, competitive. However, all are marked by significant pockets of government overview, funding, and protection. In our countries with big military procurement programs, the defense industries are the largest such pocket. However, in many of our countries government support and protection extends into space, electric power, telecommunications, and other areas of civilian "high tech." While by and large these extensions are most significant in the big high income countries, Canada has large public programs in electric power and telecommunications, and so does Sweden.

There clearly are significant differences across the nations regarding beliefs about which kind of a role government should play in shaping industrial development. The role of military concerns clearly is a powerful variable influencing this. But a relatively active government also is associated with "late" development, along the lines put forth by Alexander Gerschenkron, (1962). Aside from the arena of national security and related areas, Britain and the U.S. are marked by restrained government. On the other hand all of our low income late developing countries have quite active governments. However, there certainly are exceptions to this rule. France's Etatism goes way back in history, and while Italy is a late developer except during the Fascist era her government has been weak.

The above discussion suggests that one ought to see considerable continuity in a nation's innovation system, at least to the extent that the basic national objectives and conditions have a continuity. Although this proposition clearly has only limited bearing on the countries in our set that only were formed or gained independence in recent years—Israel, Taiwan, Korea—even here one can see a certain consistency within these nation's short histories. All of these countries have experienced dramatic improvements in living standards since the 1950s, and their industrial structure has changed markedly. Their innovation systems have changed as well, but as our authors tell the story, in all of these countries today's institutional structures supporting innovation clearly show their origins in those of 30 years ago.

For countries with longer histories, the institutional continuity is striking, at least to the study authors. Thus one can see many of the same things in 1990 in France, Germany, and Japan, that were there in 1890, and this despite the enormous advances in living standards and shifts in industrial structure all have experienced, and the total defeat of the latter two nations in World War II and the stripping away of their military. Britain of 1990 continues many the institutional characteristics of Britain in 1890, although they seemed to work better then than now.

Indeed, in this author's eyes, of the countries with long histories the one that has changed most institutionally is the U.S. The governmental roles in funding university research, and defense R&D, that came into place only after World War II, had little precedent prior to the War, and profoundly changed the nature of the innovation system.

What is Required for Effective Innovative Performance?

We have defined innovation broadly so that the term basically stands for what is required of firms if they are to stay competitive in industries where technological advance is important. Such industries span a large share of manufacturing, many service sectors such as air transport, telecommunications, and medical care, and important areas of agriculture and mining. Staying competitive means different things in different national contexts. For firms located in high wage countries, being competitive may require having a significantly more attractive product or a better production process than firms in low wage countries. For the latter, being competitive may not require being at the forefront. Indeed much innovation in low income countries involves the learning of foreign technology, its diffusion, and perhaps its adaption to local circumstances of demand or production. But in either kind of country, if technological advance in the industry is significant, staying competitive requires continuing innovation.

We, the group that has produced the country studies, think we can discern several basic features that are common to effective innovative performance, and which are lacking or attenuated in countries where innovation arguably has been weak. First, the firms in the industry were highly competent in what mattered to be competitive in their lines of business. Generally this involved competence in product design and production, but usually also effective overall management, ability to assess consumer needs, links into upstream and downstream markets, etc. In most cases, significant investments lay behind these firm capabilities. All this enabled firms to master the relevant technologies and other practices needed to compete and to stay up with or lead with new developments.

This observation does contain a hint of tautology, but is better regarded as confirmation of a point stressed above, that the bulk of the effort in innovation needs to be done by the firms themselves. While they may draw on outside developments, significant internal effort and skill is needed to complement and implement these. One cannot read the studies of Japan, Germany, Italy, Korea, Taiwan, all arguably countries where firms have displayed strong performance in certain industries, without being impressed by the authors' description of the firms. On the other hand, one is impressed the other way by the authors' commentary on the weaknesses of firms in certain industries in Britain, France, Australia, Argentina, and Israel.

Being strong did not necessarily mean that firms were large. Economists have long understood that while in some industries a firm has to be large in order to be a capable innovator, in other industries this is not the case. Many of the strong Italian, Taiwanese, and Danish firms are relatively small. Nor does it mean that the firms spend heavily on formal R&D. In some fields like electronics generally it did, at least for firms in our first two groups of countries; however in Korea and Taiwan electronics firms were often doing well with technical efforts mostly oriented towards "reverse engineering." The Italian textile industry is strong on fashion and design, and are highly innovative in these respects, but little of that work is accounted as R&D. Nor does it imply that the firms were not benefiting from publicly funded R&D programs, or favored procurement status. However, as our authors describe it, the bulk of the inputs and direction for innovative activity were coming from the firms themselves.

While our concept of a strong firm entails the ability to compete, in all of our cases becoming strong involved actually being exposed to strong competition and so do being forced to compete. As Michael Porter (1990) has noted, in a number of cases the firms faced strong rivals in their own country. Thus the Japanese auto and electronics companies compete strongly with each other, American pharmaceutical companies compete and so do Italian clothing producers. However, it is not at all clear that this generalization holds for small countries, where there may be only one or a few national firms as Ericson in Sweden and Northern Telecom in Canada. For these firms most of their competition is with foreign rivals.

Porter (1990) and Bengt-Ake Lundvall (1988) have proposed that firms in industries where a country is strong tend to have strong interactive linkages with their upstream suppliers, who also are national firms. Our studies show many cases where this proposition is verified. The supplier networks of Japanese automobile firms, and the upstream-downstream connections in Danish agricultural product processing, are good examples. The cooperation of Italian textile producers with each other and with their equipment suppliers is another. However, there are a number of examples where the proposition does not seem to hold. Pharmaceutical companies, strong in Germany and the U.S., do not seem generally to have any particularly strong supplier connections, international or national. In aircraft production, the producers of components and sub-components increasingly are located in countries other than that of the system designer and assembler.

A similar observation obtains regarding the proposed importance of a demanding set of home market customers. In many cases this holds. But in small countries or for industries that from their start have been export oriented, the main customer discipline may come from foreign customers.

While "strong firms" are the key, that only pushes the question back a stage. Under what conditions do strong firms arise? As the discussion above suggests, to some extent the answer is "spontaneously." However, our studies do indicate strongly that aspects of the national background in which firms operate matter greatly.

One important feature distinguishing countries that were sustaining competitive and innovative firms was education and training systems that provide these firms with a flow of people with the requisite knowledge and skills. For industries where university-trained engineers and scientists were needed, this does not simply mean that the universities provide training in these fields, but also that they consciously train their students with an eye to industry needs. The contrast here between the U.S., and Germany on the one hand, and Britain and France on the other, is quite sharp, at least as the authors of our studies draw the picture. Indeed these studies suggest strongly that a principal reason why the former two countries surged ahead of the latter two, around the turn of the century, in the science based industries emerging then is that their university systems were much more responsive to the training needs of industry.

While strength in "high tech" depends on the availability of university trained people, industry more generally requires a supply of literate, numerically competent people in a wide range of functions outside of R&D, who are trained to industry demands either by the firms themselves (as in Japan) or in external training systems linked to firms (as in several German and Swedish industries). Countries differed in the extent to which their public education and training systems combined with private training to provide this supply, and the differences mattered. Thus among high income countries Germany, Japan, and Sweden came through much stronger in this respect than Britain and Australia. Among developing countries the contrast is equally sharp between Korea and Taiwan on the one hand, and Brazil on the other.

The examples of Korea and Taiwan, and the other Asian "tigers," can be read as remarkably successful cases of education led growth. As the authors tell the story, the ability of firms in these countries to move quickly from the relatively simple products they produced in the 1950s and 1960s to the much more complex and technologically sophisticated products they produced successfully in the 1980s was made possible by the availability of a young domestic workforce that had received the schooling necessary for the new jobs. On the other hand, the cases of Argentina and Israel suggest that the availability of an educated workforce is not enough by itself. The economic incentives facing firms must be such as to compel them to mind the market and to take advantage of the presence of a skilled work force to compete effectively with their rivals.

Another factor that seems to differentiate countries where firms were effectively innovative from those where they were not is the package of fiscal, monetary, and trade policies. By and large where these combined to make exporting attractive for firms, firms have been drawn to innovate and compete. Where they have made exporting difficult or unattractive, firms have hunkered down in their home markets, and when in trouble called for protection. As I shall indicate later, in some cases at the same time as firms were competing abroad, they were working within a rather protected home market, so the argument is not a simple one for "free trade." Rather, it is that export incentives matter significantly because for most countries if firms do not compete on world markets they do not compete strongly. Up until recently the U.S. possibly was an exception to this rule. The U.S. market was large enough to support considerable competition among domestic firms, which kept them on their toes and innovative. No other country could afford the luxury of not forcing their firms to compete on world markets. Now the U.S. cannot either.

Of course much of the current interest in national systems of innovation reflects a belief that the innovative prowess of national firms is determined to a considerable extent by government policies. Above I have identified two features of the national environment in which firms live that seem to affect their ability and incentives to innovate profoundly, and which are central responsibilities of government in all of the countries in our sample: the education of the work force and the macro-economic climate. But what of government policies and programs more directly targeted at technological advance? This is where much of the contemporary interest is focussed. How effective have been these kinds of policies?

In assessing this question in the light of the fifteen country systems studied in this project, one strong impression is the wide range of policies targeted at technological advance. Thus in recent years, government policies towards industrial mergers and aquisitions, inter-firm agreements and joint ventures, and allowable industry wide activities, often have been strongly influenced by beliefs about the effects of such policies on innovative performance. Many countries (and the E.C.) now are encouraging firms to cooperate in R&D of various sorts. Similarly, in recent years a number of governments have worked to restructure or augment financial institutions with the goal of fostering industrial innovation; thus several have tried to establish their analogue to the "venture capital" market that exists in the U.S. As suggested, these policies are a very diverse lot and differ from country to country. Our case studies do provide scattered evidence on them, but, simply because they are so diverse, I cannot see any strong generalizations that can be drawn.

Of course, our country study authors were primed to look at government programs directly supporting R&D, and here I think the evidence collected is more systematic. It seems useful to distinguish between government programs that largely provide funds for university research or for research in government or other laboratories not tied to particular business firms, and government programs that directly support R&D done in firms. I consider each in turn.

Scholars of innovation have now understood that, in many sectors, publicly supported research at universities and in public laboratories is an important part of the sectoral innovation system. A substantial share of the funding of such institutions goes into fields directly connected with technological or industrial needs—fields like agronomy, pathology, computer science, materials science, chemical and electrical engineering.

Do our country studies support the proposition that strong research at universities or public laboratories aids a country's firms in innovation, defining that term broadly as we have? Not surprisingly, the answer seems to differ from field to field, and to be sensitive to the mechanisms in place to mold and facilitate interactions with industry. All the countries that are strong and innovative in fine chemicals and pharmaceuticals have strong university research in chemistry and the biomedical sciences. A strong agriculture, and a strong farm product processing industry, is associated in all of our cases with significant research going on relevant to these fields in national universities, or other types of public research institutions dedicated to these industries. In contrast, Argentine agriculture is surprisingly weak, despite favorable natural endowments. The author of the study of Argentina lays the blame on Argentina's failure to develop an adequate agricultural research system.

Where countries have strong electronics firms, for the most part there is some strong research in university departments of electrical engineering, and this would appear to include Japan. Government laboratories have been important sources of new electronic product designs later taken over by firms in Taiwan. On the other hand, university research does not seem of much importance to technical advance in automobiles and aerospace.

Where universities or public laboratories do seem to be helping national firms, one tends to see either direct interactions between particular firms and particular faculty members or research teams, as through consulting arrangements, or mechanisms that tie university or public laboratory programs to groups of firms. Thus in the U.S. agricultural experimentation stations do research of relevance to farmers, and seed producers, and have close interactions with them. Various German universities have programs designed to help machinery producers. Taiwan's electronics industry is closely linked to government laboratories. In all of these cases, the relationships between the university or government labs and the industry are not appropriately described as the universities or public laboratories simply doing research of relevance to the industry in question. The connections were much broader and closer than that, involving information dissemination, and problem solving. Universities and industry were co-partners in a technological community. While not important in all industries, a strong case can be made that such technology and industry oriented public programs have made a big difference in many fields.

These programs are far less visible than government programs that directly support industrial R&D, and the latter also tend to involve far more money. Countries differ significantly in the extent to which the government directly funds industrial R&D. And while most of such programs tend to be concentrated on a narrow range of "high tech" industries, programs of this sort vary significantly and have been put in place for different reasons.

I noted above that, in most of our countries, military R&D accounts for by far the largest portion of government funding of industrial R&D. Analysts have been divided as to whether military R&D and procurement has been a help, or a hinderance, to the commercial competitiveness of national industry. Of the major industrial nations, the U.S. spends by far the largest share of industrial R&D on military projects. A strong case can be made that in the 1960s this helped the American electronics and aircraft industries to come to dominate commercial markets, but that since the late 1960s there has been little "spillover." Britain has the second largest of the defense R&D budgets among our set of nations, but most of the companies receiving R&D contracts have shown little capability to crack into non-military markets. The same can be said for most of the French companies. While until recently civilian commercial spillover seldom has been a central objective of military R&D, except in the sense that it was recognized that selling on civilian markets could reduce the public costs of sustaining a strong military procurement base, it is interesting to try to understand where military R&D did lend civilian market strength and where it did not.

Analysis of the U.S. experience suggests that civilian strength is lent when military R&D programs are opening up a broad new generic technology, as contrasted with focusing virtually exclusively on procuring particular new pieces of fancy hardware wanted by the military. Increasingly the U.S. military effort has shifted from the former, to the latter. A much smaller share of military R&D now goes into research and exploratory development than during the 1960s, and a larger share into highly specialized systems development. And the efforts of the other countries in our set who have invested significantly in military R&D—Britain, France, and Israel—have from the beginning focused largely on the latter.

Space programs and nuclear power programs have much in common with military R&D and procurement. They tend to involve the same kind of government agency leadership in determining what is done. They too tend to be concentrated on large scale systems developments. Spillover outside the field has been quite limited.

Government programs in support of company R&D in telecommunications, other civilian electronics, and aircraft may overlap the technical fields supported by military and space programs, and in some cases the support may go to the same companies. These programs also tend to involve the same blend of industrial R&D support, and protection from foreign competition. However, there are several important differences. One is that, compared with military R&D, the public funds almost invariably are much smaller. Indeed programs like Eureka, Esprit, Jessi, Fifth Generation, and Sematech, are small relative to industry funding in the targeted areas. Second, the firms themselves usually have a major say regarding the way the public monies are spent, and the projects are subject to far less detailed public management and overview than are defense projects. Third, these programs are targeted to firms and products in civilian markets, and while their home base may be protected through import restriction or preferential procurement, the hope is that the firms ultimately will be able to stand on their own.

Thus while they involve a commitment to high R&D spending, otherwise these programs have much in common with other "infant industry" protection programs, many of which have grown up for reasons with no particular connections with national security, or a belief in the importance of "high tech," but simply because of the desire of a government to preserve or create a "national" industry. Infant industry protection, subsidy, and government guidance are policies that have been around for a long long time. They mark French policy since Colbert. During the 19th century and through World War II the U.S. was protectionist. The Japanese and Korean steel and auto industries, which were highly protected up until the 1980s, are more contemporary examples.

Do the infants ever grow up? Some do and some do not. The Japanese auto and electronics companies and the Korean Chaebol based enterprises are well known examples of presently strong firms that grew up in a protected market, but it also should be recognized that the American computer and semiconductor industries grew up with their market shielded from foreign competition and with their R&D funded to a considerable extent by the Department of Defense. After a period of such shelter and support, these firms came to dominate the world's commercial markets. Airbus may be another successful example. On the other hand, the country studies in this project give many examples of protected and subsidized industries which never have got to a stage where the firms can compete on their own. France's electronics industry is a striking example, but so also are the import-substituting industries of Argentina and Brazil.

What lies behind the differences? If I were to make a bet it is that the differences reside in two things. First, the education and training systems which in some cases did and in others didn't provide the protected firms with the strong skills they needed to make it on their own. Second, at least in today's world, the extent to which economic conditions, including government policies, provide strong incentives for the firms to quickly start trying to compete on world markets, as contrasted with hunkering down in their protected enclave.

The picture of government policies supporting industrial innovation that I have been presenting highlights the diversity of such policies and programs, and their generally fragmented nature—some supporting research and other activities aimed to help industry in universities or public laboratories, others connected with defense or space or nuclear power, still others aimed directly at supporting or protecting certain industries or industry groups. This is the picture I draw from the country studies of this project. These studies play down the existence of active coherent industrial policies more broadly. The interpretation they present of the industrial policies of nations widely believed to have them is closer to that of modern day infant industry protection with some R&D subsidy, than to a well structured and thought through general policy.

Some readers will dispute this conclusion, arguing that the failure of the studies in this project of countries well known to have active coherent industrial policies to highlight them and their successes reflects a serious misjudgment of the authors. The authors of those studies respond by arguing that, in fact, government policies in their countries are highly decentralized, and by pointing, the case of Airbus an exception, to the very small fraction of industry R&D accounted for by government programs.

The skeptics rejoin that, while the policies did not involve massive public monies, they had a lot of leverage on private decisions and investments. The authors respond that government leverage has been exaggerated and that where strong policies have been executed, they as often lead to failure as to success. This clearly is the position taken by our Japanese authors on MITI. Without a more fine grained understanding of technological innovation than we now have, there is no way of resolving this debate in a way that will persuade all people.

The Dispute over "High Tech" Policies

Above I stressed that the bulk of government R&D support, particularly support of industrial R&D, goes into "high tech," a portion of it through programs expressly designed to lend their firms a commercial edge. Where these latter programs exist, they tend to be complemented by various forms of protection and, sometimes, export subsidy. They are motivated and justified by the argument that if an economy does not have considerable strength in "high tech" it will be disadvantaged relative to countries that do.

But does this seem to be the case? The logic of the case and the evidence supporting it are not totally compelling.

For a firm or industry to be competitive in a high wage country certainly requires that it make effective use of skills, and technological and managerial sophistication, that are not readily available in low wage countries. The "high tech," high R&D intensity industries are of this sort, but there are many others as well. The definition of "high" tech used by statistical agencies is directly tied to R&D intensity. However, we have stressed that an industry can be characterized by considerable innovation and not have a high R&D intensity. If firms are relatively small, or if there is significant design work aimed at particular customers or market niches, while considerable innovation may be going on, the firms may not report much R&D.

Further, while national programs have tended to focus on areas like semiconductors, computers, and new materials, where technical advance clearly is dramatic, much of the economic value created by these advances occurs downstream, in the industries and activities that incorporate these new products into their own processes and products—automobiles, industrial machinery, financial services, shipping. To do this effectively often involves significant innovation and creative innovation here may generate major competitive advantage, but not much in the way of large scale formal R&D may be involved. On the other hand, it can be argued that active government policies often can be more effective when aimed to help an industry take advantage of new upstream technologies than when oriented towards subsidizing major breakthroughs. A large portion of the clearly effective public programs discussed in the various country studies of this project were or are focussed on bringing an industry up to world practice (this certainly characterizes many of the successful Japanese programs) or to spread knowledge about new developments (American agriculture and several of the government programs in Germany, Denmark, and Sweden).

Of course, the lure of "high tech" to countries that know they must be highly innovative if they are to compete with lower wage countries is not based solely on statistical illusion. The discussion above acknowledges the special place of innovation in semiconductors, computers, new materials and the like in the contemporary pattern of industrial innovation more broadly.

Advances in these fields provide the building blocks, the key opportunities, for technical innovation in a wide range of downstream industries, from high speed trains to cellular telephones to commercial banking. Many observers noting this have proposed that a nation that wants its firms to be strong over the coming years in the downstream industries had better not let foreign firms control the key upstream technologies. This argument is prevalent in some newly developing countries, like Brazil, Korea, and Taiwan, as well as today's high income ones.

Another argument seems to square the circle. It is that a nation needs to have strength in the downstream industries in order to provide a market for the key component industries. Thus, nations are supporting firms working on high definition T.V. and telecommunications, partly on the argument that if absent on the home market a nation's semiconductor and computer firms will be disadvantaged. Similarly, public support of aerospace is justified partly on alleged stimulation to upstream technology.

Put more generally, the argument is that "high tech" industries generate unusually large "externalities," which flow to national downstream firms. This possibility is one of those modelled in what has come to be called the "new trade theory" (see e.g., Krugman, 1987) which has developed a collection of arguments which support subsidy or protection as a means of gaining real national advantage. The fact that these industries are natural oligopolies who, in equilibrium, likely will support higher than average profits or wages, is another "new trade theory" argument sometimes used to rationalize protection or subsidy, on the grounds that subsidy now will yield high returns later.

The authors of our country studies clearly have different, and perhaps mixed, minds about this matter. There is a certain plaintiveness expressed in the studies of the major European countries that, while doing well in some other areas, national firms are not doing well in these critical "high tech" fields. The authors of the studies of Australia and Canada, on the other hand, seem to regard electronics envy as silly and expensive fadism.

While our country studies cannot resolve the issues, they can at least bring to attention three matters that ought to give pause to the zealots. In the first place, there does not seem to be strong empirical support for the proposition that national economies are broadly advantaged if their firms are especially strong in high tech, and disadvantaged if they are not. Thus the United States continues to be strong (and a major net exporter) in a wide range of "high technology" R&D intensive industries, but its economic growth has been lagging badly for nearly 20 years. Italy has very limited capacity in these industries, but its overall productivity and income levels have been growing briskly for many years. One can argue that France has had broad economic success more despite her efforts to nurture and subsidize her high technology industries than because of them. Japan is strong in DRAMS, but also in automobile production which accounts for much more employment and export value, and her efficiency in producing cars seems to have little to do with "high tech." And Canada, Australia, Denmark, and the United States all continue to be strongly competitive in industries based on agriculture or natural resources.

Also, as we have noted, the record of national policies expressly aimed to help high tech industries through support of industrial R&D and protection is very uneven. Indeed, the strongest positive examples occurred long ago, when the U.S. government provided broad support for advances in electronics and aircraft, and the American edge here has not proved to be durable. Other successful cases are largely "infant industry" cases (e.g., Japanese electronics during the 1960s and 1970s, and Korea during the early 1980s) where, as the companies became strong, the active and protective role of government diminished. Airbus may (or may not) be a contemporary success story. However, by and large the success record is not very good.

More, and of crucial importance, firms and projects in the aircraft and electronics industries are rapidly becoming transnational. Partly this is because of a need to share very high up-front R&D costs, which can be met by joining with other firms. Traditional intra-national rivalries tend to make firms look for foreign partners. And this tendency, of course, is increased to the extent that governments try to keep the products of foreign firms out of domestic markets and to channel subsidy to national firms. Unless the home market is very rich and the subsidies very high, firms have strong incentives to somehow form links with other firms so that they have a chance at other markets.

Today, there probably is no other matter which so forces one to step back, and consider the contemporary meaning of a "national innovation system." To what extent are there really "innovation systems," and to the extent that there are, in what ways are they defined by nation states?

What Remains National About Innovation Systems?

There obviously are a number of difficulties with the concept of a "national innovation system." In the first place, unless one defines innovation very narrowly and cuts the institutional fabric to that narrow definition, and we did neither, it is inevitable that analysis of innovation in a country sometimes would get drawn into discussion of labor markets, financial systems, monetary, fiscal and trade policies, etc. One cannot draw a line neatly around those aspects of a nation's institutional structure that are concerned predominantly with innovation in a narrow sense excluding everything else, and still tell a coherent story about innovation in a broad sense. Nonetheless, most of our authors were able to tell a pretty coherent story about innovation in their country focusing largely on institutions and mechanisms that fit the narrow definition, with discussion of country institutions more broadly serving largely as a frame.

Second, the term suggests much more uniformity and connectedness within a nation than is the case. Thus, one can discuss Canadian agriculture pretty independently of Canadian telecommunications. R&D and innovation in the American pharmaceutical industry and R&D of aircraft by American companies have little in common. And yet, one cannot read the studies of Japan, Germany, France, Korea, Argentina, and Israel, to name just a few, without coming away with the strong feeling that nationhood matters have a persuasive influence. In all these cases, a distinctive national character pervades the firms, the educational system, the law, the politics, and the government, all of which have been shaped by a shared historical experience and culture.

I believe that most of us would square these somewhat divergent observations as follows. If one focuses narrowly on what we have defined as "innovation systems" these tend to be sectorally specific. However, if one broadens the focus the factors that make for commonality across sections within a country, the wider set of institutions referred to above comes into view, and these largely define the factors that make for commonality across sectors within a country.

From the start of this project we recognized that borders around nations are porous, and increasingly so. Indeed, one of the questions that motivated this study was whether or not the concept of national innovation systems made sense anymore. I suspect that many of us come out on this as follows.

It is a safe bet that there will be increasing internationalization of these aspects of technology that are reasonably well understood scientifically. Efforts on the part of nations, and firms, to keep new understandings won in research and development privy increasingly will be futile. Among firms with the requisite scientific and technical people, the competitive edge will depend on the details of design, of production process, of firm strategy and organization, upstream- downstream connections, etc. Today, this is quite clearly the case in fields like semiconductors, aircraft, computers and automobiles. In these fields, there are no broad technological secrets possessed by individual countries or particular firms. On the other hand, strong firms have a good deal of firm specific know-how and capability.

It is also a good bet that differences across firms stamped into them by national policies, histories, and cultures, will diminish in importance. Partly that will be because the world is becoming much more unified culturally, for better or for worse. Partly it will be because firm managers and scholars of management increasingly are paying attention to how firms in other countries are organized and managed. And cross-country inter-firm connections are likely to grow in importance. Firms in industries where there are large up front R&D design and production engineering costs increasingly are forging alliances with firms in other countries, to share some of the costs, and to get over government-made market barriers. The establishment of branch plants in protected countries or regions is another mechanism. Thus, increasingly, the attempts of national governments to define and support a national industry will be frustrated because of internationalization.

What will remain of "national systems?" The firms that reside in the country, for one thing, but people and governments will have to get used to dealing with plants whose headquarters are abroad. The countries of Europe have been struggling with this matter for some time, and many of the Latin American countries, too. The U.S. is now having to try to deal with this, and Japan and Korea are beginning too. As yet, no large country seems to have made its peace with the problem, however. While in most countries, resident firms will be largely national, the presence of "foreign" firms in important industries is something that nations will have to learn to cope with better.

We noted earlier the striking continuity of a nation's basic institutions bearing on industrial innovation. A good example is national education systems, which sometimes seem never to change in their basics. While top level scientists and engineers may be highly mobile, and some high level students will continue to take training abroad, below the Ph.D. level, by and large, countries will be stuck with their nationals who are trained at home.

The nations' systems of university research and public laboratories will continue to be, largely, national, particularly the programs that are specifically keyed to advancing technology or otherwise facilitating technical progress in industry, and with built in mechanisms for interacting with industry. These programs will have to work with foreign branch firms as well as domestic ones in certain fields. But the notion that universities and public laboratories basically provide "public goods" and that therefore there are no advantages to firms that have close formal links simply does not fit the facts in many industries.

The nation's other public infrastructure, and laws, its financial institutions, its fiscal, monetary and trade policies, and its general economic ambiance, still will be a major influence on economic activity, including innovating, and these are very durable. For large high income countries at least, the lion's share of private investment will continue to be domestic, and constrained by domestic savings. And nations will continue to have their own distinctive views of the appropriate relationships between government and business.

And these will strongly influence a nation's policies bearing explicitly on science and technology. From the evidence in this study, these must be understood as an agglomeration of policies directed towards different national objectives, each with a somewhat special domain in terms of the fields and the institutions most affected, rather than as a coherent package.

All can hope that there will be a significant diminution of defense programs, but it is a safe bet that military R&D will continue to account for the lion's share of government industrial R&D spending in the U.S., France, Britain, and Israel. It is likely, however, that there will be little commercial "spillover."

Outside of defense and space, a nation's programs of R&D support will in all likelihood continue to reflect both the needs of industry and broad attitudes towards what government should be doing and how. While there will be exceptions particularly when a defense connection is argued, the United States will continue to resist programs that directly fund industrial R&D, but will use the universities as the base for a variety of programs including some directly targeted at certain technologies and industries. European countries are likely to make much more use of programs that directly support civil industrial R&D, either in individual firms, or in industry wide research organizations. And in Japan, France, and various other countries, government agencies and high tech firms will continue to be quite close.

The Diversity of National Systems: Do We Need Some Standards Regarding What is Fair?

At the present time nations seem to be conscious as never before of their "innovation systems" and how they differ from those of their peers. This consciousness of differences is leading in two very different directions.

On the one hand, it is leading to attempts on the part of nations to adopt aspects of other systems that they see as lending them strength. However, the experimentation is far from systematic, and it is highly influenced by perceptions that may have little contact with reality. Thus, the U.S. and the European countries (and the E.C.) have been loosening laws that restrict interfirm R&D cooperation, and establishing programs to encourage and subsidize it in some areas. If the chapter on Japan has got it right, this may be somewhat ironic in view of the argument that the role in Japan's rapid post war growth of cooperative R&D among firms in the same line of business probably has been exaggerated, and in any case is diminishing.

The LDCs are looking, with good reason, to Korea and Taiwan for models. But, aside from their strong support of education, high levels of investment in plant and equipment, and their pressure on firms to go for exports, these two countries have quite different innovation systems. In one, Taiwan, government research laboratories have been an important source of industrial technology; in the other, Korea, apparently they have not, at least until recently. Korea has encouraged the growth of large industrial conglomerates, and resisted foreign ownership; Taiwan has not especially encouraged the growth of large firms and has admitted foreign firms selectively. But both have been successful in building an innovative competitive manufacturing industry based on foreign created technologies and other low income nations are sensibly trying to learn from their experience.

While today attempts at emulation are at a peak, they are nothing new. The study of Japan shows how earlier in the century the Japanese tried to pick and choose from European and American experience, and came out with something quite different. The American's earlier tried to adopt the German university system, and actually built a very different one.

At the same time, perceptions of differences are leading nations to declare certain aspects of their rival's systems as illegitimate. Prominent Americans have expressed the opinion that MITI support and guidance of key Japanese industries, together with the special connections between Japanese firms and their customers and their sources of finance, amount to an unfair system, involving subsidy and dumping as well as protection. Similar complaints have been lodged against Eureka and Airbus. The Europeans complain about Japan, and about U.S. programs like the SDI claiming that such large scale government R&D support, while aimed at a military target, is sure to build commercial advantages, and that that requires response on their part. The Japanese make similar complaints, but particularly about the import barriers being imposed by other countries. Some have gone so far as to argue that presently there is a war between competing national innovation systems that only can be resolved if there are new accepted standards regarding what is fair and what is not (see e.g., Ostry, 1990). Otherwise, nations will have to adopt the norm of managed trade in high technology products.

These two aspects of the current concern about differences in national innovation systems—attempts at emulation, and expressions of hostility—are opposite sides of the same coin. They reflect a combination of beliefs that a nations performance in "high tech" is vital to its broader economic performance and security, real uncertainty regarding just how to achieve high performance, and lack of agreed upon criteria for judging what are legitimate and illegitimate government policies.

In my view, which may not be shared by all of my colleagues, the current bru ha ha seems somewhat hysterical. There is little more reason to get upset over inter-country differences in the government's role in the support and protection in "high tech" than about other areas where government policies differ sharply. For one thing, governments' anguish that their economies are fated to be surely disadvantaged if they do not have a "high tech" industry of their own probably is unwarranted. For another, beliefs that strength in high tech is due largely to promotional government policies seem grossly exaggerated.

At the same time, the studies in this project show that the institutional structures supporting technical innovation are complex and variegated. Technology and science interact in intricate ways. Both private for profit and public institutions play roles in virtually all arenas of technological advance and the efficient division of labor is not obvious. Simple minded arguments that private enterprise is what does industrial innovation and public institutions have little useful role in it are, simple minded.

In this area, it is not totally clear what one should call subsidy or protection, as contrasted with legitimate public spending or coordination or regulation.

Economists are wont to draw the line in terms of whether or not government spending or regulation or guidance can be justified by market failure arguments. If so, while public action may give advantage to a particular national industry, such support can be argued to increase economic efficiency. If not, it is considered naked subsidy or protection, and is not to be condoned. Thus, while international trade theorists long have known that a nation could enhance the well being of its own citizens *vis-a-vis* those in other countries by selected naked subsidy or protection, the argument was that, under the theory then in vogue, for nations taken as a group, this was a negative sum game.

But the problem with this line of argument here is that "market failure" is ubiquitous in the activities associated with industrial innovation, and thus subsidy or protection or guidance could be efficiency enhancing; hence the game of active industrial policy need not be negative sum. What has come to be called "the new trade theory" recognizes some of this, nervously. If there are large "up front" R&D costs, or significant learning through doing or using, or major externalities in certain activities like research and training, the simple arguments that free trade is "Pareto Optimal" (in the parlance of economists) falls apart.

Of course "market failure" is greater in certain activities than in others. Also, government competence and incentives are more likely to lead to productive programs in certain arenas than in others. Further, it is apparent that competitive protection and subsidy among nations can get beyond any level conceivably justified on grounds of "efficiency." It is in the interest of all nations to reign in such tendencies.

However, it seems unlikely that simple rules—for example that government support of R&D on public sector needs and for "basic" research is efficient and fair and direct support of industrial R&D aimed to develop products for a civilian market is both inefficient and unfair—will carry the discussion very far. This argument certainly can be used to attack Airbus. But Europeans rejoin that government help was needed to overcome the huge headstart American companies had won in large part as a spillover from military R&D, and can be justified economically both on infant industry grounds, and as a policy to avoid the development of a one company world monopoly. And what of government support for telecommunications R&D where telecommunications is a government service? Americans are prone to argue that telecommunications should be privatized, but there surely is limited agreement on that. One can try, and with some hope of success, to open government procurement to bids from foreign firms. However, what to one eye is blockage to competition in public procurement to another is a valuable close relationship between customer and steady supplier.

Nor are there clean lines separating "basic research" from applied. No one seems to object to government support for research on the causes of cancer (although a breakthrough here may give the firms with close contact with the research a major advantage in coming up with a proprietary product). But what about research to advance agricultural productivity? To improve crops growing in a particular national soil and climate? Research on superconductivity, or on surface phenomena in semiconductors, conducted in universities? Conducted in an industry cooperative research organization? In a particular firm?

The argument about whether government funding of certain kinds of R&D is appropriate and efficient or unfair subsidy of course gets intertwined with arguments about protection, and about constraints in direct foreign investments. Here countries clearly disagree regarding what they regard as appropriate. The disagreements can be discussed, and agreements negotiated. However, it does not seem to me that the question of whether or not a protected industry is "high tech" changes the nature of the discussion, or the stakes, that much.

All this is no argument against trying to establish some norms and rules regarding government policies bearing on industrial innovation, and in certain areas aiming for uniform or at least comparable policies. However, it is an argument against one nation or another getting self righteous that its ways are efficient, fair, and quite justified, and the policies of other nations are not. And it is an argument against the belief that agreeing on ground rules will be simple, if only the advice of economists is heeded.

And finally, it is an argument against trying to impose too much uniformity. Countries differ in their traditions, ideologies, and beliefs about appropriate roles for government, and they will guard the differences they think matter. A central reason why this project was undertaken was, by expanding the set of countries considered, and by trying to enable comparisons where these seemed most interesting, to try to tease out what features of national systems seemed systematically to enhance innovation performance, and what features seemed useless or worse. My colleagues and I like to believe that we have learned a good deal. But there still is a lot of room for informed differences of opinion.

Given that there is, it is not simply inappropriate for one group or another to argue for its preferred uniformity. While (as this project testifies) it is not easy to tease out signal from noise, potentially we all can learn from each other about what seems to be effective and what is not.

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Endnote

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The Changing Structure of U.S. Industrial Research: Implications for R&D Organization in the Russian Federation

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Abstract

This paper surveys the historical development and current status of industrial R&D in the U.S., in order to examine the factors affecting the location of R&D within industrial firms and the relationship between intra-firm R&D and research activities external to the firm, and to draw some implications for the reorganization of the Russian Federation's network of independent research institutes. As I note in my conclusions, the weight of historical and contemporary evidence suggests that externally performed R&D is likely to prove most effective as a complement, rather than a substitute, for research activities within the firm. The need for close links between manufacturing practice and technology development, the "tacit" character of much of the knowledge incorporated into industrial technology, and the difficulties in transmitting this knowledge across organizational boundaries all suggest that the contributions of contract or external research to industrial technol-

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ogy development will be greatest when this research is parallelled by R&D activities within the firm.

Introduction

An issue of enduring interest in the historical development of the U.S. and other industrial economies concerns the dimensions and causes of change in the boundaries of manufacturing firms. In market-based economies, what factors determine which activities are carried out within the "nonmarket" of the firm and which ones are subject to market control? Alfred Chandler's pioneering work (1977, 1991) argued that the modern U.S. economic landscape reflects an expansion of the boundaries of the firm in the late 19th and early 20th centuries. The realm of managerial control and planning grew relative to that of contract and market-based transactions within the U.S. firms that expanded to enormous size in the early 20th century. Paradoxically, the 20th-century economic development of the United States expanded nonmarket methods for the coordination and organization of many transactions. The extension of their boundaries served to spur growth and diversification within these firms, in a manner first pointed out by Penrose (1959).

Among the activities undertaken within their boundaries by these expanding firms was industrial research. Despite the arguments of Stigler (1956) that over time, industrial research would become an activity carried out by independent firms that conducted research on a contractual, for-profit basis,[2] U.S. industrial research grew most rapidly within the firm during much of this century. Since 1940, however, the privately financed U.S. industrial R&D complex has been supplemented by a large, publicly financed R&D investment in both public and private sector research facilities. The modern U.S. R&D system is a complex mix of publicly and privately funded R&D in both the public and private sectors. In recent years, large U.S. firms have begun to explore new opportunities to link their in-house research activities with government laboratories and other external sources of research. These efforts have received governmental encouragement from

[2] "... with the growth of research, new firms will emerge to provide specialized facilities for small firms. It is only to be expected that, when a new kind of research develops, at first it will be conducted chiefly as an ancillary activity by existing firms.... We may expect the rapid expansion of the specialized research laboratory, selling its services generally. The specialized laboratories need not be in the least inferior to 'captive' laboratories" (Stigler, 1956, p. 281). A more skeptical view of the role of the independent research organization may be found in Baldwin (1962).

federal legislation to accelerate "technology transfer" from publicly financed laboratories, many of which were originally established for defense purposes, to private industry.

This paper surveys the historical development and current status of industrial R&D in the U.S., in order to examine the factors affecting the location of R&D within industrial firms and the relationship between intra-firm R&D and research activities external to the firm. Do the historical development or current trends of structural change in the U.S. R&D system provide guidance for restructuring the R&D system of the Russian Federation? Certainly, the U.S. historical experience suggests that a purely market-based organizational structure is infeasible for a nation's R&D system. Instead, the U.S. and other industrial economies all maintain R&D systems in which the public sector plays a key role. Moreover, even the industrially financed portion of these economies' R&D systems operates largely within the "nonmarket" portion of the private sector.

The weight of historical and contemporary evidence suggests that externally performed R&D is likely to prove most effective as a complement, rather than a substitute, for research activities within the firm. The need for close links between manufacturing practice and technology development, the "tacit" character of much of the knowledge incorporated into industrial technology, and the difficulties in transmitting this knowledge across organizational boundaries all suggest that the contributions of contract or external research to industrial technology development will be greatest when this research is parallelled by R&D activities within the firm.

The Growth of U.S. Industrial Research

The expansion of the American economy during the late nineteenth and early twentieth centuries combined with innovations in transportation, communications, and production technologies to yield manufacturing operations of unprecedented scale. The materials analysis and quality control laboratories that were established within many of these factories were among the first industrial employers of scientists and research personnel. Over time, these plant-level laboratories expanded and were supplemented by central laboratories devoted to longer-term research.[3]

[3]Lewis argues that "Testing and analysis have continued to be of major importance in the industrial application of science down to the present time... The significance of such work in providing employment for scientists, however, gradually declined in a rel-

The expansion of industrial research within the American firm was closely linked as both cause and effect with the reorganization of the American corporation during the late nineteenth and early twentieth centuries. Technically trained managers, a strong central office staff able to focus on strategic, rather than operating, decisions, and the integration within the firm of functions such as marketing, all were associated with the growth of R&D within the firm. In-house research was better able to combine the heterogeneous inputs necessary for commercially successful innovation, to use and increase the stock of firm-specific knowledge gleaned from marketing and production personnel, and to exploit the fact that manufacturing and the acquisition of certain forms of technical knowledge were closely linked.

But in-house R&D by no means eliminated the importance of sources of industrial technology external to the firm. The in-house research laboratories of many large U.S. firms devoted a significant part of their efforts to monitoring the environment for opportunities for the acquisition of new technologies, often through the purchase of the firms holding the patents for these technologies. For much of the pre-1940 period, Du Pont research focused on developing inventions acquired from external sources; nylon and neoprene were exceptions to this rule. Many of Du Pont's major product and process innovations were obtained by the firm during this period at an early point in their development, often on the advice of the central research laboratory (Mueller, 1962; Hounshell and Smith, 1989). The research facilities of AT&T, General Electric, and Eastman Kodak performed similar monitoring roles during this period. In addition, many in-house R&D laboratories developed links with U.S. university research, especially in the publicly funded state universities (Hounshell and Smith, 1989; Thackray, 1982; Swann, 1988). In many respects, these in-house industrial research laboratories functioned as critical sources of "absorptive capacity" (Cohen

ative sense. Although the development of testing procedures and the determination of physical constants often required considerable ingenuity and imagination, routine testing itself tended to be monotonous and unattractive to highly trained personnel; in time it was increasingly assigned to non-professional employees and even handled by mechanical or electronic devices. Meanwhile, the efforts of industrial researchers came to be applied to an ever greater degree to eliminating production bottlenecks, exploring the merits of different processes, finding substitute raw materials from which goods could be turned out at lower cost, finding profitable uses for by-products, and improving the quality of various manufactured commodities." W.D. Lewis, "Industrial Research and Development," in M. Kranzberg and C. Pursell, (eds.), **Technology in Western Civilization**, Vol. 2 (Oxford: Oxford University Press, 1967), p. 622.

and Levinthal, 1989), enabling managers to evaluate the quality of and commercial prospects for technologies and academic research outside the firm.

Monitoring of the technological environment by in-house research laboratories was facilitated and the incentives for the establishment of these laboratories were increased by judicial decisions that strengthened protection for intellectual property in the late nineteenth century. Federal court decisions in the 1890s upholding the validity of patents covering goods not in production increased the utility of large patent portfolios for defensive purposes. Stronger intellectual property protection expanded the appropriability of the returns from innovation and facilitated the development of a market for the acquisition and sale of patents.

The Role of Intra-firm and Contract Research

Industrial research in American manufacturing during the 1900–1940 period developed a dualistic structure. Employment of professional scientists and engineers grew rapidly within manufacturing concerns and in independent research firms not affiliated with a manufacturing enterprise. Between 1900 and 1940, according to data from the National Research Council, nearly 350 independent laboratories were established.[4] Employment of scientists and engineers within these independent organizations grew rapidly during this period. Total employment of scientists and engineers in independent research laboratories was 3,300 in 1940 and more than 5,000 by 1946.

Contemporary observers and practitioners of industrial research hailed the growth of independent research laboratories as a development that would allow small firms without in-house laboratories to reap the benefits of industrial research. The comments in 1916 of John J. Carty, the first director of the reorganized Bell Telephone Laboratories, are representative:

> Conditions today are such that without cooperation among themselves the small concerns cannot have the full benefits of industrial research, for no one among them is sufficiently strong to maintain the necessary staff and laboratories. Once the vital importance of this subject is appreciated by the small manufacturers many solutions of the problem will promptly appear. One of these is for the manufacturer to take his problem to one of the industrial research laboratories already established for the purpose of serving those who cannot afford a laboratory of their own. Other manufacturers doing the same, the financial encouragement received would

[4] The source and nature of these data are discussed below. For additional analysis, see Mowery (1981, chap. 2).

> enable the laboratories to extend and improve their facilities so that each of the small manufacturers who patronized them would in the course of time have the benefit of an institution similar to those maintained by our largest industrial concerns. (Carty, 1916, p. 512)

The peculiar characteristics of R&D and commercial innovation nevertheless appear to have hampered the sale of research services via contract. The supply of contract research was affected by at least two broad factors. The first is the degree to which specialization in the performance of research reduces costs per unit of research output—i.e., economies of scale in specific types of research that cannot be fully exploited by in-house research laboratories. Independent research organizations may be able to profitably specialize in research services characterized by declining unit costs. Examples of these services include testing or measurement and calibration services that rely on costly, specialized equipment.

A second factor concerns the degree of interdependence between specific research activities and other manufacturing and non-manufacturing functions within the firm. Independent research laboratories are most effective in research activities characterized by low levels of interdependence with other activities within the manufacturing firm. Such interdependence has several dimensions (see Teece, 1988, for a more detailed discussion of these issues). The development of much industrial technology is an iterative process (Kline and Rosenberg, 1986) in which research, technology development, and even production activities interact; information from "downstream" activities leads to the modification and improvement of products, processes, and the research agenda. These "feedback loops" and interactions are stronger when they take place within an organization, rather than when they must span organizational boundaries. These interactions also involve flows of information and knowledge that cannot be easily codified. Communicating such "tacit" information is difficult through documents or blueprints, and requires sustained, often informal interactions and (in many cases) relies on the transfer of researchers or production specialists among different functions within the firm (such personnel transfers are extensively employed by Japanese firms in their management of new product development; see Clark and Fujimoto, 1991). These types of communication and information exchange will occur more easily within an organization rather than across organizational boundaries. Finally, the nature of these information creation and exchange activities is such that an independent research organization that does not also engage in production activities simply cannot gain access to certain types of process- or product- specific, tacit information. Production and the creation of much of the critical information for industrial technology development are joint activities; separating them among organizations may undercut their information-creating interaction.

The ability of manufacturing firms to exploit contract research may be undercut by two factors. A client firm requires substantial in-house expertise to pose a feasible research problem to an independent laboratory, or to evaluate and utilize the results of externally performed research.[5] Contracting problems also limit the role of independent research organizations. The effectiveness of contracts in the provision of research is undermined by the uncertain nature of the research enterprise, the imperfect character of knowledge about a given project, and the thin market for specialized research services. These contractual difficulties are likely to be greater for more technically complex, uncertain research projects. Assessment of the value of the results produced by an independent contractor also is difficult without complete revelation of these results; but revelation removes any incentive for the client to pay for the research (see Arrow, 1962). The small number of suppliers of specialized research services means that opportunistic behavior by one or the other party to such a contractual agreement is likely.[6] Finally, the difficulty of specifying all contingencies in a contract for uncertain, complex research projects will reduce firms' reliance on external providers for such research.

These factors affected the relationship between U.S. independent and in-house research organizations in several ways. Consistent with the argu-

[5]The argument that an in-house research facility enhances the ability of firms to exploit external research receives support from analyses of industrial research in other nations. Discussing the development of cooperative industrial research laboratories in Great Britain, Varcoe (1974) noted that "the relations [of the cooperative research facilities] with the industries and the extent to which the latter availed themselves in practice of the results were not the straightforward matters they were at first imagined to be. Smaller firms frequently had no one capable either of articulating research needs and putting them into scientifically meaningful terms or of understanding the concepts and terminology of technical literature and of relating these ideas to their own problems." (p. 30). Similarly, Caves and Uekusa (1976) note that Japanese firms invested heavily in research during the postwar period as a means of absorbing and modifying technologies from external sources: "Firms must maintain some research capacity in order to know what technology is available for purchase or copy and they must generally modify and adapt foreign technology in putting it to use—a 1963 survey of Japanese manufacturers showed that on average one-third of the respondents' expenditures on R&D went for this purpose" (p. 126).

[6]Williamson (1981) argues, "That economic agents are simultaneously subject to bounded rationality and (at least some) are given to opportunism does not by itself, however, vitiate autonomous trading. On the contrary, when effective ex ante and ex post competition can both be presumed, autonomous contracting will be efficacious" (p. 554).

ments made above, the growth of industrial research in the U.S. reduced the importance of independent research organizations. Table 1, drawn from the National Research Council surveys of industrial research, displays the proportion of total employment of research professionals in both in-house and independent research organizations accounted for by independent research organizations during 1921-46 (excluding the research laboratories of trade associations). Contract research laboratories accounted for a declining share of total scientific and engineering research employment in manufacturing and independent research laboratories during this period.

Although employment in both forms of industrial research organization was growing rapidly during this period, employment growth for in-house research substantially outstripped that for the independent research organizations. Equally important is the evidence that independent research organizations primarily served firms that had in-house R&D laboratories. In other words, contract research functioned as a complement to, rather than as a substitute for, in-house R&D. Moreover, the independent research firms specialized in relatively simple, low-risk, "separable" research activities that involved less of the intensive exchange of know-how and tacit knowledge among different phases of the technology development process.

More recent data also suggest a tendency for external R&D to complement the in-house R&D activities of U.S. firms. Data from recent National Science Foundation surveys of industrial R&D spending consistently show that the U.S. chemicals industry, one of the most R&D-intensive U.S. industries, consistently allocates a larger share of industrially financed R&D spending to external research than any other U.S. manufacturing industry. In 1975, when U.S. manufacturing spent 2.3% of industrially financed R&D on research at external organizations, the corresponding share for the chemicals industry was 3.8%. In 1976, these figures stood at 2.6% and 4.0%, respectively, increasing to 3.8% and 6.9% by 1989.[7] On the share of industrially financed R&D within each industry that is allocated to external research performers. The most research-intensive industries, especially chemicals, are consistently among the industries devoting the highest share of their internally financed R&D budget to external R&D performers.

[7] See National Science Foundation (1978), p. 20; National Science Foundation (1991), Table SD-5.

Table 1. Employment of scientific professionals in independent research organizations as a fraction of employment of scientific professionals in all in-house and independent research laboratories, 1921–1946.

1921	1927	1933	1940	1946
15.2%	12.9%	10.9%	8.7%	6.9%

Source: Mowery (1981, chap. 2).

The Changing Role of External Sources of R&D: University-Industry Research Relationships in the U.S.

Nelson (1988, p. 325) described the industrial research laboratory as the "heart" of the U.S. national innovation system. This pillar of the U.S. research system, however, now is undergoing change. Faced with escalating costs and intensified competitive pressures, many U.S. firms are moving away from the virtually exclusive reliance on intra-firm sources of technology that characterized the post-1945 period. Alternatives include university-industry research partnerships, alliances or consortia with other domestic or foreign firms, and publicly sponsored cooperative research programs. Faced with spiralling R&D costs, greater demands to monitor a broader array of scientific and engineering fields, and increased competitive pressure from other U.S. and foreign firms to get products to market rapidly, U.S. firms have had to develop research relationships with an array of external institutions that could complement and enhance the payoff from their in-house R&D activities.[8] Such relationships provide lower-cost windows on emerging technologies, allow firms to detect emerging commercial opportunities more rapidly, and spread the risks of failure among a larger number of research performers and research budgets.

Some of these alternatives and experiments represent a revival of inter-institutional research linkages that were strong before 1940 and were dis-

[8] A recent OECD study quotes a Xerox Corporation research executive's description of the firm's investment in the Center for Integrated Systems at Stanford University: "Xerox's contribution to CIS is very small compared to what we are investing internally in the same kind of research. For little additional investment we enlarge our perspective by participating in a broad program of basic research. We envision opportunities for joint interaction with the university and with other companies, as well as the ability to recruit students. On a per-dollar basis it should be a good investment." (Quoted in OECD, **Industry and University: New Forms of Co-operation and Communication**, (Paris: OECD, 1984), p. 47).

placed by the upsurge of federal funding for research in universities and industry that followed U.S. entry into World War II. Few of these contemporary experiments and initiatives are organized as strictly market-mediated, arms-length, contractual enterprises. Instead, one finds an array of "hybrid" forms of economic organization, blending elements of long-term investment, organizational links and managerial controls with market-based incentives and transactions.

This wave of proposed or actual change has important implications for our conceptualization of the historic role of the in-house industrial research laboratory. Rosenberg (1982) argued that the industrial research laboratory strengthened the links among science, technology, and profit and made the scientific research agenda more responsive to economic factors. Recently, however, change in the competitive and technological environment has reduced the capacity of the in-house industrial research laboratory within at least some U.S. firms to influence the direction of scientific research and thereby exploit linkages between basic and applied research. Does this apparent change imply a new role for in-house and external research laboratories? A brief discussion of university-industry research collaboration in the U.S. may shed some light on these issues.

University-Industry Cooperation

During the past decade, financial support from industry has established a number of research facilities on U.S. university campuses to conduct research with potential commercial value. Support for these initiatives has come from the federal government as well as private industry, as the National Science Foundation has funded the establishment of a number of engineering research centers on university campuses. The centers focus on engineering research that is often linked to engineering research with such traditional scientific disciplines as biology and physics, and have emphasized advanced computer applications. The financial structure of these centers also is novel, since it combines "seed-money" support from the federal government (as well, in many cases, as state and local governments) with major contributions from private corporations that are affiliated with the centers.

Many of these new university-industry research facilities reflect the growing importance of a multidisciplinary approach to important problems in both science and technology. Industry-supported multidisciplinary university research institutes provide an organizational "home" for the pursuit of this new cross-disciplinary research agenda. Moreover, these institutes can train young scholars and prospective industrial researchers in new techniques and research perspectives.

What benefits does U.S. industry obtain from collaboration with university researchers? By virtue of their mission as educational as well as research institutions, U.S. universities are important sources of industrial scientific and engineering personnel. Participants in university-industry collaborations can utilize these ventures as "filters" for hiring research personnel, observing the performance of potential employees before making costly hiring commitments. Moreover, the importance of people as a critical channel for the transfer of scientific and technological knowledge means that the hiring by firms of the graduates of these programs facilitates the transfer of knowledge and technology from university to industry. The rotation of industry personnel through university research facilities serves a similar function. Interestingly, this source of industrial benefit need not rely on any "handoff" of specific research results by a university to industry.[9]

In most cases, university-industry research ventures, like other forms of external research, operate as complements to the in-house R&D of participating firms. Federal government support for NSF engineering centers and other university-industry collaborative research centers builds on earlier NSF experiments in this area. The University-Industry Cooperative Research Centers Program began in 1973 as an experiment designed "to determine if federal cost-sharing during a 5-year period would enable the creation of industry-funded permanent cooperative research centers." (National Science Foundation, 1979, p. v). Cooperative research centers would improve the innovative performance of their client industries, NSF argued, by tapping the research expertise of universities. Of the three experimental programs established within the NSF program, however, only the one serving a relatively research-intensive client industry (the MIT Polymer Processing program, which included Eastman Kodak, General Motors, and Xerox Corporation among its participants) survived the cessation of public funding in 1978 (the other two programs, which respectively conducted research in

[9]Gray and Gidley's survey of NSF university-industry research centers found that "the benefits seen [by industry respondents] as most likely to accrue to companies were improved research projects in the company (mean, 2.60; 1=scarcely likely, 4=almost certain) and better personnel recruitment (mean, 2.54). Patentable products (1.62) and commercialized products (1.75) were seen as benefits which were 'somewhat' to 'scarcely likely' to accrue through Center participation." (1986, p. 29). Once again, the most commonly mentioned sources of benefit hinge on the presence within a participant firm of an R&D facility.

energy conservation technologies for the New England region and in technologies for the furniture industry, both were terminated).

The results of this NSF experiment suggest that as in the case with independent, for-profit contract research institutes, university research was most effective as a complement to the in-house R&D activities of client firms. The NSF evaluation of the program noted that:

> The nature of the industrial participation in the cooperative research efforts varies widely. At one extreme are large companies with substantial research activities such as General Motors, Xerox, and Kodak, and at the other extreme is a small construction firm participating in the NEEDS [New England Energy Development Systems] solar technology center at Dartmouth. The more substantial participation has come from the large research-oriented companies that can understand and use the research outputs of the cooperative efforts. Companies with little research background, such as the utilities and furniture companies, are traditionally conservative with respect to new technology and are traditionally dependent on their suppliers for whatever changes they adopt. (National Science Foundation, 1979, p. 30).

The successful exploitation of university-industry research collaborations for these purposes virtually requires that a participating firm maintain some in-house research capability. Indeed, successful absorption of the results of university research frequently requires that a participant firm maintain a "shadow," parallel research project within its in-house laboratories (such "shadow" projects also appear to improve technology absorption by participants in non-university research consortia).

Technology Transfer Policies and the U.S. National Laboratories

Publicly funded U.S. research laboratories, often referred to as the "national laboratories," are another potentially significant source of industrial technology external to the firm. The U.S. has more than 700 federal laboratories, with a total budget of $21 billion in fiscal 1990. Table 2 displays the sources and levels of funding for the U.S. national laboratory system. Most of the laboratories support the missions of their funding agencies. The largest share of federal laboratory spending is defense-related. The Defense Department accounts for 49% of total federal expenditures on laboratories, and the Energy Department accounts for 21%. Nearly one-half of the laboratory expenditures of the Department of Energy support laboratories whose

Table 2. Federal budget expenditures on laboratories, fiscal 1991 (millions).

	Total	Intramural	External
Department of Defense	$10,212	$8,988	$1,224
Department of Energy	4,443	427	4,016
NASA	3,278	2,573	705
Health & Human Services	1,940	1,879	61
(National Institutes of Health)	(1,463)	(1,402)	(61)
Agriculture Dept.	777	776	1
National Science Fdn.	299	187	112
Total	$20,949	$14,830	$6,119

[a] "External" laboratory expenditures include funds allocated to GOCO (Government-owned, contractor-operated) laboratories.
Source: National Science Foundation (1991), Table C-9.

primary mission is research on nuclear weapons; most of the remainder supports basic research in nuclear and elementary particle physics. The Energy Department funds roughly five times as much work within its laboratories on defense and basic physics research as it does on applied energy-related research.

The federal laboratories vary in size, staff quality, and objectives. The system includes single-office facilities employing a handful of researchers, as well as large research facilities with several hundred staff, such as Brookhaven National Laboratory. Most federal laboratories, however, are staffed by no more than 5–10 employees, and often are self-contained organizations, located within an agency or university. Many of these laboratories were established as a result of the demands for defense-related technology and research during 1940-90, and are operated by the Defense Department or the Department of Energy. They include several large facilities devoted primarily to research on nuclear weapons, a number of facilities concerned with high-energy physics research, and a few facilities that pursue a more diverse research agenda. Another large laboratory system is operated by the National Aeronautics and Space Administration (NASA).

A few laboratories (e.g., the National Institute for Standards and Technology) pursue research that is closely related to commercial technology development, but most focus on research that supports their parent agency missions, and perform research that is far removed from commercial applications. Some federal laboratories provide access to research facilities or equipment that is far too expensive for any single firm to maintain. Examples include the synchotron light source at Brookhaven (used by more than 80 U.S. universities, 23 U.S. firms, 14 other government laboratories, and 22 foreign institutions in 1989) and the Combustion Research Facility at Sandia National Laboratories, which provides specialized laser detectors and computers to study the combustion behavior of fuels. Users of this facility include Conoco, General Motors, Ford, Chrysler, Exxon, Mobil, Unocal, Combustion Engineering, and AT&T, all of which finance substantial in-house R&D facilities as well.

The federal laboratory system includes government-owned contractor-operated (GOCO) and government-owned government operated (GOGO) laboratories. GOCO laboratories are operated by contractors, often universities or private firms, and funded by federal monies. GOGO laboratories are, as their name suggests, staffed by civil servants. GOGO laboratories have in the past faced serious obstacles to developing technologies for industrial application. These problems reflect the fact that they are subject to civil service personnel guidelines and practices that reduce flexibility in hiring staff and in bringing private sector scientists, engineers, and managers into their research facilities. GOGO laboratories also are subject to the full array of federal procurement regulations, which often impedes the formation of links with private industry.

GOCO laboratories, on the other hand, have often been more responsive to the demands of technology transfer and industry- laboratory cooperation. Their exemption from federal civil service guidelines gives them greater flexibility in personnel hiring and rotation, and enables GOCO laboratories to develop more highly qualified technical staff. Other administrative practices that limit the flexibility of GOGO laboratories do not apply to many GOCO laboratories. As a result, much of the experimentation with new methods of technology transfer and linking with private firms is taking place in GOCO laboratories. Most of the Energy Department laboratories and federally funded R&D centers (FFRDCs) supported by DoE funds are GOCOs.

Policies to Promote Technology Transfer and Collaboration with Industry

During the 1980s, U.S. government officials became increasingly concerned with the economic returns to public research and technology investments, and this concern naturally extended to the federal national laboratories. More recent change in the international political and military environment has intensified demands to utilize the complex of defense-related research installations (as well as the overall defense-related R&D budget) to support research on commercial technologies. These pressures have spawned a series of federal statutes and policies that were intended to improve the commercial technological payoff from the large public investment in the national laboratories. These initiatives assumed three general forms: (a) strengthening intellectual property rights protection for technologies developed by national laboratories and liberalizing the terms on which these technologies can be licensed to private firms and nonprofit institutions; (b) mandating the establishment of offices for the management of technology transfer within each laboratory; and (c) permitting the negotiation of "cooperative research and development agreements" (CRADAs) between laboratories and private firms. With the possible exception of the mandate for negotiation of CRADAs, these initiatives assumed that the (rumored) wealth of technology within the national laboratories would flow rapidly to the private sector, once provisions were established for licensing these technologies.

Examples of Laboratory-Industry Collaboration

Many recent experiments in laboratory-industry collaboration involve Energy Department laboratories, most of which are GOCOs. An ambitious multi-laboratory cooperative effort in high-temperature superconductivity that involves Argonne, Oak Ridge, and Los Alamos National Laboratories began in 1988. The three laboratories jointly or individually negotiated 20 CRADAs with private firms during the first year of operation of the project. In an effort to accelerate these negotiations, the Energy Department experimented with the use of a standard contract for all of the CRADAs. This experiment was a mixed success, as many firms requested revisions in the model contract's terms. The treatment of intellectual property rights also departed from Energy Department policy in being unusually generous toward industry.

A significant share of the program budget for this project is devoted to technology transfer, in contrast to many previous efforts by national laboratories (see below). Moreover, the program is committed to spending funds only on projects in which industry has expressed a strong interest, thereby involving industry specialists in the formation of the research agenda. The cooperative research activities also cover the entirety of the R&D cycle, from basic research through product development, in an effort to exploit the multiple loops of interaction, feedback, and learning among phases of this cycle that typify successful technology development projects (Kline and Rosenberg, 1986). By avoiding a situation in which basic research results are "thrown over the wall" to industry, this approach may also contribute to effective transfer of results and technologies.

Another experiment in industry-laboratory collaboration is based at the Oak Ridge National Laboratory, and uses "startup" firms as a vehicle for commercializing laboratory technologies (according to the Department of Energy, 87 startups were formed during 1985–87 to commercialize technologies initially developed in Energy Department laboratories).[10] The Tennessee Innovation Center was formed in 1985, with an initial budget of $3.5 million from the laboratory's operator, Martin Marietta Energy Systems. The Center provides a range of services to entrepreneurs seeking to commercialize Oak Ridge-developed technologies, including office space, laboratory facilities, and business planning assistance. The Center also makes small investments in the startups.

Another example of laboratory collaboration with industry does not center on the transfer from laboratory to industry of a technology, but instead concerns the procurement relationship between laboratories and high-technology industries. Cray Research Corporation, a pioneering developer and producer of supercomputers, worked closely with Los Alamos National Laboratory in developing its first machines. Los Alamos was interested in Cray's supercomputers for use in designing nuclear warheads, and worked closely with the firm in testing prototypes and improving designs. Los Alamos did not perform significant R&D on the Cray supercomputer, but funded its development and functioned as an expert "lead user" (von Hippel, 1989), improving the design of the machine. Several person-years of Los Alamos staff time refined the Cray designs before the release of a commercial supercomputer. Once a commercial supercomputer was perfected, Los Alamos aided the survival of Cray by ordering the first commercial machine. By 1989, Los Alamos had purchased 14 Cray supercomputers.

A number of collaborative projects also are being studied or are underway within several military-oriented Energy Department laboratories. These projects typically focus on technologies with significant potential for both military and civilian applications. Sandia National Laboratories is working with a group of firms to improve the quality of specialty alloys, in a program budgeted at $2 million in federal funds and $4.75 in industry funds for the

[10] Unfortunately, no information is available on the number of these startups that either survived or succeeded in reaching the market with their technologies.

1989–94 period. By 1994, the entire budget for the program is to be covered by industry sources. A second program, the Advanced Manufacturing Technology Initiative, will receive $2 million in federal funds over four years.

Evaluation

Like other recent experiments in federal technology policy, most of the effects of the policy shifts and initiatives of the 1980s affecting federal laboratories have yet to manifest themselves in improved technological or competitive performance. Nevertheless, some evidence is available on the operation of these initiatives and on the validity of the assumptions on which they are based.

Beginning with the crudest indicators of success, the number of successfully commercialized technologies that emerge from federal laboratories, recent initiatives have had virtually no effect. During fiscal 1989, 297 federal laboratories surveyed by the Congressional General Accounting Office (GAO; U.S. General Accounting Office, 1991) produced only $6.3 million in royalties and 676 patents, a rather modest return on the laboratories' annual operating budget of $21 billion (needless to say, this budget supports numerous activities other than the creation of patentable technologies). These results reflect the slow response of many federal laboratories to the statutory and other policy changes of the 1980s. A Congressional investigation of federal laboratories' technology transfer programs concluded that these activities were "under-staffed, under-directed, and only marginally focused." (Committee on Science, Space, and Technology, 1990, pp. 1-2). Of the 297 laboratories surveyed by the GAO in 1991, 31% had not yet received guidance from their parent agencies on steps to implement the Technology Transfer Act of 1986, and 156 laboratory directors still lacked authority to participate in CRADAs. The GAO study concluded that the Act's "...major provisions still have not been fully implemented." (1991, p. 11). A similar conclusion was noted in a 1989 report by the Defense Department Inspector General, which concluded that neither the letter nor the spirit of the Congressional technology transfer laws of the 1980s had been implemented effectively by DoD laboratories (U.S. Department of Defense, 1989).

A portion of this unimpressive performance reflects the fact that the policy changes of the 1980s were not at all selective, and assumed that all federal laboratories were equally well-positioned to work with industry. Needless to say, this assumption is likely to prove false—the vast diversity of this network of research laboratories guarantees that not all laboratories will be equally attractive or effective sources of industrially relevant technologies. Moreover, Congress assigned a technology transfer "mission" to all laboratories, but in most cases did little or nothing to alter the specific missions or charters of individual laboratories. Most importantly, funding levels and patterns were not shifted to support research in industrially relevant technologies or to support technology transfer activities.

Most of the federal initiatives to improve the contributions of the federal laboratories to national innovative performance have attempted to remove the putative impediments to technology transfer from federal laboratories to industry. Yet, even if these policies are thoroughly and speedily implemented within all of the more than 700 federal laboratories (and there is abundant evidence that they have not been), the ultimate payoff from these policies may well prove modest. Most federal laboratory R&D is irrelevant to industrial R&D or technology, and industrial demand for federal laboratories' technology therefore is small. Many of the federal laboratories, after all, were founded to serve a clearly identified customer—the federal government, especially the military services. Many of these laboratories have worked effectively to develop and transfer important mission-related technologies to their governmental customers.

But the federal government manifestly is not the customer for most civilian technology development activities within the federal laboratories, and federal policymakers rarely have the detailed knowledge of industry conditions or needs to plan research strategies to meet industry needs. The potential contribution of the federal laboratories to industrial technology development is reduced still further by the basic research focus of many federal laboratories and the remaining restrictions on technology disclosure and transfer that are imposed by national security considerations.

Much of the Congressional and Executive branch effort to improve technology transfer from the federal laboratories has been driven by a "supermarket model" of technology transfer, which assumes that these laboratories have extensive inventories of new, industrially relevant and commercially profitable technologies "on the shelf," awaiting only a well-informed shopper to obtain and realize a profit from them. The laboratories' contribution to industrial technology development is impeded by much more than obstacles to technology transfer—it also reflects a lack of industrially relevant technology to transfer. Over an extended period of time, the federal policies of the 1980s may facilitate collaboration between industry and federal laboratories that can support learning about the needs and capabilities of one another.

But this will take time and it will yield a significant return for only a few laboratories.

Conclusions

The organization and management of industrial R&D cannot rely solely on market mechanisms. The historical and contemporary evidence from the U.S. economy suggests that contract research, along with other types of R&D performed outside of the firm, are likely to be most effective when they complement in-house R&D activities. The reasons for this complementary relationship reflect the complexity of the processes of intra-firm knowledge creation, transmission, and implementation, as well as the limits of conventional intellectual property rights and contracts to govern transactions whose outcomes are uncertain, difficult to value, subject to important market imperfections. For this and other reasons, industrial research in the U.S. and other capitalist economies has been largely a non-market activity, located within the industrial firm and subject to organizational, rather than market, governance.

In the postwar U.S., as in most industrial economies, government plays an important role in funding and performing R&D in the public and private sectors. Moreover, the recent experience of the U.S. national laboratories suggests that the process of converting laboratories from defense-oriented to civilian research will be a gradual and complex one, and is likely once again to prove most beneficial to private firms with in-house R&D facilities.

This review of aspects of the development and current structure of the U.S. research system suggests that any restructuring of the R&D system of the Russian Federation must preserve a role for government in the funding and performance of R&D. In addition, the wholesale conversion of the Russian Federation's network of research institutes into contract research organizations is likely to prove infeasible. Nonetheless, the current structure of the U.S. and other nations' industrial R&D systems is changing in ways that may increase the importance of R&D organizations, like the Federation's research institutes, that are external to the manufacturing enterprise. The key challenge is to create complementarities between the activities of free-standing research institutes and the intra-firm R&D efforts of Russian and other industrial enterprises.

A number of more specific implications of this discussion for the organization of industrial R&D in the transition to a market economy may be briefly summarized:

1. *Independent research institutes are likely to prove most effective as complements to, rather than as substitutes for, in-house R&D activities.* Efforts at reorganization of these institutes should include steps to build up integrated R&D laboratories within manufacturing organizations. The recent experience of U.S. and other industrial nations' firms suggests that external sources of research and technology may now have a more important role to play in industrial innovation, as a part of a larger system that includes a robust network of R&D facilities within manufacturing firms. Without the development of "absorptive capacity" in their client firms, however, technology transfer from the research institutes to client firms will remain extremely difficult. As the recent agreement between Sun Microsystems of the U.S. and a leading Russian computer science institute suggests, however, at least some of the firms with in-house R&D that are served by independent Russian research institutes might be foreign enterprises.
2. *The secondment or movement of people between research institutes and manufacturing organizations should receive a high priority in efforts to improve technology transfer, to develop embryonic in-house R&D facilities within manufacturing organizations, and to inform the research agenda of research institutes.* Technology transfer between external research performers and the firm is one of the most enduring problems in the organization of contract and other types of independent research organizations to serve industry. Solutions to these problems should receive a high priority in any efforts to reorganize Russian independent research institutes. A portion of the staff of selected research institutes might be transferred to employment in manufacturing organizations, with their salaries supported through some declining matching funding from public sources. These individuals could form the core of in-house R&D laboratories that would be closely linked with a "parent" independent research institute.[11] An alternative or additional policy would rotate employees from client manufacturing organizations to the research in-

[11]Care must be taken to ensure that any such personnel transfers involve high-quality employees of research institutes, rather than serving as a convenient means of eliminating less productive staff. This problem has plagued many U.S. research consortia (see Mowery and Rosenberg, 1989).

stitute on a regular basis for lengthy stays (6-18 months), and transfer research institute employees to a group of "client" manufacturing firms.

3. *The mission of transferring technology from independent research institutes to industrial firms requires recognition as an activity endowed with significant resources and close links to the research activities of the independent research institutes.* This point follows closely on the preceding argument. Technology transfer between an independent research laboratory and a manufacturing firm or other client is a resource-intensive, knowledge-intensive enterprise, requiring sustained interaction between client and research institute, and well-established links within the research institute between individuals or organizations in charge of research and those in charge of transferring research results. An important failure in the recent U.S. federal government experiments with improving the transfer of technology from the "national laboratories" is the failure to allocate resources to this specific task and to recognize it as an explicit part of laboratory missions (one error follows from the other).
4. *Strengthening the role of the Russian Federation's independent research institutes as performers of contract research requires that well-defined laws and regulations for commercial contracts and intellectual property be developed.* The development of both contract and in-house industrial R&D in the U.S. relied for their development on a well-defined system of intellectual property rights and contract law.
5. *Wherever possible, Russian independent research institutes should be linked with university programs for the training of scientists and engineers.* An important institutional strength of U.S. universities, and a factor that makes them attractive sources of external research for U.S. and foreign industrial firms, is their production of trained scientific and engineering personnel along with research. If Russian independent research institutes can expand their role in graduate education, an important channel for technology transfer and interaction between manufacturing industry and independent research institutes could be established.
6. *Selectivity and experimentation should be important components of any new policies for Russia's independent research institutes.* If the recent experience of the U.S. national laboratories is any guide (and there are striking parallels between these U.S. institutes and many Russian research organizations), no single policy is likely to be realistic or effective for all research institutes. The diversity in mission, talent, and orga-

nizational structure is too great for any inflexible general policy to be effective.

7. *The demand of independent research institutes for high-technology capital goods is a potentially important source of domestic R&D and technology for new firms in emerging industries.* As the discussion of the Los Alamos National Laboratory pointed out and as other accounts have noted, an extremely important source of federal government support for high-technology industries during the postwar period has been procurement. Both the military services and the extensive network of national laboratories influenced the growth of new domestic industries through their substantial purchases from entrepreneurial new firms.
8. *Independent research institutes are potentially important sources of new firms, as well as new technologies, and steps should be taken to encourage the "spinoff" of new firms from these organizations.* A number of the U.S. national laboratories appear to have served as important "incubators" for new, high-technology firms, typically involving the departure of a few employees to found a firm. Such "spinoff" companies may be an important channel for the commercialization of the technological assets of independent research institutes. Steps to encourage their formation include the development of better capital markets and intellectual property systems, as well as flexible provisions for leaves of absence or sabbaticals from employment in research institutes.

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Part II

Special Cases for Science and Technology Policy in the Transition to a Market Economy

The Survivability of the Russian R&D Sector and Patterns of Changes: By Example of the Computer and Software Industries

Leonid P. Malkov[1]

A General Problem of Survivability

The Initial Problem

Before the topic of this paper is indulged upon, an introduction to the general problems facing Soviet R&D is a prerequisite. The initial enigma of the R&D sphere is not so much the prospects of survivability of the system under present conditions but rather the actual emergence of such a powerful intellectual potential in the Soviet state. Foreigners may take this situation as given due to the lack of knowledge concerning the counteracting factors.

Though far from being a full list of factors, the following were instrumental in preventing the USSR from becoming an even more powerful scientific and technical power:

1. *The hostility of the authorities and official ideology regarding the intellectuals.* V.I. Lenin made extremely critical statements with respect to

[1]Deputy Director, Joint Venture "Paragraph".

this social group. Furthermore, the integration in a social class was denied to the intellectuals in the scheme of the division of society into classes according to the canonical variant of the doctrine. Thus, this group was conferred the often disdainful social status of a "stratum."

2. *The repeated manifestations of hostility by the authorities in practice, scandalously achieved in multiple ways ranging from persecution to the extermination of the most educated people during various periods of Soviet history.* The first clear sign of this antagonism were the deportation of the most active intellectuals in 1922. The attitude toward the social group as a whole, rather than toward individual persons, manifested itself as a rule in these actions.
3. *The pressure of the Soviet communist ideology took a position incomparably higher than that of any science.* Evidence of this gloomy phenomenon were all sorts of campaigns against scientific free-thought with the purpose of subordinating it to a single theory selected as an officially adopted (frequently, perfectly false) one. The most profound examples have been in the struggles against genetics and cybernetics. Yet, there exist multiple individual examples in practically every sphere of science (probably except pure mathematics): in history, economics, geography, study of literature, and so forth.
4. *The presence of a number of purely Soviet restrictions pertaining to the participation and promotion of talented youth in the sciences.* The difficulties were probably even higher recently than compared with more distant times (even in the 17th century, in the times of M.V. Lomonossov). The most widely known restrictions were based on the national principle, but probably even a more significant was the factor of obligatory acquisition of the right to a permanent residence which restricted the opportunity to live in big scientific centers for those who had not a corresponding right acquired by birth, marriage or by means of exceptions implemented in a complicated manner.
5. *The isolation of the Soviet scientific community from the events taking place elsewhere in the world.* The attitude here was the same as in the case of the ordinary citizens. But, while there it was a violation of human rights, in the case of intellectuals it additionally undermined the roots of labor productivity and efficiency. There were even difficulties in obtaining the necessary literature, to say nothing of personal communication so necessary for scientists. Suffice it to say that only three years ago, a researcher from an academic economic institute needed spe-

cial permission to obtain access to the *Business Week* magazine in the central library of Moscow.

6. *The slightly scornful attitude to the work of intellectuals* which frequently resulted in obligations to attend insignificant and non-scientific receptions forced participation in agricultural work, and still other assignments that repeatedly revealed the subordinate position of the scientist and his/her dependence upon the authorities.
7. *The task of authorities establishing total control over all structures in the society and over scientific structures in particular.* As a result, an enormously inefficient organizational structure of science existed in the form of large, very inflexible, and conservative research institutes as a rule.
8. *The totally rigid and conservative system of scientific relations combined with shortages of goods.* This was particularly noticeable in the shortage of scientific magazines and publishers. The possibilities for rapid scientific communication and promotion of talented people were extremely limited.

The list of factors that prevented a normal development of the R&D system in the USSR may be continued for some time. However, the issues are beginning to crystallize and we may state the first problem at this point.

Problem 1

How could it come to pass that despite the enormous number of factors which hindered the development of the Soviet R&D system, a vast potential had been formed that in fact surpassed the R&D structures in even the most developed countries such as the USA and Japan based on various selected parameters, e.g., the number of researchers.

A Proposed Solution

The origin of the answer is based on the attempt of a more careful reconstruction and analysis of the aforementioned arguments concerning the obstacles to a normal development of the R&D sector. The factors mentioned assume that a R&D sector of powerful potential, if created in a country with such conditions, cannot be efficient. Consequently, rational reasoning might imply that it should not have been created in the first place, or, if after the establishment its futility was recognized one ought immediately to have halted investment in further development.

This point is, in fact, a key to the answer. The paradox arises while attempting to draw a rational economic conclusion. Nevertheless, the real practice was not at all based on rational economic principles and did not pursue such objects.

For many years, the actual economic policy in the USSR was based on the following grounds:

(1) The ideology—Science has, for some reason, found itself on the Soviet Leadership's list of prestigious ideological "toys" and the pride in the number of researchers has found itself of equal rank to the pride of the tons of steel smelted or the length of channels dug. The ideological aspect precipitated incentives for the development of science not to depend on qualitative achievement but rather to be based on simple quantitative objectives. Suffice it to say that an entire department within the planning apparatus was dedicated to determining the number of researchers, post-graduate students, etc., required in the national economy.

Under the supply-driven central planning, the actual effectiveness of the R&D sector was not of great importance in assessing the well-being of the national economy; just as the use of smelted steel and created channels was essentially insignificant in appraising economic success.

Today it seems a real mystery how science has shifted from being a persecuted activity to a position of official pride. The explanation for an ideological phenomenon apparently should also be an ideological one. A probable reason may have stemmed from the feared but fond desire to borrow scientific and technical progress from the West.

(2) Political survivability—For a long time, the Soviet political leaders made policies on the basis of a seriously assumed real danger of military aggression against the USSR. After the Caribbean crisis and the change of leadership in 1964 in particular, the military-industrial complex (MIC) acquired a great influence. The importance of science was implicit in the military expansion and caused the MIC to become the lobbyer for the R&D sector and a premier employer of scientific personnel. The efficiency of work was not generally assessed and subsequently taken into account. On the contrary, a decrease in efficiency was compensated by a further expansion of the inputs in the sector.

A paradoxical system of relationships emerged: the inefficiency was a reason not for reducing the sector but, on the contrary, for its enhancement.

(3) The inertia of past decisions—The Soviet economy proved to be extremely inertial. The lack or weakness of the economic motives for the development and change was surely part of the predicament. The necessity

of resorting to extra economic stimuli, e.g., to an ideological substantiation of reforms, relegated the role of precedent in guiding on-going activities to a secondary one. Parameters regarding the science and technology sector that were taken into account while forming national economic plans were external (with respect to the results of scientific work) parameters one could easily increase, i.e., quantity, employment, investments, and others. The impossibility of considering the actual return from science within the framework of macro-economic planning led to the readiness of the state to provide incentives for the development of science even under the conditions of its appalling inefficiency, and without any change in its functioning conditions.

(4) The ambitions—Even during the most difficult historical periods, the pretentiousness of the Soviet leadership was very high. The principle to "match and surpass America," which unfolded in very different periods during the development of the Soviet economy with remarkable stability, has revealing implications. All standard comparisons of Soviet development, growth, achievement, and status were carried out essentially only in contrast with the USA. The more modest experiences and levels of other countries were all but ignored. However, the backwardness and lack of information on the situation in other countries did contribute to this phenomena. For a considerable portion of the analysts, realizing the actual level of development of the USSR proved to be a sad discovery of the epoch of "glasnost" and transformed to an irrational pessimism which was closer to the reckless optimism of the existing past than to a sober estimate of the existing situation. In any case, the ambition "to be at the level of the USA" in a number of areas (including the defense sector) ensured the maintenance of the extremely inefficient R&D system for many years to come. Again, this motive was also a non-economic one, just as the previous ones were.

Thus, the main reason for the emergence and existence of a R&D sector of power potential is explained by the fact that, until only very recently, the economic policy in the USSR was based not on economic but on political and ideological aims.

The Main Problem (Mystery, Secret) with the R&D Sector in the USSR

Until the formal demise of the USSR and still today, the R&D sector in this area continues to be plagued by growing difficulties. Let us consider some forms of manifestation of these difficulties.

(1) First flow out of sector—This feature has been characterized by an outflow of a great number of the best specialists from this sector into the private business sphere. The independent (private) business in the former USSR is just germinating, and it reveals the impact the former state R&D sector workers now in private business. However, this business has not yet gained sufficient means to carry out serious independent research. On the other hand, since the level of exploitation of developments created in the previous period is very low, many specialists now have an opportunity to initiate the production of new products which will eventually be developed in the private sector. The lack of a clear legislation and legal practice regarding disputes on intellectual property has contributed to such opportunities because state organizations find it difficult to lay claims concerning the use of their intellectual property.

This tendency has become most apparent in the area of soft-ware programming where the majority of products now sold in the private sector emerged as a result of developments carried out in the previous period within the framework of state organizations.

The present situation pertaining to R&D within the private sector resembles the situation within the private sector in the agriculture; small personal plots of an area which equals approximately 1% of the total for the country produce a significant percentage of gross output disproportionate to the quantity of inputs of many leading products. But the private sector is not merely more efficient with this respect. It uses additional types of resources not used in the state sector; often engaging in unofficial commercial operations. The present success of the non-state sector is largely connected with the utilization of the accumulated stock of knowledge and products previously created in state institutions. Yet the key to the success lies not in a mass commercialization by order from the authorities, but by market-style demand impulses perceived in the private sector. As long as the flow out of the state sector continues this will remain an influential force in the economy. Already now state institutions are compelled to be more energetic in the defense of their intellectual property, potentially limiting the access for the private sector in the near future.

(2) Second flow out of sector—In this case the reference is to the flow of the specialists which leave the country. Amongst the hundreds of thousands of people who emigrated in recent years, this flow of specialists amounts to tens of thousands of them. This rate will only increase after the law on entering and leaving the former USSR comes to effect after 1 January 1993.

Theoretically, the specialists that have gone abroad may contribute to a greater integration of the emerging post-Soviet R&D sector into world economic structures. But in practice, this phenomena has not proven to be very promising.

(3) The difficulties in financing within the framework of the state budget in connection with the budget deficit—This tendency is particularly visible within the framework of conversion and reduction of allocations for the defense sector. A considerable part of the Soviet R&D sector belonged to the defense complex. Although the conversion of R&D is undoubtedly easier than that of industrial production, it is only so in an initial stage and soon stumbles across numerous problems.

(4) International competition—Many products developed and produced in the USSR in the absence of any competition from the international market due to a policy of the hyper-protectionism have become uncompetitive by present standards. Personal computers are the most obvious and impressive example of such a situation. Accordingly, the reaction has led to a reduction of production accompanied by a subsequent decline in R&D. Now in Russia, it seems plausible that this industry will not recover from the damage inflicted by imported goods. The possibilities to create new, competitive products in the future will also be extremely limited.

So, while the state budget deficit limits the potential of government financial support for R&D, the rise in international competition requires more domestic investment in R&D in the computer industry. The onus and burden will be on private enterprise and finally carried by the consumers.

Thus, R&D in the computer industry is in a most difficult predicament and the perspectives are even more sombre. This situation generates the next problem of fundamental importance in considering the R&D sector as a whole.

Problem 2

How is it possible that the Soviet R&D sector, which had been in a satisfactory (from the viewpoint of survivability) condition in previous decades, literally came to the brink of almost complete destruction within just a few short years? How can one explain both the vitality and the weakness?

An attempt is made in the following sections to answer this question on the basis of a description of what may be considered to be the main method of obtaining results with Soviet R&D and an explanation of the relevance of economic conditions.

A Key Aspect of Development in the Soviet R&D Sector: Copying Foreign Examples

The complex conditions regarding the functioning of Soviet science have been described above. In light of the obstacles, it is remarkable that significant results of highest international calibre were attained in specific fields.

Part of the explanation lies in one of the key ways of development of the R&D sector in the former USSR. Namely, the "borrowing" of critical achievements from the experience of the most developed industrialized Western countries.

The example of the Soviet computer industry reveals two main ways of such copying. The first one was simply the adaptation of foreign knowledge to Soviet manufacturing conditions. This was particularly engaged in concerning the replication of computer equipment. Practically every computer created in the USSR has a so-called prototype, i.e., a model for copying chosen from among Western products.

The second method of copying Western achievements was direct borrowing without any agreement of the original authors or inventors. This was essentially focussed in the sphere of soft ware programming. The use of American software was initially not concealed, but even stressed. So, when the decision was made to replicate the IBM 360 computer series as Soviet EC series machines in the 1970s, one of the arguments in favor of such an action was the potential utilization of the extensive accumulated resources of software then available for these machines in the USA. Direct copying of these programs without any agreement on legal issues was rampant during this period. An Act of the U.S. Congress in 1980 set guidelines for the copyrights for software. This, however, did not deter Soviet counterfeiters. Big groups were occupied with adapting Western software for all types of computers. These then appeared on the Soviet market under other names.

Western ideas and methods always had a decisive influence on the computer industry in the USSR. An unfamiliar example: Zelenograd, an electronic industry center near Moscow, was built according to a memorandum two American engineers conveyed to Communist Party Leader N.S. Khrushchov in the late 1950s.

Aborted (Interrupted) Technological Cycles

Eventually, the method of copying Western technologies proved to be insufficiently effective. The abstract scheme based on the experience of the computer industry may be referred to as an "aborted technological cycle."

The essence of this phenomenon consists of:

1. Due to various factors associated with the R&D inefficiency in the USSR, the life cycle of the copied product was longer in the USSR than that of the original product in Western countries. Suffice it to compare the IBM 360 series machines and their analogue "EC Ryad-1." In particular, the period of launching the product into serial production also proved to be longer in the USSR.
2. As a result, a remarkable situation arose. An introduction of completely new models in Western countries saw these coming to the eve of their useful life just as their Soviet imitation appeared on the market in the USSR.
3. Consequently, the revision of a current model came to an end in the USSR and discussion commenced regarding the necessity to immediately initiate the development of a more advanced version. Political reasons also stood behind this sequence of events due to the lure of substantial central budget allocations that could be received again and for an extended period. Thus, the research life became increasingly stable and subject to less change. A disaster for market responsiveness.
4. Finally, the new project was destined to be poorly prepared because the previous work had not been completed. Yet, the same scheme repeated new product after new product. Each technological cycle was extended time after time, and was artificially aborted at some moment.

Such relationships were an amplifier of the Soviet R&D system's inefficiency.

One of the additional circumstances that made the Soviet R&D sector so inefficient causing it to even experience difficulties when copying was the extremely vague idea of the real level of development of Western hardware that the overwhelming majority of the specialists possessed. They have practically never been abroad and had almost no personal contacts with foreign specialists. This is why, according to a tradition which emerged as far back as in the times spying for military secrets, special professionals and not ordinary scientists were commissioned to search and find Western products to copy. Probably, some bright examples convinced the representatives of the communist administration that the copying method was efficient. Now, official data have been revealed that apparently demonstrate the use of *"special services"* in the task of rapid creation of an atomic bomb in the USSR.

In practice, such productive examples were sooner an exception than the rule, but there has probably been no possibility to strictly assess the level of efficiency of such a paradigm of technological development because of the secrecy associated with it all.

The Japanese experience shows that the paradigm of copying can in principle be useful and efficient, and an acceleration of technological development from an inferior level can occur. Then, a transition to the paradigm of internally motivated technological development must follow to secure successive advances.

It follows from that said above that two paradigms of technological development can be distinguished:

- that of internally motivated technological development and
- that of copying foreign technological development.

In the countries that successfully realized the latter phenomena (such as Japan), a gradual displacement of stereotypes was associated with a replacement with the stereotypes associated with the other paradigm in the process of technological change.

In the former USSR, real technological progress has been severely hampered as a result of such phenomena as aborted technological cycles. Now, under the new economic conditions during the crisis, the stereotypes of technological development must be completely changed, generating an extraordinary instability which threatens the greater part of the post-Soviet R&D sector.

New Patterns of Changes in the Russian R&D Sector (Case Study: Eight Shifts in the Russian Software Industry)

The initial point of comparison is an unspecified moment before the economic reforms in the former USSR. Depending on the point of view, this may be 1985 for some and 1988 for others. The potential disagreement concerning the dates has no bearing on the following comparisons which are based on qualitative characteristics.

From Contracts Towards a Software Market

Indeed, all countries with a long existing software industry have undergone such an evolution. In the USSR, such an evolution recurs in an almost "pure" form. The emergence of a vast market for personal computers (PCs) has led to the development of a great number of successful and rapidly growing firms purely dealing in software. An important distinction from what was taking place in other countries consists not only in a delay in time (of 7 to 10 years), but also in the connection between the level of "marketness" and the ownership forms. All conventional enterprises subject to contract programming or on-site development of unique programs were naturally and remain primarily state enterprises. On the contrary, the overwhelming majority of young firms intuitively patterning their behavior on new market methods and stereotypes belong to the non-state sector. These conditions give a quite natural process an unwarranted political and ideological color.

Present conditions in which success in software programming is measured by the size of financial returns and by the number of copies sold make the measures of performance from the relatively recent past already seem extremely antiquated. In these times in the former Soviet Union even just a few (2–3) introductions were perceived as an important success.

From Uncontrolled Software Replication Via the Black Market to a Civilized Software Market

The general tendency described above, however, represents the shifts taking place in the sphere of programming in the USSR too vaguely.

The emergence of demand for PC software in Russia did not denote that a corresponding supply immediately emerged in a market form. On the contrary, the problem of satisfying the demand was solved by using methods of "getting," not buying, just as in the spirit of tradition of the deficit economy which had prevailed in the country for decades before. In practice, this meant that software distribution was generally taking place outside the bounds of the formal economy and was realized by means of copying according the "3Es" principle: *"everything by everybody for everybody."* The overwhelming majority of such operations did not pursue any commercial interest and did show signs of improved consumer service. The attitude toward programs could be compared with the attitude to the "samizdat" literature, that is, free distribution and boasting with possession was rather a valor than a violation of some written or unwritten norms.

Ironically, this tradition was often overlapped with the state policy of neglecting intellectual property of Western companies. The idea of free copying of software was not a bit hidden and even paraded. For instance, the Soviet authorities openly stated the advantage of copying IBM 360 series machines due to the subsequent opportunity to use the vast resources of software created for the prototypes. An opportune extenuating circumstance from the Soviet view was the fact that legal protection of software was finally consolidated in the USA only in 1988, in an amendment to the copyright law adopted by the U.S. Congress.

Another factor stimulating free copying of software during the so-called "stagnation" years was the extreme difficulty to establish new ventures in order to react flexibly to changes in demand. The conventional state enterprises bound by plans commanded from the top levels of the political hierarchy eventually became incapable of developing market activities.

The initial market reaction to the demand for PC software was not the emergence of normal enterprises that could have satisfied this demand. On the contrary (and this is a general Russian tendency and typical of the nation's economic development), the first reaction was the emergence of a software "black market." This should not imply illegal dealings. Rather, the software—mainly from the West—merely began to be offered in an informal manner for money. Such offers, however, were most frequently disguised as training services, documentation assignment or product Russianization (adaptation to Russian language use), making the scale of such business hard to assess. Some justification for these activities resulted from the absence of Western companies' products on the Russian market or only sporadic sales thereof solely for hard currency. This is why no legal alternative existed, and the demand was truly high.

The following stage of development which is presently underway characterizes the appearance of actual, formally organized market structures acting within the bounds of law and market morals and norms. Basic initiators of these changes are big Western companies that have started sales of their popular products in Russia for rubles using dealer and distributor networks acting in accordance with the international practice.

From Primitive to Industrial Work in Software Distribution and Development

Even software sales that began in a market fashion and in relatively large numbers were of rather primitive character early on. The sale of a program in Russia initially meant a mere copying of the program text for the user. Market features reflected even in the name "software package" were not implemented. Only today, are necessary market attributes appearing for products which have undergone certain approbation for demand. The following features must be included in such attributes:

- availability of documentation and normal packaging;
- accessibility to a hot-line for on-line consulting of legal software users, even if only for minimal maintenance problems;
- active and mass advertising for the most prospective products facilitating visibility and acquaintance with potential users.

In this case, Western software companies are again those that initiate the development of industrial relations in software programming in Russia. The companies establish corresponding norms of market behavior via their dealers in Russia.

We consider the progress of industrial relations in the sphere of software sales to develop sooner and more actively than that in the sphere of software development. In the latter instance, industrial relations consist of the organization and division of labor between groups and individual workers. This is an incomparably difficult task because it requires daily efforts, not those valid for a single occasion only. The shift in this area appears to be in a preparatory stage.

From Autarchy (and Originality) to Dealer's Job

The previously recounted appearance of American companies that organize sales of their software products of high-quality and international popularity is considered as an independent shift on the present Russian market. Until quite recently, there was practically no legal relationship with them. Legal sales took place only with respect to products developed within Russia. Very rarely did their level approach that of Western quality standards.

The author's notion of the future of a software industry in Russia includes, in particular, the idea that Western packages will prevail in the sector of programs distributed on the market. This should not imply, of course, that the Russian software industry will disintegrate because products will chiefly be sold via subtle domestic firms and a considerable share of the income will remain in the country. It should be noted that this share will constantly grow and now already seems to exceed the income of this branch in the premarket period.

However, the major American software companies are already active on the Russian market and sell the majority if not all their packages for rubles. This is true for Microsoft (MS-Word, MS-DOS, etc.), Borland (language compilers, Paradox 3.5), Lotus (Lotus 1-2-3), Ashton-Tate (Framework, d-Base), Symantech (Norton Commander, Q&A, etc.), Nantucket (Clipper). The list could go on and on.

Russian companies that will be able to find prominent or sufficiently active Western partners will possess particular competitive advantages. Based on this understanding, many of them are purposefully in search of such partners. As a result, certain competition arises already for privileged prestigious connections, and Western companies have the opportunity to sort and choose. This is why a series of Western firms have already changed their partners in Russia or the status of their relationship with them. Following this tendency, a successive allocation of potential Russian partners between Western companies is now occurring.

From Research Institutes and Algorithm and Program Funds to Firms

The concept of the firm as it is known in market economies did not exist at all for a long time in the conventional Russian economic system. The idea of an enterprise as a half-independent economic entity subordinate to higher organizations in all key issues served as the substitute. New economic structures could emerge only with tremendous effort, while the established ones remained. Organizations were classified by the type of activities, and an expansion of the sphere of activity was not easy by any stretch of the imagination. The main problem was, in fact, the inefficiency of the initial partition into the spheres of activity. Therefore, software programming was concentrated in research institutes which had very limited possibilities to distribute their results. In addition to the institutes, a system of algorithm and program funds especially for software distribution software had been created. The separation of developers from sales had been carried out not on the basis of division of labor but as the creation of a new independent structure. As a result, the developer (neither an individual nor an organization) typically received nothing from the distribution of his program and was consequently in no way interested in its quality.

This extremely artificial economic construction started to decay with the beginning of the Soviet reforms. The process became visible in those cases when qualified programmers moved from traditional state enterprises to the firms acting according to internationally accepted market principles.

The Status of Programmers: From Anonymity to Prominence

While programming safely resided in research institutes and design offices, the programmers were in the same precarious position as the rest of post-Soviet science. They possessed a mediocre status. The programmers had no advantages for promotion within the conventional hierarchies. The opportunities of other manifestations of success were also quite limited; for instance, publication and distribution of new programs and related literature were restricted.

However, with the appearance of independent software firms and mass sales of software, the programmers' status has apparently gained extraordinary relevance. The idea of the status has, in itself, changed. Whereas earlier it seriously depended on position and rank, the new market conditions of today have made the total level of income and the number of copies sold the deciding factors. The modern status has endowed programmers with particular advantages as compared to many other intellectual professions where there is no possibility to readily produce and distribute the results of labor in large quantities.

Although programmers' incomes are, on average, surely lower than those of commercial purchasers and retailers in the computer business, it is certainly higher than the average for other intellectual professions. Unfortunately, accurate statistics are still outstanding.

Another side of the prestige is personal fame. Since computer use has become daily occurrence, more and more people have become software users. While until only quite recently there had been practically no renown Russian programmers. Yet, today, one can expect a greater individualization of the Russian programming which allows identification with the authors and developers of software, and, in particular, because of the appearance of a great number of computer magazines read not only by programmers.

Suffice it to mention a few names: A.Pazhitnov, the author of the world-wide known game Tetris; E.Vesselov, the author of the most popular Russian text editor, Lexicon, and the widely known integrated package Master; and, Books on programming by V.Figurnov that have sold hundreds of thousands of copies.

From GOST to a Market Standard

Those who handed over programs to algorithm and program funds remember that it was impossible to force a programmer to develop a good product for no particular reason. Thus, various GOSTs (state standards) were implemented as a tool that was to regulate the programmer with respect to the order of registering materials, the requirements of the documentation, and so forth.

All these strict measures have been useful in creating unique programs for use in industry and the defense sector. But from the standpoint of benefit for the mass civilian user, it has often been useless to say the least.

Now, no GOSTs are taken into account while developing and introducing new programs on the Russian market. Their part is now played by market standards, and the motive to follow them is the wish to increase competitiveness, rather than a constraint dictated from above. When, for instance, a few firms start to release products in packages together with high-quality documentation, such a form of sales quickly becomes a standard. In fact, the market standard is a production or technical solution predominating on the market as a result of buyers' preferences.

Market standards are well known in developed countries. Their basic features include:

- A market standard emerges only after a period of production, the final choice being made out by consumers. Market standards have been overdue, in Russia. Under the previous Soviet system it was impossible to start the production of almost any product without its pre-standardization. The state wanted to "protect" the consumer from the low quality of production and other effects of competitive market.
- The adoption of a market standard is carried out voluntarily, not because of legislative requirements. It should provide a great degree of freedom and satisfaction for all participants in the economic relationship.
- The market standard, though predominating, is not the only one present on the market. There are some competitive products as a rule which ensure diversity and guarantee permanent progress. In addition, some basic standards will always be set by the government, primarily for health and environmental reasons.

One can give a very characteristic and even symbolic example in the Russian software industry. The officially adopted coding of Cyrillic symbols (symbols of the Russian alphabet), the so-called basic code page, proved to be practically perfectly unusable. Instead, the so-called alternative code page became a market standard.

IBM compatible PCs have become even more of a standard in Russia than in the USA. Macintosh type machines, on the contrary, are an extraordinarily rare sight in Russia.

From Many Programs in a Small Number of Copies to a Few Predominating Packages (Mostly Imported)

Software products were published in extremely small numbers of copies in the recent past. According to a poll carried out by the GKNT (State Committee for Science and Technology), the software publishing factor was lower than 2 in the early 80s. This indicates that the majority of programs were used on one machine only. The lack of normal market stimuli and sales system stimulated the appearance of a number of primitive programs executing often similar functions not in the most efficient way.

Normal market relations will radically change this situation. A relatively small number of products, such that the profit compensates the high cost of advertising, maintenance and development, will dominate on the market. This process, clearly seen in the USA, is only beginning in Russia. With the beginning of sales of Western packages for rubles in Russia, there can be no doubt that American packages will predominate in almost all sectors. Exceptions will be relatively rare. One of these may be Lexicon (supplied together with the spell-check Ortodox), which has quite good chances in the class of simple text editors. In general, all spell-checkers on the Russian market will most likely be of home origin. But in basic product categories, the competition for the Russian market will in all probability be led by American firms. In the class of spreadsheets, it will be a battle between Microsoft Lotus 1-2-3, Excel, and Borland Quatro-Pro. From the two most popular text processors in the world, Microsoft Word and WordPerfect, both are available in Russia in localized versions. So Russia has become the place for fierce market competition between major American companies.

Scientific and Production Projects as a Method of Structural Reorganization in the Russian Economy

B.A. Rogovsky[1]

In accordance with the Program of deepening of economic reforms for the period until 1995–1996, the Government of the Russian Federation (RF) considers conversion to be one of the priorities of structural policy at the present stage of the economic reorganization. During the course of structural reorganization, the demilitarization of the economy should be secured, and also pseudo-ineffective resources should be involved in economic activity and help from a new export base. The Russian Government has chosen to pursue an active, balanced strategy to procure structural reorganization while simultaneously not standing in the way of the developing market relations, and partially guiding the pursued reforms to maintain social-political stability.

Proceeding from the government's strategic approach, the main aims of conversion are to preserve precious elements of industrial production, personnel, and innovation potentials of the defense sector and to utilize these in the modernization and reorganization of the whole Russian economy. Such a policy could facilitate a rise of the technology standard in civil branches and in the social sector, the development of the export base and import-substituting branches of industry, and simultaneous curtail military produc-

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tion to minimum levels that would still guarantee national security but with respect to the new geo-political and strategical realities.

What is necessary so that the most technologically developed part of Russian industry, enterprises and institutions of the defense complex, could play a leadership role as *locomotives* of the structural reorganization of the whole Russian economy?

Obviously, the conceptions of stabilization and growth of the economy under real commercial conditions should be based on steady, solvent demand and real investment possibilities. Such demands and possibilities can be found abroad. Consequently, the Russian economy must immediately adopt the conditions of the world market. This thesis determines chief foreign economic priorities, logic, and the doctrine, and also the direction and the main substance of corresponding reorganizations and mechanisms that are presently being created.

If the level of Russian exports is to correspond to that of our once great Super Power, and Russia is to achieve an appropriate position in the system of international specialization and division of labor, then the entire economic structure must be modernized, stressing the export of industrial products, goods and services of high technology, science-intensive products and also consecutively curbing the officially uncontrollable export of strategic raw material resources and cheap foreign purchases. In other words, it is a matter of capitalization of export earnings and the mobilization of other financial sources and investments in state projects for the purpose of promoting export-oriented manufacturing of high technology and science-intensive products.

The formation of priorities for foreign economic relations regarding potential medium-term structural shifts could be based on the following principles:

1. *Export for the sake of the export development,* or to be more precise, the capitalization of currency earnings from raw materials exports to develop industrial export potential. The main objectives of capitalization during the initial stage are the support and development of traditional export branches, and the simultaneous development of large-scale export of services: freight, foreign motor-vehicle servicing, ecological services, ordered scientific research in the field of physics and earth sciences, development of program devices, and so forth. In future, the policy emphasis may shift to the development of less traditional directions of the export, namely: science and information (with a large inherent part of value

added), services and unique knowledge accumulated in Russia. The lat ter is presently being sold in fragments at dumping prices, particularly in the field of materials, geology, and several others. Furthermore, Russia has substantial proven expertise to offer in international geological works, the development of an industrial fleet, and in the formation of large enterprises that are prepared to fulfill contracts concerning special tasks as raising sunken vessels, underwater research, floating enterprises, etc.

Russian initiatives to realize more global projects could influence its potential exports. The financial difficulties of international organizations will require rationalization measures of one kind or another. Russia could take advantage of these events and increase its export by offering to provide the international organizations with a wide spectrum of high technology services at very reasonable cost and the subsequent usage of unique equipment, procedures, scientific and technological information accumulated in the Russian defense complex. This would be of particular interest in ecological diagnostics, rescue and special tasks, medicine, etc.

2. *"Macro-marketing" of the technological integration of regions with foreign partners.* One of the most important elements of the doctrine of international economic activity is an interaction of development programs of different regions of the country. In this connection, it is very important to prepare programs that would effectively utilize scientific and productive potential of defense enterprises within the framework of conversion in such regions as the Urals, Volga, Volgo-Vyatsky, North-Western, Central-Chernozyom, South-European, and West-Siberian. Regional Structures, responsible for foreign economic activity and conversion reorganization could, in close cooperation with the bodies of the central agency, elaborate information packages concerning possibilities for defense enterprises and the most promising directions that might attract foreign and domestic investments. Such packages could include offers to develop nationwide and interstate infrastructure, to optimize industrial cooperation and sales of products within the framework of state and interregional development programs of industrial export. Such corresponding work has already begun in a number of regions and it is very encouraging that foreign business circles have taken an active interest and are participating in informational inspection of defense enterprises and on macro-marketing of their products on an international level.
3. *The support of transregional and transnational cooperation.* The realization of large-scale scientific and industrial projects must serve as a base

for the reestablishment of sound economic ties within the framework of interregional and international cooperation and collaboration on a principally new basis. The chief trouble of today's Russian economy—the rupture of the formerly existing industrial connections among traditional partners—is stipulated by the fact that such connections were of a directive and not economic nature reflecting the branch principle of forming and managing a socialist economy. The integration of enterprises on a technological base, from the extraction and manufacture of raw materials to the realization of final products, oriented on the existence of a true market and a true purchaser, facilitates the creation of a new corporative principle for Russia regarding the reconstruction of connections with neighboring foreign states, with the former CMEA-partners, and, finally, with new partners from the more distant foreign states.

International division of labor is founded on basic economic principles. As a result, the trade of completed and semi-manufactured products play an important role in this division. Long technological chains penetrate numerous countries, forming the skeleton of transnational corporations. These corporations are constantly considering what is most profitable, and where one should transport semi-manufactures to complete the next technological operation. In addition, corporate organization accomplishes that every link of a chain attains maximum economic effectiveness in relation to the quality of products. In Russia, the major portion of a technological chain is completed within the framework of one and the same branch of industry. Broad interbranch links usually put enterprises in a spot, because of unreliability and poor quality of deliveries "to the side." Technological chains are damaged by poor quality and by surplus costs, the result of the manufacturers' monopolistic positions. Only with the help of the "vitamins" of the international competition is it possible to normalize the "metabolism" of Russian economy.

However, a real danger exists in the process of establishing such links. Russian health, safety, and environment may be at risk if the approach to induce the shifts in economy is predominated by foreign partners. The influence of the latter could cause the relocation to Russian soil of potentially dangerous enterprises including nuclear power stations, enterprises recycling or disposing radioactive waste, and chemical and extractive (nature-intensive) industry with simplified technologies. One proven method of avoidance would call on independent, international examinations in the course of the development of complex international scientific-and-production projects.

Conversion is not an isolated program. It is a necessary element in a grand plan. It is a so-called macro-marketing move. Nonetheless, neither in Russia nor abroad is there an administrative body that could comprehend the whole complex of relations (including foreign economic) and possible reactions of the Russian economy to concrete management changes. The national economic point of view and interaction with other programs and problems of the present are additionally complicated by the social-political aspect in this period.

It is impossible to put into effect the market mechanism of mastering high technologies in the framework of realization of scientific and production projects without attracting adequate infrastructure of developers of such projects. In market economies such roles are assumed by different innovation structures having special venture capital. These structures do not presently exist in Russia. We consider it to be possible and necessary to involve our foreign partners in such an activity, and we are ready to provide every kind of organizational, informational and technological support.

We are absolutely aware of the fact that the limitations on free access and information have nothing to do with the assurance of the national security of Russia. The substitution of tasks of national and economic security by a more narrow circle of tasks of state security, unauthoritative rights of departments on forming information streams, redundant secrets, and constant misrepresentation of economic, scientific and technological information hinder the creation of cooperative links among manufacturers inside Russia. The consequent obstacles to forming effective foreign economic relations leads to large-scale blunders in investment, scientific and technological policy. The lack of a legal system regarding information usage, like with goods, results in activities such as practically free distribution of scientific and technological information.

Under these conditions, the Ministry for Foreign Economic Relations, through the information support of foreign participants on the elaboration of joint scientific and production projects will strive to secure a civilized information policy aimed at achieving equality and mutual benefits for all participants.

Nowadays, a number of large industrial and bank corporations and even more small and middle-sized American industrial firms strive to invest their capital in the conversion of the Russian defense industry and its scientific and technical potential. The most perspective field of international cooperation is different forms of foreign capital usage in the field of the defense complex, and related scientific and technological achievements (applied R&D,

research & development accomplishments and marketing) for their target in civilian usage oriented on the domestic and world market. In other words, it is necessary to use the possibilities of emulation and copying of the existing scientific and technological military complex to produce competitive civil products. Presently, a developed innovational potential, which can initiate rapid technological advance in the renewal of a civil machine-building, is concentrated in the defense complex (systems of automated designing, trial stands, equipment, instruments, etc.). Immediate application of this potential in civil machine-building is held up by administrative barriers and technological dissonance. The most perspective way for overcoming this contradiction is with the employment of foreign capital, in particular, through performing joint applied trial-designs and marketing.

In our opinion, the most perspective fields of foreign capital usage are the following:

- the usage of powerful main potential of isotope industry (centrifuge) for obtaining high-clear materials; primarily for electronics, as well as for the electro-technical industry;
- reorientation of the technological potential of rocket- and radio-chemistry to development of science-intensive chemistry of small tonnage (catalysts, activators, etc.);
- the usage of the machine-building potential of the nuclear and space industry for manufacturing a wide spectrum of technological equipment and devices required by the chemical industry;
- international marketing of a wide spectrum of helicopters for their further purpose-oriented operational development and replication;
- large-scale cooperation in the field of manufacturing of civilian airplanes on the basis of domestically produced glider constructions with a set of engines and managing and navigation systems, in response to international demands;
- the usage of composites, ceramics, special alloys and a wide spectrum of consolidating and protective covers for manufacturing important machine devices (primarily engines), ensuring a multiple rise of the reliability of the whole construction;
- the acceleration of work concerning the civilian uses of laser technology (the metalloconstruction cutting, ecology, medicine);
- design and manufacturing of equipment for the usage of non-traditional energy sources (including autonomous) and power-accumulating systems.

For the grading of the list of the perspective directions of foreign capital usage, it is necessary to organize extensive non-administrative, scientific-technological and economic reviews.

Russia is becoming more attractive for capital investment, also from abroad. This might be particularly so if the foreign investments are allocated within the framework of programs of technical help and assistance to the conversion of the Russian defense complex. The fulfillment of international reviews for investment and the working out of concrete scientific-and-production projects will form the real prerequisites of the effective and mutually beneficial cooperation between Russia and its foreign partners in the future.

Development of Soviet Regional Scientific Centers: A Case Study of Obninsk[1]

B.D. Yurlov,[2] *A.P. Sorokin*[3], *G.I. Sklyar, I.V. Gonnov*[4]

Characteristics of R&D Resources of the Town

The town of Obninsk was formed as a "town of science" according to the state programmes specifically conceived to solve the problems of nuclear power engineering and other questions concerning this field of science.

Obninsk is both geographically and demographically very compact. Its radius is no more than 1.5 kilometers and there are approximately 100,000 inhabitants. The concentration of scientific personnel (1,300 Doctors and Candidates of Science) and scientific and research institutes (13) is also very high. In addition, a dense network of educational organizations (15 schools, one institute of higher education, one polytechnic secondary school, two music schools, one art school, one gymnasia, a "Humanitarian Center," three

[1]This paper was written before the collapse of the Soviet Union. Consequently, numerous references refer to institutes, committees and organizations by their former All-Union name. While some have disintegrated, most of those mentioned in this paper continue to exist, but under a different but comparable designation under the present Russian government.

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specialized secondary institutions, and a large-scale system of further training and improvement of professional skills) has been established. Together, these factor for the keystones of a favorable R&D environment.

More than 4,000 people work in scientific institutions which belong to various ministries; including the Ministry of Atomic Power Engineering and Industry (*Technologia* branch scientific-production organization), the Ministry of the Aviation Industry, the Ministry of the Chemistry and Oil-refining Industry of the USSR, the USSR State Committee of Hydro-Meteorology (*Taifun* scientific-production organization), the USSR State Committee of Public Education, the Academy of Sciences of the USSR, the State Commission of the USSR Council of Ministers on Foodstuffs and Purchases. This town concentrates considerable scientific and technical potential in different fields of atomic power engineering, medical and agricultural radiology, theoretical and practical elaboration of problems concerning ecology and environmental protection.

The qualification of Obninsk institutes has changed significantly during last five years: the number of Doctors of Sciences has increased from 140 in 1985 to 173 in 1990, the number of Candidates of Sciences has increased from 1,020 to 1,155. This tendency has not been affected by staff reduction or by the possibility to work in cooperatives or small enterprises where wages are considerably higher now.

The institutes of the town perform important R&D in various fields. These include:

1. Institute of Physics and Power Engineering: conducts R&D on nuclear-power engineering plants with different objectives (reactors on fast neutrons, power engineering for distant regions, and others). The range of R&D activities pass from the stage of conceptualization, projecting, experimental perfection of systems, starting up, and operation.
2. Scientific and Research Institute of Physics and Chemistry named after L.Y. Karpov (Affiliate): investigates materials for modern technologies, including those aimed at protecting nature. Utilization in different industrial branches, such as chemistry, construction materials, microelectronics, electro-technic, and public health care. There is a possibility to apply the results of the institute's work in electronics, space apparatus construction, medical industry, and chemistry.
3. *Technologia* Branch Scientific-Production Organization: elaboration of materials, and technologies for manufacturing goods of ceramics, glass, composites with polymer, and ceramic matrix for the aviation industry.

The consequences of Technologia's efforts are utilized in automobile, agricultural and machine-building industries, and to some extent in nuclear power engineering and in chemistry. The applied R&D is conducted in cooperation with the institutions of the USSR Ministry of Automobile and Agricultural Machinery and the USSR Ministry of Chemistry.

4. Scientific and Research Institute of Medical Radiology of the Academy of Medical Sciences of the USSR: studies the fundamental basis of ionizing and non-ionizing radiation effects on biological objects and humans, as well as working out new methods of curing and preventing of radiation-related diseases, reviewing medical and biological circumstances of the Chernobyl Atomic Power Station disaster, new methods of complex radiation cures of malignant tumors, and other radiation therapy.
5. *Taifun* Scientific-Production Organization: explores new methods of biosphere estimation, physical and mathematical models of migration and transformation of pollution elements in the atmosphere, soil, and water; as well as the influence of chemicals on ecological systems and the creation of geoinformation computer systems performing information supply for monitoring.

The apparatus plant of *Signal* (the USSR Ministry of Atomic Power Engineering and Industry) and the above mentioned experimental scientific institutions form the modern production base Obninsk. Table 1 shows the distribution of employment in the town, revealing the bias in favor of scientific rather than industrial production.

The USSR Council of Ministers thrice (1973, 1980, 1985) adopted the Decrees on the development of Obninsk municipal economy. The above-mentioned Decrees made it possible to combine the resources of different ministries and departments for town construction purposes. Obninsk construction was under the supervision of the Physics and Power Engineering Institute (which played the role of a general contractor) by a single developer, the Obninsk department of construction, an affiliate of the USSR Ministry of Atomic Power Engineering and Industry. The fact that the town is supervised by the high-priority USSR Ministry of Atomic Power Engineering and Industry allows the resolution of problems concerning socio-economic development in the town, satisfaction of the requirements of the consumer market and also generous development of the experimental base of the R&D institutions.

In spite of a high concentration of scientific and research organizations in the town, their interdepartmental dissociation precluded any significant scientific and technological cooperation during a number of years. As state enterprises became more independent some signs of a tendency cooperation between organizations of the town slowly appeared. For instance, cooperation between the Physics and Power Engineering Institute and the affiliate of the Scientific and Research Institute of Physics and Chemistry facilitated the establishment of the *technetsia* manufactured generators which are used for diagnosing malignant tumors in a number of medical centers of the country. This reduced the imports of technetsia generators. Curing patients with malignant tumors using the BR-10 neutron reactor pencil of rays method was implemented in the Physics and Power Engineering Institute. The experts from the Physics and Power Engineering Institute and of *Taifun* Scientific-Production Organization work together on the problems concerning the remedying of the Chernobyl disaster circumstances.

The Science and Research Institute of Medical Radiology of the Academy of Medical Sciences of the USSR (the State Registrar for more than 500,000 people injured in the Chernobyl disaster) participates in an international program of the World Health Organization (WHO) on research concerning the medical effects of the Chernobyl disaster. In order to ensure the completion of this program Obninsk is considering the establishment of the International Center on Radiation and Medical Problems with affiliates in Bryansk, Belarus, and in the Ukraine. The government of Japan has subsidized the program with 20 million US dollars for the period of 1991–1995, particularly for pilot projects related to the research. The WHO is studying the possibility to expand the entire program with an additional financial injection of 180 million US dollars to begin work in such directions as oncology, psychological and genetic effects.

The complex program of the RSFSR on scientific study concerning the Chernobyl disaster has been elaborated. The program will be fulfilled by the association of scientific institutions in Obninsk which have highly qualified personnel in different branches of radiology. This association is represented by the All-Union Scientific and Research Institute of Agricultural Radiology, the Scientific and Research Institute of Medical Radiology of the Academy of Medical Sciences of the USSR, the Physics and Power Engineering Institute, the Institute of Atomic Power Engineering, and the Central Institute of Improvement of Professional Skills. This complex program is an integral part of *"The state program of the RSFSR on amelioration of the Chernobyl disaster circumstances for 1991–1995."* This program is coordinated with *"The State Union-Republican program of urgent measures for 1990–1992,"* and there are some positions which were amended to the Union-Republican program, such as radiation and anthropogenetic pollution effects on humans. This program also identifies urgent measures for 1991–1992 which are connected with the problem of relocating the population of the polluted regions of the RSFSR and also other questions such as personnel training and improvement of skills of salvage workers at Chernobyl.

The total value of R&D in 1991–1995 is budgeted at 175 million rubles, including 80 million rubles of urgent measures in 1991–1992. Presently, the RSFSR Council of Ministers are deliberating about the complex program financing.

The suggestion to establish a scientific and research center with the title "Physical and Chemical Problems of the Emergency Situations" has been studied. It was suggested to create such center as an affiliate of Scientific and Research Institute of Physics and Chemistry. Within three years, such a center will facilitate the improvement of methodogical, material, and technical base of specialized research departments including; manufacturing of progressive cloths for overalls, isolation materials, neutralization of spray containers and miasmata, emergency readiness of water-plants and equipment, securing ionized radiation in the field, polymer sorbents for extraction of oil products from water, and many others. The position of the Center must be defined in the departmental hierarchy that will, from its budget, finance 40% of the Center's expenditures for three years (6.5 million rubles per year) with the remaining 60% to be earned on a contractual basis. The prospective total value of work of the Center can amount to 16 million roubles in the first three years of operation.

Considering the available scientific and personnel potential of the town, there appears a necessity to further transform the Institute of Atomic Power Engineering into the higher educational institution as a State Technical University. An expert commission, consisting of the leading scientists of Obninsk, elaborated a proposal for transforming the Institute of Atomic Power Engineering into a University and establishing new faculties in addition to the existing physics and power engineering faculties in the medical-biological, ecological, radiation, materials for space apparatus construction, humanities fields.

The Obninsk Department of International Conversion Fund was established in lieu of realizing the proposed conversion in the town. These will be integrated into the complex strategy for the transition of the defence industry to manufacturing civilian goods and as a solution to economic and social problems. The Obninsk Department Program is intended to promote the spin-off of R&D results in such directions as: non-traditional power-engineering, production of isotopes and implementing of reactor technologies, new non-metallic materials and their technologies, ecology, manufacturing of electronic equipment, machine-building for diary industry, and organization and improvement of professional skills.

As international experience shows, small enterprise activity is very important for demonopolization of the economy, competition and innovation. At the same time, it is necessary to avoid the collapse of efficient large organizations. In restructuring R&D organizations, we proceed from the necessity to promote cooperation within the groups of large and small enterprises and between these two groups. At present, 240 small enterprises and 274 cooperatives with a total number of employees amounting to 6,000 people are registered in Obninsk. The overall revenue collected by small enterprises in 1990 amounted to 50 million rubles. 61 cooperatives (22.3% of the total number of cooperatives) are engaged in scientific and research activities and in developing computer programmes. Their income in 1990 amounted to 17.2 million rubles (32% of the total income). For the moment it is very difficult to estimate the efficiency of small enterprises because the majority of them are engaged in trade operations. The task now is to promote their industrial innovation activity.

Social and Demographic Structure of the Population in Obninsk

The social structure of this science town is shown in Table 2 (six scientific and research institutes are listed for illustration), and the demographic structure is shown in Table 3.

On average, directors of scientific and research institutes are 56 years old, and deputy directors are 54. As for the main categories of scientific positions (chiefs of departments and chiefs of laboratories) the structure is the following: chiefs of departments—68% are older than 50, and 11% are older than 60; chiefs of laboratories—55% are older than 50 and 7% are older than 60. Only 10% of chiefs of departments and 15% of chiefs of laboratories are between the ages 30 and 40. In some rare cases, people younger than 30 occupy positions of chiefs of scientific departments.

Only 7% of the total number of Candidates of Sciences are young scientists less than 33 years of age. The average age of people defending a Candidate thesis is 35–40, while the average age of Doctors of Sciences is 56.

Infrastructure of the Town

A Decree of the USSR Council of Ministers allotted in 1986–1990 60 million rubles for investments in construction objects of municipal economy, trade, public catering, communications, health care, and cultural and welfare facilities in the town of Obninsk during the period 1986–1990. The amounts of allotted capital investments for construction projects in the town at the end of the twelfth five year-plan in 1985 are shown in Table 4.

The main indices of the development of communication means, public automobile transport, trade and public health care are shown in Tables 5–8 inclusive.

Key Issues Facing Science and Technology in Obninsk

The main problem lies in the abrupt reduction of financing for fundamental R&D. Thus, financing for the Institute of Physics and Power Engineering amounts to 65% of its capacity, the affiliate Scientific and Research Institute of Physics and Chemistry is only financed to 70% (the financing of fundamental work amounts to 10%), the financing of *Technologia* Branch Scientific-Production Organization amounts to 80%. The financing of R&D in ceramics for engines of different purposes was reduced to a critical level. Some scientific institutes are financed at the same level as in 1990. This puts them in a difficult position due to the total increase of prices for services and the reductions in the state budget. The main cause of the existing situation is the reduction of financing in the field of atomic power engineering and defense industry in the absence of any state program on conversion. The potential returns from conversion are immense, but considerable initial investment is required. Despite the difficulties with financing, truly productive projects are continuing. However, the most important fundamental research projects *buran* (avia-space research) and *Topaz* (thermoemission transition of nuclear energy into electric energy) were downsized. This was done despite the fact that the work was conducted on a very high professional level and the results achieved were a valuable contributrion to the world scientific community.

Table 9 shows the reduction of financing in fundamental science as compared with the total volume of scientific and research work of scientific and reserach institutions in Obninsk.

The general tendency is that applied sciences are not exempt from the present critical situation. The increase of wages in the Academy of Sciences became a disincentive for young specialists to enter industrial research institutes. Also, the increase of wages for medical workers may, in the nearest future, cause an outflow of specialists from medical science to practical public health care.

Five research reactors and 17 stands are in the operation in the scientific and research institutes of the town. They presently still satisfy industrial safety standards. However, regarding the long-term exploitation of the experimental base, obsolescence must be compensated by rapid renovation. Modernization, and additional measures for the improvement of nuclear plant safety require substantial financing. It is necessary to analyze and to resolve the problems concerning further development of the experimental reactor base of scientific and research institutes.

Despite all efforts, the level of the technical base has fallen behind modern standards: the main courses were a lack of super-computers, and an inability to communicate with other centers. Information technologies are developing very slowly in Russia. The personnel training in post-graduate courses has deteriorated and, as for the competition, it is on the same level or even worse. The problem lies in the difficulty to choose candidates because of a lack of accommodation and low wages. The analysis of the data in the twelfth five-year plan shows that only 25% of those who finished post-graduate courses can defend their thesis in time. Only 15% of the total number of Candidates' theses were defended by post-graduates.

Social Problems of the Town

The existing economic situation in Obninsk has become rather problematic; the town was integrated in All-Union structures and ties that have been recently destroyed and now it is impossible to change everything at once. The former Union, Russia, and the region refused to resolve the problems facing the town. At present, the provision of goods has become much worse, the deficit of consumer goods has been intensified, the volume of civilian construction has been reduced, the objects of municipal economy have not been put into operation in time, and so forth. These factors aggravate the social problems of the town, including those which have become socially significant, such as housing and employment problems.

The existing and lowering rates of construction accentuate the housing problem (see Table 10). The queue of those who need to improve their housing conditions is constantly growing. The housing problems in the town are depicted in Table 11.

In 1987, a complex program for housing construction until the year 2000 was developed in Obninsk. The program envisages housing construction by a general contractor for the years of the twelfth, thirteenth, and fourteenth five-year plans corresponding to 320,000, 380,000, 460,000 square meters respectively. The completion of the planned quantity of dwellings will prove to be very problematic as early as in the thirteenth five-year plan, as there was no confirmation about the available resources already in 1991. The volume of work fulfilled by the Obninsk department of construction will be reduced by at least 20%.

Because of the abrupt reduction of centralized state deliveries, the problem of securing supplies cannot be solved solely by the town's department of worker's supply which belongs to the USSR Ministry of Atomic Power Engineering and Industry. The manufacturing enterprises in the town do not produce sufficient consumer goods and services to meet the inhabitants' demand. Consequently, the residents must resort to barter operations which have become the basic form of transactions now. Additional supply can be secured via direct contacts with agricultural organizations or the fields owned by enterprises of the town.

Due to the sudden decline in financing for scientific and research institutes, and the related lack of state orders for the institutes and industrial enterprises, the problem of potential unemployment was sure to become a reality. The measures to prevent unemployment in the main branches of industry will be constructed as follows:

- creation of a data base for labor resources in the town;
- creation of a municipal system for retraining personnel using existing centers;
- creation of funds for social protection and support using the assets of enterprises and the municipality;
- new job detection and creation; and,
- establishing additional working places in the existing enterprises and institutions of the town.

The maintenance of sufficient employment creation in such a little town as Obninsk will prove to be a very difficult problem.

Perspectives

The perspectives for future R&D activities are different in different organizations. For instance, in the *Technologia* Branch Scientific-Production Organization the R&D activity will become much less profitable than manufacturing consumer goods made of glass, composite materials, ceramics. Yet, leading experts of *Taifun* and *Technologia* Scientific-Production Organizations and of the Institute of Physics and Power Engineering consider their institutions to have very highly qualified personnel and experimental and production bases to fulfill research in a number of important fields. The institutes' activities could be significant and progressive if the following conditions are satisfied:

- receipt of order to work out a complex project of Atomic power station or some projects (Institute of Physics and Power Engineering);
- 40% financing from the state budget (Scientific and Research Institute of Physics and Chemistry, *Technologia* Branch Scientific-Production Organization)
- restoration of the experimental base (creation of neutron accelerators, etc.)

The optimistic outlook for *Taifun* Scientific-production Organization will be 10–15% staff reduction and retraining of a number of specialists, outflow of up to 40–80% of scientific personnel, and a 15–20 years setback.

In the transition period, the demand for R&D will, without a doubt, decline. Self-finance and conversion in science now means "driving in nails with a microscope." The only task is to survive. If the measures on economic protection are not adopted, then the Institute of Physics and Power Engineering may survive but all the best personnel and associated ideas that constituted a level of scientific achievement which out-paced the United Staes by 15–20 years (that is, in the case of the creation of *Topaz*—a fully automatized and safety nuclear plant with thermoemission converter of energy) will be lost.

The reduction of financing by both the state and enterprises causes enormous problems. In order to protect R&D institutes from bankruptcy a precocious R&D policy is necessary at the state and enterprise levels.

Changes in R&D organization

The financing of applied sciences from the state budget has essentially terminated. Applied R&D must now be financed from the income gained by the sale of its products. It is necessary to organize research work in such a way that it could stimulate the labor productivity. This will require strong cooperation between R&D and production activities. In order for the latter to be achieved, designers and producers should work together in the same economically viable scientific and production organizations. The previously monstrous scientific and research institutes must be transformed into firm-like organizations, consisting of small economically and legally independent enterprises, performing and implementing R&D simultaneously. Another way (for instance, for the Scientific and Research Institute of Physics and Chemistry) to receive more or less protection is to enter the Academy of Sciences.

All in all, it would be both timely and reasonable to implement:

- competitive character of R&D finance, and allocation and distribution of state orders for R&D projects;
- contractual character of scientists' employment to provide flexible conditions for research team formation;
- creation of conditions to provide financial support for research work in a given prospective field, without any obligations of the collective to receive any concrete results during a fixed period of time;
- information distribution and discussion of R&D results;
- release of scientific institutes from non-R&D activities: i.e., housing construction, maintenance of pre-school institutions, maintenance of institute transport, creation of municipal services of auxiliary character, and servicing other scientific institutions on a contractual basis;
- establishment of enterprises and joint ventures to initiate and engage in research programmes and the implementation of results; and,
- cooperation with foreign countries (Germany, Great Britain, USA, Italy and others) in establishing joint ventures for production and research.

In the near future considerable financial means will be necessary for increasing wages, re-equipping the experimental basis, and for housing.

International Cooperation

The Institute of Physics and Power Engineering has extensive international relations in the following fields:

- physics of low and medium energies;
- physics and techniques of reactors working on quick neutrons;

- hydrodynamics, heat exchange, etc.

The closest potential commercial scientific and technical cooperation will be with Libya and India. There are also very good ties with the International Atomic Energy Agency (IAEA).

The Scientific and Research Institute of Physics and Chemistry is the leading and largest institution specializing in radiation chemistry technology. The institute has registered considerable achievements in the fields of semiconductors, modified polymer materials, and filtration techniques. Future perspectives can only be realized if initial financing is secured in advance.

The Science and Research Institute of Medical Radiology was chosen as the base organization for creation of the International Center on Problems of Radiation Medicine. It actively engages in large-scale projects on a bilateral basis with the European Council, and Norwegian and other companies.

There are considerable difficulties in Obninsk that prevent the organization of international cooperation. Obninsk does not have the status of a so-called "open town," which is accompanied by a lack of high-standard hotels in town, inability to book the flight tickets and change passports, and a lack of good communication facilities (telex, telefax).

Work of Soviet Scientists Abroad

At present, a number of specialists from the Institute of Physics and Power Engineering work abroad on a contractual basis.

In case the law on free exit is adopted the possibility for young talented scientists to go abroad will become reality. These circumstances will inherently cause the reduction of scientific potential not only of the town but of the country. The experts will leave, taking with them new technologies, methodologies and experience. Of course, the main incentives are financial and many of the more flexible younger generation will take advantage of the attractive Western offers.

In Russia, the opinion still prevails that only people with very low morality can leave their Motherland. In general, scientists will only go abroad to work for a fixed period of time and such a situation is quite normal in the world. On the other hand, considering the present economic situation in Russia, it would be extremely undesirable to lose the most talented, energetic and innovative specialists for any period of time. It is necessary to adopt organizational and economic measures that will induce each scientist to apply his talent, experience, and ideas and ensure him or her the corresponding remuneration.

Openness of the Town: Its Contribution to the Development of Science

The new openness of the town must promote the development of contacts with the world scientific community, potentially making Obninsk an international scientific center. This would require Obninsk to become the home of global scientific institutions (for instance, the world center of information with specialization in different branches of science). The openness could attract the necessary foreign capital, foreign science and technical experience, modern technologies and equipment, and experience of commercial organizations by establishing joint ventures, conducting symposia, and so forth.

Openness is an indispensable condition for institutes and enterprises to function efficiently, and a powerful incentive to develop the town as a scientific center. These elements may together be a catalyst to generate an abrupt spurt in social and economic development of institutes, enterprises and residents of the town.

However, alone this will be insufficient. The policies of the town should be considerably changed: for example, to defend commercial secrets and "know-how", and to prevent the outflow of scientific ideas to other firms and companies elsewhere. It is necessary to establish the previously absent exchange of information among organizations within Obninsk.

New Forms of Organization of Scientific Community Life in Obninsk

The continued existence of a scientific community can only proceed on a basis of business and economic interests. The total social organization would, in the case of this town, be most favorable under conditions set by elaborating complex programmes for a number of existing institutes (similar to the program for Chernobyl).

According to the estimates of leading scientists, the shortcomings of a local scientific community activity are: weak mutual ties, practically not a single inter-institute creative collective, no cooperation on solution of scientific problems and general questions of life in the town. The peculiar characteristics of Obninsk are departmental barriers and a natural economy. It is necessary to stimulate the cooperation of scientific and research institutes in the search for solutions to scientific and economic problems.

A reasonable prerequisite would see the establishment of a municipal scientific and technological council at the initiative of one of the institutes. This council (or maybe some other organization) should be responsible for the following:

- which problems are being solved by the institutes;
- difficulties (theoretical, technical) which can be overcome with the help of other institutes on a contractual basis.

The council should publish a bulletin accessible to every institute of the town. The bulletin would contain the information about the unsolved (or difficult to solve) problems and questions. Indeed, a so-called "Coordination council" did exist in the town until 1968 and it seems there may be renewed relevance for such a functional body in the name of saving the scientific potential of Obninsk.

Table 1. Distribution of employment in the Obninsk economy.

Sector	No. employed	percent of total
Science and science servicing	22,500	37.6
Industry	7,400	12.4
Construction	8,500	14.2
Transport and communication	1,640	2.7
Municipal and consumer services	1,550	2.6
Trade	4,160	7.0
Publich Health Care	2,760	4.6
Education	1,360	2.3
New forms of national economy (JVs, cooperatives, Joint Stock societies etc.)	6,000	10.0
Other	9,870	16.5
Total	59,820	100

Note: 6056 people registered in town work in the country (10,1% of the the total number of employees).

Table 2. Social structure of scientific and research institutes' employees in Obninsk.

Scientific and research institutes	Total number of employees	Of them: men	women
IPPE	9723	5755	3968
Technologia	4080	1675	2405
Taifun	1910	839	1071
SRIMR	1881	531	1350
Affiliate of SRIPC	1300	762	538
AUSRIHM	1268	303	965
Total:	20162	9865	10297
(%)	100	49	51

Note: Institute of Physics and Power Engineering (IPPE)
Technologia Branch Scientific-Production Organization
Taifun Scientific and Production Organization
Scientific and Research Institute of Medical Radiology (SRIMR)
Scientific and Research Institute of Physics and Chemistry (Affiliate of SRIPC)
All-Union Scientific and Research Institute of Hydro-Meteorology (AUSRIHM)

Table 3. Demographic structure of scientific and research institutes in Obninsk.

Scientific and research institutes	Total number of employees	by age: ≤ 40	41–50	51–60	> 60
IPPE	9723	4899	2067	2181	576
Technologia	4080	2545	1275	176	84
Taifun	1910	978	466	331	135
SRIMR	1881	1197	427	233	24
Affiliate of SRIPC	1300	526	385	346	43
AUSRIHM	1268	757	341	146	24
Total:	20162	10902	4961	3413	886
(%)	100	54	25	17	4

Note: Acronyms are defined in Table 2.

Table 4. Capital investments in construction in Obninsk (mln.rbls.).

	1985	1989
Capital investments	28.7	39.5
including:		
construction of public entities	13.4	18.0
housing construction	15.3	21.5

Table 5. Main indices of communication development in Obninsk.

	1985	1989
Number of post-offices	10.0	10.0
Number of telephone-subscribers(thous.)	24.8	28.1
Number of trunk-lines	287	325

Table 6. Main indices of passenger transportion in Obninsk.

	1985	1989
Total number of buses	230	240
of them:		
on municipal routes	86	84
on intertown routes	27	36
Avg. Length of bus-routes in town (km)	138	133
Passengers per km of route per year	382.4	486.8

Table 7. Trade indices in Obninsk.

	1985	1989
Number of trade outlets	68	69
Number of public catering establishments	92	99
Floor area in retail shops (sq.m.)	193	184
Inhabitants per public catering establishment	1004	1037

Table 8. Public health care in Obninsk.

	1985	1989
Number of polyclinics	5	5
Total number of beds in hospitals	1095	1040
Number of doctors of all specialities per 10,000 inhabitants	53.6	51.8
Number of nurses and sanitary personnel per 10,000 inhabitants	116.5	112.7

Table 9. State Budget allocations for scientific activity in Obninsk.

	1985	1986	1987	1988	1989	1990
State financing as % of total budget for research projects	65	63	62	51	44	30–40
Financing of fundamental science as % of total research budget	25	21	17	10	8	7

Table 10. Completion of housing units (thousand of m^2).

1985	1986	1987	1988	1989	1990
54.8	49.1	66.1	69.4	73.7	72.3

Table 11. Housing problem in Obninsk.

Number of families registered to receive accommodation	12258
Of them:	
live in communal flats	1443
live in hostels	5847
registered for more than 10 years	224
Number of families received or improved accommodation in 1990	1694

Conditions for R&D in Higher Education Institutions in the United States and Russia: A Comparison

Nadezhda Makarova[1]

Introduction

The end of the Cold War, recent events in Eastern Europe, and the disintegration of the Soviet Union moved international economic competitiveness to the center of the world stage. Today, access to natural resources is no longer the key to economic success and technology has proven to be more important. Competition on today's markets requires continual improvement and innovation. A country's ability to secure its position in the new world order is only possible with a well-educated work force which is one key requirement for technological advance. Knowledge and people have become the main economic resources that determine the position of every developed and developing nation in the new world order. All of this requires a dedication to both applied, and basic research, and cooperation in investigations between Academies of Science, Higher education institutions, and industry.

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Therefore, the problems associated with the organization of R&D, such as financing, planning, cooperation between science, industry and academic organizations, utilization of R&D results, and forms of new technologies transfer from science to industries are major topics of concern in Russia. For the purpose of the following analysis of the aforementioned concerns, one needs to define and compare the state of R&D in Russia with a certain pattern. First of all, it is necessary to choose a suitable systematic pattern of analysis.

Types of Higher Education Institutions: Classification and R&D Activities

Higher education systems in the world are based on diverse traditions regarding the relationships between government and institutions of higher education, the relationships between research and teaching, the links between higher education and graduate employment, and the organization and management of the institutions.

Most experts agree that only three different models of higher education formed the basis of higher education systems in West Europe and the rest of the world:

1. The British, which underlined a firm educational process and training a broad mind;
2. The German, which promoted a close link between research and teaching and supported the freedom of learning; and
3. The French, which was particularly concerned with training specialists.

However, there are many reasons to use the higher education institutes in the United States as a comparison, because, as T. R. McConnell said over thirty years ago: "there is no system of American higher education. It is safe to say there never will be. Diversity of support, control, organization, aims, programs, and students will continue to be the most evident characteristics of post higher educations in this country" (in Altbach, 1991). The distinctive characteristics of higher education in the United States are the diversity and decentralization of higher education which include the combination of several elements—the British undergraduate liberal arts college, the German research and graduate faculty, and the professional schools. Furthermore, not only differences exist between higher education schools in the

United States and in Russia, but also numerous common traits. These main distinctions and common traits are listed below:

- After World War II, the higher education systems of the United States and the Soviet Union became the both open or hidden measures for assessing strengths and weaknesses of higher education in these nations and those with similar systems. The education system in the United States was partially a step ahead of the European model and partially a product of it. In Eastern Europe, the socialist countries were mainly influenced by the Soviet structure.
- The American system is guided by market forces rather than planning. Competition is intense among institutions—for students, high-quality faculty, and research support. Planning is carried out at the level of individual institutions and states rather than on a national basis other than some basic principles. The system is, in principle, linked with public institutions, although some state authorities include the private sector in their planning mechanisms. In Russia, the central planning mechanism was the sole organizational instrument and, only now, market forces begin to function.
- As it was already mentioned, the American university system is based on combinations of several elements. There exists a diversity of curriculum, standards, and degrees within as well as among institutes. Such diversity was not known in Russia. Indeed, there was and still exists high standardization of curricula, degrees, and bureaucratic control over the education process. New forms of the higher education institutes appeared only recently in Russia.
- A high share of the R&D financing in the United States is concentrated in the elite universities, closely connected with the government institutions responsible for the allocation of R&D funds. Also in Russia, R&D resources are concentrated in a few of the best universities and colleges and, as in the USA, these conduct also intensive military-oriented studies.

The comparison of R&D in higher education institutions is not only useful, but also necessary. Prior to the selection of several qualified institutions, one has to consider various types of higher education institutes in the United States and in Russia.

Higher education institutes in the United States are not as easily classified as institutions in many other countries. There are more than 3,000 institutions of higher education in the United States (public and private) which do not play equivalent roles in science and engineering (S&E) education and research. The schools range from two-year vocational oriented community or junior colleges to four-year colleges and further to research universities with a full array of graduate and professional schools. The two-year colleges award associate degrees and are equivalent to the first two years at a four-year college or university. The latter two additionally offer graduate training at the master's degree level. Universities boast a wide spectrum of special programs for various fields at the undergraduate and graduate levels, including the doctoral and post-doctoral study. Many, in addition, include professional schools such as medicine and law. Institutes of technology and polytechnical institutes are generally similar to universities, but they focus on science and engineering and do not have any law or medical departments.

A widely used classification of colleges and universities has been developed by the Carnegie Foundation for the advancement of Teaching (Carnegie 1987). The Carnegie classification was conceived in 1970 and revised in 1976 and 1987. The foundation's classification scheme is based on several factors, including:

1. Amount of Federal support;
2. Numbers and levels of degrees awarded;
3. Number of programs awarding degrees;
4. Belonging to liberal arts institutions.

In 1987, the Carnegie Foundation for the Advancement of Teaching, using data gathered by the United States National Center for Education Statistics, classified the 3,389 degree-granting higher education institutions into categories based on the level of degree offered. There were roughly 1,800 private and 1,500 public institutions, about 2,000 offered programs lasting four years or more, while 1,300 (900 of them public community colleges) offered two-year programs.

There are more than 500 higher education institutes in Russia (57% of all institutes of the ex-USSR) in which about 3 million students attend courses (55% of all students of the ex-USSR) (CSAER, of the USSR 1986). This means that there are less than one-sixth as many institutions of higher education in Russia than in the United States, where only 25% as many students are trained and 20% as much instructional staff is employed as in the USA.

The higher educational institutes in Russia are usually distinguished by technical, polytechnical, humanitarian, medical and pedagogical institutions, universities and military schools. They support programs which range from four-years (usually humanitarian and some military), five-years (universities, polytechnical and some technical institutions) and six-years (medical and some technical institutions). Most of these institutions (including all those in Moscow and St. Petersburg, as well as all universities) additionally offer graduate training at the master's degree level, and some of them at the doctoral level.

In Russia, most higher education degrees are given in technical fields: about 36% of all degrees granted in Russia have been granted in engineering. These engineering graduates receive technical training in highly specialized engineering fields. This training differs from the general and theoretical engineering education taught in the United States where engineering principles can be applied widely to new products and processes.

There is no comparable system of classification in Russia to that of the Carnegie Foundation in the USA. The Russian classification which existed until today is linked to the subordination of the higher education institutes to some ministry. Before the disintegration of the USSR, Soviet institutes were subordinate to either the All-Union Ministry of Education, or the respective Republic's Ministry of Education, or the industrial Branch Ministry, or a combination of these. The R&D funding pattern of higher education institutions reflecting such an organizational structure and financial support for the institutions of multiple subordination (for example, to the All-Union Ministry of Education and to a Branch Ministry) was significantly higher.

Statistical indicators depicting R&D activities in higher education establishments in the United States and in Russia differ considerably. In the United States, the information about R&D fields has great significance. For example, there are such indicators as number and percentage of science and engineering fields in universities and colleges by total R&D volume and fields; federal and non-federal R&D expenditures at universities and colleges by field and source of funds; employment of scientists and engineers at universities and colleges by fields and source of funds; percentage of recent doctorates in surveyed departments by field; and many others. There never were and are still no such indicators of R&D at higher education institutes in Russia, yet the necessity for them is obvious. Another group of R&D indicators which are in the higher education statistics of the United States but not in Russia, characterize the collection procedures, staff, and operating expenditures in the libraries.

More or less similar indicators characterize R&D expenditures at higher education institutions in the United States and in Russia and also expenditures for facilities and certain equipment by performers and sources. The key sources of funds for R&D in the United States are the Federal government, the State and local governments, industry, and institutional funds. As a rule, the support for conducting R&D at American colleges and universities on the part of specific agencies (Ministry of Defense, Agriculture, NASA, NSF, etc.) are considered separately. The sources financing for R&D at higher education institutes in Russia are very limited: the state budget and contracts with firms, where the former has traditionally provided the lion's share.

In order to characterize the facilities and certain equipment in US R&D, one usually uses the following indicators: capital fund expenditures by field, source of funds in current and constant dollars, and current fund expenditures for research equipment by field. The analogous indicators in Russia are: balanced cost of equipment at higher education institutes and current fund expenditures for research equipment.

All these distinctions between R&D indicators certainly hampers the comparison between R&D at higher education institutions in the United States and in Russia. In evaluating the aforementioned information the following conclusion may be made: it is no simple process to select adequate indicators and relevant higher education institutes in the United States and Russia for comparison. In addition, access to statistical information describing Russian R&D activity in higher education institutes is rather limited (1986 is the last year). Also, this information is not always authentic.

Upon surveying R&D performing higher education institutes that were subordinate to the All-Union Ministry of Education in 1986, sixteen of them were located within Russian territory: five universities (Voronezh State University, Gorky State University, Irkutsk State University, Tomsk State University, and Rostov State University), three polytechnic institutions (Gorky Polytechnic Institute, Saratov Polytechnic Institute, and Ural Polytechnic Institute), and eight institutions of different Branch Ministries in Moscow and St. Petersburg (Leningrad Institute of Mining, Leningrad Institute of Light Industry, Leningrad Textile Institute, Moscow Radio Engineering Institute, Electronics and Automation Institute, Moscow Steel and Alloy Institute, Moscow Chemical Engineering Industry Institute, and Moscow Machine-Tool Production Institute). All are higher education institutes of a mid-rank. It was impossible to receive the information about the best institutes in Russia. The usual reason was the subordination of these institutes to military or closed ministries where the majority of research was confidential. As a result, R&D performed in these institutions remained mostly unpublished or published in restricted literature.

Statistics on R&D in universities and colleges in the United States usually include the best fifty research universities and the best one hundred universities. Many are well known around the world for research excellence including, for example, the Massachusetts Institute of Technology (MIT), Stanford University, the University of California at Berkeley, the University of Michigan, and Cornell University. In order to make a meaningful comparison with the Russian roster, the last fifteen universities and S&E colleges among the top 100 universities and colleges in the United States were selected. MIT was added to the list as a model of one of the best S&E higher educational institutes (see Table 1).

The first step in the present comparison is an analysis of total financial support for R&D at higher education institutions in the United States and in Russia by source of funds.

Financial Support of R&D at Higher Education Institutions by Source of Funds (1970–1985)

In the United States, nearly all academic research is carried out in small subset of the more than three thousand institutions of higher education. About 25% of all federal funds for R&D go to the top ten institutions and 40% go to the top twenty. These percentages have remained virtually constant over the past two decades.

Annual R&D expenditure at higher education institutions in the United States was estimated to be slightly over $10 billion in the mid-1980s, about 2.5% of gross national product. One of the important characteristics of American higher education is the diversity of sources from which colleges and universities derive their support. Government at all levels (federal, state and local) provide almost half the total.

While public institutions derived about 60 percent of their revenue from government sources (almost half from state governments) and less than one-fourth from payments for instruction from students, private institutions present a very different pattern. The latter received less than one-fifth of their support from governmental sources (only 2.5% from state and local governments), but almost half from students in the form of payment for instruction. The federal government has been the major funder of research in colleges and universities. In the fiscal year 1986, over two-thirds of university R&D budgets came from the federal government. Higher educational schools spent only 12% of total R&D funds in the nation, but over half of the Federal funds for basic research.

The pattern of growth in expenditures has been inflated during this period. Between 1972 and 1975, R&D expenditure (in constant dollars) increased at an average annual rate of about 1%. From 1975 through 1980, the average rate was 5%. After 1980, it levelled off and in 1983 growth was only about 1% above the 1980 level (refer to Table 1).

R&D expenditures at higher education institutions in Russia, as noted earlier, have only two sources that are usually reflected in statistical reports: financing from the state budget and non-state financing. Information about R&D expenditures at individual Russian higher education institutions between 1970 and 1985 is not available, but, as already noted, more than half of the higher education institutes in the former Soviet Union are now in Russia. Thus, we can use the data previously collected by the State Committee for Statistics (Goskomstat) for an analysis of the main tendencies.

R&D expenditures at higher education institutions in the USSR were estimated to be slightly over 1.5 billion rubles per year in the mid-1980s, about 0.2% of gross national product. At official exchange rates, this amounts to about 2 billion dollars (official exchange rates in the mid-1980s: 1 US dollar = 0.75 rubles). This is only one fifth of expenditures in the United States. At 1 US dollar equal to 5 rubles, which was the black market exchange rate at the time, USSR R&D expenditures were thirty-three times less than US expenditures. Expenditures from the state budget for R&D at higher education institutes within the borders of the Russian Republic were about 180 million of rubles (or about 240 million US dollars at official rates and 48 million at the black market rate), twenty times and one-hundred-fifteen times less respectively than in the United States. The expenditures from non-state sources in the USSR and in the United States were approximately equal.

In the mid-1980s the Soviet higher education sector derived about 12% of its R&D revenues from state sources. The share of these sources decreased from 21% in 1970 to 12% in 1985, indicating that government was consistently economizing on higher education. The pattern of growth was not very strong during this period. Between 1970 and 1985, state R&D expenditures increased at an average annual rate of only about 4% (Table 1).

Comparing R&D expenditures at the top sixteen higher education institutions in the United States to those in Russia as shown in Tables 2, and 3, the contrast between the level of financial support for R&D in these countries becomes even more obvious. Total R&D expenditures at the fifteen selected universities and colleges in the United States (i.e., without the expenditures at MIT) were on average higher than at the top sixteen higher education institutes in Russia by a factor of four (at the official rate of exchange) and by a factor of 34 at the black market rate. The government support of R&D in the higher education sector of the United States (federal, state and local) was 14 or 99 times higher than state support in Russia depending on the exchange rate. In the USA, support from the Academy of Sciences and industry was 1.5 times and 10 times higher than in Russia respectively.

An example of a higher education institute not subordinate in Russia to the All-Union Ministry of Higher Education was the Moscow Institute of Radio and Electronics, seventh on the list in Table 3 by volume of total expenditures. This institution received markedly less state financing compared to Russian institutes under direct Ministry of Higher Education authority or compared to an institution of equivalent rank and status in the USA. For 1986, Table 3 illustrates that state support for R&D in this institute was 242,600 dollars (when 1 $ US = 0.75 rbls.) or 36,400 dollars (when 1 $ US = 5 rbls.).

For the sake of comparison, we draw the reader's attention to Table 2 and the seventh ranked US institution selected in our sample by volume of expenditures: Mississippi State University. State support (federal, state, and local) was 156 times higher for this institute than for the Moscow Institute of Radio and Electronics (at the official exchange rate). The share of contributions from Academy and industry in these institutions were approximately equal.

Thus, we draw the conclusion that, in the mid-1980s, the R&D at universities and colleges in the United States received an appreciably larger amount of the state financial support for R&D, than any higher education institutions in Russia.

Due to the absence of information concerning R&D expenditures of Russian or former Soviet higher education institutes after 1985, the following reasoning is based on research and observation by the author.

Today, the situation with R&D support has changed considerably: on the one hand, the expenditures from the State budget can not increase under present circumstances and the inflation effect will in fact cause the real value to decrease. On the other hand, financing through commercial contracts is increasing. This increase, however, is sometimes difficult to recognize, because the traditional methods of accounting elucidate the sources of expenditures not financed by the state. The new forms of financing are connected with a new commercial structure in Russia; namely, the so-called *maloe* *predprejatie* (the small enterprise). *Maloe predprejatie* affiliated with higher education institutions are organizations that include only a limited number of members (most of them are instructional staff of the higher education institutes, only few post-graduate students and students), are self-accounting and offer various forms of activities, including R&D. Usually, there are several enterprises associated with higher education institutes. For the latter, this has become a chief source of funds for research and development. Unfortunately, due to the novelty of this economic organization, little information concerning the activities of such enterprises, has been collected. Indeed, even the methods to accurately compile this information are yet to be developed and implemented.

Furthermore, financial support for R&D at scientific organizations (including higher education institutions) is to some extent based on the character of work (basic research, applied research, development), so we devote the next section to review basic characteristics of R&D at higher education institutes in the United States and Russia.

The Mechanism for Financial Support of Basic and Applied Research

For the purpose of analyzing the characteristics and funding of basic and applied research and development conducted in higher education institutions in the United States, the following definitions of the National Science Foundation are used (National Science Foundation, 1984).

- basic research has as its objective a fuller knowledge or understanding of the subject under study, without specific application in mind;
- applied research is directed toward gaining knowledge or understanding necessary for determining the means by which a recognized and specific need may be met;
- development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes.

While total investment in R&D has grown significantly during the last decades in the United States, the relative emphasis on basic and applied research and development has remained rather stable since 1970: development has fluctuated between 63% and 69%, applied research between 21% and

24%, basic research between 9% and 14%. National Science Board, 1991). In 1989, private American firms performed 85% of development, followed by Federal in-house laboratories, which performed 11%. Firms also did most of the applied work (72%), while the academic sector and Federal in-house laboratories were each responsible for 12% of the total.

Universities are known as the traditional home of basic science in the United States and accounted for half of all basic research performed in the nation in recent years. Only 18% of basic research was conducted by private enterprises and 12% by in-house Federal Government laboratories (Teich and Pace, 1986).

Thus, industry has been dominant in both funding and performing development and applied research, the Federal Government dominated the funding of basic research, and research universities dominated the performance of basic research in the USA. Consequently, we can judge the scale of basic and applied research at higher education institutes in the United States, as in Russia, on the basis of R&D expenditures by source of funds.

There was constant growth of total R&D expenditures at higher education institutions in the former USSR between 1970 and 1986, with the largest portion distributed in Russia. However, the spending on basic research did not change during this period. This was accompanied by a continual decline in expenditures on department investigations.

The analysis of R&D expenditures by source of funds in the former USSR and in Russia, which was considered earlier, reveal that basic research was not the major task in the 1980s and has not regained a prominent status in the R&D programs of higher education institutions in Russia (contrary to those in the United States). This phenomena has arisen despite the fact that the conditions for basic research at higher education institutions is far better than at other scientific organizations in Russia.

Equipment and Facilities

Due to the significant role of capital expenditures on scientific equipment and facilities at higher education schools in the United States, it is interesting to analyze their development.

Capital expenditures from federal sources for R&D at higher education institutions in the United States declined steadily from 1972 to 1986, recovering thereafter. Nevertheless, in 1989 they had attained only the 1976 level (refer to Table 4). This decline is sharply accentuated when inflation is taken into account. While support from non-federal sources did increase, the growth rate was insufficient to compensate for the negative inflationary effect. Thus, in 1989, total capital expenditures were barely more than in 1980 (in constant dollars) and federal funding was down to one-third of its 1972 level in constant dollars (U.S. Department of Commerce multiple editions).

The result of this decline in expenditure has been the growing obsolescence of research facilities and instrumentation in the United States higher education schools. The magnitude is achieved due to the continuous increase (above inflation) in the cost of sophisticated instrumentation (generally in the range $100,000 to $1 million range), and the relative decrease of funds available (at all levels—federal, state, local and university) to purchase such equipment.

The cost of scientific equipment have increased four times since 1970 and a whole new range of technologies have become standard accoutrements in research laboratories over the past few years. One investigation found that the average age of university instruments was twice that of instrumentation at quality industrial laboratories (Ibid). In addition, research equipment has been estimated to have a lifetime as short as three to eight years because advances in instrumentation due to internal research projects. As a consequence, the Departments of Defense and Energy, leading R&D performers in the nation, have also increased instrumentation funding. Higher education schools have begun to explore in-house methods of dealing with these issues, employing solutions such as creative debt financing, user charges, and limited partnerships.

The information about capital expenditures and current fund expenditures for research equipment at higher education institutes in Russia does not exist. However, as noted earlier, the data collected under the former Soviet higher education organization can be used as proxy in order to recognize the main tendencies in Russia, where the majority of the All-Union institutes were located.

There was constant growth in costs of equipment at the higher education institutes in the former USSR between 1970–1986, yet the yearly expenditures for equipment did not increase and even slightly declined between 1983–1984 (refer to Table 5). Thus, the renewal of capital funds was very slow. Several authors have noted that the obsolescence of machines at higher education institutions must to be guided by material production. In the 1980's, the average annual increase of equipment in the Soviet national economy was about 5%; at the higher education institutes the average annual increase of equipment was between 2% and 4%, indicating that the renewal of capital equipment was even slower here than elsewhere in the economy. Consequently, the majority of higher education institutes lacked state-of-the-art equipment for research. An exception was the S&E higher education institutes of double subordination (the average annual increase of equipment in these institutions was 5%), but, as a rule, that which was more rapidly replaced was of less sophistication.

In order to perform meaningful research and development accurately, efficiently and rapidly, electronic computer equipment is essential. Since 1985, the growth rates for the utilization of computers increased: in 1984, the higher education institutes subordinated to the All-Union Ministry of Education received 80 computers and, in 1985, already 263. One year later, there were 7,028 computers employed by the All-Union Ministry of Education in its institutions: 54% of these computers were at higher education institutes in Russia. Nevertheless, a quantity as this was clearly insufficient for 293,816 instruction staff, 42,837 undergraduate and 2,983,081 total students enrolled. According to the report for 1985, more than 70% of 6,765 computers were older and near obsolete models (CSAER of the USSR, 1986).

Information about contemporary computer security in Russian institutions of higher learning is absent. The situation now is consistently improving, mainly due to the use of different forms of funding instruments including contracts and cooperative agreements. In fact, the cooperation is such that the computers and other equipment, which are the property of the *maloe predprejatie,* are usually used for R&D at higher education institutes.

Thus, the integration between higher education institutions, scientific organizations, and industry is of growing importance for today's Russia. Indeed, the primary motive is the joint exploitation of instrumentation and facilities, especially the newest and most expensive equipment.

Integration of Academia, Industry, and Science

There are different objectives behind an integration of higher education institutes, industry, and scientific organizations in the United States and in Russia. The main purposes of this integration in the United States is to improve their own and the nation's competitive positions, prevent stagnation, and discover new markets. The key to such achievements is to mobilize all scientific and technological resources, including higher education institutions which still possess untapped reserves, whose contribution can be increased by adopting appropriate policies. Indeed, universities in the United States contribute to the structural revitalization of the national economy by assisting small and medium enterprises as well as by generating entirely new high-technology businesses.

In recent years, considerable attention has focused on university-industry research cooperation in the United States. Industrial firms have sought ways to augment their basic research portfolios and their innovative capabilities and higher education institutes have explored new sources of research funding. A variety of cooperative R&D arrangements, particularly in emerging areas such as biotechnology, have increased the importance of university research (primarily long-range basic research which industry is reluctant to support in its own laboratories) to meeting industrial needs, as well as industry's broader need to keep track of current developments in all fields of S&E (facilitated by contacts with university researchers) in order to remain at the forefront of technological competitiveness.

While industrial funding is not expected to be a substitute for federal support of university research, the growing relationships are widely regarded as significant and mutually beneficial. Many universities have actively sought the enhancement of existing relationships and the establishment of new ones, while industrial firms have begun competing with one another to develop connections to the top universities, and the federal government has set up programs and otherwise sought to encourage the trend. The new arrangements have raised new questions concerning federal and institutional policies relating to academic freedom, protection of intellectual property (such as patents and copyrights), anti-trust regulations and technology transfer (refer to R. Stankiewicz's recent work (1985) for more details).

In Russia, one of the main purposes for the aforementioned integration was a direct external economic lever to improve the recruitment and training of students and the method in which they are employed after graduation. Integration can lead to mutual economic dependence between higher education institutes on the one hand and the research institutes (both academic and industrial) on the other. But, it is necessary to note that the most profound current incentive for integration and mobilization of all scientific and technological resources is to secure the survival of science in Russia during the transitionary period and thereafter.

Unfortunately, the post-Soviet scientific community has been and continues to be plagued by a low level of interaction between higher education institutes and industry as a result of the lack of crucial links between science, technology and production over decades of communist rule. Additional problems arise as a consequence of the organizational disparity between universities and industry. Therefore, it seems inevitable that higher education institutions must and will undergo a variety of institutional adjustments. Many of the organizational experiments now taking place at the higher education institutes/industry interface can be viewed as precursors of more fundamental changes to be expected.

Finally, it is not realistic to expect that further strengthening of the relations between industry and higher education institutes will be based primarily on greater financial support because the future additions to industry-funded programs for the United States, Russia, or every country with a substantial R&D sector are likely to have a relatively narrow focus. Most industrial sectors are under increasingly vigorous competitive pressure, subsequently forcing them to concentrate on higher return/lower risk R&D investments. But the cost and complexity of modern research is such that no one single country has the resources to do it all (in the electronic industry the current generation of memory chips requires an investment of between $100 and $300 million to set up a manufacturing plant, but by the end of the decade the cost will be about $1 billion). Apart from this, recent developments have indicated that finance and capital markets, much of manufacturing, and almost all of the higher technology business have become globalized. The globalization of high technology business is changing the interaction between industry and higher education institutes, causing the higher education institutes to become more international also.[2]

Main Conclusions

This comparison of R&D at higher education institutions revealed that the conditions for R&D in these countries, particularly the financial support, is still far more state-dominated in Russia than in the USA. Also a product of different levels of economic development in this countries, these circumstances mainly stem from distinct government policies regarding the academic sector in the United States and in Russia.

[2]While support for universities in different countries by non-national based corporations is growing, the universities and institutions of higher education, nevertheless remain essentially national institutions in spite of rapid globalization of the world. Not one is completely and solely supported by the global community and the financial base of the higher education institutes are as yet not international. Even more so, it is often aggressively national. There are many reasons for this "aggression," and so long as higher education institutes funding remains national, their progress toward the globalization will be limited.

The American university is the traditional home of basic science. The traditional home of Russian basic science are the Academy of Sciences and some selected academic institutions. In Russia, the main purpose of the higher education institutions and universities is the training of specialists. Thus, the state financial support of R&D at the higher education institutes in the United States is incomparably higher than in Russia. The financial support of R&D from non-governmental sources are approximately equal in relative terms.

There was a decline of capital expenditures at higher education institutes in the mid-1980s both in the United States and in Russia. This decline has resulted in the growing obsolescence of research facilities and instrumentation in these countries. The median age of instrumentation in higher education institutes in Russia and the United States was several times more than the average age in industry. In order to compensate for such growing deficiencies in the United States as in Russia (though with a definite lag), efforts are being undertaken to more actively promote the integration between higher education institutes, scientific organizations and industry. In Russia, low levels of interaction between higher education institutes and industry are the result of a lack of mutual objectives and motivation between science technology, and production. In the United States, several authors also report a low level of such interaction, which sooner is the consequence of the organizational disparity between universities and industry.

Despite the positive efforts, negative tendencies continue to arise in higher education institutions in Russia: for example, the low and declining levels of government financing, poor capital funds, old-fashioned forms of organization and occupational training, and still others. Now these problems begin to convert into a crisis of higher education system in Russia. Consequently, higher education institutes in Russia are far form the standards of these in the USA with respect to finance, equipment, information networks, and organization of education programs. This makes the process of the former's integration in the world high education network very difficult. Nevertheless, foreign support of R&D in some Russian universities, colleges, and institutes with high scientific potential can be promising. R&D expenditures in Russia are very low compared to those in Western industrialized countries and the qualification of scholars is rather high; an indication that investments in Russian R&D performed at higher education institutions could be quite efficient, productive, and generate a high rate of return.

Table 1. R&D Expenditures at higher education institutions in the USA and USSR by year and source of funds.

USA, 1970–1983 (millions of US $):					
Year	Total	Federal gov't.	State & local gov'ts.	Industry	Institutional Funds
1970	2335	1647	219	61	243
1971	2500	1724	255	70	274
1972	2630	1795	269	74	305
1973	2884	1985	295	84	318
1974	3023	2032	307	96	370
1975	3409	2288	332	113	417
1976	3729	2512	364	123	446
1977	4067	2726	374	139	514
1978	4625	3059	414	170	623
1979	5361	3595	470	194	728
1980	6060	4094	494	237	827
1981	6818	4559	548	291	974
1982	7261	4749	593	330	1088
1983	7745	4960	599	370	1231

Source: National Science Foundation, 1984.

Table 1. Continuation

USSR, 1970–1985 (millions):						
Year	Total		State budget		*"Commercial"* contracts	
	rubles	$ US	rubles	$ US	rubles	$ US
1970	487	649	102	136	385	513
1971	563	750	110	147	452	602
1972	661	881	125	167	536	714
1973	734	979	135	180	599	798
1974	823	1098	140	1897	683	911
1975	895	1194	141	189	753	911
1976	975	1300	146	195	829	1105
1977	1019	1359	146	195	872	1163
1978	1102	1469	157	209	944	1259
1979	1165	1553	161	215	1004	1339
1980	1245	1661	164	219	1080	1441
1981	1301	1735	163	218	1183	1577
1982	1374	1832	169	226	1205	1606
1983	1457	1943	178	238	1279	1705
1984	1489	1986	185	246	1304	1739
1985	1544	2058	186	248	1357	1810

Source: Reports of R&D at higher education institutions subordinated to the All-Union Ministry of Education, 1986.
Note: exchange rate (1 dollar = 0.75 ruble).

Table 2. R&D expenditures at selected higher education institutions in the United States, by source of funds.

Institutions of the USA, 1989	Institut. category	Total	Federal Gov't	State & local gov't	Industry	Academic insti- tutions	Other sources
		thousands of US dollars					
Total		1,080,503	552,886	88,915	84,932	246,625	79,614
Massachusetts Institute of Technology	private	287,157	215,140	3,211	39,650	6,692	22,464
Alaska-Fairbanks University	public	56,701	26,659	2,101	3,039	21,869	3,033
Clemson University	public	56,699	12,484	16,245	3,849	22,486	1,635
Florida State University	public	55,245	24,897	1,566	832	25,449	2,501
Washington State University	public	55,173	22,697	2,268	2,258	22,945	5,005
University of Oklahoma	public	53,956	1,702	3,502	1,991	24,226	7,667
Auburn University-all campuses	public	53,814	15,179	1,357	4,111	17,667	3,287
Mississippi State University	public	53,670	17,694	20,334	3,886	5,416	6,340
Oklahoma State University	public	53,655	14,116	1,853	1,645	34,613	1,428
Georgetown University	private	53,597	37,351	217	4,370	8,278	3,381
University of California-Riverside	public	53,213	15,584	2,441	1,094	31,449	2,645
University of New Mexico	public	52,970	23,934	5,660	2,496	11,732	9,148
Tufts University	private	50,424	40,771	773	8,010	847	23
University of California-Santa Barbara	public	50,067	39,227	1,036	2,645	4,878	2,281
Kansas State University of Agric. & Applied Sciences	public	47,302	15,951	21,133	1,790	6,384	2,044
University of Texas-Health Science Center Houston	public	46,860	29,500	5,668	3,266	1,694	6,732

Source: Science & Engineering Indicators, 1991.

Table 3. R&D expenditures at selected higher education institutions in Russia, by source of funds.

Institutions Russia, 1986	Institut. category	Total	Govern't	Academy institutions
		thousands of rubles		
Tomsk State University	public	19,206	6,033	13,174
		3,841[a]	1,206[a]	2,634[a]
		25,608[b]	8,044[b]	17,565[b]
Leningrad Textile Institute	public	17,670	1,842	15,828
		3,534[a]	368[a]	3,165[a]
		23,560[b]	2,458[b]	21,104[b]
Gorky State University	public	15,556	5,549	10,008
		3,111[a]	1,109[a]	2,001[a]
		20,741[b]	7,398[b]	13,344[b]
Ural Polytechnic Institute	public	14,748	2,263	12,486
		2,949[a]	452[a]	2,497[a]
		19,664[b]	3,017[b]	16,648[b]
Rostov State University	public	14,549	5,616	8,933
		2,909[a]	1,123[a]	1,786[a]
		19,398[b]	7,488[b]	11,910[b]
Moscow Institute of Steel & Alloy	public	8,876	1,924	6,952
		1,775[a]	384[a]	1,390[a]
		11,834[b]	2,565[b]	9,269[b]
Moscow Institute of Radio & Electronics	public	8,288	182	8,105
		1,657[a]	36[a]	1,621[a]
		11,050[b]	242[b]	10,806[b]
Gorky Polytechnic Institute	public	8,044	287	7,827
		1,608[a]	57[a]	1,565[a]
		10,725[b]	382[b]	10,436[b]
Saratov Polytechnic Institute	public	8,005	400	7,604
		1,601[a]	80[a]	1,520[a]
		10,673[b]	533[b]	10,138[b]
Irkutsk State University	public	7,908	3,615	4,293
		1,581[a]	723[a]	858[a]
		10,544[b]	4,820[b]	5,724[b]

[a]Thousands of dollars according to the black market exchange rate of 1 \$ = 5 rubles;
[b]Thousands of dollars according to the official exchange rate of 1 \$ = 0.75 rubles.
Source: Reports of R&D at Higher Education Institutes Subordinated to the All-Union Ministry of Higher Education.

Table 3. Continuation.

Institutions Russia, 1986	Institut. category	Total	Govern't	Acacemic insti-tutions
		thousands of rubles		
Voronezh State University	public	6,232	999	5,233
		1,246[a]	199[a]	1,046[a]
		8,309[b]	1,332[b]	6,977[b]
Leningrad Minning Institute	public	6,037	950	5,125
		1,207[a]	190[a]	1,025[a]
		8,049[b]	1,266[b]	6,833[b]
Moscow Textile Institute	public	5,195	827	4,368
		1,039[a]	165[a]	873[a]
		6,926[b]	1,102[b]	5,824[b]
Leningrad Institute of Textile & Light Industry	public	3,740	272	3,468
		748[a]	54[a]	693[a]
		4,986[b]	362[b]	4,624[b]
Moscow Institute of Chemical & Mechanical Engineering	public	3,181	326	2,855
		636[a]	65[a]	571[a]
		4,241[b]	434[b]	3,806[b]
Moscow Institute of Machine Tool-making	public	3,066	368	3,434
		613[a]	73[a]	686[a]
		4,088[b]	490[b]	4,578[b]

[a]Thousands of dollars according to the black market exchange rate of 1 $ = 5 rubles;
[b]Thousands of dollars according to the official exhcnage rate of 1 $ = 0.75 rubles.
Source: Reports of R&D at Higher Education Institues Subordinated to the All-Union Ministry of Higher Education.

Table 4. Capital expenditure, current fund expenditures for research equipment and instructional staff at higher education institutions in the United States, 1976–1989.

	1976	1977	1978	1979	1980	1981	1982
	Thousands of $ US						
Capital Expenditures at higher education institutes	1,646,920	1,431,650	888,250	925,870	932,302	1,023,037	964,596
Current fund expenditures for research equipment	na	na	na	na	na	281,521	270,433
Instructional staff	na	812,000	809,000	823,000	846,000	865,000	865,000
	1983	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**
	Thousands of $ US						
Capital Expenditures at higher education institutes	1,047,421	1,085,709	1,096,266	1,304,256	1,471,715	1,607,184	1,650,365
Current fund expenditures for research equipment	269,846	316,403	388,344	438,304	446,678	474,775	468,821
Instructional staff	na	na	na	na	na	na	na

Sources: NSB, 1991 and US Dept of Commerce, multiple issues.

Table 5. Balance cost of equipment, current fund expenditure for research equipment and instructional staff at higher education institutions in Russia, 1976–1989.

	1976	1977	1978	1979	1980	1981	1982
	Thousands of Rubles						
Balance cost of equipment at higher education institutes	1,768,738	na	2,284,239	na	na	na	3,541,590
BMX	353,747	na	456,847	na	na	na	708,318
OX	2,358,317	na	3,045,652	na	na	na	498,875
Current fund expenditures for research equipment	42,449[e]	na	54,821[e]	na	na	na	141,333
BMX	8,489	na	10,964	na	na	na	28,266
OX	56,598	na	73,094	na	na	na	188,444
Instructional staff	257,488	251,517	269,300	272,790	276,281	283,404	285,885

	1983	1984	1985	1986	1987	1988	1989
	Thousands of Rubles						
Balance cost of equipment at higher education institutes	3,819,710	3,962,228	4,306,788	na	na	na	na
BMX	763,942	792,445	861,357	na	na	na	na
OX	5,305,152	5,015,478	4,894,077	na	na	na	na
Current fund expenditures for research equipment	66,355	57,850	113,292	na	na	na	na
BMX	13,271	11,570	22,658	na	na	na	na
OX	88,473	77,133	151,056	na	na	na	na
Instructional staff	297,527	295,724	293,816	na	na	na	na

Source: Ibid.

Legend: na — not available
[e] — estimation
BMX — thousands of dollars black market exchange rate: 1$ = 5 rubles
OX — thousands of dollars official exchange rate: 1$ = 0,75 rubles

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Part III

On Fundamentals for Restructuring R&D in the Transition Process

R&D Organizations in Russia: Freedom-Shock

Leonid Kosals[1]

This paper contains an analysis of the social-economic situation in state R&D organizations (RDO) of Russia.[2] At present, these organizations are undergoing a specific stage of *"freedom-shock."* The rapid trend towards liberalization of life in Russia has been accompanied by government policies that include drastic decreases in State demand for scientific projects. As a consequence, it has become clear that many research institutes are not ready for economic freedom. They were not able to adapt to the changing demand for experimentation and consultation on the part of state enterprises, and to the new demand from the gradually emerging private sector. As it turns out, managers of scientific organizations were unprepared and unable to lure new customers for their developments, to modify the inner structure of their institutes, to alter the methods of financing their work, and to create new incentives for their personnel.

According to my observations, a downward trend regarding the situation of RDO became noticeable as early as 1989–1990. As state budget allocations began to decline, RDO personnel sought funds via alternative means that simultaneously lead to promotions and rapid career advances. Unfortunately, there was no prompt reaction to this situation on the part of RDO managers. Remuneration and opportunities for the young specialists in state academic R&D were paltry compared to the coveted offers in private business. The

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[2]This work was a part of the research project "R&D Management in the Transition to Market Economy (Co-leaders: Dr. S. Glaziev, Russia, and Dr. R. Levin, USA) at the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

decrease of financial assistance form the state constantly intensified shortages of quality personnel, equipment, instruments, reagents, and so forth, driving a considerable part of Russian RDO into a state of *freedom shock*. Certainly this shock was variable in its gravity, allowing some RDOs to recover from it. However, their numbers are few thus far. Moreover, a latent process of decay began in many RDOs—a portion of qualified staff has left and the majority of those who remained started using their organization solely as a place of registration. The people continue to be formally employed in their institutes, but in reality they actually either work on contracts for commercial organizations, conduct private business, or simply keep their jobs until retirement due to the old-age pension entitlement.

At the same time, many RDOs have initiated changes. Within these new structures, new firms involved in spreading and disseminating R&D results and consulting began to appear. The transformation of the internal organization often resulted in the dismissal of unproductive workers.

This report is devoted to a description of how Russian RDOs actually endure the *freedom shock*. The background study was empirically based on a sociological survey encompassing 21 institutes in Moscow, Novosibirsk, Voronej, and Vladimir; in these institutes 565 managers of units (divisions, laboratories), directors and their deputies were surveyed. The investigation has covered representatives of physical, mathematical, chemical, biological, geological, technical, agricultural, and medical sciences. Approximately 25% of the surveyed people were employed in military RDOs, the others in institutes concerned with civilian R&D. The survey was conducted in academic institutes and in industrial research organizations. Both large and small research institutes were selected; among these were organizations in a comparatively reasonable social and economic situation as well as others on the brink of collapse.

Social and Economic Situation in RDOs

The situation in RDOs was investigated on the basis of the question: "What is the situation in your Institute?" The replies were distributed as follows:

The situation is good	2%
The situation is difficult, but the main research potential has been retained	82%
The research potential is lost, the organization has actually collapsed	14%
Other	2%
Total	100%

Thus, only about 15% of the surveyed research units are in the situation of actual disintegration. The majority indicated that despite present difficulties, the main research potential has been retained.

The situation varies by regions. The most difficult (reflected by the evaluations of the respondents) situation was observed in Vladimir where the inquiry was carried out among department leaders of institutes in a research town specializing in military related projects. In this case, no respondent evaluated the situation of his institute as good and as many as 44% have indicated that the organization has actually collapsed (as compared with an average of 3–4% of the respondents in the civilian RDOs).

The military R&D sector proved to be in the most critical position —the share of decaying research units was more than 10 times that in the civilian R&D sector. This did not occur by chance. A key part of the cause has been the secrecy and accompanying isolation of military R&D; until recently, institutes with a defense profile were prohibited to have foreign visitors and were isolated from the penetration of whatever changes happened elsewhere in the country. After the events of August 1991 the situation changed dramatically. Due to a sharp reduction of military orders, the privileged specific financing and material supplies for defense-related R&D were canceled. Consequently, the military has suffered most at the hands of *freedom shock.*

Vexatious working conditions for scientists are particularly typical for the present situation in R&D institutes. This is clear from the survey replies to the question: "How are the work conditions and what specifically is lacking?":

Good conditions, everything is available	12%
Lack of machinery, equipment, instruments	69%
Housing space is lacking for employees	30%
Shortage of finances	7%
Lack of information, literature	1%
Everything is lacking	2%

Note: The respondents could give more than one answer, therefore the total is not 100%.

The managers also critically evaluate not only working conditions in their units but also people's attitude towards their work. They have pointed out that the personnel's attitude towards work is:

good	15%
varies:	
partially good, partially bad	50%
bad	35%

Moreover, by evaluations the attitudes of the people surveyed towards their work has, on the whole, changed for the worse during the liberalization of the Russian economy over the last 5 to 6 years. The attitude changes have been as follows:

attitude improved	34%
attitude worsened	38%
attitude unchanged	28%

At the same time, according to the opinion of the institute managers the quality of the research products developed in their institutes has on average changed for the better over the last 5 to 6 years. The responses with respect to research product quality indicated:

improvement	33%
retrogression	26%
unchanged	41%

Thus, a paradoxical situation has arisen. Although the respondents' attitude toward their work has deteriorated, the products of their efforts have not necessarily suffered as a result. This paradox can be explained by the effect of a social mechanism compensating consequences of the worsening of workers' attitudes towards labor. As a matter of fact, people ensuring the high quality of institute work have partially compensated the deficiencies in the work of their badly working colleagues by doing it over again, fulfilling some part of the others' functions, etc. This type of compensation is possible until the people with high quality of work are predominant in the unit. Despite the prevailing decline in attitude towards labor, there is no immediate negative effect on the results of the work. The potential deficiencies will with all probability arise, though with some lag. Evidently, in the research institutes surveyed, the accumulation of a critical mass of employees with a detrimental attitude towards work has not yet taken place and, for the time being, the deficiencies in their work are still compensated by those with a positive attitude towards labor and high quality work. However, if the declining trend in R&D employees' attitudes continue, then a critical mass of bad workers may be accumulated and it will be no longer possible to compensate their low quality work. Subsequently, a sudden spasmodic drop of quality in research products will take place.

This type of social competition may take place in stable R&D units that scientists formed, based on common goals and values and striving for the achievement of best results. Respondents' assessments of their R&D units were of the following character:

Stable	64%
Stable nucleus, remainder fluctuating	18%
Completely unstable, proceeding with disintegration	18%

Thus, about two-thirds of the units in the examined group were considered stable by respondents. The others are unstable. What were the dynamics influencing the stability among the units of varying types during the last year of transition? In order to determine this, we asked managers about how many research workers entered and left their units during the last year. We also asked that their responses be given separately for highly qualified staff and junior employees.

As is seen from Table 1, the unstable R&D collectives have been launched on a path of rapid disintegration. If this rapid tempo is maintained in the future, then these units will cease to exist in 1 to 3 years or perhaps earlier. And, this refers to about one-third of all units surveyed.

According to respondents' assessments, a portion of the scientific workers would like to work abroad—40%. The share of young academics with this goal number is 1.5 times more at 60%. The desire to go abroad to work is particularly noticeable amongst scientific workers in collapsing R&D units (see Table 2). This trend, however, is also visible among the employees of the stable R&D collectives as well: more than one-third of all the highly qualified workers and more than a half of the young ones.

In our investigation the questionnaire was amended in order to determine employees' motivation to leave their R&D units.

The managers' impressions were as follows:

Low salaries	69%
Instability of the organization	19%
No promise for the future	16%
Absence of housing and other social facilities	9%
Conflicts with administration	3%
The employees can not cope with their work	2%
The employees no longer wish to work in science	2%

Clearly, the main motive for leaving was low payment of scientific workers. Indeed, their average salary (based on survey results) was about 500 rubles a month at the beginning of 1992, which is 1.5 to 2 times lower than in industry. Other important motives influencing relocation, the instability of scientific organizations and absence of future perspectives for the employees. These are motives directly related to the disintegration of scientific organizations.

In an average Russian RDO there are now usually 30–40 scientific separate institutes, each consisting of 15–20 scientific workers. In spite of reasonable stability at the individual institute level, many of the scientific collectives are disintegrating. And, due to the pyramid effect, one fading collective symbolizes the abandonment of a multiple number of individual institutes.

The decay process of established organizations and individual units is the inevitable social cost of the attempt to establish a market system in Russia.

Business Experience of RDO

In considering the problems of "science" and "market," three central issues stand out. Firstly, and most crucial, the sharp decrease of State budget allocations. The second issue follows directly from the first and refers to the necessity of RDOs to look for additional financial resources elsewhere in the economy. The third issue is focussed on the use of new opportunities by the R&D institutes as offered to them by the new state rehabilitation policy. The situation arising due to these circumstances is evaluated using so-called "market" terminology (such terms as "demand," "competition," etc.). In this case, however, it has only relative character considering its application to the present conditions of economic life in Russia.

Nowadays, Russian RDOs find themselves in a "quasi market situation." No longer do any strict state guarantees exist that secure adequate demand for their scientific products. The post-Soviet R&D institutes of today are forced to search for real customers and enter into contract agreements as done elsewhere in the world where market economics prevail. The survival of Russian R&D organizations now depends a great deal on the availability of real customers for their research products.

This conclusion was founded on replies to the questionnaire inquiry: "Are there customers available for research products of your institute (unit)?" The R&D managers responded as follows:

No customers available	20%
Customers available	80%

The optimistic overall result is somewhat deceiving when the regions are viewed individually as in Table 3. The optimal situation is in Moscow, where the managers have pointed out that a generous stock of customers exist for the products of their R&D units. The worst situation is in Vladimir, where customer availability ranks 23 percentage points lower than in Moscow. Recalling the particular specialization of R&D institutes in the field of military developments in Vladimir, the situation at the moment of the survey was not as catastrophical as one may have expected.

Setting up a market system in the field of research and development envisages the presence of competition for the customers' attention. Our questionnaire asked whether the managers of the institutes have felt such competition? The responses listed in Table 4 imply that such competition actually takes place in the Russian research and development sector, albeit variably among the scientific centers.

The strongest competition was visible also where the greatest number of potential customers had been recorded; namely, in Moscow. Vladimir, which had registered a lack of expected customers, was also confronted with the weakest competitive conditions. Nevertheless, the majority of the people surveyed were of the opinion that competition is present between institutes for customers within the country as well as abroad. In fact, domestically speaking, the managers indicated the presence of an average of three competing R&D institutions.

Still, it would be premature to speak seriously about the availability of real market competition in the field of research and development at the time of this survey. Presently, one can only reflect on an anticipation of competition. As a matter of fact, all the RDO are state-owned and will continue to be formerly bound by multiple instructions in their economic activities. Those RDOs are protected from bankruptcy even in the event of an unsuccessful search for customers. And, if ever such a state RDO is to be liquidated, then the reasons will rather be administrative and political than economic.

The above-mentioned lack of true competition is especially accurate at the international level. In the replies depicted in Table 4, Russian R&D managers were aware of very few foreign firms that might be interested in acquiring research results. Due to this relatively small pool, which could increase significantly with the progressive integration of Russian R&D in the global scientific community facilitated through improved communication and information systems, there exists some wrangling for the still small group of foreign potential customers. However, this is still far from market style competition.

Although there is little real market competition in the field of research and development for the moment, just the anticipation of competitive forces has proven to flush out more new customers than was the case where competition was avoided. R&D managers and institutes facing competition made greater efforts to find customers and were rewarded (see Table 5). The number of those who found new customers is 1.5 times higher among the ones enduring the competition.

In order to operate more or less successfully under market conditions, any organization must study the demand for its products and its dynamics. In an effort to determine whether this was in fact happening in the RDOs surveyed, the managers were asked: "Have you studied the demand for the products of your research organization?" It turned out that demand was studied by 53% of the respondents, while 47% have not given it any thought. Thus, the majority of managers did investigate the possibilities of marketing their product in a more consumer oriented fashion. These R&D managers have realized that the survival of their organizations will depend on the visibility and demand-determined character of their research results. Such factors are instrumental in determining the demand. In the market analysis regarding the products of their R&D institutes, managers expected demand to:

remain unchanged	21%
increase	37%
decrease	34%
collapse	8%

The expectations of managers should not be considered pessimistic, particularly in lieu of the anticipated difficulties associated with the overall national transition to a market economy. Indeed, more than a half of the respondents expected the demand for their products to either increase or at least remain unchanged.

The interest of R&D institute managers in the demand for scientific goods and their expectations of possible changes in that demand were considerably variable depending on the scientific center, as portrayed in Table 6. In Moscow, leaders of R&D institutes were most actively studying the demand for their products. Recall, that this was also the city where competition was perceived to be greatest. Both Moscow and Novosibirsk respondents were most optimistic about possible changes in the demand for scientific products. The leaders of scientific units in Vladimir were most pessimistic and showed least interest in analyzing potential demand for their research products. The pessimism and limited interest of Vladimir managers were the result of very recent and unanticipated information concerning a radical decrease in military orders. In addition, the situation regarding conversion of the military RDOs must, as yet, be clearly defined. Presently, uncertainty exists with respect to whether state budget funds will be available for this process.

Thus the majority of RDO managers have some experience working without state support when they have been left to their own resorts. Most of them, at least at the theoretical level, are reasonably familiar with the definitions of "demand," "competition," "marketing," and "bankruptcy," although none of these managers have ever been subject to bankruptcy procedures or an education in marketing rules as they are known in today's market economies.

The process of liberalizing the economy and society of Russia began in Moscow. Consequently, managers of R&D organizations in Moscow are most experienced in business life. The liberalization process reached the so-called military towns later than other places; that is, the towns where modern weapons and defense equipment were designed and produced. Until recently, these towns were largely insulated from economic changes that effected the rest of the nation. They enjoyed priority status. For this reason, the mentality in military RDOs now resembles the stereotype of leaders in civil institutes 2 to 3 years ago. However, the rate of transformation in the country now is far more dramatic than it was only several years ago. In addition to the problems facing their specific sector, it has become increasingly troublesome for the leaders of the military RDOs to plunge into the modern economic and social reality of Russia without the experience of activities on the "Soviet market," which the civil leaders have already acquired.

An analysis of the business experience of RDOs is testimony to the fact that the established organizational and economic forms of their activities have become outdated. The most common type of such an organization was a state scientific research institute employing an average of 700–800 people and subordinate to a Branch Ministry or the Academy of Sciences. A latent process of disintegration of these institutes, the degradation of the system of state management, as well as the appearance of a non-state research organizations sector, compels managers of existing RDOs to search for ways to revive their institutes.

Attempts at Revival

The principal changes in RDOs are likely to follow two paths:

1. The changes in relations with the Ministries. The main issue revolves around whether and, if so, to what degree the RDOs should remain subordinate to the respective Ministries.
2. The change in the economic status of a research institute. The potential alternatives are: to maintain a single organization, to split up into several independent institutes, to remain a state-owned organization, or to establish a non-state research firm.

A free rational choice of a type of subordination for an RDO envisages estimating positive and negative implications of the existing type, comparison with others, and a final decision based on such a comparison. The R&D managers' impressions regarding the implications of subordination was tested by posing the question: "What are the positive and negative sides of the existing subordination of your RDO?" As is seen from the assessments of managers presented in Table 7 the disadvantages in the existing subordination system predominate. Nevertheless, the responses also indicated the presence of positive factors resulting from a formal association with a Ministry, such as guarantees for financing research projects, salaries, and material and technical supplies.

The conclusion to be drawn due to the predominance of negative points over positive ones as a consequence of subordination is statistically supported by the replies to the survey question; "Should your RDO change its subordination?" The responses were distributed as follows:

Preserve existing subordination	43%
Transfer to a different Ministry	5%
RDO must become independent	52%

At the same time the managers have no illusions about the consequences of leaving the safe refuge of the Ministry. Although this decision can resolve numerous present issues, the majority of R&D managers realized that some problems will be aggravated and new difficulties will be provoked. This is clear from the following replies to the question: "What difficulties are ahead for your organization if it becomes independent?"

Financial situation will be aggravated	59%
Difficulties regarding the material and technical supplies for research and experimentation	48%
Redundancy of some divisions and the dismissal of many workers on the grounds of redundancy	47%
Cancellation of research projects which do not produce results for immediate practical applications	33%
Loss of customers	13%
Internal conflicts	12%
Weakening international contacts	8%

The RDOs have long been integrated in the Ministerial hierarchy in one manner or another. It is difficult to predict how a research institute will fare on the open market, separated from most of the structural and organizational ties that had traditionally secured its livelihood. The managers were asked their opinion with respect to the possible consequences for a R&D institute once it had broken its ministerial ties and whether this would improve or aggravate the performance and vitality of individual RDOs. The managers indicated:

The institute will improve its position	31%
Nothing will change	13%
The situation will deteriorate	38%
The institute will disintegrate	18%

Thus, the opinions of the leaders diverge. While slightly less than a half believe their Institute will not worsen its position, 56% expect the contrary to take place—leaving the Ministry will aggravate the situation.

Despite the expected difficulties, the managers appear determined to initiate changes. They want to change both the RDO subordination to Ministries and the economic status of their organizations. This is the conclusion one can draw from the replies to the question: "Is it necessary to change the economic status of your RDO? If yes, then how?" The detailed answers were as follows:

Nothing should be changed	26%
Create an enterprise division for high technology within the RDO to implement the results of RDO projects	40%
Transform the RDO into a joint stock company	29%
Divide the RDO into several organizations	25%
Merge the RDO with an industrial production enterprise	11%
Sell the RDO to a foreign firm	8%
Combine the RDO with a University	5%
Transform the RDO into a private organization	4%

The managers' plans to transform their organizations are rather radical; 75% of them think it necessary to change the economic status of their organization. The potential changes are directed towards production and commercial activities, i.e., setting up a production plant within the institute, transformation of the institute into a joint stock company, and so forth. The implementation of these plans may lead to the reorientation of a considerable portion of the RDOs from pure scientific research to solely commercial or a combination of scientific and commercial activities. During this process, the loss of some scientific potential is inevitable. However, such reorientation is, on the whole, positive. In principle, it can improve the creative and intellectual potential of newly arising Russian business, making it more receptive to technological innovations. And, finally, such reorientation may accelerate the development of a real market economy.

Potential Entrepreneurs

If ever a market for research and development is to be established in Russia, then a wide strata of entrepreneurs must be activated. However, it is questionable whether the present social basis is appropriate for the formation of such a strata. Uncertainty also exists regarding the availability of capable persons willing to participate in entrepreneurship connected with science and the practical realization of scientific ideas?

Considering the possible magnitude of these obstacles, it is in the interest of a successful transition to a market economy that we determine the managers' willingness to initiate entrepreneurial activity. Therefore, managers were asked the question: "Would you like to establish a private research organization?" The answers revealed that 26% of the respondents wished to set up a private firm. If one cans assume this assessment to be correct and combines it with the fact that the number of scientific units in the RDOs of Russia number about 50,000, then the quantity of potential entrepreneurs solely from the available managers could constitute over 12,000. In principle, this quantity of entrepreneurs would be sufficient for the initial formation of a market for research and development and competition in the marketing of scientific products would be established.

The aims to be pursued by the owners of the newly created research are, however, very important firms as are the reasons they chose to start their own businesses. In order to ascertain their actual intentions, managers were asked the following question: "Why would you like to establish your own firm?" The responses were distributed as follows:

Improve the personal standard of living	80%
Create a strong research group	63%
Make developments useful for the production	49%
Obtain a significant scientific result	42%
Establish contacts with western firms	34%
Attain commercial success	30%
Achieve personal independence	24%
Acquire the opportunity to make important decisions	11%
Establish a private research	4%

It is striking that the motive of achieving personal independence by establishing one's own firm was one of the more infrequent answers. The most popular objective reiterated was the keen desire to improve one's well-being. At the same time, commercial success was revealed as a relatively less important motive. The major intentions of R&D managers, if they were given the opportunity to establish firms, were admiral and less profit oriented. A strong desire among specialists calls for achieving meaningful scientific results for the benefit of improving production. This is, to a large extent, the product of traditional discipline and scientific aversion to market directives.

Based on these motives, it is possible that a market will be formed where the agents will operate not so much for the sake of profit-seeking but rather for a small and stable income. The R&D specialists will be striving to find important sponsors while simultaneously demonstrating a low inclination to take risks.

Indeed, such conduct is quite natural at present. The living standard of scientists is not high and the risk of failure in starting one's own business is very high. Thus, by respondents' estimations, the present probability of success in the attempt to establish a private firm is only 28%. It is obvious that with so low chances for success, very few will be willing to start their own business.

However, the mere fact of the availability of such plans among a considerable part of the respondents provides sufficient grounds to suppose that there is a social basis for creating a market for research and development. Yet, the query arises with respect to who constitutes this group of potential entrepreneurs. According to our analysis, the potential entrepreneurs do not differ from "state science supporters" according to any particular features as age, work period appointment, or formal scientific achievements. Nonetheless, they do differ regarding their systems of values or, to be more precise, regarding more pronounced aims concerning the existence of their organizations. Thus, only 33% of the potential entrepreneurs believe that their organization must retain the existing subordination, while the corresponding number among the "state science supporters" is 44%. The former are more optimistic about the prospects for their RDO's future upon leaving the existing subordination: 41% of potential entrepreneurs think that their organization will improve its position compared to only 27% of the "supporters of state science" with the same opinion.

The preceding points elucidate R&D managers' desires and expectations with respect to establishing private research and development enterprises free from direct state intervention. As a logical epilogue, our survey concluded by inquiring about the nature of the conditions that must be present for the managers to undertake the still very risky process of establishing a private research firm. Their responses were as follows:

Guarantees for private property on behalf of the State	60%
The transfer of some part of the property belonging to the RDO into the private ownership	52%
Renting some part of the RDO property	38%
The possibility to obtain an inexpensive credit	37%

The most important condition has institutional character and envisages a change in the governmental attitude towards private property. Nowadays, this attitude on the part of higher authorities is not clearly defined. The government's attitude towards private property is more or less positive but that of the Supreme Soviet of the Russian Federation was, so far, rather indefinite and contradictory. In addition, the attitudes of local authorities were still more reserved. Consequently, it is unrealistic to expect the radical implementation of Russian R&D managers' plans to establish private firms before the authorities' attitudes towards private property is not changed, unified, and predictable.

Conclusion

Today, Russian RDOs find themselves in a state of *freedom-shock.* They endure a massive burden of economic and social problems. A latent decay process is going on in many institutes. While the number of scientists completely breaking out of the scientific community remains fairly low, the inflow of young people to RDOs has abruptly decreased.

These processes are the social cost of the liberalization of the economy and political life in Russia. In addition, the inherited functions and structures of research organizations do not correspond to the requirements of a free society and deregulated economy. Therefore, this shock is inevitable during the transition process towards a liberated modern society.

However, the *freedom-shock* is slowly passing. New (for Russia) types of scientific research organizations are beginning to appear; the state RDO are looking for new forms and directions of activities. A social basis for the market economy in the field of R&D is being created. If social stability is achieved and retained, the *freedom-shock* may completely disappear in a few years. In the process, a scientific community corresponding to the requirements of a modern society will have been created.

Table 1. Dynamics of employment of scientific workers in R&D units of various types (in percent).

Type of units	Net change in staff (S)	including: Highly qualified employees	Junior employees
Stable	-7	-4	-3
Stable nucleus	-31	-12	-10
Disintegrating	-26	-14	-4

Note: $S = (\frac{(Sn-Sl)}{Sp}) \times 100\%$, where Sn = number of newly employed;
Sl = number of those who left;
Sp = total personnel in the R&D unit.

Table 2. R&D Managers' assessments of the desire among scientific employees to work abroad (in percent).

Type of units	Persons wishing to work abroad among: Highly qualified employees	Junior employees
Stable	37	54
Stable nucleus	40	68
Disintegrating	50	70

Table 3. Potential customers for research products in selected Russian cities (in percent).

Cities	Customers available	Not available
Moscow	95	5
Novosibirsk	86	14
Voronej	78	22
Vladimir	72	28

Table 4. Presence of competition for customers in selected Russian cities (in percent).

Cities	Competition for customers: domestically		abroad	
	yes	no	yes	no
Moscow	76	24	68	32
Novosibirsk	67	33	69	31
Voronej	69	31	61	39
Vladimir	50	50	23	77

Table 5. Influence of competition on the success of finding new domestic customers for R&D results in Russia (in percent).*

Availability of Domestic Customers	Appearance of new customers	No new customers
With competition availability	74	26
Without competition	55	45

*R&D managers' replies recorded in response to the question: "Have you found new customers during the last years?"

Table 6. R&D managers investigating the dynamics of demand for R&D results in selected Russian scientific centers (in percent).

Scientific Centers	Those studying demand	of which: % expecting demand not to change	to increase	to decrease	collapse
Moscow	64	21	47	31	1
Novosibirsk	55	25	46	25	4
Voronej	54	23	38	38	1
Vladimir	47	12	21	47	20

Table 7. Managers' assessments of implications regarding the existing subordination of their RDO (in percent).*

Positive implications:	
Stable financing	37
Guaranteed employment	23
Guaranteed material and technical supplies	22
Relative independence from a customer and current requirements of production	18
Representation of the interests of the organization directly to the Government	13
Social facilities and other fringe benefits (privileges) for the workers	9
Negative implications:	
Impossible to reward employees according to performance	47
Appointment of directors from above	28
Large financial payments to Ministry	28
Impossible to rationally reorganize the management of the RDO	28
Regulation of the choice of research topics from above	22
Limitations for establishing non-state structures within the RDO	11

*Managers could give more than one answer.

Privatization Policy and the Potential Effects on R&D Organization

Alexandr Kazakov[1]

The law concerning privatization was adopted in the Russian Federation in July 1991. However, until January 1992 privatization was implemented in practice only on an extremely limited scale. This can be explained by a number of factors.

The major problem was the existence of property sharing. This proved to be a crucial obstacle to the determination of whether an enterprise belonged to federal, regional, or municipal authorities. The issue remained unsolved for a prolonged period.

Furthermore, after the law had already been adopted, there was no clear conception of the local nature of its implementation. The process of privatization was more and more lost in idle talk. In turn, this caused the stagnation of the process to create a legislative and legal basis for privatization. Until January 1992, the process of establishment and development of an organizational infrastructure for privatization was extremely lethargic.

With the adoption of the *"Principle Provisions for the Programme of Privatization"* by the Government of Russia, one of basic deterrents to rapid privatization processes has been removed. Major legislative acts and conventional documents, which regulate the sequence and procedure applicable for these processes, have been introduced. Since February 1992, the center authority and responsibility for privatization procedures have been shifted

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to the regional level, making it yet even closer to practical organizational moves.

It is worth mentioning that, on the whole, the privatization policy of the Russian Government is supported by local authorities. Sessions of 69 Regional and Territorial Soviets have adopted local programs of privatization, which essentially have no contradictions to the conception laid out in the official *Principle Provisions for the Programme of Privatization.* In other regions, local programs have been tested in labor teams and at sessions of local Soviets to be subsequently discussed at regional sessions in the nearest future. After month-long, active disputes, the decision of the Tomskyi Regional Soviet regarding a suspension of the *"Principle Provisions..."* powers on the territory of the region was rejected by the subsequent session.

The regional programs differ from the governmental program chiefly due to the absence of an opportunity to accomplish the compulsory tasks stipulated in the latter. For instance, in only 2 out of 69 programs approved by local authorities will the income management from privatization be a regional responsibility. In the remaining cases, the appointed property management committees consider these as too difficult, unrealistic, and beyond their means. This conclusion is confirmed by the analysis of recent financial receipts obtained from privatization. Out of eight billion rubles planned for the first quarter of 1992, only 414 million rubles have been received in January–February. However, the funds received in March are expected to be twice as much (850 million rubles).

In practice, the process of privatization has been modified over time. Originally, objects were sold on the basis of developed legislative documents. In fact, the right to rent or lease objects to enterprises was sold, which subsequently have the right to buy to objects outright. This may be explained by the fact that the employees of these enterprises are entitled to net profits which are quite significant in many cases as a result of the price rise and are often sufficient for acquiring property even within the first year of the lease.

The most active sales took place in January and February 1992 in the Ekaterinburgskaya, Rostovskaya, Kaluzhskaya, and some other regions. The participants in privatization (primarily employees)were most active in the Nizheorodskaya, Ekaterinburgskaya, Vladimirskaya, Samarkaya, Permskaya, and some other regions. The proficiency of the privatization process and the willingness of the population to participate is explained mainly by sufficient preparation of the proper regional committees for a process of wide-scale privatization.

In general, the privatization concept included in legislative and standard documents of the Government have been confirmed as the correct direction to follow. At the same time, the analysis of the socio-economic and political situation requires considerable acceleration of the implementation of personal privatization accounts and other simplified ways of a voucher-type distribution of titles among the citizens of Russia.

At present, the success of the governmental privatization policy depends on factors related to time. The *"Principle Provisions for Programme of Privatization"* and the subsequent legal documents have appeared at a critical moment in the transition to a market economy. Any further delay would result in a return to a state in which privatization becomes lost in an idle verbal struggle between the central government and regional and branch trade unions. The privatization policy of the Government is carefully followed by political opponents. Its weaknesses and contradictions in its implementation may provoke social conflicts.

However, the necessity for rapid application is accompanied by various dangers because of a permanent inflow of official clarifications, which often change rules of the game. Such a situation is unavoidable if the participants of the process loose the correct direction. The true privatization must also be accelerated due to its influence on the associated fiscal problems. For this reason, it is necessary to resolve a number of essential and practical problems that continue to obstruct privatization.

In 1992, most enterprises will become private by means of the transformation into open-type joint-stock companies. Irrespective to the preferences to be granted for staff members, this method of privatization may be too complicated for the present legislation even if preferences are granted individually. In conformance with the *Law on Property,* the net profit of a state-owned enterprise may be used by its employees and similarly, in the case of a joint-stock company the employees may expect a share of net profit proportional to their stocks in the common property. It is also necessary to clarify a mortgage-mode for the operation of state-run enterprises, a privatization policy with respect to the leased enterprises, and to ensure the coordination of legislative acts as a whole.

The privatization of large industrial facilities, which have complex internal structures, is another problem. It is necessary to fix rules for the determination of limits of complex facilities for potential privatization. In order to specify preferences for the employees of such facilities, it is necessary to determine "limits" of ownership for their employees. There are also problems concerning the privatization of enterprises that were established as joint-ventures of state-owned enterprises, and further problems of the privatization for the employees of those enterprises.

When "small" objects are subject to privatization, it is necessary to ensure no contradiction of distinctive norms of privatization with respect to the general trends of the privatization policy. Any correction of this policy when only a single buyer is acceptable, which is aimed at preventing bankruptcy, can be added together with a strict control mechanism to avoid breaches of trust. Such breaches are possible in this case and may cause social and political troubles, not to mention increased opposition to the privatization process.

At this time, it is necessary to prepare a financial infrastructure for privatization, as well as institutions and means of selling stocks in order to prevent a slowdown of privatization in the second stage of the process. Furthermore, it is necessary to create a clear system of informational support to control and monitor privatization. This would include:

- arranging a system of meaningful statistics, and
- ensuring wide access to information provided by the property committees.

The management of R&D, both at the privatized and to-be-privatized enterprises can soon reap the benefits of membership in an increasingly market-oriented economy. Nevertheless, the change from state-ownership and all its associated security to private self-management will cause firm managers to review the values of various segments of their enterprise. As we now know, R&D had a very special position in the past. Therefore, a sector of the economy which had even been insulated and isolated from Soviet-style market transactions will be forced to delve into the rigors of market life with the rest of the enterprises as a result of the extensive state privatization program.

Changes in Russian Science Administration Policy: The First Steps

Aleksei E. Levin,[1]

Since the fall of 1991, Russian science administration and policy have undergone important transformations. Far-reaching changes have been made in the agencies responsible for the administration of science and higher education. In particular, a Russian Academy of Sciences has been created and new Russian science policy-making agencies have been set up.

Among the changes that followed the attempted coup in Moscow in August 1991 was a major reorganization of the state agencies responsible for the administration of science and higher education. On 20 November 1991, Russia, the largest of the successor states of the former Soviet Union, ceased financing some eighty central agencies.[2] As a result, the structures of science administration, as well as those of defense-related research and development, have begun to disintegrate rapidly; some laboratories, including those of even the best research institutes, are often unable to procure some of the most basic materials, such as high-quality spirits for the conservation of biological specimens.[3] On 21 November 1991, Russian President Boris Yeltsin issued

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[2]For example, about half of the main and one-third of the subsidiary research institutes subordinated to government ministries reportedly received budgetary financing to the end of 1991 (Radikal, No. 40, 1991, p. 3).

[3]In October 1991, the Institute of General and Inorganic Chemistry of the USSR Academy of Sciences did not have nitric acid and oxygen cylinders (information received by the author from Professor Sergei Dembovsky). Shortages such as these have been caused to some extent by the disorganized state of industry and the procurement systems and thus cannot be regarded simply as an outcome of the recent political changes in Russia.

a decree restoring the Russian Academy of Sciences and paving the way for the dissolution of its USSR counterpart, which had existed since 1925. Important changes have also occurred in two science policy-making agencies: the USSR State Committee for Science and Technology and the Russian State Committee for Science and Higher Education.

The Soviet versus the Russian Academy of Sciences

The first steps toward formally establishing a Russian Academy of Sciences were taken in January 1990.[4] Subsequently, the Yeltsin government used the idea of a Russian Academy as a political weapon in its confrontations with the central government. Former Soviet President Mikhail Gorbachev's decree from 23 August 1990 granted full autonomy to the USSR Academy of Sciences and gave the Academy exclusive ownership rights to the state property that had previously been at its disposal. The decree, however, was not fully recognized by the Russian Supreme Soviet, which insisted on the Republic's right to manage, among other things, the Academy's land, buildings, and collections. In February 1991, when the political confrontation between the Kremlin and Russia's White House was much in evidence, the Russian parliament gave the green light for the establishment of a Russian Academy of Sciences. On 25 March, the Presidium of the Russian Supreme Soviet approved the creation of a special body, the Central Organizational Committee, whose task was to work out the organizational structure of the new institution; it also appointed Academician Yurii Osipov as the chairman of the committee.

On July 17, the Central Organizational Committee approved the regulations for the initial elections to the Academy.[5] Later, the committee assumed some additional prerogatives that it had not been formally granted by the Russian parliament; and it began virtually to function as the interim ruling body of the future Russian Academy of Sciences. It appointed twelve regional committees to organize and supervise the elections and published

[4]See Aleksei E. Levin, "Soviet Science: Towards a Civil Society," Report on the USSR, No. 44, 1990. For a history of the bizarre bureaucratic and public games that preceded the establishment of a Russian Academy, see V.P. Fedotov's article in EKO, No. 8, 1991, pp. 55–61.

[5]Poisk, No. 33, 1991, p. 4.

the list of candidates running in the elections.[6] The regional committees were given the right to appoint 70% of the electors; 20% were appointed by the USSR Academy of Sciences, and the remaining 10% by the Central Organizational Committee itself. In early December 1991, the electors met in Moscow to vote in the two rounds of elections. The final vote took place on 6 December; thirty-nine candidates were elected full members of the Academy and 108 corresponding members. Among the latter was chairman of the Russian Supreme Soviet Ruslan Khasbulatov. No fewer than twenty-one of the thirty-nine newly elected full members live in Moscow, despite the stated intention of the Central Organizational Committee to overcome the alleged monopoly of the "metropolitan" scientific community.

Immediately after the failure of the August coup, the Russian government began taking over important central institutions, particularly the financial ones. The leadership of the USSR Academy of Sciences found itself in a rather awkward position since it definitely could not afford to alienate Yeltsin and his associates and thereby risk losing budgetary financing by the Russian treasury. On 17 September 1991, in an apparent attempt to avoid a direct confrontation with the Russian leadership, the Presidium of the Academy voted in favor of abolishing its All-Union status and reinstating its former name, the Russian Academy of Sciences, by which it had been known from 1917 to 1925.[7] Only one day earlier, the USSR State Council had passed a non-binding resolution aimed at ensuring that the sciences were funded jointly by the republics. This move was preceded by a meeting between Gorbachev and the president and vice presidents of the Academy on 12 September 1991.[8] Apparently, the resolution was a symbolic, albeit well-meant gesture; but the problem of jointly funding scientific research was still not solved.

The decision taken by the Academy's Presidium on 17 September seemed to reflect grave doubts among members of the Academy about that institution's chances of survival without the direct patronage of Russia. After Gorbachev had met with the leaders of the Academy on 23 September (the second such meeting within one month) and had repeated his pledge to secure adequate funding for the sciences, the Presidium decided on 1 October to recommend the preservation of the All-Union Academy of Sciences as a body of elite scientists modeled partly on the European Academy (which was

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[6]Ibid., No. 44, 1991, pp. 3–4, and 13; and No. 45, 1991, p. 2.

[7]*Izvestiya*, 18 September 1991, p. 1.

[8]Ibid., 17 September 1991, p. 2.

established as a "joint venture" involving twenty-four countries) and partly on the US National Academy of Sciences. The resolutions adopted on 17 September and 1 October were finally approved by the Academy's General Assembly on 10 October 1991.[9]

Also at the 1 October meeting, the Presidium yielded to demands by the influential Voters' Club of the Academy and other reform-minded scientists. It approved the plans to convene a conference of the Academy's research employees, the first ever in the history of the institution. On 13 November it was announced that the conference would take place in Moscow from 10 to 12 December and that a wide variety of problems would be discussed, such as organizing and financing research in Russia, social protection for scientists, laying the legal foundations for the activities of research institutions, and the migration of scientists. It was also announced that the delegates to the conference would be democratically elected at the Academy's research institutes in the proportion of one delegate per 100 research employees.

Even before the General Assembly of the USSR Academy of Sciences had adopted the resolutions mentioned above on 10 October, the Academy's leadership met with Khasbulatov and proposed that its newly elected members be invited to participate in the December session of the Academy on an equal footing with the other members. This "integrated" general assembly would then adopt the charter of the new "unified" Russian Academy of Sciences (drafted by a specially appointed Conciliation Commission headed by the Academicians Yurii Osip'yan and Yurii Osipov), define the Academy's structure, and elect its ruling bodies. The proposal, reportedly endorsed by Khasbulatov and Yeltsin, aimed to establish a restructured Russian Academy of Sciences by 1992 in which membership would be elected more democratically and research employees would have more say in management affairs. In addition, the December conference of research employees was seen to constitute an initial step toward the first All-Russian Congress of Scientists. Both ideas (the restructuring of the All-Union Academy of Sciences under the aegis of Russia and the holding of the congress) were finally given Yeltsin's official blessing in the Russian president's programmatic address to the Congress of People's Deputies on 28 October 1991. The next day, Yeltsin met with the chairman and other leaders of the USSR Academy of Sciences and personally

[9] Poisk, No. 42, 1991, pp. 1 and 4–5.

pledged that Russia would provide its newly restructured, unified Academy with sufficient funds.[10]

It is still unclear how the problem of the continuing existence of some formerly All-Union academic structures will eventually be solved, and indeed, whether it will be solved at all. On 11 October, the presidents of all republican academies, including those of the independent Baltic States, participated in a session of the Council of Presidents of the Academies of Sciences, which was also attended by the President of the USSR Academy of Sciences, Yurii Marchuk.[11]

At the session, it was decided to establish a special committee charged with drawing up a document on the creation of a new interrepublican Academic institution as well as with drafting its charter. If ever created, this institution is unlikely to have research institutes of its own but will possibly be affiliated with some large research centers whose activities are deemed by the new sovereign states to be mutually beneficial.

In 1990 and 1991, all the republican academies of sciences gained full financial and administrative independence from the USSR Academy. Beginning in 1992, they were to be funded predominantly by their own states. Even in 1991, some 80% of their financial resources came from the central government via the USSR State Committee for Science and Technology. Although the leaders of the republican academies seem genuinely interested in establishing some international framework for future cooperation, the final decision on whether to go ahead with the creation of a new interrepublican academic institution is likely to be determined mainly by political and economic factors. The same applies to a planned interrepublican agency responsible for administrating funds for the sciences.

The 1991 budget of the USSR Academy of Sciences was some 10% larger than that for 1990; but owing to the fact that the average costs of scientific research increased by 120%,[12] the Academy made a loss in real terms. In 1991, the Academy's total revenues amounted to 2.5 billion rubles: 1.4 billion received in budgetary allocations, 450 million in capital investments, and

[10]Information received by the author from the Vice President of the USSR Academy of Sciences Oleg Nefedov.

[11]Information received by the author from the Director of the Staff of the Council of Presidents of the academies of Sciences, Professor Sergei Gubin. The council was established after the presidents of all fifteen Academies of Sciences (the USSR Academy and fourteen republican Academies) had signed an agreement on cooperation in September 1990.

[12]Information received by the author from the Vice President of the USSR Academy.

200 million earned on a contractual basis. However, in 1991 the Academy's budget deficit totaled 200 million rubles.[13] Some of its largest institutes, such as the Institute for Space Research and the Institute of Physical Chemistry, were facing a financial crisis. To make matters worse, the Academy received no hard currency for purchasing foreign equipment.

The Academy's financial prospects for 1992 continued to be uncertain, although the Russian leadership promised that its budgetary allocations will be more or less equal to those of 1990 in real terms. A national foundation for funding scientific research, announced in Gorbachev's decree "On the Status of the USSR Academy of Sciences" of 23 August 1990, had still not been established by the time the Soviet president lost his political power, and the formal abolition of the USSR on 31 December 1991 made the creation of the foundation rather unlikely. The Russian authorities reportedly drew up plans to create a similar body for Russia, which was regarded as a much-needed Russian analogue to the National Science Foundation in the United States. It was reported that the Russian agency would initially be subordinate to be newly created Russian Ministry for Science, Higher Education, and Technological Policy, but eventually it was expected to be granted an autonomous status.[14]

New Science Policy Agencies

Before the August 1991 coup, both the Soviet Union and Russia had their own state agencies in charge of science policy: the USSR State Committee for Science and Technology, chaired by Academician Nikolai Laverov, and the Russian State Committee for Science and Higher Education, chaired by Professor Nikolai Malyshev. After the coup and the resignation of Valentin Pavlov's government, Laverov lost his chairmanship of the USSR State Committee and the Yeltsin administration began taking over different central agencies. For its part, the USSR State Committee reacted promptly to the change in the political situation: on 10 September 1991 its leadership appealed to the Russian government to transfer the committee to Russian jurisdiction.[15] The transfer was announced in a special decree issued by the

[13]Information received by the author from the Director of the Main Planning and Economic Directorate of the USSR Academy of Sciences Aleksandr Konoshenko. See also Konoshenko's interview with Poisk, No. 47, 1991, pp. 1 and 3.

[14]Ibid., Nos. 47 and 50, 1991, pp. 5 and 1, respectively.

[15]Radikal, No. 39, 1991, p. 1.

Russian Council of Ministers in October.[16] As a result, Malyshev moved to Laverov's spacious office and preparations began for the merging of the two committees. By 1 November 1991, it looked as if no further changes would take place; moreover, the future of the Russian State Committee appeared quite secure.

However, within less than a week, Yeltsin had decided to re-organize his administration. In accordance with his decrees of 6 November, the Russian State Committee for Science and Higher Education was abolished and replaced by a newly established Ministry of Science and Technological Policy.[17] For several days Malyshev's fate seemed to be hanging in the balance; but in the end, he was appointed to the newly created post of Russian State Councillor for Science and Higher Education. Rather a strange position under the circumstances, since the Russian State Council did not survive Yeltsin's reorganization. Boris Saltykov, formerly the deputy director of the Analytical Center of the USSR Academy of Sciences, was appointed to head the new ministry. At first, there were some doubts about which ministry would be in charge of Russian universities and other higher education schools, but on 11 November 1991 the Committee for Science and Public Education of the Russian Supreme Soviet and the leaders of the new Russian government decided to give the new ministry full responsibility for higher education as well.[18] This agency, which was promptly renamed the Ministry for Science, Higher Education, and Technological Policy, is staffed mainly by the personnel from the former USSR and Russian State Committees as well as from the Russian Ministry of Education. The ministry will reportedly employ a total of 1,200 officials.

Saltykov, a specialist in economic forecasting and the economic sector of scientific and technological research and development, was born in 1940 and graduated from the Moscow Physico-Technical Institute in 1964. Subsequently, he spent three years in the graduate school of Serguei Korolev's missile research center in Podlipki (then called NII-88, now the Central Research Institute of Machine Building). After completing his graduate studies, he worked at the Central Economic and Mathematical Institute of the USSR Academy of Sciences in Moscow and at the Institute for Economic Forecasting. Saltykov belongs to the same group of market-oriented economists as the former Russian deputy prime ministers, Egor Gaidar and Aleksandr

[16]Poisk, No. 44, 1991, p. 2.

[17]Kommersant, No. 43, 1991, p. 25.

[18]Information received by the author from Academician Yurii Ryzhov. See also Poisk, No. 47, 1991, p. 5.

Shokhin. In fact, it was Gaidar who proposed that Saltykov be offered the ministerial post.[19]

Another noteworthy recent appointment was that of Anatolii Rakitov to the newly created post of science and technology policy adviser to the president. Rakitov is a specialist in science philosophy and science policy as well as the head of two independent self-financing research centers, INFORAN and ISTINA. In the middle of November he had only two secretaries and a personal assistant, but it is likely that the size of his staff will increase considerably. Malyshev's staff, on the other hand, will reportedly be reduced to a bare minimum.

Both Saltykov and Rakitov are likely to exercise considerable influence over Russian science policy. Malyshev is said to have been brought to Moscow by former Russian Prime Minister Ivan Siaev and thus is unlikely to have much influence over Yeltsin. In lengthy conversations with the author in November 1991, both Saltykov and Rakitov stressed that the viability of Russian science policy would depend mainly on its ability to encourage marketable innovations, to create conditions for the free exchange of information, and to secure sufficient funding for the most productive and internationally respected branches of Russian science. Ratikov made it clear that he would support the preservation of a strongly defense-oriented research and development program and the extensive exchange of technology between the civilian and military sectors for the economy. He also agreed with Saltykov that the formulation of a viable Russian science policy would be a rather lengthy process but that work should begin immediately.

1991: The Final Developments

On 21 November Yeltsin issued the long-awaited Decree No. 228 "On the Organization of the Russian Academy of Sciences."[20] This rather hastily prepared document, which was signed under exceptional circumstances,[21] stated that the Russian Academy of Sciences should be restored as "the supreme scientific body of Russia." The decree granted the Academy the right to self-management and gave it exclusive ownership rights to all the

[19] Information received by the author from Saltykov.

[20] Poisk, No. 48, 1991, p. 1.

[21] On 20 November financing of the USSR Academy of Sciences ceased in accordance with Yeltsin's decision to terminate the allocation of Russian budgetary funds to a number of All-Union agencies. The next day, when Yeltsin was about to leave Moscow for an official visit to Germany, Velikhov caught him in time at the airport to secure his signature on the decree restoring the Russian Academy (see ibid., p. 3.).

state property in Russia that had formerly been at the disposal of the USSR Academy of Sciences (for example, buildings, laboratory equipment, and research ships). The decree also ruled that all full and corresponding members of the USSR Academy of Sciences as well as the members of the Russian Academy (elected in December) would be made full and corresponding members (depending on their former status) of the new Russian Academy of Sciences. Yeltsin also granted the new Academy some financial privileges, including exemption from all taxes. These measures were to be subsequently approved by the Russian Supreme Soviet.

The first conference of the Academy's scientists took place as planned from 10 to 12 December 1991; that is, several days after the elections to the Russian Academy had been held. The conference was co-chaired by Academician Evgenii Velikhov and a member of the board of the Voters' Club, Aleksei Zakharov. The debates focused mainly on the draft charter of the Russian Academy submitted by the Conciliation Commission but reportedly drawn up by Academician Andrei Gonchar, at the time the secretary of the Department of Mathematics.[22] The document stated that corresponding members of the Academy would be permitted to participate in the proceedings of the General Assembly virtually on an equal footing with the full members; as indeed would the elected representatives of rank-and-file scientists who were to constitute as many as one-third of the delegates to the assembly sessions.

These privileges evidently failed to impress the majority of the more radical delegates, who decided that the draft charter should be altered to state, among other things, that 50% of the delegates to the General Assembly should be rank-and-file scientists. The conference tentatively endorsed a document entitled "General Principles of the Organization and the Activities of the Research Institutes of the USSR Academy of Sciences," which had been drafted earlier.[23] The decisions taken by the conference were submitted to the December session of the Academy's General Assembly. The General Assembly session took place on 16 December 1991 and was attended by 1,100 full and corresponding members (including those newly elected) as well as some 280 representatives of rank-and-file scientists who, for the first time, were allowed to participate in the debates and elections. On 17 December, Osipov was elected the first president of the unified Russian Academy of Sciences in the first multicandidate presidential elections in the history of

[22]Information received by the author from Zakharov.

[23]For an early version of this document, see Poisk, No. 14, 1991, pp. 1 and 3.

the Academy. His principal competitor, Academician Velikhov, lost in the final round of voting. The same day, Yeltsin addressed the assembly and promised once more that Russia would fund its national academy. The assembly endorsed the charter submitted by the Conciliation Committee, but only for one year. A new position of first vice president was created, and Gonchar was elected to fill this post. Osip'yan was replaced by Aleksandr Andreev as vice president in charge of physical science and mathematics; and Vice Presidents Velikhov, Konstantin Frolov, Oleg Nefedov, and Laverov were reelected. Rem Petrov (biology) and Vladimir Kudryavtsev (social sciences), however, failed to win a majority; they will remain in office until the next meeting of the General Assembly, scheduled for March.

By the middle of December, Ratikov had completed a draft report on developing science in an independent Russia. The draft, which was endorsed by Saltykov and then sent to Yeltsin for consideration and approval,[24] proposed that effective institutional and economic links be established between the hitherto separate branches of sciences; that is "academic" science, "university" science, and "ministry" science. The last includes its mammoth military-targeted subbranch which, in 1990, consumed 75% of research and development's total budgetary allocations.[25] The draft also proposed abolishing all legal distinctions between these branches and creating a unified legal, financial, and managerial "operational space" for Russian science. The state would surrender its traditional role of sole supervisor of Russian research and would adopt a more modest position as one of its patrons. The document recommended laws that would create a stable legal environment for scientific activity in Russia,[26] and it introduced the concept of "domestic technology transfer," which could open channels between military and civil research and development. Finally, it proposed that solid financial support be given only to the most internationally recognized, renowned areas of Russian science and to those areas of applied and developmental science that might come up with innovative production techniques and products within two or three years. It remains to be seen how this document, which could become the pillar of future Russian science policy, will be put into practice.

[24]Information received by the author from Ratikov on 21 December 1991.

[25]Poisk, No. 50, 1991, p. 3.

[26]The proposed legislation seemed more or less similar in design, if not in content, to the four draft laws on science policy prepared by the former USSR State Committee for Science and Technology by the end of 1990. These draft laws were never passed by the USSR Supreme Soviet (see Aleksei E. Levin, "New Draft Legislation on Science Policy in the USSR," Report on the USSR, No. 22, 1991.)

Conclusion

Science in the former Soviet Union seems to be in a state of flux. The old centralized command administration is on the verge of extinction, while a new diversified and competitive science policy is about to emerge. New institutions are being created, and new faces are appearing. Some ideas, however, are too radical to be realized under current conditions and are likely to be put aside, despite the fact that they have a large number of advocates. For example, the idea of transforming the Academy of Sciences into an association (or associations) of virtually independent research centers, endorsed and strongly advocated by the Voter's Club, would hardly bring about that institution's liberation if immediately put into practice; indeed, it is much more likely that the Academy's successor (or successors) would be forced to deal with a large number of bureaucratic agencies. But Russian science is still very much alive and would benefit from a prompt and effective science policy. It remains to be seen whether the new reformist leaders of Russia are able to provide such a policy. Saltykov, in his address to the first conference of the Academy's scientists, reportedly made the following plea: "You have got your freedom, so do your best to find money."[27]

[27]See Saltykov's interview with Izvestiya, 8 January 1992, p. 2.

Economic Reform Impact on Soviet R&D

Serguei Glaziev,[1]

Abstract

Transition from a centrally planned to a market economy includes the complete restructuring of research and development (R&D) organization. R&D institutions lose administrative and financial protection with the destruction of ministries and state bodies responsible for R&D. Privatization of state enterprises, liberalization of labor and capital markets, and opening of the post-Soviet economy have changed the R&D environment in a radical way. The adaptation of R&D organization to these changes is not easy and involves the collapse of a large number of research institutes and scientific schools. At the same time, commercialization of R&D is taking place and new structures of R&D activity emerge.

The paper includes three parts. The first describes basic features in R&D organization in a centrally planned economy. The second part includes an analysis of economic reform impacts on R&D performance. The third and final section describes changes in R&D organization since 1987 when the transition to a market economy in the former Soviet Union began.

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The author is grateful to Dr. Motorygin for the useful comments and information he provided for this study.

military-related industries received everything they needed to conduct necessary research, while other industrial RIs usually suffered from a shortage of inputs and lack of finance.

The Academy of Science is organized as a special ministry of science, ruled by a Presidium responsible to several hundreds of academicians. The Academy's basic organizational routine, decision-making and resource-allocation procedures are similar to those in industrial ministries. The Presidium of the Academy played the same role for RIs of the Academy, as ministries did for industrial RIs. However, there was one important difference. Officials in resource allocation bodies of the Academy were appointed by and responsible to academicians who usually occupied posts of the directors of RIs in the Academy. Thus, the same people play key roles in all of R&D management, finance, and allocation of resources. This lead to an over-concentration of power and control over R&D resources in the hands of small groups of academicians and suppressed any competition between scholars and RIs for financial and material resource support. As a result of this monopolistic organization, a large part of Academy R&D is concentrated on obsolete topics and themes, which were usually protected by powerful lobbies in Academy management bodies.

Higher education R&D was organized in a different manner. Research and development was considered a secondary activity of higher education establishments; in fact, their main task was educating students according to more or less standard programs. Some favored universities and colleges preparing specialists for work in scientific and high-tech organizations having RIs of their own. However, most R&D is conducted by laboratories and faculties according to their R&D plans.

Thus, a research institute managed by a director appointed by the corresponding higher authority was the basic unit of R&D organization in CPE. Each RI was part of central-planning hierarchy. Research institute activities were determined by plans received from the supervisory organization accompanied by the necessary resources and finance. The latter were distributed according to the priorities of the supervisory organization which, in turn, depended on priorities and established routines set from above.

R&D management routines in a CPE was rather similar to an industrial production organization. It was characterized by the absence of competition, supermonopolization, and bureaucratization. However, there was an important difference. There were no clear indicators of basic R&D performance such as volume of production in industry. Decisions in this situation were made according to personnel preferences of R&D bureaucrats, who usually

R&D in a Centrally Planned Economy

R&D organization in a centrally planned economy (CPE) is set forth by its basic institutions where administrative control rules over economic activity. Three sectors of Russian R&D—industrial, academy and higher education science—mainly differ from each other by the type of supervising organization. Industrial R&D was managed by corresponding Ministries which have special departments and funds for this purpose. Academy R&D was managed by the Presidium and Departments of the previously All-Union and Republican Academies of Science. Higher education R&D was managed by corresponding departments of the State Committee of Education and of Republican Ministries of higher education. R&D activity in different sectors is coordinated by the Science and Technologies Committee, corresponding department of the State Planning Committee, and the Military-Industrial Commission, which supervise the most important R&D programs and distribute financial and material resources for them. Until 1987, the key role in this coordination was played by the Science Department of the Communist Party Central Committee.

Industrial R&D was conducted in production–administrative units (PAU), controlled by ministries and subordinated to central authorities. Each PAU consisted of state enterprises which resembled divisions of large corporations rather than independent firms. As a monopoly, PAU was neither interested in profit maximization, nor in demand responsiveness in the markets, where they were the only suppliers. There was lack of incentives for innovations in this environment, where production was organized by several dozens of ministries-monopolies. Nevertheless, ministries were required to maintain a technological level of production according to the prescribed state standards and demonstrate technological achievements before the central authorities. For this purpose, these organizations not only have plants and factories, but also research institutes, design bureaus, and laboratories closely connected with industry.

Industrial research institutes (RI) were financed from state budget sources via special funds supervised by corresponding ministries or state R&D programs. RIs also received additional funds by conducting contract research enterprises (this source became rather important after state enterprises received the right to profit accumulation in 1987). Industrial RI had access to resources through Departments of Supply of corresponding Ministries. Finance and supply for a particular industrial RI was determined by the position of the corresponding ministry. High-priority RIs of had poor information about recent changes in world science. The absence of clear indicators of R&D performance resulted in the weak responsibilities of R&D managers under the centrally planned system (CPS). This lead to the poor quality and over-concentration of resources in R&D. New directions of R&D were often suppressed because they undermined the privileged position of R&D managers in power. A typical example of this was the suppression of genetic and cybernetic sciences in 1950 in spite of the great successes of the soviet scholars in these new fields.

There was no principle difference between basic and applied research organization. Most basic research was conducted in the research institutes of the Academy. The main difference between them and industrial research institutes was, perhaps, less strict labor discipline and more opportunities for the formation of R&D plans in the bargaining process with state authorities. Under the CPS, the Academy enjoyed privileged status and was financed directly from the state budget. RIs of the Academy also received additional funds by participating in various industrial programs financed by various ministries, the Science and Technology Committee, and contract R&D for industrial enterprises. Furthermore, Academy RIs had easy and guaranteed access to necessary inputs via the special Department of Supply for the Academy, which had a priority position in the state supply system.

An important feature of the CPS was strong inter-branch and inter-organization barriers that prevented information exchange between scientists in different organizations. Basic and applied research were separated from each other by organizational autarchy of industrial ministries and the Academies of Science. R&D plans of different institutes and organizations were coordinated by corresponding bodies in the Central Committee of the Communist Party, the State Planning Committee, the Military-Industrial Commission, and the State Science and Technology Committee. However, the coordination was rather poor other than for military-industrial R&D that was managed according to the interpretations of clear indicators and objectives. The organizational barriers between R&D in the Academy, higher education, and industry, as well as between different industries split the scientific community into different groups with weak communication between them. The barriers were maintained due to self-inflicted isolation of RIs, a strict system of ministerial and state secrecy, and by poor communication channels. The result was duplication of efforts, bureaucratization, and quality and efficiency decline of research and development.

The mechanism for R&D self-organization, typical of a market would prove ineffective in such an environment. It has been replaced by administrative control and resource allocation based on a bargaining process between RIs and their corresponding supervisory state management bodies.

The mechanism for innovation diffusion in CPEs was different from the one functioning in a market economy. The main driving forces and factors determining innovation diffusion in a market economy—competition, learning-by-doing, economies of scale, decreasing marginal profits with saturation of demand, etc.—were simply absent in the Soviet CPE. Introduction of innovations, resource redistribution, and new technology diffusion were decided in accordance to priorities set by central authorities in state plans for economic development. In CPEs, most profits were transferred from enterprises to the state budget and then returned to industry with respect to decisions made by the government and Gosplan under the pressure from ministries. The latter as well as individual enterprises had no possibility to receive super-profits or other incentives for the introduction of innovations. These, innovations were usually introduced according to the plans for new technology introduction, which had relatively low priority and were determined by production plans.

The only exclusion to this customary process was the defense industry, which tended to face real competition. Besides, the top political authorities interested in the USSR's international prestige sporadically promoted radical innovation diffusion. The priority of defense tasks and the real competition in this sphere were the reasons for the high concentration of R&D resources in the military-industrial complex (MIC). Ministries and enterprises of the MIC, contrary to civil branches of industry, were especially interested in innovation introduction and growth in the level of technological achievement needed to satisfy the demands of the Ministry of Defense. Inside the MIC, real competition existed between enterprises in their effort to procure orders and, consequently, for survival under conditions of strict administrative control. This competition stimulated research and the introduction of innovations. Status, rewards, and the drive for the competitive edge attracted the best specialists and highly skilled workers to the MIC—only there they found demand for new technologies.

The mechanism described above lead to stratification of the Soviet economy into two sectors with different technical levels. The priority sector, connected with the Defense Ministry and with prestigious projects, existed at the expense of the other part of the national economy. Unfortunately, the return flow of resources and modern technologies from a priority sector such as defense to the rest of the national economy was insignificant because civil PAU were not interested in implementing innovations that would change the organizational and material supply routine. In addition, MIC branches were not interested in spin-off or any profitable use of technologies. This stratification prevented the technological development in the national economy and inevitably caused a decrease in economic efficiency.

Another characteristic feature of the mechanism for technological change in a centrally planned economy was the approval of imitation rather than invention. The MIC technical development in the MIC was, in part, determined by innovations in the industrial sector of the "potential enemy." These innovations would subsequently be introduced in centrally planned economy as the Soviet Union with a lag, and were limited to defense branches. Another incentive for innovations was estimation by top authorities that the technological lag was significant. These innovations primarily had the imitation character and were supported by the import of necessary equipment.

Thus, the mechanism for R&D organization and technological change in a centrally planned economy was significantly different from that in a market economy. For decades R&D institutes in the USSR were part of the administrative hierarchy and were protected by corresponding political institutions. The weakening and destruction of the latter during the reform process raised innumerous problems of R&D maintenance and support. Radical reform of the national economic management system involved corresponding changes in mechanisms of technological evolution as well as in the resource allocation. A delay in R&D restructuring may lead to the destruction of very sensitive scientific potential of the country.

Economic Reform Impact on R&D Environment

It is noteworthy that Perestroika, a plan to force the centrally planned economy to undergo systematic changes, began from the attempts to accelerate economic growth and to overcome the increasing technological gap between the Soviet and market economies. According to our measurements, the average technological gap in major industries increased from 10–15 years in the mid-1950s, to 20–30 years in the mid-1980s. Since the mid-1970s, it increased significantly, especially in the high-tech sector. Attempts to accelerate technological change between 1985 and 1987 were based on central planning methodology and were undertaken to reduce this gap. However, under the conditions accompanying the structural crisis, these attempts failed. Further deterioration, both of living standards and relative technical performance of the military industry, compelled central authorities to change the system. However, distinct disproportions in technological structure within the Russian economy even increased during the next years of economic reform.

The most distinguishing feature of the structural changes in the successor Russian economy is their spontaneous, unmanageable character. None of the officially adopted programs of economic reform have been implemented. This is a result of the unrealistic character of the programs as well as of the government's inability to implement them. The present situation is characterized by accelerating inflation (which reached 19% a year in 1990 and 170% only in April 1991 due to the price reform), drastic fall of production (which reached 10% in the first quarter of this year in comparison with the first quarter of the previous year), collapse of supply relations between enterprises and regions, deterioration of living standards, and increasing chaos.

In spite of the spontaneous character of the previous Soviet economic reform, its guidelines were formed early. They included: growing independence and commercialization of state enterprises and local authorities, growth of commercial non-state sector, and the weakening of the state regulation.

With the State enterprise (SE) law of 1987, the administrative responsibility of the Ministries was partly substituted by responsibility delegated to employees' collectives, which received rights to make strategic decisions and control administration. These changes towards self-management lead to a decline of innovative activity in the state sector. Subsequently, the economic behavior of workers acquired dual character. They were simultaneously interested in wage increase and in labor intensity decreases. The introduction of innovations was usually connected with changes in the distribution of responsibilities among the personnel and increased labor intensity. This conjured resistance of workers to the implementation of innovations. Under the conditions of self-management, the administration of SE had insufficient power to overcome the workers' resistance as long as SE still received enough revenues to maintain wages at a satisfactory level. This was no surprise in lieu of the high monopolization of the Soviet economy. According to some estimates, 50% to 66% of industrial products were produced by one or two enterprises. The weakening of state control and commercialization of SEs in this absence of competition did not stimulate innovation activity and lead to price increases simultaneous to decreases in production and quality.

After the new Law concerning leasing and the Decree about establishment of joint stock companies, the commercialization of SEs took the form of a state directed transformation program converting enterprises into self-management firms paying rent for leased property to the state. The government departments receiving these funds were primarily the corresponding ministry or other supervisory body, or joint stock companies whose shares were distributed between other state enterprises and institutions (ministries, local authorities, banks, workers' collectives, etc.). Usually, enterprises together with ministries founded a commercial bank in the form of a joint stock company and used it later as a majority shareholder of transformed SE stocks. This cross-ownership structure became a typical form of spontaneous privatization in the Soviet economy.

Transforming state enterprises into joint stock companies enabled managers to more or less free their firms from state control. Increased freedom was accompanied by stricter budget constraints. However, the benefits of more opportunities considerably exceed the loss of state subsidies. Nevertheless, both of these changes lead to the dilemma of declining R&D expenditures. Under this cross-ownership structure, managers of state enterprises received all rights of private entrepreneurs without any of the related responsibilities. The instability of this system stimulated managers in short-term profit-seeking behavior despite being on the verge of bankruptcy. Indeed, rather than reinvesting excess profits, irresponsible managers directed these resources to their own semi-private firms. Under these circumstances, managers of state enterprises lacked sufficient incentives to increase their efficiency and to invest in R&D.

Spontaneous privatization encompassed not only industrial production, but R&D as well. Under the conditions inherited from the Soviet CPS, state research institutes and enterprises could not prohibit the imitation of their inventions by other firms. The turbulence and ambiguities of the transition period enticed private firms to resort to industrial espionage; to use and sell inventions and know-how developed by state organizations. One of the most customary, wide-spread forms of industrial espionage was and continues to be the part-time employment of specialists from state enterprises, who had access to the necessary information. This mechanism to transfer new technologies did not stimulate R&D itself, but rather only the transfer, and not the researchers themselves, but entrepreneurs selling the *stolen* intellectual products. Of course, free access to new technologies stimulated their diffusion. However, in the absence of clear ownership rights and with no system of royalties payments, it became increasingly unclear how to secure adequate financing for continued R&D in this new situation.

Weakening state control over SEs was accompanied by the decline of the respective authorities' responsibilities concerning SEs' performance, including the support for industrial R&D. After the introduction of the new tax system in 1991, ministries lost the rights to collect any part of SEs' profits. This destroyed the source of an important flow of state subsidies for industrial R&D. In the process of collecting part of SEs' profits, ministries redistributed a portion into special industrial funds for science and technology development. With the introduction of the new tax system, these funds were abolished. They constituted approximately one-third of all industrial R&D funds. Their abolishment lead many industrial RIs into financial trouble.

The collapse of the state budget system was another heavy blow for the R&D sector, especially for basic research concentrated in the Academy and MIC, both of which received in numerous state subsidies. The state budget revenues in the first quarter of 1991 were 70% less than forecasted; the state budget deficit at the end of the first quarter reached the amount expected for the whole year. This occurred for two main reasons. First, most of the Republics refused to pay their contributions to the All-Union budget. In spite of continuing debate about the All-Union treaty, they had already spent a large share of the reserved funds on social programs of their own. Second, the tax revenues were much less than planned because of an extraordinary decrease in production. Thus, conventional sources of basic R&D expenditures were paralyzed, while new sources did not appear. Republics' governments spent their revenues on populist social programs, while research institutes suffered from a severe financial crisis.

In this situation, state budget R&D expenditures decreased. This decrease was especially dramatic in the military-industrial complex. Cuts in military expenditures were largely at the expense of R&D. Expenditures for R&D in the MIC decreased from 15.3 billion rubles in 1989 to 13.2 in 1990 in nominal terms. Taking 19% inflation in 1990 into account, the real decrease amounted to 33%. In 1991, many research institutes in the MIC did not have enough contracts to maintain wages of their staff at a sufficient level.

The debilitating financial crisis in the state R&D sector caused a significant brain-drain from the state research institutes to the emerging private sector. By 1992, nearly 12% of Russian GNP was produced by the private sector. In spite of its still modest but growing share in GNP, the private sector has played an important role in structural changes and growth prospects look promising. R&D in this sector was conducted by cooperatives and semi-private research units based on state property without clear property rights (so-called small enterprises, limited companies, etc.). The non-state sector conducted 13.5% of all R&D in 1991, a rapidly growing share.

Nevertheless, it would be unreasonable to expect the automatic restructuring of technological change with the development of the commercial sector in Russia. At least three prerequisites are necessary. First, mechanisms of market competition must be thoroughly formed. Second, recession of the speculation boom is necessary in order to make the introduction of innovations profitable. Third, it is very important to promote the interest of entrepreneurs in the long-term development of production. All this requires time, during which a dramatic increase of innovational activity in the national economy can hardly be expected. More likely, one can expect a re-orientation of R&D resources towards incremental innovations because of the short-term orientation of collectively managed firms based on wage maximization.

Reforms in R&D

Marketization of R&D began with the adoption of the Government Decree *On transformation of research organizations on the basis of complete self-accounting and self-finance* on 30 September 1987. According to this Decree, state research institutes receive some autonomy with respect to the formation of R&D plans and access to different sources of finance. The ministerial organizations and monopolies in R&D were abolished and prices of R&D products were liberalized. Though there were no changes in the property rights system, commercialization of research institutes took place and a R&D market appeared. Research institutes began to seek demand for their products and to adjust their R&D to the consumers' needs. The transfer of new technologies from the R&D sector to industry increased, as well as R&D expenditures of industrial enterprises. The share of contracts between industrial enterprises and research institutes of the total R&D expenditures of the latter increased from 30% to 70% in one year (1988) only. The number of these contracts increased 2–3 times and industrial R&D output increased 1.64 times (1.43 times in constant prices). At the same time, the number of employees in R&D decreased by 4% to 18% in various industries and time required for R&D project realization decreased 1.2–1.5 times on average.

This boom in industrial R&D was caused by several reasons. The first, and perhaps the most important, was the adjustment of R&D resources to real industrial demands. The second was the appearance of market incentives for productivity growth; research institutes received opportunities to distribute and accumulate profits according to individual enterprise policy.

Together with price liberalization, this stimulated the institutes to mobilize resources, to increase output, and to seek demand for their products and services. Research institutes also gained the opportunity to increase wages in certain proportion to an increase of output in order to stimulate labor productivity growth. Third, SEs still had soft budget constraints. With the 1987 *Law on State Enterprise* they also received the rights for profit distribution. At the same time, deregulation of SEs was accompanied by a decrease in their payments to the state budget as well as to supervisory organizations, and the new tax system had yet to be introduced. SEs in several industries received privileges to not pay to the state budget at all. The SE savings, allocated to investment and development purposes, sharply increased in this situation easing their potential for R&D financing. Fourth, lack of competition between research institutes and lack of experience in assessing the real market values of new technologies induced prices of R&D products to increase. In spite of the existence of officially adopted methods for price calculation (based on the distribution of estimated profits from the utilization of R&D innovations between producer and consumer), actual prices were set in accordance to the bargaining power of partners. Profitability of research conducted by RIs for SEs was 1.5–2 times higher than of the research conducted for state agencies. It is not surprising that the share of state bodies' orders in research institutes activities decreased by 40%, while the share of SEs' orders increased by 2–4 times. Nevertheless, according to official estimates, the increase in R&D output growth was not higher than 8%.

Another important source of innovation activity growth in 1988 was liberalization of entry into the R&D market. Since 1987, the establishment of various non-state enterprises in the R&D sector was permitted. They could be organized in the form of cooperatives, youth centers of science and technology activity, and branches of non-profit social organizations. Since 1988, rapid growth of the non-state R&D sector commenced (refer to Table 1).

The typical role of a non-state R&D firm has been to act as an intermediate agent. It usually had only a small staff to arrange contracts between R&D consumers and specialists who were to conduct the research work. These specialists usually worked for such firms on a part-time basis, working simultaneously at state enterprises or research institutes. The majority of non-state firms performed only intermediate services between organizations that order R&D and teams of individuals that conducted the requested R&D. This service mainly included the transfer of payments for R&D from the SEs to individuals conducting the R&D. For these operations, non-state firms received a commission which varied between 5% and 50% of the contract. The demand for such operations was caused by different regimes of wage control in state and commercial sectors. SEs had rather limited opportunities in spending their funds, particularly on wage increases. By sub-contracting R&D to non-state firms, the SEs received much more freedom in spending their money.

On average, a non-state R&D firm formed 50–100 temporary teams of specialists per year. For each person permanently employed in such a firm, there were from 2 persons in cooperatives to 120 persons in youth centers conducting research in temporary teams. More then 1.4 million contracts with people working in temporary teams were signed by January 1990. Even if we assume that some people were simultaneously working for several firms, this was a very high number in comparison with 1.5 million of registered R&D staff in the country. More than half the scholars in Russia worked in the non-state R&D sector by this time. Yet, the majority of them continued to be employed at their job in the state sector as well.

Actually a large number of these non-state firms was organized on the basis of state enterprises and used their resources, equipment and workers for the fulfillment of the orders which they received from the same enterprises. Usually, these private firms were established by the corresponding SEs' managers or by their friends and relatives. In fact, such firms constituted a part of the state enterprise which was used to transfer SE revenues into wages of its managers and specialists. The basic advantage of non-state firms was a low control over transactions of all kinds in comparison to the state enterprises. In particular, firms in the private sector had many more opportunities to convert money from bank accounts to cash. On this basis, a mutually beneficial symbiosis of state enterprises and private firms emerged. Private firms gained access to cheap resources through state enterprises; and, state enterprises' managers, in turn, acquired new opportunities to redistribute income to salaries through private firms. Incidentally, the commission rate charged by non-state firms was similar to the rate of the ruble exchange from SEs' accounts to cash.

Another advantage in sub-contracting R&D projects to non-state firms was to minimize various expenditures for the maintenance of state R&D institutes. Members of non-state firms' temporary teams usually conducted their "commercial" research at the state research institutes (where they are employed) using the equipment at no extra cost. In fact, these temporary teams "privatized" amortization costs, rented intermediate materials and services, and intellectual property of their "mother" state research institutes and enterprises. The latter had, of course, to carry additional costs to cover the expenditures of R&D which their employees conducted for non-state organizations. In this way, resources for R&D production were actually redistributed into wages and salaries. This situation was considered a positive adjustment of R&D organization to the changing economic environment. The symbiosis of state and private R&D organizations mentioned above, provided opportunities to maintain incomes of scholars at a sufficient level in order to avoid their exit from the R&D sector. However, this did undermine the long-term growth of the organization where R&D is really performed.

Thus, numerous cases existed in which new private firms were subsidized by SEs and could not have survived without access to their resources. These private firms do not compete with the state RIs, but seek their support and protection. However, there are some cases in which real competition did exist—for profits, financing, labor, material and information resources. Research institutes of the MIC, which suffer both from strict control by corresponding government bodies and from the cuts in the military budget, were very vulnerable under such competitive conditions. As a consequence, it was of little surprise to record a significant brain drain from the MIC research institutes to the non-state firms, together with information and know-how, since 1988.

This brain drain from state research institutes was not only caused by larger incomes and wages in private sector. Since 1989, state regulation of R&D activity increased. The government was very concerned with wage increases in the R&D sector. In some design and research institutes the levels of some managers' wages increased 5 to 8 times after they received opportunities for price setting and profit distribution. Several cases were even discussed by the Council of Ministers. However, the average wage increase in industrial research institutes was 20%–30%, compared to 64% output and 130% profit growth.

In an effort to restrain the wage increases, government introduced several measures as a part of anti-inflation policy. These included: special tax on the wage increase and limits to the wage increase, which were set in accordance with output increases since 1991.

Restrictions on the wage increase were accompanied by the dramatic decrease of R&D expenditures in the state budget (see Table 2). This was particularly pronounced in the military-industrial complex as elaborated below. In the first quarter of 1991, the state expenditures for R&D were 25% less than planned because of the collapse of the state budget system. The prospects for the future were unclear and then still depended on the *All-*

Union Treaty. As a result, enterprises became the main source of financing for R&D. This source was very unstable and sensitive to the changes in national economic performance. Enterprises were primarily interested in incremental innovations with a short pay-back period. The growth of their share in R&D expenditures lead to to a decrease in the share of basic research in research institutes activities. In 1988, basic R&D expenditures in industrial research institutes decreased by 50% and average R&D project expenditures decreased by 40%, while the share of enterprises' contributions towards industrial R&D increased from 51.2% to 66.4%.

As alluded to earlier, the increase of SEs' R&D expenditures in 1988 could partially be explained by their soft budget constraints. Since 1989, budget constraints of the SEs' became much stricter; combined with their commercialization they became ineligible for most state subsidies. Local authorities began to collect payments for land use, pollution, and so on. Since 1991, taxation of SEs' profits was introduced and all previous privileges were abolished. The main part of SEs' profits was subsequently collected via federal, republican and local taxes. Therefore, SEs' potential to finance R&D decreased. Together with the introduction of strict wage regulation, this inevitably led to the decrease of SEs' R&D expenditures. In 1989, these increased by only 25% (in comparison with 64% in 1988), in 1990 there was no growth at all, and in 1991 they fell dramatically.

A deterioration of SEs' financial situation was not the only reason for a decline in their R&D expenditures. Although it may initially be perceived as ironic, a further explanation for the reduced investment in R&D by SEs' lay in their acquisition of more opportunities for income distribution. These changes induced managers to take SEs' expenditures more seriously. Under the pressure of workers, managers preferred to increase wages rather than R&D expenditures.

In order to prevent the mass bankruptcy of industrial research institutes, government decided to form the special non-budget fund for R&D finance in each industry. Ministries and SE associations joined forces in establishing this fund based on production cost of a particular industry's output. The rate of this specific value-added tax was between 0.8% and 1.3% in different industries. Contributions of SEs to this fund are considered production costs and excluded from taxation. These funds became the major source of financing for basic R&D projects in industrial research institutes and helped prevent the bankruptcies of numerous large industrial research institutes in 1991 and 1992, when prices were liberalized and inflation increased dramatically. The revenues of these funds increased together with the growth of production costs due to inflation.

This, however, was not the case for the Academy of Science research institutes which were financed by the Fund for Basic Research, a fixed subsidy from the state budget. Due to increasing financial chaos after price liberalization and collapse of the All-Union institution in 1992, it was impossible to plan the state budget for the whole year. The budget was formed for each quarter with a delay of 1–2 months. As a consequence, academic research institutes suffered considerably under uncertainty while awaiting subsidies that were eventually transferred from the state budget with large delays. Due to the rapid inflation, the real value of the subsidies depreciated enormously during the waiting period. The restrictive and uncertain financial policy conducted by the Ministry of Finance damaged the R&D resources in the Academy. Many academic research institutes were unable to pay wages for several months and lost their best researchers.

The partial restructuring of the R&D financing system in 1991 was an intermediate and insufficient solution for the problems relating to the survival of the research institutes. However, it was the natural reaction of the overbureaucratic state R&D management system to the increased instability. This reaction was directed towards the maintenance of the existing institutions of the R&D organization. For instance, the semi-obligatory contributions of SEs to the industrial R&D funds were considered as production costs and excluded from the taxation, while the expenditures of firms for their own in-house and outside R&D had to be deducted from profits. This system helped to maintain large R&D projects conducted by the leading industrial research institutes (as well as ministerial bureaucracy in charge of distributing subsidies from industrial R&D funds), but completely blocked R&D development of in-house and external character, not to mention market-style transactions.

The adaptation of R&D resources to the market environment will require more radical restructuring of the R&D sector.

Prospects for Restructuring Russian R&D

Transition to a market economic system caused the destruction of the basic institutions of Russian-type R&D organization inherited from the Soviet economy. These institutions were established by a central planning system based on resource allocation and could not adjust to a market environment. The restructuring of R&D organization become inevitable. In the early 1990s, this restructuring proceeded spontaneously and was followed by the waste of accumulated R&D resources and collapse of existing scientific schools and organizations. Six such major issues are described hereafter.

First, commercialization and privatization of state enterprises destroyed ministries that were responsible for and coordinated channels of industrial R&D finance and resource supply. Deterioration and, in some cases, abolishment of industrial ministries powers revealed that market demand for R&D from enterprises was not sufficient to maintain industrial R&D at the previous level.

Second, substitution of the centrally planned system of resource distribution with a market changed the whole system of the R&D financing and support. A large number of R&D organizations were concentrated on prestigious and military high-tech projects. High priority determined the sufficiency of their financial and resource supply. In fact, market demand for this R&D was very poor and did not adequately compensate the previous large scale government R&D programs.

Third, democratization of decision-making procedures at all levels of state authorities undermined the power of Academy and military-industrial lobbies, which actually determined resource allocation decisions including issues concerning plans and funds for various R&D projects and organizations. For instance, after this democratization it became much more difficult to receive financing for prestigious expensive R&D projects. Members of new legislative bodies were deeply concerned about the sensibility of different R&D programs financed from the state budget. The new governmental and parliamentary authorities were no longer under the influence of the former academic nomenclature and various pressure, rent-seeking groups.

Fourth, research institutes were organized like industrial enterprises and managed in a bureaucratic manner. Usually they are rather large with standard inflexible linear organizational structures and multilevel hierarchies. The inertia of the management routine in research institutes was very high and adjustment to market economic condition proved rather difficult.

Fifth, R&D organization of the early 1990s was characterized by low managerial competence. A career in the bureaucratically-managed research institutes, which operated in a very stable and monopolistic environment, was mainly determined by personal relations. Separating the scientific community with organizational and information barriers annulled any potential competition in the selection of people according to their scientific achievements. In addition, no possibilities existed to follow a purely scientific career—under the bureaucratic organization of R&D there were only administrative channels for personnel growth. The scientific community was suppressed by an administrative management routine. In order to be influential, a scientist had to occupy some official position in the administrative hierarchy. The dominance of administrative success among the factors determining one's career in R&D, lead to the concentration of incompetent people at the highest and middle levels of the R&D hierarchy. Under central planning, these were the people who determined the flows of resources for R&D and controlled the information exchange channels between central authorities and the scientific community. At the 1991 level of R&D activity, managers in the state R&D sector had insufficient competence to manage research institutes in the new environment. These lead to the deterioration of the competitive position of state research institutes and to the exodus of specialists and resources to the non-state commercial sector and abroad.

Sixth, transition to the market required a radical change in criteria judging R&D performance. The basic criteria was to be competitiveness of R&D products. These change the whole former paradigm of R&D organization which was oriented toward the fulfillment of directives and formal indicators determined by government authorities. In order to meet this challenge, radical restructuring of R&D management became a necessity.

In an effort to overcome the above mentioned problems and to prevent the collapse of R&D in the transition period, radical restructuring of R&D organization and of state science and technology policy is a fundamental step. This restructuring must include: reorganization of research institutes in the privatization process of state enterprises and destruction of ministries and other administrative supervising bodies, restructuring of the state system of R&D financing and support, introduction of appropriate intellectual property rights legislation and state innovation policy, and reform of the education system. Changes in R&D organization must be accompanied by corresponding changes in the demand for R&D products. New technology development and diffusion is determined by the institutional structure of the economy. Here, restructuring R&D organization is considered as a part of more broad changes, including demonopolization of industry, large-scale privatization, change of the state regulation system, reform of financial and banking system, and so forth.

The basic problem of R&D restructuring in the transition to market is to provide sufficient demand for R&D products. In the situation of supermonopolization of the Russian economy, transition to market does not provide guaranteed stimulus for innovational activity. Privatization of SEs will, in fact, lead to increasing prices and declining production. Thus, demonopolization and development of competition is the key prerequisite for successful R&D restructuring.

Spontaneous privatization has commenced in 1989–1991 without any demonopolization. Transformation of SEs into self-managed and cross-owned joint stock companies has been followed by the rebirth of organizational monopolies in the form of various corporations, associations, and others. Another drawback is the uncertainty concerning the property rights of the transformed SEs. Using other state enterprises and banks as shareholders of their enterprises, managers evade ministerial control, but do not obtain any new owner. Usually, after the transformation of SEs, the managers lose responsibility for the long-term development of the enterprise but receive opportunities for current revenue distribution. As a result of this spontaneous privatization, short-term orientations toward consumption maximization become dominant, while innovation activity and demand for R&D decrease.

Large-scale privatization started in the second half of 1992 with the transformation of SEs into joint-stock companies and changed the picture regarding the distribution of property rights. With time, these should be clarified, as well as the responsibilities of managers. Immediately following transformation they will be responsible to the corresponding ministries and the State Property Fund, later to the trust companies which will hold shares on behalf of the state, and finally to the private owners after privatization is complete.

At the same time the privatization program for 1992 does not consider the technological and production structure of SEs. The industrial ministries were designed and behaved like large corporations optimizing their internal structure according to the environment. The present SEs are, in fact, more like parts of the large industrial production organizations than like independent firms. Their independent privatization can drastically increase the transaction costs in the economy and destroy the production of high value-added final goods.

In order to provide favorable conditions for innovations the appropriate privatization program is necessary. It should provide a clear property rights system, which would determine the responsibility of managers regarding the long-term development of privatized enterprises. At the same time, privatization should not destroy the existing technological links between enterprises as well as information flows between enterprises and research institutes. It appears sensible to create vertically integrated corporations on the basis of the present agglomerations of SEs. Privatization of the latter can be operationalized by selling or granting their shares to responsible management in corresponding holding, investment funds, or trust companies, which should play the role of institutional investors interested in the long-term development of "their" firms. For this purpose, the share arrangements may be organized as mutual or state funds managed by private firms with strict government control over their profitability and portfolio structure.

Research institutes cannot be privatized like enterprises. The form of each research institute's transformation should depend on its role in the industrial technological development. The so-called main research institutes responsible for technological development of the whole industry could remain in state ownership supervised by a corresponding Ministry, or they should be transformed into consortiums owned by firms interested in the relevant R&D performed at the particular institute.

Research institutes, which are now part of scientific-production unions (NPO), should be transformed into the firms' R&D departments before the latter's privatization. On the basis of such NPO, several small high-tech firms can be organized in the process of privatization. Research institutes with no clear specialization, yet still conducting useful applied research, could be transformed into centers of contract R&D that will offer their equipment and space to various research teams. In fact, many research institutes are already transformed in such way.

Research institutes can also be transformed into self-managed organizations leased or owned by their employees or staff members, private institutes, joint ventures, and still others. In some cases, these institutes can be transferred to universities and colleges. The choice of an appropriate form should depend on the character of research activity (basic or applied research), prospects of self-finance, access to necessary inputs, level of research and quality of R&D resources, and importance for the technological development of particular industry.

Transformation of industrial research institutes should be undertaken simultaneously with the privatization of corresponding industries. Transformation of the research institutes of the Academy of Science assumes the restructuring of the latter as a prerequisite. In order to provide conditions for self-organization of the scientific community and normal scientific development, debureaucratization of the Academy is an absolute necessity. It should be transformed from the supervising management body into a set of service organizations offering various services for research institutes and scholars (information supply, publications, material supply, conference organization, etc.). In the same way, the State bodies responsible for higher education should be transformed simultaneously with liberalization of the higher education system. The present inefficient system of directing state subsidies to higher education establishments should be substituted by subsidies to students and diversification of sources for funding higher education.

Transformation of research institutes in the process of privatization should be accompanied by a restructuring of the R&D financing system. The present flow of subsidies from the state budget to the research institutes via their supervisory organizations (such as the Academy of Science or an industrial ministry) should be substituted by various foundations and management bodies with different tasks offering subsidies and R&D contracts to all organizations and scholars on a competitive basis. The first steps have already been taken by the foundation responsible for the Basic Research Fund. It has been formed based on former state budget subsidies mainly used to finance basic research in the research institutes of the Academy. The main shortcoming regarding this organization lies in its solo position as the only Fund receiving substantial state subsidies for basic research while it is controlled by the Academy bureaucracy. Consequently, one can hardly expect real competition for grants from this fund. In order to overcome the supermonopolization in the organization of basic science, more funds of this kind, which expose the expertise of research scientists and the worthiness of grant allocation procedures, are a necessity for a functional R&D market.

Such funds should also be established to promote industrial R&D. The state support for industrial R&D is especially important in the transition period, when demand for R&D from firms is insufficient for reasons mentioned earlier. The funds to support industrial R&D can be organized on the basis of the already introduced special tax for financing R&D expenditures. In the present situation characterized by an instable and partially collapsing state budget as well as very high inflation, it appears sensible to introduce this tax as a law in order to procure reliable sources for R&D financing. Industrial funds financed by this tax should be independent of ministries' authority and should be managed by councils appointed by the President. These funds should finance R&D programs of national importance, technology imports, and grants for scholars and subsidies for research institutes.

Subsidies for research institutes will be necessary to preserve them during the transition period for two reasons. Firstly, temporary state subsidies can protect accumulated R&D potential throughout the transformation process of the state financial system and enterprises adjustment. Secondly, such insulation mechanisms simply ease the transformation of the entire R&D sector. As already documented, the present private R&D sector is subsidized by the state financing channeled through state enterprises and research institutes. The bankruptcy of the latter would undermine the existence of non-state R&D firms. The majority of them could not survive without indirect support from the state organizations and access to their resources. Some experts propose that this support should continue for a certain period to secure growth of private R&D activity. When the latter become strong enough to conduct independent research and to purchase R&D resources from state enterprises and research institutes in bankruptcy, subsidies to the research institutes can be eliminiated. Some subsidies explicitly for basic research would be necessary in the future, but their share in R&D expenditures should decrease with the growing demand of private firms.

Basic research has an open and international character. The development of international cooperation is crucial for the partial solution of the financial problems of Russian research institutes and for the integration of the Russian scientific community in the world. It is sensible to allow and encourage Russian scholars to participate in competitions for grants from Western foundations. A part of the Western credits should be spent to improve international communications channels and contacts for Russian scholars. This includes the development of telecommunication networks, supply of Russian research institutes with science and technical information from abroad, education and temporary work of scholars abroad (as well as foreign scholars in Russia), their participation at international conferences, and so forth. Joint R&D consortiums and research institutes is another form of foreign finances for Russian R&D and integration of the Russian in the global scientific community.

In future, state R&D expenditures should mainly be concentrated on programs of national importance. These programs can be financed by state authorities responsible for industrial development. Each program must have clear objectives, time schedule, and its own budget. Large programs could be adopted as a separate part of the state budget, while medium and small programs could be adopted as a part of the corresponding state bodies' budgets. Each program should be self-managed (by the state body, by a special administration, by a firm or consortium of firms, etc.). The type of management depends on the purpose of the program and the goals for its implementation. Use of funds allocated to specific programs should be flexible: for example, for subsidies, grants, privileged credits, state orders for certain products manufacturing, and so forth.

During the transition period, state programs should remain an important instrument for resource allocation aimed at overcoming the structural crisis of the national economy and encouraging modernization. Technological diversification in the Russian economy and the corresponding price structure has been the cause of inefficient resource allocation on the basis of short-term profit-seeking behavior which could become typical for private firms under continuing unstable economic conditions. State programs would be necessary to overcome the inertia of the obsolete economic structure and to initiate progressive technological changes. These programs would also be necessary for the conversion of enterprises in the military-industrial complex and their adjustment to both internal and external market demand. Market disproportions in the Russian economy can not be overcome by liberalization alone. Active long-term industrial policy is necessary to secure the recovery from structural crisis.

The transformation from a simple dispersion-type to a program-oriented type of planning presupposes radical restructuring of the state management system. The main problems of this restructuring are: shortage of resources, lack of competence, and inadequate structure of state bodies. The industrial ministries responsible for the production in corresponding industries should be substituted by functional ministries responsible for the development of the corresponding sectors of the national economy.

With marketization of the economy, the share of R&D expenditures in state budget should decline, while the share of private firms should increase. State industrial policy should provide sufficient stimulus for enterprises to undertake long-term investments and innovation activity. The basic requirements herefore are economic stability and an adequate system of property rights. Taxation is also very important. In order to promote long-term investments, including R&D expenditures, the main burden should be carried by natural resources rents and property taxes. Investments and all kinds of R&D expenditures should not be taxed as production costs. Tax privileges for priority industries and services which cannot achieve sufficient profits immediately (like communications), could also be granted. Introduction of these principles would be impossible without restructuring the present taxation system which is based on the taxation of manufacturing value-added and consequently, suppress innovation activity.

An important part of industrial policy during the transition period is foreign trade regulation. In spite of a comparatively high technological level in certain industries, the majority of Russian enterprises and products are presently non-competitive on the world market. Russian managers have never been exposed to the market or profit maximization. Quality requirements are of less importance than volume of production in a centrally planned economy. Competitiveness was never considered as something important. For this reason, the imitation technique was widely used to introduce new technologies. Together with poor quality, this has become the main obstacle for the export of Russian high-tech products. Time is needed in order to master these obstacles. Such a transition period requires the careful liberalization of import policy: too rapid and it may ruin the Russian procedures and R&D resources, too slow and it will postpone foreign trade liberalization. A gradual long-term step-by-step process of reducing import tariffs should be implemented.

A similar policy should be implemented regarding protection of intellectual property rights. Some kind of multi-step program of intellectual property rights regulation should be adopted long before its actual implementation to allow a sufficient adjustment period.

These guidelines for restructuring Russian R&D organization need further elaboration. A special set of programs should be developed for R&D restructuring throughout the process of economic reform.

Table 1. R&D output by non-state organizations (billion rubles).

	1987	1988	1989	1990	1991*
R&D expenditures of different types of organizations	0.03	1.2	4.7	6.0	6.15
including:					
Youth Research Centers	0.022	0.85	1.1	1.45	1.5
Permanent Research Teams of All-Union Society of Inventors	-	0.07	0.1	0.15	0.15
Permanent Research Teams of Union of Science and Engineers Society	-	0.12	0.35	0.5	0.5
R&D cooperatives	0.008	0.17	3.15	3.9	4.0

*Estimated.

Table 2. Indicators of non-state R&D organizations activity.

	Number of centers (councils) empowered to create Permanent Research Teams (units)	Number of functioning Permanent Research Teams (thousand* units)	R&D expenditures in Permanent Research Teams (million rubles)	Number of employees in Permanent Research Teams (thousand persons)
Youth R&D Centers				
1.01.89	500	60.0	850.0	600.0
1.07.89	570	70.6	1000.0	706.0
1.01.90	602	77.7	1100.0	776.5
All-Union Society of Inventors				
1.01.89	55	4.7	70.8	25.0
1.07.89	70	9.9	94.0	64.0
1.01.90	100	15.0	110.5	82.0
1.07.90	100	16.0	157.0*	58.0
Union of Science and Engineers Society				
1.01.89	145	10.6	123.2	65.2
1.07.89	267	16.9	189.6	96.0
1.01.90	451	38.0	349.0	273.0
1.07.90	765	33.0	560.0	470.0
R&D cooperatives				
1.01.89	2076	-	167.1	55.0
1.07.89	5800	-	868.0	182.4
1.01.90	10400	-	3151.3	321.5
1.07.90	11300	-	2062.2	298.1

*According to signed contracts.

Part IV

Conclusions and Implications

Implications and Prospects for R&D Management in the Transition to a Market Economy

Christoph M. Schneider[1]

Introduction

With its large, educated population, more than adequate amount of scientists and engineers, and an abundance of resources, the status of the USSR as one of the world's greatest industrial powers would have appeared to be assured. However, this was not the case.

A blending of economic and innovation theories has impressed on us that the social manner of doing things should make all of us better off. Soviet-style socialism did not achieve this. In no such circumstance, did the central planning system prove that it could achieve results superior to those of other systems. In fact, the inadequacies of management techniques based on communist central planning principles have made the overall successes of capitalist market economies appear much more respectable had the latter not such an opposite example to be compared with.

However, the talk of mismanagement of research and development in the former Soviet Union or, rather, preceding management based on distorted economic signals leaves much room for improvement and future promise.

[1]Economic Transition and Integration Project, IIASA, Laxenburg.

It allows one to assume that a reorganization of R&D management under new conditions as part of the transition to a market economy could lead to the blossoming of this sector. As a key element of economic growth, the appropriate style of investment in R&D could, in turn, act as a catalyst facilitating and aiding expansion and development benefiting domestic Russian residents and influencing the status of the successor Republics (mainly Russia) of the former USSR in the international scientific, technological, and economic communities.

History has proven time and time again that there is no future without a past. This is no less true in the field of research and development, or in the science and technology sector as a whole, than in any other area. Perhaps even more so, due to the value of an accumulated stock of knowledge in the propagation of new innovations. Throughout history and most accountable since the first industrial revolution of the 19th century, the impacts of new innovations have influenced the organization and development of society from technological, economic, and cultural perspectives. Countless major and minor challenges and opportunities have been afforded by developments in new technologies. The potential for new innovation lies in a long-standing commitment to support domestic R&D that cultivates and secures national technological capabilities.

The Soviet Union made such an historical investment. Successful science was part of cultural pride and identity; in fact, it was anchored in the ideology. Today, the USSR no longer exists, but, to a large extent, its science and technology sector, which boasted one of if not the largest R&D establishment in the world in its time, lives on for the most part in the new Russian Federation.

Already during Gorbachev's years of *perestroika* between 1985 and 1991 in the USSR and even more so now in the modern Russia, which is undergoing remarkable changes in all spheres at the hands of courageous reformers, have efforts indicated a continuing importance of the role of scientific and technological development. Russia is faced by a dilemma in becoming part of the international S&T community where results and performance determine success: preserving the potential of the enormous S&T establishment (which may in truth be too large for its own good), while attempting to become more efficient and productive by rationalizing and letting the market determine what is needed. As it was, the system cannot and will not serve the needs of a modernizing market oriented economy. However, a scientific-research base is important to a modern economy.

The Importance of R&D: From the Soviet Union to Russia

From the Scientific Perspective

In the Soviet Union from Lenin to Gorbachev, science and technology, in one form or another, were heralded as the universal remedy for all problems. It was to make Soviets better off at home and the country's position more important internationally. S&T were considered to be the highest form of culture, the path to social prosperity; it was to serve the masses rather than be exploited for individual profit. The scientific community had fantastic dimensions and enjoyed special status in ever sense of the word. The products of scientific endeavor were to be the springboard to technological advance and economic growth superior to that elsewhere, particularly in the Western capitalist countries.

Previously, Soviet science could be proudest of its achievements in military and space technology. Unfortunately, both did little directly for consumer welfare, and even indirect spin-offs were extremely limited (though this should be no surprise if we are well informed about deficiency of defense R&D spin-offs in the West). The Soviet-style of R&D management cultivated a progressively growing technological gap to the West in many scientific fields despite the system's basic natural advantages. These included the capacity to mobilize resources to achieve *"mission-oriented"* innovations, to train the labor force with the appropriate research and design skills, to acquire specific foreign technology, to theoretically avoid potential duplication with its centralized determination of innovation, its mandatory enforcement of introduction of innovation, and its centralized investment and materials allocation (Linz, 1992, p. 65).

Decades of hearing that scientific and technological advance will cure socio-economic decay but perceiving and experiencing only sparing results, has made the Russian public skeptical of the actual recovery power of R&D investments for economic improvement. In addition, a premise gaining more recognition is that, in Russia today, the central government is acclaimed to be more progressive and reform oriented than the local authorities and often (state) enterprises. This indicates that the Academy of Sciences, some industrial ministries, and special committees will carry much of the responsibility to get a new style of R&D underway. Of course, they will partially be carried by past momentum and significantly by the hordes of scientific and engineering workers and equipment of yesterday.

Perestroika, by definition and in reality, facilitated the introduction of democratization of management and decentralization in existing scientific institutes (for better or worse) in an effort to restructure institutionalization and reorient motivation in the Academy of Sciences, industrial institutes, and government. Evidence from personal interviews with scientists generally document their continuing belief that scientific activity is value free. Hence, given the right political system and social foundations, and freedom to work without interference, their research naturally would produce great benefits for society (Josephson, 1992, p. 29). Russian policy-makers are now in the position to grant the scientific profession such an environment. Some progress has been made and the first results are promising. One example has been that the relative freedoms and flexibilities have seen the rebirth of independent professional organizations of scientific experts, more than a half century after the Communist Party wiped such groups out (ibid, p. 30). Such developments reveal that characteristics of the Western scientific community can be successfully and rewardingly integrated during the reorganization of R&D management in Russia.

The USSR was simply plagued by a central planning system that was actually based on bargaining elements which distorted economic signals and lead to a futile effort to implement the optimal plan due to the disguised void to reality—the *"inefficiency hole."* However, the advantages that have become remnants of the former system can catapult Russian R&D and industrial potential to unexpected heights under the conditions characteristic of a new political and economic environment which the reformers are attempting to foster.

Not only will Russian R&D rejoin the mainstream of the international scientific community, but also the country of Russia will rejoin on both economic and technological foundations. One crucial to the success of the other.

Russian R&D has inadvertently been obliged to become a part of the global scientific and technology system at a time when many of the leading R&D nations are facing similar problems, though to a differing extent, to those that have arisen in the RFR's bid to create a market economy. In the West, budget deficits are burdening governments, forcing federal funding cutbacks wherever possible and S&T habitually falls victim in the process. Particularly, of course, fundamental science which is most strongly supported by the government in the West. In Russia, reduced funding in basic science could have a substantial human cost due to the large number of scientists and technicians employed in this branch. Of course, the accompanying increase in freedom to change to a job in another institute, field, or completely different sector (as long as experience or education allows), which was previously unknown, may take up some of the slack. In fact, many persons may finally take the employment they wished to achieve with their education (where possible) rather than the position that was commonly determined for them.

Additionally, R&D in general but to a greater degree the applied side is being forced to earn its way in the world. So, what the Russians perceive as a result of becoming a market economy is a feature confronting Western applied science (though conventionally rather well-supported primarily by the private industrial sector anyway) in an effort to make what appeared to be a good system more cost effective.

Partly as a result of simple necessity to prevent the R&D sector from completely vanishing, the reorganization of R&D management in Russia began with more urgency after the break-up of the former Soviet Union. Russia, as the largest of the successor states, ceased financing more than eighty central agencies including structures of the former scientific community (Levin, 1992, p. 1). However, within a few months the Russian Academy of Sciences[2] had been formed, replacing the Soviet counterpart, and a metamorphosis and merging of the former USSR State Committee for Science, and Technology, the Russian State Committee for Science and Higher Education, the Committee for Science and Public Education of the Russian Supreme Soviet, and the short-lived Ministry of Science and Technological Policy of the RFR into one unified agency, the Ministry for Science, Higher Education, and Technology Policy of the RFR. Thus, some of the administrative changes have been embarked on, members of the Academy are elected in more democratic fashion, and funding mechanisms are guaranteed but not yet organized. Much is left to be done in the reorganization of R&D management embodied in a new diversified and competitive science policy that is emerging in the transition to a market economy, but a start has been made.

From the Enterprise Perspective

The changing economic environment in Russia, with reformulated institutional, organizational, and motivational structures, requires modifications of the existing innovation decision-making process. In an effort to integrate in the world economic system and produce goods of international standards for the domestic as well as foreign market, Russian managers face many new de-

[2]As it had originally been known from 1917 to 1925.

cisions; one of which is considering how to best allocate their R&D budgets. The price they can procure on the market and the diffusion of their product will determine their revenue from which the R&D budget is derived; this is characteristic of applied research in Western market economies. Under such conditions managers can finally truly evaluate rewards and risks of investing in and introducing innovations.

Under Soviet-style research and technology management innovations were more imposed on enterprises from the hierarchial industrial/institutional system above them. Whenever possible enterprises balked in the face of changes due to the then ruling incentive measures. The gradual reduction in the magnitude of expected punishments for not meeting orders between 1953 and 1982, lead to a lack of discipline and enforcement (Ellman and Kontorovich, 1992, p. 10). Managers and directors of enterprises (whether these were research institutes responsible for producing innovations or factories ordered to produce final products) had less motivation to reach output targets. Instead of punishment, superior levels of the hierarchy revised their targets downwards resulting in a cumulative brake on technological change.

Yet, as the present reforms continue one of the major barriers to innovation in the past is significantly shrinking in importance: namely, the supply of inputs to be utilized with the new technology. Under the old system a manager had to already mount considerable effort to secure the inputs for the old-style of production, suggesting that the introduction of new techniques would have confronted him with a potentially double negative effect—loss of bonuses due to reduced output as a result of retooling, and forecasted difficulties in the supply of newly required inputs further impeding production. The former distribution system has mostly vanished now. A functional new one has yet to be developed. The doors to input supplies are open domestically and international to whoever can pay the price.

Today, the enterprises have essentially two choices with respect to innovation. Either they innovate themselves, basing their decisions on consumer demand, supply conditions, costs of inputs and so on, or they may choose to imitate. However, the simple method of imitation utilized in the past will no longer be sufficient; products will have to be developed further by domestic (preferably in-house) R&D personnel to match the specific requirements of local demand. But, the enterprises cannot achieve these results during the transition on completely their own accord. A combination of market signals and government planning is needed to speed economic development and growth (OTA, 1992, p. 11). The latter, as the Soviet Union found out the hard way, cannot replace the advantages of the market and forces of competition.

It is, however, now quite clear that free market principles based on perfect (or even imperfect) competition provide sufficient incentives to invest in as much R&D as would be socially optimal for a whole nation. This is the argument used to justify government intervention. Examples from Japan, South Korea, and Taiwan, nations that all experienced exceptionally rapid growth, reveal the presence of state intervention to alter but not destroy market signals. Protection of the domestic market and direct funding of R&D were forms of intervention, as were policies to steer low-cost capital, preferential access to foreign exchange, assistance in negotiations with foreign companies for access to technologies, and support of domestic technology development and implementation through a variety of fiscal incentives (ibid, p. 10). Thus, numerous examples exist in how the Russian government can best utilize its domestic R&D potential while preserving the drive for entrepreneurship.

Furthermore, should the enterprises prove to be duly successful, then their products will also be sold in the West, in turn influencing the market, prices, and industrial organization there.[3] Evidence from historical developments in other nations, which have been resurrected from rather dismal situations to become economically and socially successful (i.e., Japan, Germany, some NICs), would tend to indicate that imitation will be the initially favored strategy at least for the immediate transitional phase. As world levels of quality and selection come within reach, supported by the very capable domestic R&D sector, the role of innovation will again substantially increase. Of course, the industrial structure will make a difference.

Russia has inherited the industrial structure cultivated by decades of communist industrial policy. In general, it is one dominated by labor and capital intensive industries, but recently there have been signs of at least a willingness to shift to more modern industries along the path of industrial evolution. Countries beginning much later than the USSR on the road to industrialization like Japan, South Korea, and Taiwan have already gone through more shifts. They began also with labor and moved to capital

[3]We are reminded of the shift of certain types of production to newly industrialized countries as in the cases of steel, chemicals, or automobiles. The specific advantages of these nations drew these manufacturing industries to their soil and have in a number of situations developed these further to become substantial exports of the resulting products themselves. Simultaneously, a reorientation is required in those more mature nations from which the manufacturing initiatives originally came.

intensive industries, moving primarily from light manufacturing and import substitution to heavy and chemical industries. However, these countries all went one additional step further than the USSR. They have moved into the knowledge intensive industries which have facilitated the production of products (i.e., computers) that have allowed the development of downstream industries and consequently promoted economic growth and development.

Although much enterprise activity will be devoted to satisfying the backed up demand resulting from decades of no selection, the enterprises will be joining the world at the research and technology level on the one hand, and on the product level on the other hand. R&D based technological change (particularly production technology) and diffusion of that technology will contribute to economic growth and the improvement of the standard of living, inevitably making Russian producers and consumers important elements of the world economy.

The International Aspect

In our modern world, reality has come to prove that science and technology have become a world-wide phenomena. The process has been underway for some decades and international exchange and participation have been crucial to the successes of numerous nations that had to climb back from serious economic and/or technological setbacks. The value of open borders to scientific exchange, which includes the flow of experts, ideas, experiences, assistance, and supporting materials (such as computers), has been valuable as a catalyst for economic growth and development in the past.

Russia was once no exception. Even as far back as Peter the Great and Catherine the Great in the seventeenth and eighteenth centuries respectively, were Swedish, Dutch, Danish, Prussian and many scholars and technicians of other nationalities invited to perform their craft in Russia, while Russians were sent to England and elsewhere for training and study. It was under communist rule in the twentieth century when the Soviet Union turned a cold shoulder to the ever increasing multilateralization and internationalization of both basic and applied research efforts, not to mention development.

Although the internationalization of research and development became significant enough after World War II to warrant more serious study, the real surge appeared in the 1980s and continues today. More and more international scientific associations and consortiums are being established in an effort to spread the risks and costs of research and development, to gain from the pooling of scholars from disparate fields in different nations, and to be assured a privilege to the results of the cooperation. It has become increasingly difficult, costly, uncertain and less fashionable to *"go at it alone."*

In addition, the accompanying advantages of foreign direct investment and multinational corporations' activities are chief determinants in the acquisition of foreign technology. The significance of these elements increases when one considers that much of the newest and most protected Western technology was already being chiefly transferred by multinationals in the late 1980s. In each case the value of the domestic research and development base influences the attractiveness of a particular country for foreign interests and investors. Judging by the stock of scientific resources inherited from the Soviet Union, Russia will have much to offer and be an attractive partner in international research. Thus, it seems Russia has chosen to return to the world stage of science and technology during a time when more interaction between the players is desirable and much can be gained by each.

Becoming a part of the world economy and transforming the internal system to a market oriented style simultaneous to the opening of the S&T sector will facilitate a working environment more conducive to better technological choice and more efficient use of R&D resources. Prices of products, costs of inputs, and returns on investment will finally have a meaning in choosing policies and projects. Links to the world will do much for the development of domestic markets to which domestic research and technology must cater and from which demand impulses are expected to aid in guiding reformulation of principles and institutions.

One of the keys to a future for the Russian S&T sector is to sever all links to the former legacy of ideological orientation. Cooperation with other nations, mainly those of the industrialized West, will prove to bear important fruits for the development of Russian R&D, molding it to be a significant factor in economic growth. Benefits can be realized in the procurement of marketing- and technological assessment infrastructure, policy-setting processes, methods for science management, means for modernizing and retrofitting those branches of industry worth saving, and measures for determining and demonstrating how applied research can be used to make traditional industries competitive (Popper, 1992, p. 114).

It would be incomplete to consider the international aspects of the importance of R&D and technology for economic growth without citing the case of Japan. Notwithstanding the differences, a comparison with the Russia of today makes the Japanese case especially useful due to similar historical events and lessons for the future. Already in the pre-WWII period Japan had entered a phase of international isolation that extended until the end of the war. Postwar Japan inherited a technological gap to Western industrialized countries and inflated heavy industries (machinery, metals, and chemicals) often associated with the previously extensive military sector.[4] Inward foreign investment was practically prohibited and to compensate for the isolation the state increased the allocation of resources to research and development. This strategy was, however, unsuccessful in closing the technology gap to the Western leaders. If there were no mention of names or dates, this portrait could just as fittingly apply to the late phase of the Soviet Union and the early predicament facing Russia.

One of Japan's most notable solutions to the dilemma was to acquire advanced foreign technology in many ways, with an emphasis on knowledge rather than capital, largely exclusive of inward direct investment (Goto, 1991, p. 10). The Japanese perceived technology as knowledge and information embodied in many forms ranging from persons to equipment. In postwar Japan a vigorous program of personnel exchange with the leading Western nations was initiated and supported at both the enterprise and scholastic levels. Japan also imported the *backlog* of technologies developed overseas during the war, and soon moved to new technologies not yet pervasive elsewhere and developed these further at home for both the foreign and domestic markets. The entire process of effectively utilizing imported knowledge and technology to create Japan's own technological base and promote economic growth was helped by the level of indigenous science, research, development, and technology (primarily created during the isolation period) and a well developed education system. Firms were very active in importing, concluding technological agreements with American and Western European companies, and in sending engineers and managers abroad regularly to search, find, and return with interesting and useful things being done elsewhere.

This short account of the postwar Japanese situation was to reveal the benefits of utilizing effective international R&D policy to spur domestic growth. Although there are not all too many such examples, it gives a hint of successful measures that can, in one form or another, be useful in the management of Russian R&D during the transition to a market economy. Growth will create a demand for more advanced technology, which promotes growth in turn. Advanced technology can be produced at home or acquired from abroad. The latter is not an automatic product of the cyclical process

[4]The percentage of heavy industry production in total manufacturing output was 79% in 1944 (Goto, 1991, p. 6).

described, but requires a deliberate effort on the part of the buyer and the appropriate environment into which it is introduced if it is to be productive.

Prospects and Prescriptions for R&D Management and Technological Advance in the Transition to a Market Economy and Beyond[5]

Reform, Transition, and R&D

The presentation of R&D in the Soviet economy in the previous papers of this book reveal the enormity and complexity of the task to appropriately manage this factor. It has particular relevance due to its position at the core of the relationship between science and technological growth. Management of research and development in the USSR was characterized by a conflict between political, national, and historical priorities (competing at all levels of science and technology), and countless distinct cultural and regional peculiarities. Although the economic transition has been recognized as necessity and reality, the existing influences appear to adhere to an excess devotion to maintain all institutions and employment in R&D, including the applied area. Different solutions are required in both the basic and applied areas. Since the break-up of the Soviet Union in late summer 1991, the processes of transformation in Russian science administration and policy have been accelerated, but have yet to be successfully concluded.

Two major factors have differentiated Eastern and Western R&D systems. They are:

1. *The origin of basic research.* A great portion was conventionally done in the special research institutes of the Academy of Sciences rather than in the higher education institutions. In this sense, the Soviet system most resembled the French system of those in the West. Generally, there are different mixes in the West, but determining the precise mixture for the Russian R&D community is, perhaps, not the most crucial issue at present.
2. *The role of the enterprises.* In the planned economic system, industrial R&D was not the responsibility of enterprises' management. If *pere-*

[5]The views and propositions made throughout this section are founded on the author's personal discussions with leading experts and policy-makers from Russia and Western nations who participated at an IIASA conference on *Research and Development Management in the Transition to a Market Economy* in Moscow in July 1991.

stroika, in its new form under the Russian reform-oriented leadership, proceeds and competition is successfully established through demonopolization and privatization, the present system will prove to be infeasible and the number of free standing or independent industrial research laboratories will diminish because the industrial enterprises will themselves take up the research. Building a R&D laboratory into the enterprise allows the firm to work effectively and in a proprietary fashion with the laboratory to reduce the actual needs for formal legal instruments (as patents) in order for companies to best appropriate their returns.

The organization of science often reflects the organization of the economy. The differentiation and separation between fundamental and applied science is a crucial policy issue. This has direct implications for the distinction between basic and commercial R&D. The latter depends not only on the quality of R&D personnel. In a market economy, resources for applied R&D are primarily allocated by the market mechanism in a decentralized manner responding to market forces. Resources for basic research are largely supplied by the government. Thus, a review of the experiences and literature on the integration of science and technology in a market economy would seem in order before considering policies that can propagate a simple division of R&D activities into non-profit (fundamental) and commercial (applied).

Research and development, like the general situation in the USSR, was confronted with a lack of interactions between users at economic, societal, and regional levels. In analyzing Soviet R&D, a number of criticisms can be distinguished that have not been uncommon in the West. These include:

1. Technological progress in the USSR has been characterized as proudly originating essentially from its own roots. This influenced the manner in which scientists and engineers solve problems, often far from economic reasoning, particularly in the short term, as it is unnecessary to start most investigations for new innovations or inventions from scratch in today's international scientific community.
2. Science has habitually neglected the market influence of society's demands. Science and technology appeared to be more imposed on society in the centrally planned economies than in the West. S&T were based much more on social integration in Western than in socialist society. It is considered by some to be a paradox that a capitalist based system has lead to a better quality of life.
3. A major problem was the branch system or monopoly, which has been previously discussed in this paper. While management of S&T in the So-

viet Union is rapidly becoming increasingly obsolete causing significant inefficiencies and unproductiveness in the economy, the advanced western industrialized countries are building new systems with technological growth potential.

The Russian science and technology policy, which is being developed parallel to the other measures for economic transition, could have a more relevant and applied perspective for dealing with issues concerning the management of R&D if the following initiatives were undertaken:

1. Conversion of the defense-oriented R&D to concentrate more on civilian issues. This is, at least to a some extent, beginning to happen. In fact, some specific branches within the military-industrial complex (MIC) was already responsible for producing certain civilian goods in the 1980s under the still communist leadership. Additionally, there is a need for simultaneous commercialization and privatization of the state MIC that can make conversion effective.
2. Directing a portion of the scientific effort towards specific areas that are less sensitive to short term price changes so that valuable resources and potential will not be lost.
3. Closer interaction with other policy areas. Science does not operate in a vacuum, so it should not be isolated from but integrated in society and economy facilitating the liberation of creativity and the encouragement of exchanges and reviews.
4. Closer ties with user needs. These make R&D effective and commercializable. If R&D is linked to industry in a more competitive environment, it is consequently tied to user needs.
5. Actual integration of R&D into industry in order to link it more closely to the production process and eliminate administrative and bureaucratic inefficiencies and barriers. This implies a need for the development of more in-house research.

With regard to the time horizon of R&D activity, an increased devotion to short term projects causes the squeezing out of relevant long term research. Furthermore, the question concerning the portfolio of R&D has been a contentious issue in the West; this was also true in the final phases of Soviet reform and is still the case now and will continue to be so in the Russian reform of R&D policy. The rise of the independent industrial research laboratory owned by the firm in the West, was to separate some of the scientists and engineers from short term work. A typical example of the structure is a central laboratory (dealing with longer term issues) and decentralized laboratories that are closer to production, doing shorter term, demand oriented work. A final note related to timing: the R&D community of the former USSR and now especially in Russia is struggling to accommodate economic reform and not the other way around.

In order to make valuable contributions when proposing alternative measures for change, good and reliable statistics must be available to work from. Numerous questions have arisen in the discussion surrounding the reform of Soviet/Russian R&D management and the science and technology sector on the whole with respect to the availability of such statistics, their value, reliability, comparability and meaning. Information provided indicates a need for major restructuring in the field of R&D statistics in Russia. Before any policy decisions are made, it is crucial to have a clear and undistorted picture of the existing situation (i.e., R&D performance and potential). There is a need for modern and comparable statistics because the historical data collected are the product of the old institutional structure and were normally presented in isolation. The new style in the last years of the USSR and in the first years of the RFR is to rely heavily on surveys. But, whether these generate the best results, particularly because so much depends on who is filling in the questionnaires, is uncertain.

As a result of traditionally inflated numbers coming from the Soviet Union, there is much interest in the precise definitions of the measures reported. For example, whether only full-time workers are included in R&D employment, who is actually classified as a scientist,[6] what precisely distinguishes a higher educational institution, what should or should not be included in material and technical resources and so forth. The meaning of certain indicators must also be clarified. For example, the age of equipment leads to questions of whether they were *state-of-the-art* when purchased, or an increase in graduate students may not have as positive an increase as first thought if, as in the US, there is a strong influx of foreign students (indicating that the number of domestic students may actually be decreasing while the total is increasing). Finally, the key will be a successful restructuring of R&D categories to best allow domestic analysis and international comparisons (possibly on a value basis). A first step may be to compare the

[6]In the United States, only 35% of scientists are directly employed as R&D personnel, while 45% are employed in related activities. These make an essential contribution to research development and growth without being immediately associated with R&D. They are involved in marketing, communication, exchange programs, etc.

definition of former Soviet categories or indicators with those defined in the Frascati Manual and routinely used in OECD countries.

The Survivability of R&D

Western experts often question why and how the Soviet science and technology sector was able to grow so large in the presence of such formidable obstacles. Obviously, there were political and ideological goals at the foundation, not those of the economy or the market.

The decline of state R&D financing must be seen as a process of weaning the R&D sector from full state dependence. Market forces inevitably result in a dilemma; no success without failure. But, the uncertainty incorporating the risks of failure and the benefits of success provide precisely the incentives required for competition. On the whole, Soviet state enterprises did not show sufficient initiative. Thus, private entrepreneurs may do better in striving for survival. In the case of computers for example, it appears that a great market for specialized and tailored software existed in the USSR. However, having the best technology will only be part of the success required to achieve market share, others are development, service, marketing, and so on.

Science and technology is a mixed system in most western economies. The key is to move the research into an innovation quickly so that it can enter the market soon in order for the benefits of the product to be available. In the steel industry, for example, the producers themselves develop the research due to inter-industry competition (this is referred to as suicidal R&D, but if they do not do it, their competitor will). While the decrease in Soviet state funding was been accompanied by an increase in contract funding, the quantity of research contracted out in the West is kept to a minimum. The Western combination of in-house and external R&D is a perfect example of the mix of market and planned economics: internal R&D is more part of planning rather than market because the risk is high, there is uncertainty that often makes contracts unenforceable, and once much has been invested in a project there is a desire to preserve that continuity.

Soviet policy-makers should proceed with caution when attempting to directly apply present western standards with respect to R&D management in any industry or sector because many of these standards are undergoing transitions in the West. It would be preferable to aim for longer term goals rather than short term advance that would only close in on a current level that may prove to be obsolete by the time it is attained.

R&D and Technological Change

The Soviet economy appeared to be the most monopolized in the world of industrialized nations. Soviet innovation was a function of the bargaining process and is associated with rising inflation. In comparison, western innovation has been identified with falling prices as a result of reduced costs brought about by the diffusion of the innovations.

The following four factors are essential to successful innovation in the West and could, to varying extents, contribute to improved R&D management in Russia:

1. Industrial R&D is largely financed by firms and done in the industrial laboratories owned by firms. The R&D must be done in facilities that are directly responsible to management.
2. A competitive approach to technological change. Russian S&T experts identified the domination of monopoly power (the failure to have a competitive industrial structure) to have hindered innovation. Thus, there is a need to restructure in order to encourage competition.

   A look at the industries with great growth and clear technological progress in the West reveals that they have all been characterized by avid competition. A diversity of approaches to technological change developing simultaneously is an essential element that generates technological change in a market economy. Competition is required to provide incentives (i.e., the threat or risk of failing, not to mention the sweet taste of success).
3. Scientists and engineers enjoy freedom to move. Mobility is essential for creativity. Communication is required in generating a proper structure conducive for innovation. Of course, too much mobility is deleterious for the firm's innovative activity due to proprietary reasons.
4. University research plays an important role in industrial innovation in the West. The usual mechanism is people in industry identifying the needs that would be profitable and then reaching back to science for the answers. Thus, it is need and demand driven rather than science driven, though science facilitates finding the solutions.

The Russian Federation cannot now simply look toward contract research to solve the non-market problems of the S&T sector. Towards the end of the communist era in the 1980s, when reform had become an inevitable requirement for survival, contract research was frequently identified as a favored route to achieve market orientation in research and development. More emphasis should be accorded to the need for a move toward in-house research. The fact that Soviet R&D laboratories were and have commonly remained, in a way, disconnected from manufacturing presents a real problem. A possible solution may be to divide them up by assignment and subsequently allow the market to direct the labor to those fields in demand.

Some of the problems that previously plagued the R&D community in the USSR and continue to burden it under Russian authority are not unique and, therefore, should not be viewed so pessimistically. Inevitably, due to the market environment that is at its basis, Western science does not have an overall, coherent, concentrated, and organized unified quest for truth; rather, there is an intense individual sense of competition. This competition may not be without costs. But the advantages of dissemination of scientific results are very great in the West, and thus it is actively inspired. From this perspective, the results of a recent survey investigating R&D managers behavioral reaction to the reform of R&D organization, which revealed that managers generally favored decentralization, private ownership, mobility and other aspects of reform, are encouraging and display courage and ambition on their part. On these grounds, the outlook for Russian S&T becomes more positive.[7]

The area of international technology transfer is important and will gain in importance as the process of transition to a market economy continues. An entire chapter of this paper has been devoted to this subject. The emphasis on the export of technology is understandable due to the need for hard currency, but a more appropriate policy orientation would have the emphasis on technology imports. This will bring the necessary results for long term modern economic growth if the surrounding environment is receptive.

The current need for foreign currency should be secondary to the effort to build up internal welfare based on domestic economic growth. Some experts contend that the more technologies can be imported, the faster they will grow, assuming that the domestic research and technology levels are at least sufficiently compatible to facilitate easy and useful assimilation. The technological balance of payments will be negative, but the trade balance could be running a large surplus (as in Japan, Germany, South Korea, Taiwan, and others). Other problems (including hard currency shortages) will

[7]Refers to the survey concerning managers' interpretations of R&D organization and structure within the framework of the economic reform program. This study was presented by Leonid Kosals at the IIASA conference *R&D Management in the Transition to a Market Economy* in Moscow, July 13–15, 1991.

be solved in the long run, but some strategic vision from the state on R&D imports can be helpful immediately (particularly where problems may arise with respect to the financial limitations of enterprises).

Possibilities for R&D Restructuring

One of the first places to begin restructuring with some of the greatest potential rewards is the monstrous, until recently well-financed military-industrial complex. Conversion of the military industry is a common and widely discussed topic in Western industrialized economies. Countries like Japan or the USA have gone through quite extensive conversion programs in the past.[8] The conversion can come from above in the guise of a centrally planned conversion, or it can come from below when each enterprise seeks its own destiny. The latter, decentralized manner was typical of the USA. In Japan, conversion was sudden, but goals of the ensuing policies were to facilitate competition with an early emphasis on serving the world market with domestically developed products. Conversion from below is usually more successful because it produces products and technology that the civilian sector is demanding. The reorientation from the defense to the civilian sector has great potential due to the big backlog of demand for civilian products which has arisen during the decades of concentrating on military production.

The Russian Federation has many assets that can be provided through conversion and the transition to a market economy. Many firms of the defense ministry are already producing a number of civilian products, primarily because no civilian firms engage in such production. Also, this great nation has a very well educated and highly trained population, particularly in the fundamentals. The West will need to provide assistance in certain areas such as education (exchange of students, scholars, managers, etc.) and technological agreements. Knowledge is more important than equipment (and much cheaper because it requires less foreign exchange) in the long run when the purpose is to build up domestic S&T potential.

In developing the appropriate environment for progressive R&D there is an essential need for the construction of legal support for innovative activities. The law is to be a facilitator rather than a barrier for R&D. It is difficult to provide a complete legal structure for research, development,

[8]In 1945, the USA had to undergo a much larger conversion than that facing the Soviet Union. At that time, approximately 40% of US GNP was devoted to defense. In Japan the large military sector, which was built up during WWII, disappeared overnight after the war.

innovation, and diffusion. This structure must be adaptable and flexible as more is understood about the innovative process. Of course, providing model forms of contracts and legislation is valuable, but scope must be provided for adaptation and evolution of such documents.

Preservation of the rights of individual scientists is very important. The individual inventor may not play a big role alone in developing innovations, but his role in an R&D enterprise is and will be crucial. There is a definite need for support for the intellectual labor market. There is no question that the concept of property rights must be clarified. In the West, different industries use different methods in appropriating rewards from R&D such as secrecy, lead time, patents, and others. Market orientation gives enterprises alternative modes for appropriation and there may be a lesser role for the more formal methods (i.e., copyrights, patents, trademarks) as would be expected ex-ante.

It is ironic to observe that in the transition of the Soviet Union to a market economy, it is Lenin's question that we face: *What is to be done?* This section attempts to move us a considerable distance in thinking about this question.

There seems to be general agreement among both experts of Soviet/Russian R&D and scholars of Western R&D systems that basic, fundamental R&D will need support during the transition to a market economy in Russia and thereafter. There is no economy which relies entirely on private funding in this area. It is the nature of basic research that it investigates not directly profit-making areas, in which firms (profit oriented in a market economy) tend to under-invest. Applied research should be primarily funded by the private sector with the exception of private R&D that are aimed at or tailored to specific national preferences (i.e., defense), and in areas where goods are not really traded in the market (i.e., health, environment, ecology, and others).[9]

Funding becomes a key issue in the transition as there may be inadequate demand for applied R&D during this stage of development. The danger of insufficient private sector demand is the potential loss or destruction of valuable human capital (research teams, etc.) that may be very productive in the future Russian economy. These may need to be the beneficiaries of some transition (temporary) subsidies.

As stated earlier, a diversity of organizational forms is ultimately desirable. The same organizational form is not necessarily appropriate for all

[9]This is representative of the organization of R&D funding in most market economies.

types of S&T activities. Many western experts are strong advocates of the view that the market should select appropriate organizational forms, but the market can only achieve such a solution with a decentralized style of laboratories and institutions with a variety of alternatives. Therefore, some science and/or industry might be quickly integrated into a new system, while others may stand alone for some time.

Let it be re-emphasized that even if one believes that R&D done within the manufacturing enterprise will become the dominant organizational form, engaging the existing laboratories in contract R&D activities is likely to be a viable route during the transition if market forces are allowed to operate in full. It may prove to be tough for laboratories to be absorbed into firms, because they may want to enter manufacturing directly. The latter is just another route the market provides. For market purposes, it is irrelevant whether the laboratories buy enterprises or vice versa.

In returning to the problem of inadequate demand for R&D products during the transition, it appears that the applied field will face more difficulties than the basic area, though both will need some forms of support. It may prove to be unavoidable to continue a similar magnitude of (only) financial support from the state budget to basic science as was the case in the recent past. This must be accompanied by simultaneous, substantial changes with respect to establishing principles of competition for funding, competing sources, peer review, expert assessment for determining national priorities, and so on.

Applied research presents a more formidable problem. Assistance will be required in the interim, but if it is too generous it can deter and defer the development of competition, innovation, and the benefits thereof. Transitional subsidies may make sense, but a new tax might accomplish the same results. The operation of the tax should be studied more closely to determine whether rules that govern the tax distort, in any way, the laboratories' or enterprises' choice of organizational structure. Experience has shown that it is preferable to avoid taxes that create an incentive to promote stand alone research laboratories or solely contract research. Any tax scheme is required to be neutral, while providing adequate funds for investment and development.

Finally, there is a fundamental dependence of scientific and technological reform on legal and economic reform. In the legal sphere, the central issue is the establishment of property rights of all forms (intellectual and material). The more quickly an appropriate legal framework is in place, the more rapidly the transitional problems will disappear.

In the economic sphere, it is clear that for rational technological assessment at the enterprise and national levels one needs the right prices (those that reflect the market determined supply and demand). Demonopolization is essential to allow competition to drive R&D investment. There are two separate benefits to demonopolization:

1. Some competition will turn out to be better than no competition, and
2. In terms of increased size of total private resources invested in R&D, demonopolization and consequent competition will facilitate an improvement of the functioning of the selection process (the moving toward more desirable organizational forms).

Labor mobility is also of major importance in the economic sphere. S&T workers must be free to choose their employer and vice versa. To restrict labor mobility is to exclude a large fraction of the potential benefits of economic reform.

Some Concluding Remarks

So, what can one extract from all the preceding analysis? The Soviet-style central planning model has demonstrated that it may be possible, at least for a while, to reasonably plan production (supply) and even to steer the desires of the public depending on the ideology underlying the political system in order to plan the consumption (demand). Yet, Soviet-style socialism in all aspects of the economy including the management of research and development, particularly in comparison to the principles ruling a market economy, has proven that it is incapable of planning innovation to achieve the conditions corresponding to modern economic growth and development.

Innovative activities, that is research and development, are creative, dynamic, and evolutionary processes that depend on an economic environment that will provide:

(1) the financial support when it is warranted and required to realize and introduce an idea for commercialization that will increase overall social welfare, and
(2) the rewards that result in the continued interest of individuals and various types of public and private groups (institutes or companies) to engage in R&D and make technological change a cumulative process.

As Schumpeter emphasized, innovation is spontaneous (though ultimately founded on previous achievements) and occurs at a non-linear rate over time. Thus, truly productive research and development, which supports the progress leading to the successfully and continually transforming societies in which the standard of living has reached the level we in our western industrialized nations have become so accustomed to, can only really flourish where economic policy has laid the foundations of a market system. One in which the consumers' desires reverberate all the way to the researchers and scientific experts who must respond, and for whose investigations, experiments, and development certain forms of free and secured financing is always available but not automatic. Only potential success in a competitive arena can procure the necessary resources to generate the success. Of course, as is evident in Western examples, this does not preclude the presence of some strategic government intervention to aid the cause, not to interfere with but rather to support the functions of a R&D market.

Although this may be thought of as wasteful at first, it is really a method for improving efficiency. Namely, fewer valuable resources are discarded on worthless prospects, or at least not before their time has come. In addition, the actors are endeavored to inevitably provide the optimum currently available in an effort to stay ahead of any competitors. The resulting choice for the broad populace, the consumers, starts the process all over in a continuous, dynamic fashion.

In the former Soviet Union, the entire economic system was in a static state—no dynamism, no change, no evolution. Like the dinosaur, it did not alter its characteristics, behavior, habits, or relations with other components of the changing system in order to accommodate the modifications in the environment. And, like the once mighty and feared dinosaur, the technological strength of the old union of Soviet Republics is confronted with potential demise. The only way *not* to follow in the footsteps of this prehistoric analogy is with the implementation of appropriate R&D management in the transition to a market economy. There must be competition, demand responsiveness, and international support and exchange, as well as cleverly directly government policy.

In the past, a number of economists have frequently called attention to a tendency to under-invest in R&D in the private sector; that is, firms devote too few resources to the development of new technology.[10] There are several reasons for this. Firstly, by now we know that R&D is a risky activity and many firms appear to be rather risk averse. But even more important are the short-term time horizons within which business operates that make

[10]See, for example, Mansfield (1980) and Rosenberg (1980).

it difficult for firms to appropriate the benefits that society receives from new technology. In addition, some industries or even specific R&D activities are characterized by certain indivisibilities such as economies of scale or industrial fragmentation which prevent some, often small organizations from undertaking them efficiently (Mansfield, 1980, p. 139). As a result, several of the experts contend that a more extensive system of government subsidy is needed to better articulate society's legitimate longer-term R&D needs and to strengthen the incentives of business in technology development involving more distant payoffs (Rosenberg, 1980, p. 129). Considering all these difficulties in enabling productive and efficient R&D for the general benefit of society under market economic conditions, central planning may look like an attractive alternative at first glance.

In fact, the Soviet-style of central planning as it was formulated in the 1930s and 1940s was based on numerous principles that could have solved the potential problems arising in a market structure. The Soviet scheme for R&D management was expected to be accompanied by many benefits, including the effects of larger scale, the potential to eliminate duplicate work, the extension of time horizons, and the selection of projects according to social (not private) rates of return.

While this style of management originally satisfied at least the planners' requirements, the increasing inability to detect all the rapidly growing needs of both society and producers lead to inadequate quantity and quality of output in both the R&D and manufacturing sectors despite the overly abundant rate of growth in inputs. Indeed, during the extensive-growth policy environment of the 1950s and 1960s, the planners' demand for innovation focussed on technologies that increased the quantity of output, rather than on cost- or resource-saving technologies that were the key to a modern-style growth future.[11] Therefore, the same politico-economic conditions that promoted a valuable and enormous R&D sector (as inefficient or unproductive as it has been accused of being) also created an environment where this sector was essentially detached from the production or consumer sector. The real demand was lost in the R&D management process.

By the end of the communist leadership in the Soviet Union, the R&D sector had become riddled with issues that were reason for concern when anticipating the future. Soviet scientists and engineers were simply engaging in R&D activity in an overburdened bureaucratic environment. Bureaucratic

[11]See Linz (1992) for a thorough discussion of planners as barriers to innovation (pp. 68).

barriers to communication and low scientific mobility added the isolation of R&D workers from their domestic peers to their relative international solitude. There was generally a rather low sophistication of equipment and supplies, and especially a lack of access to computers that could have made scientists' and engineers' work many times more efficient. The age structure of leading Soviet researchers led to a dominance of the old (in ideology and age) directors of institutes that were against change. A bargaining style of politics developed that caused the acceptance of scientific overemployment at the expense of underutilization.

But rather than continue to describe the problems of Soviet R&D, more enthusiasm should be shown for the positive aspects: the achievements of scientists and engineers in the admittedly difficult working conditions in Soviet laboratories other than in some particular sectors. In fact, the Soviet system did have some virtues that also deserve attention. These begin with the enhanced level of prestige afforded the scientist on ideological grounds; until the relatively recent past, their annual income was higher than that of firm managers—quite contrary to the situation in, for example, the USA. In general, the Soviets were devoted to consistent long-term approaches to problem areas and the use of well proven techniques.

Just previously, the low sophistication of equipment and instruments were alluded to as detrimental, yet even this had its positive side. It fostered craftsmanship and creativity, and a low technician to researcher ratio. This, however, resulted in numerous scholars, particularly the younger ones, having functions very different from those they had been trained for. Combined with a relatively high standard level of idleness, this indicates that a considerable amount of the educated capacity was not utilized in a productive manner. Yet, such a phenomenon was not specific to the input side of the R&D sector, but also typified the output side. A high proportion of research work was left unused (or incomplete) *"on the shelf"* and firm inventories were full of non-installed domestic and foreign new machinery. Communist leaders of the former Soviet Union had recognized this problem and repeatedly voiced their concern at various party congresses since the early 1940s regarding the large quantity of scientific discoveries and important inventions that lie around for years or even decades without being introduced into practical applications (Berliner, 1987, p. 72). Who knows what the potential impact may be if only a portion of the idle capacity were harnessed?

The possibilities seem unabounding. Particularly today, when Russia is undergoing the transition to a market economy and the economic, institutional, and ideological foundations upon which the scientists' and engineers' working environments were predicated for so long have finally been all but swept away. The former official Western discrimination and the parallel reluctance of the East to become too dependent on the West are both no longer barriers to Russia's opportunity to rejoin the global mainstream in research, technology, and economics.

Science and technology establishments in Russia, are well endowed with qualified personnel and other factors (R&D expenditure taking a proportionately larger share of national income for many decades under Soviet leadership than was and is usual in the West), and are, contrary to others in Central and Eastern Europe, substantial as far as the world scientific community is concerned. The concentration of scientists and engineers in the R&D institutes could provide an ideal environment in which the giant S&E workforce can be introduced to the functions and characteristics of a market economy with respect to science and technology. Russia does not have to fall into the classical position of a product-cycle follower as many of its neighbors might. During the transition and possibly for some time afterwards, imitation may be the dominant style of technological advance, but the ever present innovation should soon become more significant.

Therefore, in a nutshell, Soviet-style R&D management resulted in an unproductive and inefficient use of and a low if not negative social rate of return in the long-term on the enormous resources going into the promotion of scientific and technological activity. Under new management methods, such as those characteristic of a country as Russia, attempting to complete the transition to a market economy, much of the R&D resources created under the former regime could effectively be used to generate crucially needed growth in the economy. This growth could lead to an improvement of the Russian economy and renewed prominence for the Russian S&T community, but based on reality and not the plan. Russia's position in the world market, and the latter's functions with respect to Russia would change.

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