RUSSIAN APPLIED RESEARCH AND DEVELOPMENT: ITS PROBLEMS AND ITS PROMISE

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Chapter 1

Introduction

Leonid Gokhberg, Merton J. Peck, and János Gács

1.1 Why Applied R&D Matters

In the decades following World War II the USSR was one of the two great powers in research and development (R&D); the other was the United States. In 1990 the USSR had over 1 million researchers, more than any other nation except the United States. Its achievements (especially in nuclear and space R&D) contributed to the picture of the USSR as an R&D superpower. The Soviet economy was research intensive, and after the breakup of the Soviet Union many observers considered the R&D sector to be one of the most valuable assets bequeathed to the new Russia. Science and technology (S&T), freed of the rigidities of central planning, was held to provide the basis for high-technology exports and eventual economic growth. Like many of the rosy hopes for Central and Eastern Europe, the prediction was wrong. The R&D sector went into a precipitous decline that continued until at least 1995. Neither the promised exports nor the growth materialized.

This collection of papers contributes to answering the question, What went wrong? We stress the word "contributes." Recently Russia has experienced a downturn in real output that is greater than that of the worldwide depression of the 1930s. Obviously the R&D sector could not be insulated from its consequences, and for our purposes we take that event with its complex origins as given. The impact on the R&D sector, however, was particularly severe, indicating a particular vulnerability of the sector to the adverse economic conditions between 1991 and 1994. Certainly its inherited main features impelled this decay. R&D was financed centrally by the government at a time when fiscal austerity prevailed. R&D was organized under industrial ministries at a time when their powers were declining.

R&D had a weak voice in the government and parliament when lobbies of industry and agriculture were speaking loudly. These factors are well known, but the detailed ways in which these general factors worked to radically downsize and partially destroy the R&D sector inherited by Russia are less understood. The chapters in this report add to the understanding of these complex events.

It is a painful story to tell, for the careers of many scientists and engineers were ruined. It may also be a costly situation to remedy; R&D teams and organizations, once disbanded, cannot be easily reassembled nor can expertise, once unused, be regained. A loss in the R&D sectors then is harder to offset than in other sectors.

The decline was more pronounced in the applied R&D sector than in basic research. Thus the number of researchers in the Russian Academy of Sciences (RAS), engaged primarily in basic research, declined from 137,000 in 1990 to 112,000 in 1994 (18 percent), while the total number of researchers in Russia fell from 1,227,000 to 540,000 (53 percent).

Although applied R&D accounts for nearly 90 percent of Russia's R&D expenditure, it is not just size that gives it greater economic significance than basic R&D. Applied R&D is the basis for innovations – namely, the introduction of new products and processes into the economy. It is only when innovation occurs that the population benefits from science and technology. Despite this, basic research has always had the attention of the media. R&D is visualized by many as an Einstein at his chalkboard, a Fleming in his laboratory, or a Szilard at his cyclotron. Yet it is the more mundane activities such as designing a faster machine to produce disposable diapers or a better operating system for a computer that account for the billions of dollars spent on R&D in every industrialized economy. Such applied R&D activities raise productivity, which is the ultimate source of improved living standards.

There is another significant characteristic of applied R&D that differentiates it from basic R&D. The results of basic research are usually published; the tradition of sharing results is long and strong in academic science. A company can benefit from published basic research whether the authors are in Cambridge, England, or Cambridge, Massachusetts. Not so in applied R&D. The results are often patented, giving exclusive use to the inventor, or kept as a trade secret. Applied R&D is considered a weapon in the competitive struggle among corporations and its value depends on maintaining its exclusivity. Companies seldom give away the results of applied research. In the high-technology sectors, every competitor devotes substantial applied R&D activity to its exclusive needs. The same logic applies to nations. If a nation wants to rely on high-technology exports and advanced technology for economic growth, it will need an effective applied R&D sector for the same reasons that companies do. Alternatively it can purchase applied research by paying for know-how, patents, and the like or access applied R&D by inviting a multinational corporation to locate a plant within its boundaries. One way or another, a nation must pay for applied R&D; there is no free lunch.

A nation's applied R&D capability, however, is only a necessary condition for economic advancement. It is not a sufficient condition. Introducing new products or processes requires good manufacturing techniques, marketing skills, and aggressive competitive strategies; capabilities neither developed nor prized in the former Soviet Union.

In spite of all the changes since 1991 the Soviet system of R&D organization is still in force and is shaping the emerging R&D sector in Russia. It is already evident that only part of the vast Soviet R&D sector can and should be saved. Given that Russia needs an applied R&D sector and given that it will be smaller than the Soviet one, the first question considered in this volume is whether the dramatic decline of the applied R&D sector since 1991 has proceeded too far or is the sector still oversized.

The concern, however, is not merely about the size of the applied R&D sector. There is also the question of what R&D structure and organization will best serve Russia in the long run. What is to be saved is being determined in part by governmental policy and in part by the actions of R&D organizations themselves. The organizations are not inert boxes on an organizational chart but collections of talented individuals able to adapt to new conditions. The struggle to survive is clearly occurring. It may not have as its outcome a good organization for the R&D sector. The chances of survival depend in part on the economic and political positions that these organizations inherited from the Soviet era, in part on the entrepreneurial skill of managers and staffs, and in part on their influence in the political and bureaucratic process. None of these attributes are necessarily correlated with the long-run value of an organization to the Russian economy. In asking what kind of applied R&D sector will best serve Russia, we are, of course, asking how does this ideal compare with what is emerging.

The third question considered here deals with the present and future role of government policy. If this volume were about applied R&D in the United States or Japan it would be mostly about large companies such as IBM or Mitsubishi Electric and the small ones that have been highly innovative. This is because most applied R&D in market economies (apart from that for defense) is company financed, company directed, and company performed. In a competitive market profit prospects determine the level and direction of R&D spending.

In the Soviet Union, however, enterprises did not have this role but rather they maintained the tradition of passivity with respect to R&D. R&D was largely supplied to the enterprise as a free good. The Soviet applied R&D system was linear with a progression from the R&D institutes, which did the research, to the design bureaus, which used research results to design a product or process, to the experimental plants, which carried out pilot production, and to the enterprise that carried out the mass production and so introduced the new product or process into the economy. The chain was held together by participating organizations that were subordinate to the industrial or branch ministries which were responsible for various sectors of the economy. R&D, like most everything else in the Soviet era, was government directed and financed.

The expectation was that with the transition to a market system manufacturing enterprises would take over the ministry role of coordinating R&D with the needs of manufacturing. Enterprises would direct R&D and finance applied R&D in response to market signals and pressures. In the process the enterprises would support the separate R&D organizations, obtaining their services by contracts. None of this has happened on a significant scale. The enterprises, like the R&D organizations, were dramatically affected by the overall downturn in the economy. They too became involved in a desperate struggle for survival. Support of R&D, with its long-term payoffs, was considered a postponable luxury. The institutions that make enterprises effective in market economies are missing. The financial system is in infancy and fails to provide long-term capital. Ownership rules and corporate governance are primitive. Macroeconomic stability is inadequate for long-run decision-making. Corporate law is yet to be developed, let alone implemented. Property rights of all types are threatened by the Russian mafia.

The consequence has been that the government has had to keep on providing the funding for most R&D. The choice was either government funding or none at all. And with the funding came the governmental setting of priorities for applied R&D. The story of Russian applied R&D in the transition thus is one of government policy. The avowed long-run objective of policy still remains the creation of an applied R&D system more like the enterprise-financed and directed organizations in industrialized economies. The difficult questions are, How can public policy encourage this evolution from government support of R&D to enterprise sponsorship of R&D? What should public policy be in the interim? Should the role played by the Russian government in the long run be different from or larger than the role played by governments in other market economies.

To sum up, this report is concerned with three broad questions:

1. Was the decline in applied R&D from 1991 to 1995 too steep or too modest for the welfare of the Russian economy?
2. How should the organization and structure of Russian applied R&D develop over the long run?
3. What role should public policy play in Russian applied R&D?

The chapters that follow do not explicitly or directly answer these three questions. Rather they examine particular aspects of the applied R&D system as it developed in the first four years of the transition from its Soviet character. They also describe the Soviet system, focusing on its legacy to Russia and particularly the unsuccessful changes introduced in the *perestroika* era to decentralize decisions. Only implicit answers are given in the chapters, but in the concluding chapter we confront the three questions directly.

The remainder of this introduction discusses the origins and organization of the volume and defines a few concepts used in the chapters.

1.2 The Origins and Organization of the Volume

This report traces its origin back to the spring of 1990 when then Soviet Deputy Prime Minister Nikolay Laverov asked the International Institute for Applied Systems Analysis (IIASA) to do a study of the Soviet R&D sector. This work was to be done in collaboration with the USSR State Committee for Science and Technology and the USSR Academy of Sciences under the general title of "Research and Development Management in the Transition to a Market Economy." In November 1990 and in March 1992 conferences on this topic were held with participants from the USSR (first conference) and Russia (second conference) together with scholars from the West.

The conclusions from these two conferences were summarized by Peter de Jánosi and Vladimir Mikhailov in several propositions in an earlier IIASA volume (Glaziev and Schneider, 1993):

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. . . .
3. The lack of adequate demand for all forms of research is a major problem of the transition. . . . Consequently there may well be a need for transitional subsidies.
4. International experience has shown that a diversity of organizational forms is desirable. . . . The predominant organizational form, the one most important, is the in-house proprietary form done within large corporations.
5. Finally, there is a fundamental dependence of science and technology reform on the success of overall legal and economic reform.

The chapters in this volume, written three and one-half years later, still support these five propositions. The difference, as already suggested, is that the transition proved to be more lengthy and more difficult than expected in 1991. The shift from transitional governmental support to that from enterprises that follows from the first and second proposition remains to be accomplished. There is little demand for R&D, so the transitional subsidies continue. Organizational forms are still largely the independent R&D institutes of the Soviet era. Enterprise R&D (in-house proprietary R&D) is uncommon. And the economic and legal reforms of proposition five are still to be implemented.

Since the first publication, much has happened that deserves analysis beyond simply the observation that reality has proved more difficult and unpredictable than anticipated. Accordingly it seemed worthwhile to the IIASA leadership and the senior officials of the then Ministry on Science and Technological Policy (MSTP) to have a second report focused on applied R&D. (In March 1997, the Ministry was renamed the Ministry for Science and Technology of the Russian Federation.) This volume is that report. The chapters were written by Russian senior officials and established scholars. It was recognized that the project would also benefit from the expertise of scholars of R&D policy from outside Russia. The two types of experts worked together during the three conferences that were organized. Chapter outlines were the subject of the first conference in July 1995; first drafts were presented at the second conference in December 1995; and final drafts were discussed at the third conference in April 1996. Since then, the April drafts have been extensively edited.

The chapters trace the complicated story of the transitional years, 1991 to 1995. In Chapter 2 Leonid Gokhberg describes the main features of the Soviet system and why it was inefficient and so alien to the principles of a market system. He shows that many features of the Soviet system have persisted and continue to plague the efforts of Russian officials to restructure the R&D sector. In Chapter 3, Viacheslav Alimpiev and Alexander Sokolov describe the past and current institutional structure for applied R&D, including the changes in the Soviet era and in the transition. They show that it is an oversimplification to think of a single Soviet or transitional R&D system; rather there were repeated modifications and experiments, all retaining, however, the fundamental features of a planned economy. These two authors also report on the emergence of new organizational forms that relate to R&D, particularly the creation of financial and industrial groups that bring together financial institutions, manufacturing enterprises, and R&D institutes in ways analogous to Japanese *keiretsus* such as Mitsubishi or Mitsui.

In the next chapter Leonid Gokhberg reports that the signs of recovery in a few sectors will have a favorable impact on applied R&D. Exports often play a major role in the recovery. Some sectors – particularly those in light industry – continue to decline with few prospects for a turnaround. The economic situation of a sector is a major determinant of its R&D activity, thus showing on a sectoral level the proposition mentioned earlier for the entire economy – a high level of R&D activity requires at least some economic health.

In the fifth chapter the authors, Serguei Glaziev, Il'dar Karimov, and Irina Kuznetsova examine innovation activity. They find that its significant decline in the transition is primarily due to the poor financial health of enterprises. They offer several policy prescriptions, going beyond R&D policy to consider the implications of macroeconomic policy for innovation activity.

The sixth chapter by Levan Mindeli discusses the integration of Russian R&D into the international economy. The USSR deliberately isolated itself from the international R&D activity that emerged after World War II. Western nations added to the isolation by limiting exports to the Soviet Union of some high-technology goods that might have strategic value. After 1991 most barriers were removed, and the new Russia began to be part of the international system. International R&D activities in industrial economies are carried out by enterprise-to-enterprise transactions for mutual profits. Russia's participation in this process is limited by the financial weakness of its enterprises. Direct investment by multinational corporations – another way for the international diffusion of technology – has also been low, reflecting greater economic and political uncertainties in Russia than in other economies in transition. The Russian government has instituted policies to encourage international R&D activities and to offset the weakness of enterprise involvement. Still given the size of the economy, Russian participation in the international R&D system has been modest though it is growing from its low starting point.

Chapter 7 by Andrey Fonotov and Lioudmila Pipiia critically examines current and proposed public policy. The authors point out that any support for R&D has the opportunity cost of less support for activities serving other economic or social goals. It is not enough to show that some R&D activity is desirable; it must be shown that R&D support on the margin is more beneficial for society than the activity that will be forgone. Inevitably, R&D support will be politically controversial. The second major point in this chapter is that governmental support should no longer be distributed among organizations on the basis of their financial requirements. Instead it should be allocated according to the importance of their research for Russian society. Competition should be used as far as possible in allocation decisions. The authors also propose a system of repayment of government support from the revenues of successful projects. Such radical changes naturally have encountered opposition among research organizations, and the change is likely to occur gradually.

This quick tour through the chapters fails to do justice to the many issues discussed. We can do no better than to invite the reader to turn to them.

1.3 Caveats and Definitions

Before doing so, however, we need to say a word about the editorial process. We regard the volume as an integrated report on Russian applied R&D rather than a collection of conference papers. As a result we have been bold in the editing. We have rewritten some pages to clarify their message. We have cut out sections that duplicated material in other chapters. We have even moved material from one chapter to another. Still we have tried to preserve the essence of each author's original paper, and we have given each author an opportunity to review the final version.

The definitions of various terms are given in the chapters in which they are used. There are some terms, however, that occur in almost every chapter including this one – terms such as basic research, applied research, development, and innovation.

All these terms have been standardized by the Organisation for Economic Co-operation and Development (OECD), and we adopt its definitions. *Basic research* is activity aimed at obtaining new knowledge of the underlying foundation of phenomena and observable facts without any particular application or use in view (cf. OECD, 1994c). It can be either experimental or theoretical, and it usually takes as its starting point existing scientific literature. In contrast, *applied research*, while also aimed at acquiring new knowledge, is directed primarily toward a specific practical aim or objective. Note that the difference between the two kinds of activity is the objectives that are sought. In practice the distinction is less subjective than first appears since the two kinds of research are often carried out by distinct types of organizations that correspond to the two objectives.

Development (or experimental development) is the activity directed at the creation of specific new products or processes, or at the substantial improvement of those already produced or installed. Much of the work of engineers in designing, say, the Boeing 767 would be classified as development. *Innovation* is the transformation of an idea into a new or improved product introduced to the market, or to a new process used in industry and commerce. To the reader unfamiliar with this terminology our definitions are likely to be unsatisfactory. There is no precise boundary that separates basic from applied research or applied research from development, despite the substantial literature on these definitions. All we can offer in defense is that R&D statistics for Russia and every other country are based on these definitions and they have proved their worth. Other terms used almost as frequently in this volume are applied R&D and S&T activity or policy. *Applied R&D* simply means the combination of applied research and development as just defined. *Science and technology* is a broader concept that includes scientific and technical education and scientific and technological services as well as R&D.

Chapter 2

Transformation of the Soviet R&D System

Leonid Gokhberg

The current R&D establishment of the Russian Federation largely reflects its Soviet origins. The Soviet R&D system had three special characteristics: it was very large; it was centrally directed; and it was government financed. These features are ill-suited to a market economy, so it was not surprising that the R&D sector underwent a crisis in the first years of the transition (1990–1994).

This chapter presents a brief description of the transformation of the Soviet R&D system. In the first section the major features of the Soviet system are described. The impact of the transition from central planning to a market economy on R&D is then examined in Section 2.2. In the R&D sector, as elsewhere, the transition has not been easy. Only a part of the R&D sector inherited from the Soviet era can and should be preserved. This chapter addresses two questions: Will the decline in the R&D sector stop before it becomes so extensive as to be an irreversible loss for Russia? How can the R&D system be transformed to meet the requirements of a market economy? The chapter concludes that, while the R&D sector has made some major adjustments, many more remain.

2.1 The Soviet System

2.1.1 Historical background

The R&D potential which Russia currently possesses has its origins in the prerevolutionary era. The czarist period established a tradition of excellence and provided exceptional contributions to the world's stock of knowledge. The practice of performing most R&D in institutes of the Academy of Sciences, leading universities, and military laboratories was also established during this era. Only a few of the largest industrial enterprises had R&D departments to serve their internal needs.

The institutional characteristics of the czarist era became the basic elements of the R&D system set up after 1917. The political objectives of accelerated development of R&D to serve military requirements and the industrialization of the economy led to strengthening existing research institutes and establishing new ones. Universities responded to political directives aimed at tailoring higher education for the masses and the training of "proletarian specialists," particularly engineers. Universities, where the most prominent Russian scientists carried out both training and research, now became almost exclusively training centers with relatively little R&D activity. Thus, contrary to the pattern of R&D growth taking place in Western universities and industrial companies during the interwar period, Soviet R&D was increasingly concentrated in research institutes of the Academy of Sciences and of the industrial ministries.

The overall growth of the sector was unmistakable. From 1922 to 1940 employment in the Science and Scientific Services sector grew from 35,000 to 362,000, and its share in total employment increased from 0.6 percent to 1.1 percent. Intensive investment was made in R&D facilities and equipment, and it became possible to carry out research in the most important areas of science and technology.

During World War II the Soviet R&D system demonstrated its ability to mobilize R&D for the production and improvement of weapons. The need to concentrate human, material, and financial resources on military R&D increased the government's role in identifying national S&T objectives and in implementing large-scale R&D projects. The defense R&D complex was formed during World War II. Its size increased in both absolute and relative terms. This expansion in military R&D accelerated the growth of total R&D. By 1950, employment in the Science and Scientific Services sector totaled 714,000 – 82 percent higher than in 1940.

In the 1950s, 1960s, and 1970s the R&D sector continued to expand; by 1990 R&D personnel exceeded 2.8 million in the former USSR. The expansion of R&D was largely in employment rather than in equipment and facilities, but the applied R&D organizations remained separated from production. About half of the R&D effort was for military purposes. The 1980s, however, was a decade in which the Soviet R&D sector lost much of its dynamic character, and the indicators of R&D inputs and outputs showed decline. The inefficiency of the centrally planned Soviet R&D system began to take its toll. Simultaneously the overall rate of economic growth began to slacken, basically for the same reasons: the exhaustion of sources for expansion and the lack of adjustment mechanisms in the centrally organized system.

2.1.2 The problems of the Soviet system

The Soviet R&D sector received increasingly more resources, but the sector lacked an effective market to direct R&D and to make timely structural changes. Negative factors, which have only recently been identified, and which still damage Russian development, were deeply rooted in several features of the Soviet R&D system.

Dominance of Political Objectives

Over a period of decades, Soviet science and technology was guided primarily by political objectives, especially increasing the military capability of the state. In addition, the USSR, as a superpower, followed an ambitious strategy in all fields of science and technology, and an oversized R&D sector was one consequence. Allocation of resources to particular S&T fields reflected the sectoral structure of the national economy, notable for large shares of mining, metallurgy, and heavy machine-building, which itself was ideologically determined. The manufacture of high-tech products and consumer goods and the provision of services were given considerably less emphasis; these sectors were relatively small in the Soviet Union compared with other industrialized economies.

The traditional "technocratic" orientation of Soviet science resulted in a disciplinary structure that was, and still is, significantly different from the structures in other industrialized countries (see *Table 2.1*). For many years, the Soviet emphasis was on engineering, a field which accounted for some three-quarters of all R&D. In the United States the engineering sector does not exceed half of gross expenditures on R&D (GERD). The differences between the Soviet and US patterns of R&D expenditures are especially pronounced in medicine and related life sciences (3 percent in Russia and about 10 percent in the United States) and natural sciences (22 percent and 30 percent, respectively). The share of total agricultural R&D is also very low – between 3 and 4 percent. The amount of future-oriented engineering work was modest as indicated by the fact that basic research constituted only 5 percent of total R&D in engineering. This neglect of basic research does not provide a good basis for future development of technologies (Gokhberg, 1994).

Furthermore, in the 1980s the Soviet system of allocating resources for R&D was unable to provide adequate facilities and equipment even for internationally recognized areas. In 1990, 60 percent of R&D institutions did not own the buildings they operated in, and when market conditions emerged these institutions were threatened with eviction. In the case of biotechnology, for example, 50 percent of

Table 2.1. Percentage distribution of major R&D indicators in Russia by field of science.

	Researchers[a]	R&D expenditure[a]	R&D equipment[b]
Natural sciences	22.2	17.6	21.0
Engineering	65.8	72.6	71.1
Agricultural sciences	3.5	3.6	1.4
Medical sciences	3.4	3.0	3.3
Social sciences, humanities	4.9	3.2	3.3
Total	100.0	100.0	100.0

[a] 1994.
[b] 1989.
Source: Author's estimates; discrepancies in totals are due to rounding.

the R&D institutions did not have experimental facilities; 35 percent did not own their buildings; and 20 percent of the research equipment was more than 10 years old. The proportion of high-cost R&D equipment (as a percentage of the total value) with specifications equal to or above that of world standards varied in the research field as follows: only 14 percent in biotechnology, 21 percent in machine-building-related research, and 24 percent in general physics and astronomy, informatics, computers, and automatization. This indicator was highest in electrical engineering (35 percent) and physical chemistry and technology of nonorganic materials (41 percent); but, even these levels were insufficient to achieve the most advanced scientific results.

Structure and Organization

The Soviet R&D sector was marked by a peculiar institutional structure and organization that continues to influence its development during the transition period in Russia.

Research institutes separated from both enterprises and universities were the principal organizational form for R&D in the Soviet Union, and this is still so in Russia (see *Exhibit A1.1*). Along with institutes conducting research as their primary activity, there were also other units specializing in development (such as design, construction projects, and experimental work) which worked independently of industrial enterprises. Only a few universities and enterprises combined R&D with education or production.

R&D was also guided by the general principles of the Soviet administration. Like other organizations, R&D institutions were attached to specific branch ministries, each of which supervised an industry or sector of the economy. Ministries had exclusive control over their assigned sectors of the national economy including the related R&D. Allocation of resources was influenced by “weights” of particular ministries in governmental hierarchies and in the political process. In the 1970s, the years in which the Soviet bureaucratic system flourished, there were some 70 major ministries and other governmental agencies such as state committees and central departments. Despite recent frequent changes in the central bodies, their number remained about the same. This situation made scientific communications and intersectoral R&D projects difficult.

Soviet R&D was organized into four major sectors.

- *The Academy Sector*: Basic research was concentrated largely in the Academy sector, which included the Academy of Sciences and branch academies of agricultural sciences, medical sciences, and education. The division of activities into sectors was not complete, and basic research was also carried out in a small number of non-Academy R&D institutes, which mostly served military industries, and in some elite higher education institutes. The Academy also carried out about 20 percent of total applied research in 1990. Formally, the highest body in the Soviet Academy was the General Assembly composed of lifelong members – the academicians. Academicians were outstanding scientists, but the honor was also given to directors of major Academy institutes and to heads of the most prominent military research units as well as to rectors of elite universities. Academicians also included some top-level governmental officers. As representatives of the Soviet Union’s political and intellectual elites, academicians were included in the network that influenced political decision-making. The status of academician was extremely prestigious, and the competition for election to Academy membership was (and still is) intense.

  The USSR Academy had a hierarchical structure similar to that of the branch ministries, with the Presidium at the top, sectoral and regional departments at the middle level, and research institutes at the bottom. The Presidium was elected by the General Assembly and was responsible for the operational management of the Academy including allocation of funds and resources to the institutes and the review of institute research plans.
- *Higher Education Sector*: As noted earlier, R&D was largely separated from higher education. This separation damaged the status and scientific authority of the universities. As a result the quality of R&D in higher education was often second-rate. The exceptions were certain elite universities and a few prestigious engineering colleges that maintained a tradition of high-quality research. These exceptions were given more resources and enjoyed higher status than the other educational institutions.
- *Industrial R&D Sector*: This sector was engaged primarily in applied R&D. In the Soviet period, each branch ministry established its own network of

R&D units, most of which served the branch as a whole and its administration rather than specific enterprises. Most branch research institutes and design bureaus had a limited range of activities as they were oriented to the needs of specific industrial sectors. The branch principle of applied R&D resulted in monopolies in the development of particular technologies and hampered intersectoral diffusion of technology.

The most advanced part of industrial R&D was devoted to national security. The R&D infrastructure of the defense industry was represented by approximately 700 R&D institutions that occupied leading positions in many technological areas. Defense research units contributed not only advanced applied R&D, but also achievements in strategic, mission-oriented, basic research in many important fields (nuclear and high-energy physics, mechanics, space exploration, new materials, computer science, and electronics), which had been developed as a part of defense R&D.

In 1990, defense R&D constituted some 40 percent of total R&D expenditures in the USSR. Approximately 74 percent of defense industry R&D institutions were located in Russia. These institutions employed 77 percent of all the personnel engaged in defense-related research. Some 90 percent of the USSR defense R&D expenditure was assigned to units located in Russia (CSRS, 1993, p. 268).

Defense-oriented research institutes together with the Academy sector received the highest political priorities and were supported by extensive state actions implemented in various forms – direct budget funding, centralized supply of imported research equipment, construction of modern buildings for the most prestigious institutes, hard-currency appropriations for missions abroad and for scientific literature, high salaries, and even extended holidays. An extensive social infrastructure within the Academy of Sciences and defense research units provided employees with better housing, medical and child-care services, foodstuffs, and consumer goods than generally available. Employment in the Academy and defense industry was significantly more prestigious than in civilian industry R&D institutions or in higher education. The result was that the highest-quality personnel were in the two former sectors. These practices created a significant stratification of the national R&D establishment. Civilian industrial institutes were poorly supported compared with the favored Academy and defense institutions which represented the best of Soviet R&D.

- *Enterprise Sector*: R&D units in this sector were financed by industrial enterprises. Activities were largely directed at the immediate needs of the enterprise, such as adapting external R&D to specific production conditions and modernizing current products. The enterprise sector was the least developed of the four major R&D sectors and, in terms of expenditures, by 1990 accounted for about 8 percent of total Soviet R&D effort.

Taken as a whole, Soviet R&D was carried out in a rigid administrative system. This created strong interest groups that resisted change. The R&D capability and efficiency differed from sector to sector. As a result, each R&D institution's chances of surviving the subsequent transition varied.

Geographic Concentration

Geographic concentration of R&D in the most developed regions occurred during the decades of Soviet rule. Among the 15 Soviet republics, Russia dominated with 58 percent of the R&D institutions, 54 percent of the higher educational establishments, 69 percent of the post-graduate students, 68 percent of the R&D personnel, and 75 percent of Soviet R&D expenditure. Russia's share in the Union's R&D expenditure was five times that of Ukraine which ranked second. The R&D expenditures of Belarus, Kazakstan, and Uzbekistan ranged between 1.3 and 3.4 percent of the Soviet Union's R&D expenditures, and R&D efforts in Kyrgyzstan, Tajikistan, and Turkmenistan did not exceed 0.2 percent of Soviet expenditures. Within Russia itself, the central economic region around Moscow accounted for over 30 percent of USSR R&D spending, with Moscow allotted over 30 percent of the national total.

The uneven geographical distribution of R&D was largely determined by tradition and political decisions. The network of Academy research institutions and leading establishments of higher education were concentrated mostly in large cities – the capitals of the former Union republics and the centers of administrative regions. This pattern reflected the concentration of governmental bodies under the Soviet system; in addition, scientist and engineers were attracted to the better living standards in large cities. The institutions of the Academy and the university system were first established in Moscow, St. Petersburg, Kazan, Kharkov, Kiev, and Lvov. Major centers of scientific and technological information, libraries, and archives were also in the main cities. At the same time administrative constraints were placed on the expansion of existing institutes in established cities which led to the creation of the so-called science cities on the periphery of the large cities. Thus, the Moscow region is famous for its centers of academic research in biology (Puschino), physics (Troitsk), nuclear energy (Dubna, Protvino), chemistry (Noginsk), and agriculture (Nemchinovka).

The need for secrecy led to the founding of approximately 60 separate closed defense and nuclear research settlements, some located in remote areas. The highly qualified staffs residing in these towns were employed at unique research facilities and experimental manufacturing plants. The total population of these towns was over 3 million. The community services of the towns depended on financial support from the local research institutes.

R&D activities in the newly developing regions (the North, Eastern Siberia, and the Soviet Far East) were largely in the Academy institutes and in the research units attached to local authorities. These activities gave political prestige to the national republics and helped to solve local economic and social problems. In most cases they were not able to satisfy the local industries' demands for R&D services, so many leading mining research institutes and design and project organizations (e.g., oil, gas, coal industries) in Moscow and St. Petersburg were active in serving enterprises in distant regions. In fact only about 20 percent of applied R&D performed in Moscow was directed toward enterprises in the city or its region.

Management and Administration

The administrative system of R&D management did not have the tools to rationalize at the microlevel. The annual allocation of funds to an R&D institute depended on its size. As a result, there was no incentive for institute directors to close obsolete research programs, thereby downsizing the overall budget of their institutes. The implementation of new research projects often meant establishing new laboratories.

Increasing concentration of R&D in large institutes was characteristic of the 1950–1970 period, when average R&D employment per institution grew fourfold. An attempt was made to restrict the establishment of new R&D institutions, but this purely bureaucratic measure could not stop increases in R&D employment. The average staff size in R&D institutions grew by 66 percent between 1970 and 1988. In the early 1990s, an average R&D institution employed 418 staff members, including 214 researchers (*Table 2.2*). The R&D institutions in Russia were larger than most comparable units in other nations. Research institutes that were not integrated with enterprises were twice as large as other types of R&D units. In the atomic and defense industries some research institutes employed a staff of thousands. Large R&D units were generously provided with funding and equipment and gradually dominated particular fields of S&T, while small units fared poorly. Such distortions in the organizational structures of R&D in favor of large institutions reduced the flexibility of the system.

Bargaining System

The Soviet R&D model shaped under centralized planning was in effect a bargaining system in the absence of a market. Centralized management and control, multi-level hierarchical institutional structures, and departmental barriers were based on

Table 2.2. Average staff size of R&D institutions on 1 January 1991.

	Total R&D Personnel	Researchers
Research institute	609	321
Design organization	334	155
Higher education institution	240	157
Industrial enterprise	317	153
Median	418	214

Source: Author's estimates.

noneconomic factors driven by politics. Demand for and supply of R&D services was set by state plans rather than by orders from producing enterprises.

Perestroika reforms in 1988 and 1989 introduced new economic arrangements for the R&D system; these new arrangements were part of the concept of *khozraschet* (self-financing of R&D institutions and enterprises). R&D institutions became increasingly independent in the selection of research objectives and received the right to create project portfolios on the basis of negotiated contracts with enterprises that used R&D. The reforms brought about the first *de-étatisation* (a form of denationalization) of research institutes and gave staff members the right to rent buildings and equipment from the government to address their own research agenda.

Initially, the changes created new links between R&D and industry via direct contracts. However, research institutes started to raise contract prices and to focus on simpler, short-term projects in order to gain premiums for completed work. Institutes dominating particular R&D areas gained the most: in such institutes revenues exceeded costs by as much as 60 percent. In 1988, R&D institutions attached to 18 industry branch ministries completed more than 107,000 contracts for enterprises, a 2.6-fold increase over 1987, although the average cost of an R&D project decreased by half. Small-scale R&D projects, particularly those based on work completed earlier, were the most profitable activities. Less profitable basic and long-term applied research was neglected. This experience shows that partial reforms in the absence of a real market environment and institutional changes cannot correct distortions in an unbalanced R&D system, but rather strengthen the short-term orientation of R&D.

R&D vs. Innovation

Specific institutional and organizational principles of the USSR's R&D (departmental barriers and R&D separated from industry) emphasized research at the expense of innovation. This research and development vs. innovation imbalance became the crucial factor in the sluggish innovation activity.

Table 2.3. Growth rates percentages of selected R&D input and output indicators in the former USSR.

	1971–1975	1976–1980	1981–1985	1986–1989
R&D expenditure[a]	10.4	6.4	6.4	13.9
Number of prototypes of new machines and equipment developed[b]	–	–7.4	–6.2	–26.4

[a] Average annual growth rate for the period (at current prices).
[b] Growth during the period compared with the previous period.
Source: Author's estimates.

Despite an increase in R&D expenditures in absolute terms until 1990, R&D output and innovation declined steadily from the mid-1970s (see *Table 2.3*). The number of major inventions introduced in 1990 was half that in 1985. The level of quality of innovation activity was also lower in 1990 than previous levels. The share of products at the highest technical level (defined as higher than the best compatible products available worldwide) declined from 9.1 percent in 1980 to 4.5 percent in 1989. More than 70 percent of the total number of innovations was aimed at minor improvements of existing, mostly obsolete, technologies. Such improvements were implemented relatively quickly, but in two or three years they were no longer useful. In the 1980s, 25 percent of documented innovations had already been registered as inventions 6 to 10 years earlier.

Diffusion of innovation was a weak point of Soviet R&D. Generally, innovations were introduced in one or two enterprises, and only 13 percent of innovations were used by additional enterprises, mainly in allied industries. Even in cases where the USSR had a leading position in the development of significant innovations (e.g., oxygen converters and continuous steel-pouring technologies) the country fell behind others in diffusion of the innovations. Thus, in 1960, when the Martin steel process was beginning to be replaced by the oxygen converter system, the shares of output from the new process were the same in the USSR and in the United States. By 1985 almost all of the output in the United States was by the new process; in Russia, however, by 1993 only half of the output was by the new process. A similar situation occurred with the use of continuous steel casting: in the United States, Japan, and Germany the new system accounted for between 75 and 90 percent of the poured steel output in 1990 compared with 30 percent in Russia (Centre for Economic Conjuncture, 1994, p. 4). The slow diffusion process of the Soviet era is one reason catch-up remained a dominant theme in the Russian S&T strategy.

The low rate of innovation and diffusion reflected the lack of incentives for enterprises to introduce new products and processes. In the Soviet system prices were based in part on costs, reducing the incentive for an enterprise to introduce new processes to lower costs. The centralized planning system ensured that almost all output would be sold, reducing the incentive for an enterprise to introduce new products to gain sales volume. The planning system emphasized the increase in the volume of output, not its quality or cost. There were few provisions for rewards for managers and staff of an enterprise that introduced an innovation.

Autarkic Policy

The autarkic policy of the Soviet Union was also applied to science and technology. Forced economic isolation of the USSR before World War II and negligible international cooperation during the Cold War gradually resulted in a technology level that lagged behind the international community, especially in the application of industrial technology. In some areas domestic programs simply duplicated those abroad, wasting resources instead of gaining from collaboration in international efforts. In spite of the prominent achievements in such fields as space research and nuclear physics, Russia's contribution to world S&T literature has decreased from an 8.6 share in 1981 to a 2.7 share in 1993. The country's ranking in international patenting indicators is even worse: its share does not exceed 0.1 percent of the total patents granted in either the USA or Europe (European Commission, 1994).

In this section I've listed the features of the Soviet system that continue to cause inefficiencies in Russian applied R&D activity. The transition to a market economy has encountered many obstacles in research organizations as managers and officials seek to maintain obsolete institutional structures. This factor has prevented a timely reaction to changes in the environment and obfuscated the urgent need for structural transformations.

2.2 R&D Trends since 1991

2.2.1 Initial impact of the transition

The present-day situation of the Russian R&D sector reflects the impact of economic, social, and political factors associated with the dramatic changes of the transition from the Soviet Union to the Russian Federation and from central planning to a market system. Several developments that occurred outside the R&D sector have had a major impact on it. First, the introduction of a market economy gave a new qualitative characteristic to the Russian economy. The dominance of state-owned enterprises has fallen sharply. In 1994, private industrial enterprises accounted for 79 percent of industrial output and 72 percent of industrial employment (State Committee on Statistics, 1995d, p. 317). Market activity became pervasive in all sectors of the economy, even those that remained dominated by public enterprises. Second, there was a major economic crisis as shown by a fall of 38 percent in real gross domestic product (GDP) from 1991 to 1995. Inflation was high, sometimes as much as 25 percent in one month. The economic decline resulted in an increasing burden on the national budget and, consequently, the impossibility of maintaining government appropriations for R&D at their previous real level. (The budget deficit reached approximately 10 percent of GDP in 1994.) Investment by enterprises fell by 73 percent from 1991 to 1995 reflecting the poor financial position of enterprises, the decline of the domestic market for capital goods, and increased competition from imports. The economic crisis led to a drastic decline in the demand for R&D and innovation by enterprises.

In the R&D sector these trends resulted in a major downsizing. This downsizing was accompanied by a fall of the prestige of R&D employment caused in part by the decline in real wages, especially when compared with the business sector. In public opinion surveys, the prestige of scientific activity was considered fairly low among persons with higher education, especially those under 40. Approximately 67 percent of respondents thought that the role of S&T in Russia was falling, and among people with advanced degrees this opinion was expressed by 80 percent of those interviewed (CSRS, 1996a).

The breakup of the Soviet Union created problems for R&D activity because many institutions were designed to serve all 15 republics. Russia's R&D institutions and universities, for example, served the other republics extensively in both R&D and training. Simultaneously, a number of research institutes, industrial R&D units, and special facilities (such as the space-launching site in Baikonur and the Crimean and Armenian observatories) found themselves outside the Russian Federation without proper links to Russian units. The USSR Academy of Sciences as a single administrative structure was dissolved. As a result, inter-republic research programs have been discontinued and R&D contracts between institutes and enterprises in different republics have been canceled. Furthermore, the R&D capacities of the newly independent states inherited from the Soviet era are not matched to the needs of these new national economies.

A further factor has been the decentralization of decisions with a decline in the role of the state and an increase in that of industrial associations, enterprises, and local authorities. The unstable political situation and frequent changes in government policy and replacement of leading officials adversely affect the making and implementation of strategic and tactical decisions of public policy including those for S&T. Decisions are often influenced by leaders of research institutes who are close to powerful politicians.

Finally, Russian R&D is gradually being integrated into the international R&D community. Participation of Russian scientists and engineers in international S&T

projects, employment abroad of Russian researchers, the establishment of foreign companies in Russia, and joint ventures involving Russian and foreign organizations are some of the ways Russia has entered the international S&T market. As stated in a recent Organisation for Economic Co-operation and Development (OECD) report on Russian R&D,

> Many Russian scientists, especially in the younger generation, are becoming quickly integrated into the international scientific community. The changed situation has also confirmed that Russia does indeed possess considerable scientific talent, and this is a source of optimism for the future. [OECD, 1994a, Vol. I, p. 21]

2.2.2 The downsizing of the Russian R&D sector

All the transition economies in Central and Eastern Europe have experienced reductions in the size and quality of their R&D sectors that have been unparalleled in recent decades. For example, Russian total R&D expenditure in 1994 was only 23.1 percent of that in 1990 in real terms (*Exhibit A3.1*). The share of gross domestic expenditure on R&D declined from 2.0 percent in 1990 to 0.82 percent in 1994. OECD data indicate that by 1994 Russia fell below the median in the group of countries with low R&D potential such as Ireland, Iceland, Spain, and New Zealand. Such comparisons alarmingly demonstrate the low level of R&D financing in Russia. In most other countries in the Commonwealth of Independent States (CIS) the R&D percentages of GDP were even smaller (Gokhberg, 1996a).

The high level of militarization of Soviet R&D by 1990 has been noted in several publications (Gokhberg, 1991; CSRS, 1993; OECD, 1994a, Vol. II). In the transition the share of R&D in total military expenditure decreased from 19.8 percent in 1989 (USSR) to 10.2 percent in 1995 (Russia). Lack of a well-grounded national military doctrine makes it impossible to judge the rationale of current expenditures on defense R&D.

The objectives of R&D have changed with the downsizing. In 1991, defense R&D accounted for nearly 43 percent of total R&D. In 1994 this share decreased to 26 percent due to the reduction of defense programs (*Exhibit A3.2*). Russia's proportion of R&D spending on defense is now at a level characteristic of other nuclear powers – the United States, the United Kingdom, and France. Within nondefense R&D, the general advancement of research has increased its share (12.5 percent of GERD in 1994). Within R&D oriented to economic development those efforts aimed at economic efficiency and technological development of industry represent 8.8 percent of GERD. However, the shares allocated to strategic goals such as protection of human health and the rational utilization of energy make up only 3.2 percent each; environmental protection receives an even smaller share,

Table 2.4. Percentage distribution of GERD by source of funds.

	1986[a]	1988[a]	1990[a]	1991	1992	1993	1994
Budget funds	86.4	78.8	79.4	95.0	91.9	92.5	61.0
Non-budget funds[b]	11.4	16.8	18.0	2.6	4.4	4.6	6.3
Funds of enterprises and R&D institutions	2.2	4.4	2.6	2.4	3.7	2.9	32.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a]Data refer to the former USSR.
[b]Before 1991, centralized funds.
Source: CSRS, various years.

only 1.6 percent of GERD (these research directions are not itemized in *Exhibit A3.2*).

2.2.3 Financing of R&D

The downsizing of Russian R&D after 1990 was accompanied by some shifts in its sources of financing. Enterprises played a small role – no more than 4 percent of R&D was financed by enterprises during the 1989–1993 period (*Table 2.4*). Between 1990 and 1992 the macroeconomic situation discouraged such spending.

The government has remained the main source of R&D general funds; non-budget funds were introduced in 1992 to finance R&D of enterprises in specific sectors. The funds are termed "non-budget" because they are derived from voluntary contributions of enterprises at the rate of 1.5 percent of the value of their sales rather than from taxes. The funds largely support applied R&D of value to the industry of the contributing enterprises (for details, see Chapter 7). However, the amount collected in 1992 was lower, by a factor 15, than the level anticipated, as many enterprises did not pay their share. Moreover, some funds were channeled to financing the introduction of new products manufactured by enterprises. In our estimate, the share of these non-budget funds in 1992 and in 1993 accounted for only 4.4 percent and 4.6 percent, respectively, of Russia's total R&D expenditures.

The lack of alternatives to government support has compelled the Soviet-style centralized system of R&D financing to continue into the transition years. Government funds provided over 90 percent of Russian GERD in 1993. The government, however, has failed to provide adequate funds to maintain the Soviet R&D establishment Russia inherited. In 1994 government R&D financing in real terms was only one-fourth that in 1991 (*Exhibit A3.8*). The decline in financing was so pronounced that an orderly restructuring of R&D institutions was impossible. The provision of government budget support was also characterized by uncertainty for only one-half to two-thirds of the planned appropriations for R&D were actually delivered, making efficient management of their use difficult.

During the Soviet period appropriations for R&D occupied a very modest place in government budget spending: from 1970 to 1990 their share was between 3.4 and 4.8 percent of the total budget. As the transition proceeded, government budgetary support of R&D continued to decline with R&D accounting for only 2.8 percent of the government budget in 1994, the lowest share in 25 years (*Exhibit A3.9*). Despite numerous declarations, state policy failed to raise R&D to a high-priority position in the years of transition. Instead, R&D became a major victim of budget cuts to reduce the government deficit. In addition, the failure to meet the planned expenditure was greater for R&D than for other expenditures. R&D spending was subject to the so-called residual principle of state budgeting carried over from the Soviet era (Gokhberg, 1991). This principle gives low priority to activities such as R&D and education; only the residual of the state budgets, after the financial needs of high-priority activities have been met, are available for these low-priority activities.

By 1994 two significant changes could be observed in R&D financing (*Exhibit A3.4*). First, non-budget funds, introduced in 1992, became a more significant factor in R&D financing than earlier (particularly, in the more prosperous industry sectors); they accounted for 6.3 percent of GERD. Second, business enterprise financing became increasingly significant, accounting for 19.9 percent of GERD. The enhanced role of enterprises resulted from the sharp decline in government spending rather than an absolute increase in financing from enterprises. Still both developments suggest that centralized government financing was gradually being replaced by a variety of sources of which enterprises were the most significant.

Recently, there have been attempts to change the structure of budget appropriations for R&D. The changes were effected through the shift of the three main budget orientations for civil R&D which are coordinated by the Ministry of Science and Technological Policy of the Russian Federation (MSTP). These items are:

1. Institutional funding of R&D institutions, aimed at maintaining staffs, facilities, and equipment.
2. Financing of R&D by priority objectives in the framework of government S&T programs, programs of federal research centers, and international programs.
3. Financing of specific projects by the newly established goal-oriented budgetary foundations for basic research, humanities research, and promotion of small enterprises in S&T.

The budget appropriations for these items are given in *Table 2.5*. Institutions in the first category are allocated institutional funding according to their size; funding

Table 2.5. Structure of budget appropriations for civil R&D (%).

	1991	1992	1993	1994	1995[a]
Institutional funding of R&D institutions	79.9	79.2	83.5	81.7	72.0
Priority R&D objectives	18.1	17.8	14.4	14.0	20.3
Specific budgetary funds	2.0	3.0	2.1	4.3	7.7
Total	100.0	100.0	100.0	100.0	100.0

[a] Preliminary estimate.
Source: Author's estimates.

does not depend on the areas or results of research. More than half of this institutional funding is targeted to R&D institutions in the industrial sector, meaning that budget funds continue to substitute for applied R&D financing by enterprises. In contrast, the financing of R&D in the framework of government S&T programs and other priority objectives (the second category) is results-oriented. In this category funds are distributed by the MSTP directly to R&D institutions for specific research projects. In spite of the imperfect nature of establishing programs, setting priorities, soliciting tenders, and evaluating results, this approach can concentrate limited budget resources on priorities that correspond to the urgent tasks for Russia's development. A results-oriented allocation of financing also introduces competition into the activities of research teams through a system of grants and contract awards. This is a step toward the formation of a new structure for R&D that corresponds to the reality of a market economy. The ratio of the results-oriented financing of R&D to that of R&D institutions is a rough indicator of the effective transformation of S&T policy in the transition. The MSTP is committed to results-oriented allocation of R&D funds, but pressures from the Academy, ministries, and departments have prevented it from moving more radically to distributing R&D funds competitively. Clearly, a more radical move to results-oriented financing would decrease the traditional role of the Academy and the ministries in managing the institutes subordinated to them. Hence the share of the budget appropriation for civilian R&D to fund institutions rather than projects has declined from 80 percent in 1991 to only 72 percent in 1995.

Finally, since 1991 numerous R&D projects have been financed by foreign research centers, commercial companies, and international organizations. In spite of the small share of foreign funds in total Russian R&D effort (2 percent of GERD, 1.9 percent of that in the business enterprise sector[1]), this financing marks the beginning of direct links between Russian R&D institutions and foreign partners. For a number of organizations listed under the defense industry, foreign orders, largely for civilian R&D, are now their only source of financing.

2.2.4 Shift in the activities of R&D institutions

Under the impact of the transition to a market economy, activities of R&D institutions are gradually changing (*Table 2.6*). This process is connected with the tendencies of R&D institutions to reorganize themselves to adapt to the new economic environment and particularly to survive under severely unfavorable financial conditions. These changes have altered the four major R&D sectors.

- *Academy Sector*: The USSR Academy has been transformed into the Russian Academy of Sciences (RAS). The RAS has largely retained the commanding position of its USSR predecessor and maintained administrative control over the activities of its research institutes. To date, the Academy has not significantly changed the structure and bureaucratic organization it had in the Soviet era. Using its considerable political influence, the Academy has managed to retain its budget financing better than other R&D sectors. Government financing has largely been in the form of support to basic research. Basic research amounted to 58 percent of the Academy's 1994 expenditures, up from 52 percent in 1990 (*Figure 2.1*). Applied R&D continues to account for more than one-third of the Academy's activities. Academy institutes have maintained some participation in budgetary-financed goal-oriented S&T programs. As a result, the Academy sector somewhat increased its proportion in the total value of applied R&D between 1990 and 1994. With respect to development, Academy institutes are usually not competitive with industry R&D units, so this is a minor activity accounting for only 7 percent of the 1994 Academy R&D effort. In 1994 an attempt was made to establish a new administrative body – the Technological Academy – to manage defense R&D institutions. The measure would have significantly increased the Academy's role in applied R&D, but it was defeated.
- *Higher Education Sector*: The recent economic difficulties have reduced the role of university R&D as R&D is no longer considered an economically "profitable" activity and has become a marginal one in many universities. R&D is no longer carried out at 40 percent of higher education institutions, and the 150 newly established private universities have little interest in R&D. The higher education share in GERD declined from 6 percent in 1990 to 4 percent in 1994.

  The universities' share in basic research increased (in both absolute and relative terms) because applied R&D performed on contracts with industry decreased sharply, leaving them more dependent on budget funds for basic research. The share of basic research in overall R&D in universities doubled and by the beginning of 1995 had reached 39.6 percent, almost 10 times higher

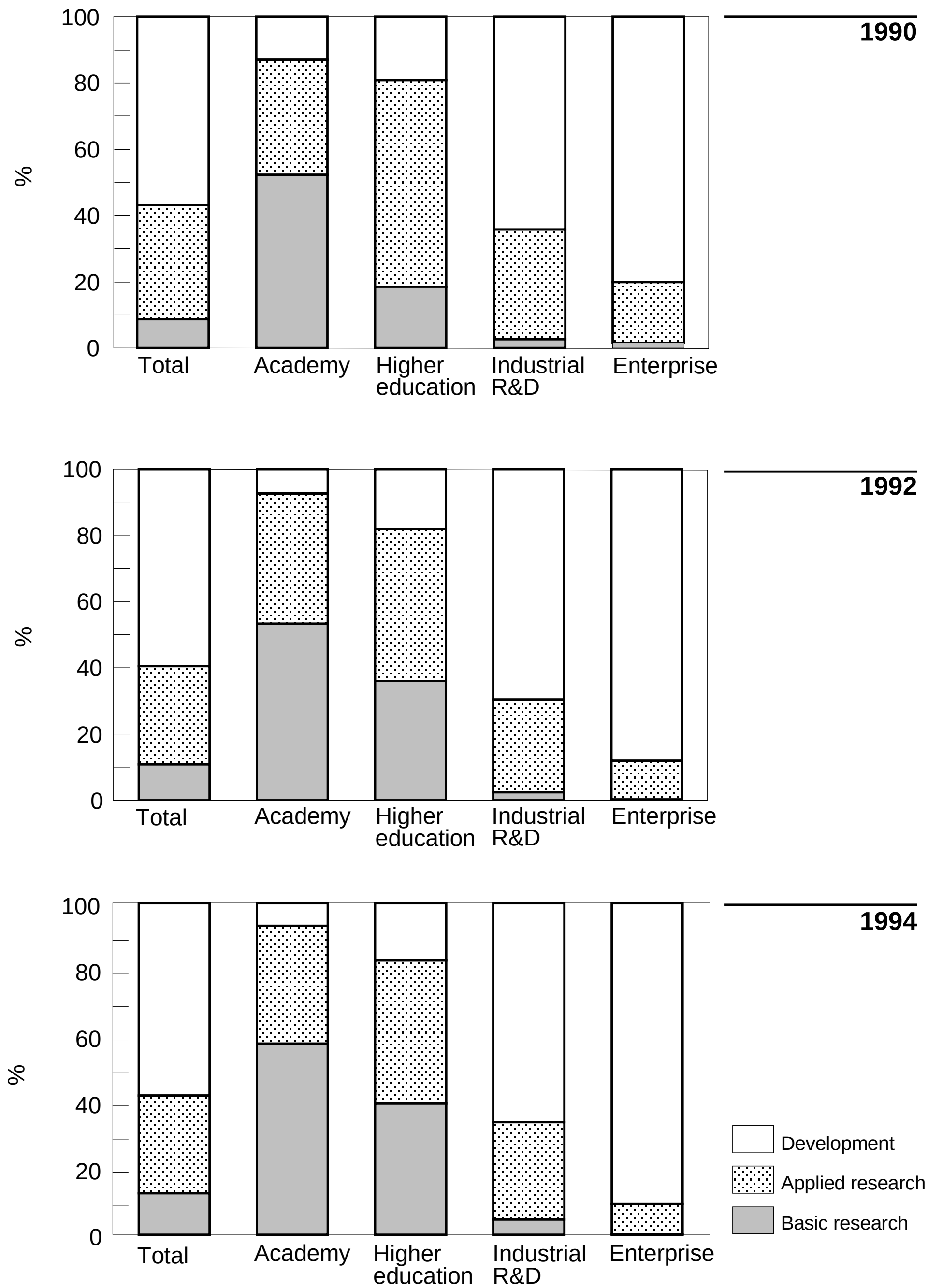

Figure 2.1. Percentage distribution of R&D conducted within R&D institutions by type of activity and sector of performance.

Table 2.6. Percentage distribution of R&D value performed within R&D institutions by type of activity and sector of performance.

	Academy	Higher education	Industrial R&D	Enterprise	Total
Basic research					
1990	62.4	12.9	23.8	0.9	100.0
1992	66.4	16.8	16.7	0.1	100.0
1994	58.2	13.3	28.4	0.1	100.0
Applied research					
1990	10.6	11.0	75.7	2.6	100.0
1992	18.1	7.8	72.1	2.0	100.0
1994	15.2	6.2	76.7	1.9	100.0
Development					
1990	2.4	2.0	88.7	6.9	100.0
1992	1.7	1.5	89.1	7.6	100.0
1994	1.5	1.3	87.5	9.7	100.0
Total					
1990	10.5	6.1	78.5	4.9	100.0
1992	13.6	5.1	76.2	5.2	100.0
1994	12.6	4.2	77.0	6.2	100.0

Source: CSRS, various years; discrepancies in totals are due to rounding.

than the sector's share in the national R&D total. Universities, however, are having difficulties competing with Academy institutes in basic research and with industrial organizations in applied R&D; therefore, they are gradually losing their position in the overall R&D effort. Universities carry out few development activities. In 1994 they accounted for 1.3 percent of all development spending (*Table 2.6*).

- *Industrial R&D*: This sector has retained its share of GERD of over 75 percent. Industrial R&D institutes have retained strong links with enterprises, usually in the framework of institutional structures that have partly replaced branch ministries such as associations, financial industrial groups, or large conglomerate firms. As a result, these institutes have responded to the short-term requirements of enterprises. Their share of long-term research has declined as enterprises have little interest in financing such activity, given the current financial situation. Deterioration of the financial position of the large industrial R&D institutes, however, has forced them to increase their efforts on basic research financed by the government (especially in the case of the defense industry), thus competing directly with Academy institutes for support. As a consequence the Academy sector's share in Russian basic research declined from 62 percent in 1990 to 58 percent in 1994, while the share of industrial R&D institutions increased from 24 percent to 28 percent (*Table 2.6*).

- *Enterprise Sector*: This sector, with a relatively small proportion of R&D, has increased its emphasis on development activities. Development constituted 80 percent of enterprise R&D activity in 1991 and 91 percent in 1994. These R&D activities are usually financed by the enterprises themselves. There was a modest increase in the enterprises' share of the total R&D effort from 4.9 percent in 1990 to 6.2 percent in 1994 largely because some enterprises needed to maintain their in-house R&D units (*Table 2.6*).

At the aggregate level these changes have led to an increase in the share of basic research in total GERD from 8.8 percent in 1990 to 16.9 percent in 1995. According to this indicator, Russia comes close to the leading industrial countries; the share of basic research in total national R&D is 13 percent in the United Kingdom and Japan, 14 percent in the United States, 19 percent in Germany, and 23 percent in France (National Science Board, 1991, p. 344). It is important to note that the increase in basic research is only in its share in total R&D. Expressed at 1990 prices, Russian basic research in 1994 was equal only to 23 percent of its 1990 amount.

A new methodology, developed by the Centre for Science Research and Statistics (CSRS), to survey Russian R&D by OECD standards allows us to glance at the sectoral pattern of R&D in Russia. This new sectoral classification is based on the performance of R&D rather than its financing (see Annex 2 for a description of the sectoral classification).

Data on R&D performance show that the enterprise sector dominates Russian R&D. Its share in 1994 accounted for 66 percent of GERD, almost the same as the OECD average of 67.4 percent in 1993. It matches the indicators of large economies such as the United States, Japan, Germany, the United Kingdom, and France (OECD, 1995a, p. 22). The internal composition of the enterprise sector in Russia, however, is different from that in the OECD, as it comprises mainly independent research institutes working for industry rather than enterprises. The share of the government sector performing R&D in Russia was 28.1 percent of GERD in 1994. This is double the OECD average (12.7 percent in 1993). The R&D activities of the Academy of Sciences accounts for most of this difference.

The share of the higher education sector in Russia is small in comparison with other industrialized countries. In 1994 higher education institutes represented 5.9 percent of GERD; the share in OECD member countries was, on average, 3 to 4 times higher. Russia's private nonprofit sector comprises only 7 research institutions contributing less than 0.1 percent of GERD in 1994 compared with 2.9

percent in OECD countries. The rise of scientific societies, nonprofit foundations, and institutions should contribute to the growth of the nonprofit sector's R&D efforts.

2.2.5 The struggle to survive

The sharp fall in government financing made R&D institutions search for alternative sources of financing. Some of the new activities undertaken to raise revenue were related to R&D such as information services, testing, quality control, and consulting. Other activities were remote from R&D such as manufacturing of products for sale, leasing of equipment and buildings, marketing, and printing services. These new trends began even before the 1991–1992 reforms (Gokhberg, 1991; CSRS, 1992, 1993). Beginning in 1990, there was a gradual increase in the share of activities unrelated to R&D and, by 1995, such activities made up 10 percent of the total activity of R&D institutes (*Table 2.7*). Until 1992, R&D projects had been more profitable for R&D institutions than other activities, but since then, according to our estimates, work other than R&D has become more profitable (CSRS, 1993, p. 221). Some R&D institutions began intensive efforts to occupy the earlier underdeveloped niches in the rapidly shaping market infrastructure, and the growth in production and business services outstripped activities with an S&T orientation. By 1994, a number of R&D institutions managed to reequip experimental plants for small-scale production and began rendering information, computer, and marketing services to newly established banks, trade, insurance, and tourist companies. However, the possibilities of developing non-R&D activities with the facilities and personnel of R&D institutions have physical limitations. The most common non-R&D activity has become leasing real estate and equipment.[2] According to CSRS survey data by the end of 1995, 51 percent of research institutes were leasing their premises, 15 percent were leasing equipment, and 24 percent were engaged in production for the market.

There are three main microlevel strategies for R&D institutions:

- Continuation of R&D as the main activity.
- Reorientation to other S&T, production, and related services (which may include cessation of R&D activity).
- Orientation to commercial operations such as leasing real estate and equipment.

In most cases R&D institutions follow some combination of all three strategies. However, in 1994 approximately 221 design bureaus and construction project organizations discontinued all R&D activities.

Table 2.7. Percentage distribution of the value of projects undertaken by R&D institutions by type of activity.

	1989	1990	1991	1992	1993	1994	1995[a]
Basic research	6.4	8.0	8.4	9.7	9.5	10.5	9.2
Applied research	32.7	31.5	30.0	26.3	25.2	24.9	22.0
Design and projects	35.8	36.1	33.9	34.4	35.9	–	–
Production of prototypes	7.8	8.9	10.3	13.9	13.9	48.8	49.7
Construction projecting	8.8	7.0	7.3	4.5	4.7	–	–
S&T services	4.0	4.0	5.1	4.4	4.6	7.4	8.7
Others	4.5	4.4	5.0	6.8	6.2	8.4	10.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] Preliminary estimate.
Source: Author's estimates.

2.2.6 Human resources of Russian R&D

Microlevel adjustments by R&D institutions to the economic environment explain to a considerable extent the current trends in R&D employment, which at first glance look puzzling. From 1990 to 1994 R&D expenditures measured in real terms were reduced by almost 77 percent, while employment in R&D institutions decreased by only 43 percent (*Exhibit A2.1*). This is an indirect indication of the worsening renumeration of researchers and the decline of actual R&D activity by the remaining research staff.

The process of reduction in employment in R&D institutions has been uneven. During the first stage between 1989 and 1991, the employment reductions were concentrated in the technical and support staffs in an effort to keep research teams together. The reduced number of technicians, laboratory assistants, and support workers inevitably reduced the productivity of scientists who were often forced to combine research with support activities. By 1994, the proportion of support personnel stabilized at 42 percent of the total employment, compared with 37 percent in 1990 (*Exhibit A2.2*). The share of researchers continued to decline, reflecting the fact that many research institutes are gradually turning toward economic activities and away from scientific activities.

Most of the staff reductions were voluntary departures, reflecting the outflow of scientists and engineers to the business sector – the so-called internal brain drain. The opportunities and rewards in business have made the sector increasingly attractive to qualified and enterprising people. Seventy-one percent of those leaving R&D employment list higher salaries as a prime reason for their decision. Highly qualified researchers can easily find employment in the rapidly growing business sector, and many top-level managers of banks, industrial groups, joint ventures, and newly privatized companies have doctoral degrees in scientific fields. This redistribution of talent in favor of new market segments is probably a gain for the national economy as a whole but a loss to research. Less-qualified staff members, experiencing difficulties in employment, are returning to the relatively low-salaried positions in the budgetary-supported R&D sector, thus restaffing the support positions.

With the reduction in the number of R&D personnel, the share of researchers with advanced degrees increased from 7 to 10 percent from 1989 to 1994 (*Exhibit A2.2*). Over this same period there was an absolute growth of 16.2 percent in the number of doctors of science. The change reflects the tendency of the young staff members without advanced degrees and holding junior positions in the R&D institutes to leave in large numbers.

The Academy sector has had the smallest reduction in personnel. R&D personnel in the RAS decreased by only 14 percent from 1990 to 1994, which is almost one-third of the average decline in Russia (38 percent) and in industrial R&D institutions (38 percent). Full-time R&D staff declined by 60 percent at universities and by 42 percent at R&D units in enterprises.

Employment in R&D is determined in part by noneconomic motivations. According to a 1995 survey conducted by the CSRS almost 60 percent of all researchers and 70 percent of those in the Academy were planning to continue as researchers since they regard research as a lifelong commitment. Only 3 percent of respondents declared a firm intention to change their jobs. Approximately 72 percent of respondents emphasized that their interest in the profession is the main reason for staying in science; 34 percent hoped for an improvement in the R&D situation.

The improvement that they hope for is primarily better salaries. In 1988, the introduction of a contract-based management mechanism in R&D institutions contributed to a sharp increase in researchers' salaries. At the beginning of 1989, for the first time in many years, the average monthly salary in R&D rose above that in industry. Salaries began to decline in relative terms in subsequent years, and by 1992 the average salary in R&D was 64 percent of the average for the economy as a whole. Only special efforts by the government allowed this ratio to increase to 73 percent in 1995.

Averages hide an important fact: salaries in the R&D sector can rarely match salaries in other sectors, so few talented young researchers will remain in R&D. Conversely, researchers 60 years and older are less likely to leave R&D institutions and earn almost 40 percent above the average in the R&D sector. The research institutes' inability or unwillingness to offer competitive salaries is an important factor in the outflow of persons in the more active working-ages and in the reduced inflow of young scholars. The result is the aging of R&D personnel. As many as 44 percent of the doctors of science are over 60 and the average age of RAS members is between 63 (for economists) and 72 (for international relations experts).

Many scientists who continue their research careers frequently supplement their income with a second salary. Arrears in R&D salary payments by the institutes leave many without any income for months at a time and even those who are paid regard their salaries as inadequate. To survive, many researchers take part-time employment outside their institutes. According to a CSRS estimate, 57 percent of all researchers have contracts with private firms and 80 percent of these researchers are mainly employed by the Academy.

In addition to the internal brain drain and diversion of effort from R&D institutions, there is an international migration of Russian scientists. A recent study by the CSRS, using data from the Ministry of the Interior, provides a good estimate of the proportion of R&D personnel that has emigrated from Russia (*Exhibit A2.13*). Emigrants accounted for only 0.5 percent of the total outflow of staff from the R&D sector. This indicates that the process of external brain drain has not taken on serious dimensions. Furthermore, part of the flow of emigration is driven by ethnic factors with the economics of the labor market playing only a minor role.

In addition to migration of R&D personnel, there has been an outflow of researchers for temporary work abroad. The most frequent participants in this type of migration are researchers from the Academy sector. In 1991–1992, 1,101 researchers of the RAS were on long-term tours abroad, in 1993 the number increased to 2,639 (3 percent of total RAS employment). Fifty-five percent of these individuals were under 40; 19 percent were doctors of science; and 51 percent were candidates of science.

These numbers include the "double-life" scientists who spend considerable time abroad but retain their connection with the Russian institute and their Russian residence. While the numbers cited suggest a rather modest quantitative impact, one should realize that it is the highly qualified, talented specialists who are placing their efforts abroad rather than in the work of domestic Russian R&D. If they return with greater skills, Russian R&D gains, but if they do not return to full-time employment or return only when their productive years are over, Russia loses. The absence of these researchers may have serious consequences on a number of highly qualified scientific groups and promising research areas (Gokhberg, 1996b; Nekipelova *et al.*, 1994).

Our analysis has shown that Russian S&T has approached a turning point: the demand for R&D has already radically shifted and the supply (including efficiency and quality) is also going through changes. Its future depends more on the reforms for the entire economy than on reforms specific to S&T. These reforms will determine whether the post-Soviet R&D system becomes a high-value, economically adjusted, and effectively operating entity in a flourishing industrial state or a marginal element in a raw-material-oriented economy. It is obviously important to create the conditions under which the vital forces of Russian R&D can make Russia a prosperous member of the international community.

Notes

[1] Such estimates do not include grants and scholarships allocated to separate scientists for individual research since the statistics are traditionally oriented to legal entities as reporting units. Besides, such grants, as a rule, are for basic research.

[2] Thus, what we are observing is not simply "polarization of R&D spectrum" (Radosevic, 1994). Between 1989 and 1995, small changes in the shares of the extremes or "poles" – namely, those of basic research and development – were offset, but now some of the former share of applied research is filled by non-R&D activities.

Chapter 3

The Institutional Structure of Applied R&D

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The institutional structure of Russian applied R&D is best understood as a complicated product of its historical evolution. In order to identify the determinants of the current institutions, the developments of the Soviet era introduced in Chapter 2 are further detailed in this chapter. In 1991, the Soviet era ended and the Russian period began in a dramatic fashion. That change created new institutional structures and problems which we illustrate in this chapter by describing the R&D organization for metallurgy. The chapter concludes with a survey of the current legal structures for S&T.

3.1 The Evolution of R&D in the Soviet Era

3.1.1 The early Soviet era (1917–1955)

As indicated in Chapter 2, the Soviets took control of the institutional science structure of czarist Russia in 1917. In the 1920s several large research institutes were established, and these became the primary organizational form for carrying out R&D. At this time different sectors (Academy, higher education, and industrial R&D) were established.

In 1931, the Soviet government decided to reorganize the network of research institutes. Organizations were classified by function as research institutes, design bureaus, or pilot plants. The reorganization made clear distinctions between central research institutes in the individual ministries doing advanced research and sectoral research institutes carrying out narrower and more applied projects in research institutes at places of higher education, laboratories in factories, and experimental facilities tied to production units. Sectoral research institutes were directly subordinate to ministries or ministerial departments in charge of large parts of the economy. The Academy of Sciences directed institutes that focused primarily on basic research.

Regional development of applied R&D was provided by the established affiliates of central branch research institutes and new industrial R&D institutions in regions where industries were developing. For the most part, however, R&D remained concentrated in large industrial and cultural centers such as Moscow, Leningrad, Kiev, and Kharkov. In 1939, some 90 percent of R&D personnel was located in Moscow and Leningrad. The development of industrial R&D in eastern regions of Russia occurred only during World War II, when large numbers of research institutes were moved east.

3.1.2 R&D as a national resource (1955–1985)

The next stage was characterized by the perception of S&T as a powerful resource for national development. The importance of R&D was demonstrated by the creation of the State Science and Technology Committee of the USSR in 1957. In 1965, the Committee was transformed into the State Committee on Science and Technology (SCST) of the USSR. This body was responsible for developing a general strategy for R&D and coordinated overall economic policy among the main governmental agencies, such as the State Planning Committee (Gosplan), the State Committee on Material and Technical Supplies, and others.

This stage was marked by major growth in technical potential. Many, mostly small, research institutes were established. The period of economic reforms in the 1950s (characterized by decentralization of management) saw the development of industrial R&D in peripheral regions. Large industrial research institutes were set up in places with the largest concentration of industry. In the 1960s, the Siberian branch of the USSR Academy of Sciences, along with academies of sciences in many Soviet republics, was established. Applied R&D remained largely within industrial research institutes. A large proportion of applied R&D served the military sector, which consumed about one-half of the Soviet Union's R&D resources.

The infrastructure of R&D institutions had a linear character that was defined even more precisely as time went on. Applied research was performed within sectoral research institutes under the control of industrial ministries. The results of the research were used by design bureaus of the same ministries to design prototypes for industrial production. The prototypes were tested in experimental production before mass production began. The linear structure from research institute to design bureau, to experimental production, and finally to mass production was similar in all sectors of manufacturing. Initially this system was efficient because it avoided duplication of research and ensured that R&D would be oriented to the priorities of industry. Subsequently, because of the lack of feedbacks in the system and its inflexible structure, the efficiency of R&D sharply decreased. The output of applied R&D was often below international standards, but its monopoly character hid this weakness.

During this period a distinct system of managing industrial applied R&D was established. Within the framework of industrial ministries, the connection of science to industry was accomplished by a single organization that managed the entire cycle from performing applied R&D to the application of its results to industrial production. An active role was played by sectoral ministries and their departments, which strove to provide S&T services to all of their activities.

The system of rigid administrative planning that was used elsewhere in the Soviet system was applied to S&T. Within industrial ministries, S&T departments were responsible for managing R&D activities. Industrial ministries also supervised the All-Union industrial associations (AIA) and industrial associations (IA). The integration of the R&D stages varied during the Soviet era, but a typical organizational pattern is shown in *Figure 3.1*.

The industrial ministries determined research topics and the allocation of R&D resources. Projects executed by branch research institutes were financed by the appropriate ministries. In the late 1970s and the early 1980s a new system of R&D organization was appended to the old one: large and important projects were implemented within the framework of national S&T programs. This new approach, however, brought about limited changes. For instance, R&D institutions responsible for the the fulfillment of these programs had no authority to provide financing to research institutes in adjacent branches, so there was no stimulus for the implementation of projects that crossed ministry and industry boundaries.

3.1.3 *Perestroika* (1985–1991)

By the mid-1980s the growth rate of the gross national product (GNP) had slowed. This decrease was partly due to reasons not directly related to the planning system. The rate of growth in the supply of fuel decreased because new oil and gas fields required tremendous investments. Only a part of these investments could be appropriated, but even these outlays were sufficiently large to leave fewer resources for other growth-promoting activities. Increased military spending reduced resources available for production investments. A lower rate of investment, in turn,

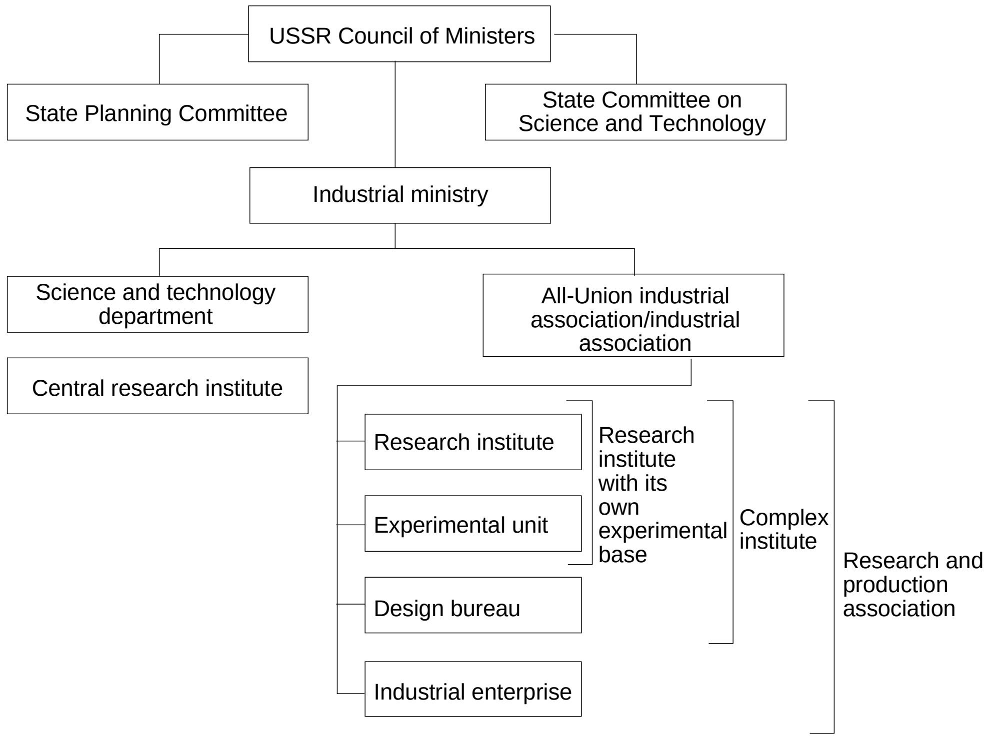

Figure 3.1. Typical organization of civil industrial R&D in the USSR.

reduced the rate of growth of productive fixed assets. Apart from these factors, central planning proved to be ill-suited to the requirements of economic growth of the 1980s, which depended more on sophisticated, fast-changing, manufactured products, such as integrated circuits, and less on standard commodities like steel. Development of S&T was hampered by poor feedbacks in the chain from R&D to the customer, the absence of mechanisms promoting innovation, and the lack of competition and entrepreneurship. While the reasons for the emergence of *perestroika* were numerous, this new policy line was in part a response to a disappointing record of economic growth.

In the *perestroika* period, R&D expenditures increased in key S&T fields such as microelectronics and automation. Still, the rigid branch structure of S&T management and the lack of incentives for enterprises to utilize research results limited the contribution of S&T activity to economic growth. New organizational forms were introduced to overcome the barriers between industrial sectors, to promote interdisciplinary R&D, and to accelerate the application of R&D results to the national economy. These institutional structures included research and production associations (RPAs) and intersectoral science and technology complexes. RPAs were first established in the mid-1960s and proved to be efficient at improving R&D and innovation activities in pre-reform Russia. RPAs brought together institutes and enterprises to form, within one organization, the whole cycle from research to mass production for a sector of industry. Intersectoral S&T complexes included research institutes, design bureaus, and industrial enterprises from different sectors of the economy. Their main task was to organize applied interdisciplinary research and to implement the results in production. In a number of such complexes, technologies were developed that were above the average world level. Examples of these can be found in the fields of mechanization, metallurgy, membrane technologies, and ocular microsurgery. Most applied R&D, however, produced results and designs below world standards.

During the economic reforms of 1986–1990, several branch R&D institutions were made subordinate to RPAs and to production associations (PAs). The new organizations somewhat accelerated the process of innovation as R&D institutions became engaged in the immediate supervision of the downstream introduction of their developments into production. However, the associations, as a rule, gave little attention to strengthening the research capacities of R&D institutions. Priority was given to solving current problems of enterprises to the detriment of long-run research.

The *perestroika* policy reinforced decentralization with more decisions made at enterprise and departmental levels. As mentioned in Chapter 2, with the introduction of *khozraschet* (a system of partial independence and self-financing for enterprises and R&D organizations) contracts between research institutes and industry became the basis for financing applied R&D. Market relations (contractual prices on scientific services and independence for R&D institutions to serve selected customers) and freedom for enterprises to choose their R&D suppliers were introduced. The 1990 Law on the Enterprise and Entrepreneurial Activity gave even more leeway to individual enterprises. Disintegration of RPAs was one consequence of the new freedom, for many enterprises withdrew from their associations. Enterprises did not consider RPAs important, particularly in the short run. Experimental units were often separated from associations in order to profit from small-scale production. Lack of interest in scientific results had a negative impact on most R&D units of PAs and RPAs.

The state priorities in creating R&D-performing institutes are shown in *Table 3.1*. The table shows that the industrialization period and the period between 1955 and 1975 were the most active periods for creating new institutions in all fields of applied R&D except biotechnology and nuclear engineering. From 1976 to 1985 a stagnation in institution-building in R&D was evident by the decrease in

Table 3.1. Percentage distribution of institutions performing applied R&D in 1995 in fields of S&T by year of establishment.

	Year of establishment								
Field	To 1925	1926 –35	1936 –45	1946 –55	1956 –65	1966 –75	1976 –85	1986 –95	Total in 1995
Power engineering	8.2	16.8	8.2	12.5	22.6	18.8	5.8	7.2	100.0
Electrical engineering	9.2	10.8	10.4	14.8	24.4	14.8	7.2	8.4	100.0
Electronics, radio engineering	7.9	5.1	6.5	11.0	20.2	16.4	12.0	20.9	100.0
Communications	3.9	6.5	3.9	18.2	16.9	23.4	11.7	15.6	100.0
Automatics and computer engineering	5.2	10.4	6.8	9.3	19.9	24.8	9.7	13.9	100.0
Mining	5.1	10.6	6.4	12.3	29.2	16.9	10.6	8.9	100.0
Metallurgy	4.4	12.7	7.8	8.8	28.3	16.1	9.8	12.2	100.0
Mechanical engineering	5.7	15.3	9.1	11.0	26.2	15.4	8.2	9.1	100.0
Nuclear engineering	5.9	2.9	11.8	14.7	17.6	8.8	14.7	23.5	100.0
Instrument engineering	4.2	6.8	9.4	12.5	26.4	17.4	10.6	12.8	100.0
Printing, documentary reproduction, film engineering	6.1	15.2	12.1	9.1	21.2	21.2	9.1	6.1	100.0
Chemical technology, chemical industry	6.8	14.4	8.6	9.0	26.2	16.9	8.4	9.7	100.0
Biotechnology	13.3	12.0	6.7	6.7	16.0	20.0	9.3	16.0	100.0
Light industry	3.8	29.1	5.1	2.5	31.6	19.0	2.5	6.3	100.0
Food industry	3.7	18.5	9.3	4.6	18.5	12.0	11.1	22.2	100.0
Forestry and wood-working industry	7.5	20.0	10.0	8.8	28.8	16.3	3.8	5.0	100.0
Construction, architecture	8.2	15.0	6.4	12.7	24.0	16.8	6.4	10.5	100.0
Agriculture and forestry	11.6	20.4	4.7	8.8	14.1	16.9	9.0	14.5	100.0
Fishery	19.4	12.9	4.8	9.7	12.9	17.7	12.9	9.7	100.0
Water distribution systems, amelioration	8.9	16.7	8.3	8.9	16.7	20.8	10.7	8.9	100.0
Transport	3.3	12.3	9.1	13.6	16.9	19.8	7.4	17.7	100.0
Housing, communal, and social services	0.0	16.7	7.1	9.5	23.8	21.4	11.9	9.5	100.0
Medicine and health	13.2	14.3	9.3	9.0	11.1	14.0	10.6	18.5	100.0
Total	7.2	13.7	7.8	10.5	21.8	17.7	8.9	12.4	100.0

Source: CSRS, 1996a.

the number of new institutions in almost all fields of S&T. Since 1985 the changes have been mostly in the form of restructuring existing research institutes.

3.2 Changes in R&D Organization

3.2.1 Governmental organization

The transition to a market economy since 1991 has had a major impact on R&D. As detailed in Chapter 2, the first development was a sharp decline in R&D expenditures and in the number of personnel employed in the R&D sector. The decline was pervasive but most marked in applied R&D.

The second development was a series of major organizational transformations, beginning at the highest levels of state management and extending to individual R&D institutes. The changes at the top occurred as the Russian Federation supplanted the Soviet Union. The State Committee on Science and Technology was replaced by the Ministry on Science and Technological Policy (MSTP) and Gosplan, by the Ministry of Economy. Many branch ministries were closed. Privatization of R&D institutes, the establishment of large financial industrial groups, and the founding of technically oriented small businesses created new forms of organization for S&T activity. Changes at the top reflected the search for public policies to preserve the most valuable part of the R&D sector. In individual R&D units, the changes reflected a search for ways to survive in the economic crisis that has burdened Russia since 1991. *Table 3.2* shows that the number of R&D units decreased in all but three sectors (railways, geology, natural resources).

In September 1993, a new comprehensive system of federal bodies was established. Decisions on the development of science and technology at the federal level were assigned to the Interdepartmental Coordination Commission on Science and Technology Policy. In February 1995, this commission was transformed into the Governmental Commission on Science and Technology Policy, headed by the prime minister of Russia. The Council for Science and Technology Policy was also established, and is headed by the president of Russia. This council considers the strategic problems of S&T and makes recommendations for S&T policy. The committees on education, culture, and science of the State Duma and the Council of Federation are responsible for the preparation of legislation related to S&T.

Regional interests are an increasingly important new influence on government science and technology policy. The new Constitution of the Russian Federation assigns S&T development to the joint competence of the federal and regional authorities. Management bodies for regional S&T (departments, committees, and others) have been created in 35 regions of Russia. Regional associations of scientists

Table 3.2. Number of R&D institutions affiliated to civilian industrial ministries.

Ministry	1992	1993	1994
Petroleum	115	93	98
Machinery	409	404	360
Metallurgy	82	73	66
Fuel	73	62	62
Railways	34	38	36
Stone, clay, and glass products	47	36	29
Construction	74	70	67
Communications	27	21	22
Agriculture and food products	323	292	258
Fishery	42	32	33
Geology	52	52	55
Natural resources	38	37	38

Source: Authors' estimate.

and regional coordination centers serve to unite representatives of various R&D institutions with regional authorities.

To increase democratic activities since 1991 various public unions of scientists have been founded. Between 1991 and 1995, more than 60 new public academies were established to function as independent, nonprofit bodies; these new academies complement the 160 existing S&T and engineering societies. Most of the new organizations have regional branches. The Russian Union of Scientific and Engineering Society combines 30 S&T societies and 73 regional departments. The Union of Scientific Societies, established in 1993, incorporates about 50 organizations such as the Russian Physics Society, the International Union of Instrument-Makers, the Academy of Engineering, and the Academy of Natural Sciences. Through these institutions, scientists have the possibility of influencing government S&T programs.

3.2.2 Reform directions

The changes needed to make Russian R&D efficient are extensive. The research and technological organizations should be more flexible, more competitive, and more responsive than they are today. Administrative barriers between branches and disciplines must be removed, and science and industry must integrate into new economic and legal organizations. Integrated activities could be accomplished through state research centers, centers of contractual research, technoparks, and financial and industrial groups. Establishments that currently make up the Academy and higher education sectors should be included in any process of restructuring.

R&D institutions should function independently within the science and technology market. State bodies should be responsible for a limited number of tasks, especially the choice of state priorities in S&T, development and financing of government S&T programs, and the support for a market infrastructure for technology transfer.

The most radical way of overcoming intersectoral barriers would be a complete withdrawal of R&D institutions from the branch management bodies. Such a radical change requires careful analysis of R&D institutions and their distribution according to the sector of science, the branch of economy, and their stage in the innovation cycle. On the basis of such an evaluation, the best structure for the new market conditions could be determined.

One possible way of reorganizing the network of R&D institutions is a system proposed by the MSTP in 1992. The proposal suggested changing the organization of research institutes and their financing according to their role in the national R&D effort. Large research institutes would be transformed into the centers of contractual research. These would be dominant in a given field of study, reflecting the economies of scale of staff, equipment, and facilities. They would become the "incubators" of new knowledge and technologies. These centers would function in accordance with the government S&T programs, using their capacities to fill R&D orders from interested customers. They would also receive state financing to perform both basic and applied research. Close cooperation of such centers with higher education institutions would be required and would take various forms including joint research projects, exchange of researchers, and grants from the centers to universities for specific tasks.

Branch R&D institutions that perform R&D in a narrow field with a limited number of customers would be supported by a consortium of industrial users. R&D institutions that are even more specialized (for example, performing R&D predominately for one enterprise) would be incorporated with its customer as a joint research and production company. Finally, industry R&D institutions with a high share of basic research, oriented to the acquisition of knowledge for general use, would become part of the system of academic science.

The Russian Academy of Sciences and branch academies of sciences should also be changed significantly, particularly with respect to applied R&D. The independence of the Academy research institutes should be increased, perhaps by making them state R&D institutions. They should be financed by the government R&D budget on a competitive basis, with a focus on solving the most important S&T problems of the Russian Federation. The role of individual scientists and research teams could be enhanced by a system of competitive grants. Finally, the scientific councils of the Academy could act as boards of experts to advise the government.

This restructuring faces two difficulties. The sharp reduction of R&D financing has forced R&D organizations to concentrate their energies on survival in a tough market struggle with other institutes; the system is already burdened with strong conflicts. The other difficulty is that the government's priorities and strategic purposes remain uncertain. Only since 1995 has the MSTP managed to execute some of the measures needed for restructuring the R&D system.

An important component of the new science policy is the formation of a network of state research centers (SRC). These institutes are to conduct world standard research, employ highly qualified staffs, and use state-of-the-art equipment. In 1993, legislation was adopted supporting the concept of the SRC along with state regulations on their activities and provisions for government financial support. Measures in the SRC legislation include tax and customs privileges and decreased utility and communications tariffs.

By 1996, the status of SRC had been assigned to 61 research institutes (*Exhibit A1.5*). The MSTP, which manages this program, intends to pursue a rigorous selection policy in granting SRC status; the main criteria are conformity to the priorities of the state science and technology policy and the probable contribution of the institute's work to the Russian economy. The SRC status of each center is to be reviewed every other year by the Governmental Commission on S&T Policy (see Chapter 7).

The government is currently asking its agencies to inventory their R&D network and to determine their organizational and legal forms, their main fields of research, and their privatization plans. The Governmental Commission on S&T Policy will consider the reports and will make decisions on revising the structure of the R&D institutions.

The value of these reports is limited by the sectoral organization and reliance on current officials to provide information. Early returns show that the reports contain only general information, the views of decision makers in sectoral departments, and requests for additional financing. None of the reports recognizes the fact that the new situation requires the creation of incentives for enterprise financing of R&D to lessen direct governmental support of R&D units.

Transformations also require changes in the attitudes of individual researchers. A 1995 poll of researchers conducted by the Centre for Science Research and Statistics (CSRS) found that most researchers think Russian science and technology is falling far behind world standards and that professional qualifications of researchers are declining. More than 80 percent consider the lack of financing the main reason for the current crisis in R&D whereas only 36 percent list low demand for R&D. The old system of direct government support persists in the thinking of many researchers, despite the dramatic changes since 1991. Clearly the attitudes of researchers must change if the R&D system is to be more market oriented.

3.2.3 Privatization in the R&D sector

Privatization was expected to accelerate the adaptation of R&D institutions to market conditions. A number of specific provisions have been established for the privatization of R&D institutions. Some are to remain publicly owned and some are to be subject to state control even after privatization.

Privatization in the R&D sector began in 1992. In that year 118 institutes were privatized, together with 40 design and construction project and exploration organizations and about 100 R&D divisions of industrial enterprises. In 1993, the number of privatized R&D institutions more than tripled. The MSTP reports that, by the end of 1994, 19 percent of the R&D institutions, employing 17 percent of R&D workers, were privatized. This situation has led to a general shift in the pattern of ownership of R&D institutions. By 1995, there were 796 R&D institutions reestablished as joint-stock companies (with participation of the government) and 150 fully privately owned organizations – or 20 percent and 4 percent of the total, respectively (*Exhibit A1.3*). Together they employed 20 percent of R&D personnel (*Exhibit A2.10*).

Privatization has occurred in all kinds of organizations performing applied R&D. About 100 of these are in the defense sector, including such large organizations as the Sukhoy Design Bureau, the Tupolev Design Bureau, the Moscow Helicopter Plant, and the Energy Research and Production Association which, despite its name, is engaged in space-technology applications. The privatized part of the R&D sector receives a considerably smaller share of government funding than those that have remained state owned.

In July 1994, a governmental decree addressed the privatization of R&D institutions. According to this decree, the ministries and departments were to determine if R&D institutions fit into one of the following categories:

- Firms that are forbidden to privatize.
- Firms that are to be transformed into institutions financed by the federal budget.
- Firms that are liable to be transformed into joint-stock companies with 100 percent of the shares held by the state.

R&D institutions not classified into one of these categories could be completely privatized under the general privatization legislation. In about 20 percent of the privatized institutions, however, the government has retained full control over the property; in some cases, it has retained a “golden share,” giving it the right to approve key decisions such as a merger with another institution even though the government is a minority owner. For other institutions, however, the government has no role in management after privatization.

By the fall of 1995, some 900 sectoral R&D institutions were either privatized or in the process of privatization with the status of 1,100 organizations still to be determined. In 1996, the government drew up a list of 616 R&D institutions that cannot be privatized.

In 1995, the MSTP, jointly with federal ministries, carried out a survey that found that the state still owned 61 percent of the 1,890 institutions surveyed. The majority of the rest had some form of a joint-stock company. The most extensive privatization had occurred in the civilian industrial sectors: by July 1995, 60 percent of these R&D institutions were partially or fully privatized. The other extreme is agricultural R&D institutions; only 10 percent of these organizations had been privatized.

Many governmental agencies consider it impossible to definitively assess the effects of privatization. That is why officials and experts often argue that there should be a cautious policy and that state control over the main research institutes should be retained in priority fields.

3.2.4 Financial industrial groups

Privatization has prompted the development of financial industrial groups (FIGs) in which independent organizations agree to work together. Such groups make it possible to unite the R&D capacities of industrial research institutes, the production capacities of industrial enterprises, and the capital available from financial institutions.

Financial industrial groups are created in accordance with the president's edict of 5 December 1993 and with the 1994 Statute of Financial Industrial Groups and the Order of Their Creation. In November 1995, the law on Financial Industrial Groups was adopted. FIGs are defined as the commingling of enterprises of any ownership form with banking and investment organizations, which may include foreign companies. Financial industrial groups can be created by agreement among organizations or by the exchange of shares (mutual selling of shares to group members or transferring them to a trust management). FIGs are subject to some antimonopoly limitations (*International Encyclopaedia of Engineering*, 1994). By the beginning of 1996, there were 30 FIGs in Russia, and several other organizations were in the process of registering. According to a forecast by the State Committee for Industrial Policy, there could be as many as 150 FIGs by the end of 1997.

FIGs now include a total of 470 organizations with 2.5 million employees. Such giant enterprises as Norilsk Nickel, Kuznetsk, Magnitogorsk, and Novolipetsk metallurgic plants, large automotive enterprises, and the Chelyabinsk tractor plant have all become members of FIGs. Some FIGs have implemented huge projects with foreign partners; for example, FIG Urals Plants have developed a modern communication system jointly with Siemens, Ericson, and other Western companies. The establishment of international FIGs in countries in the Commonwealth of Independent States (CIS) began with the Interros group which was registered in September 1995.

The share of the state ownership in FIGs does not exceed 25 percent. Groups differ both by number of participants (from 8 to 30) and by type of participating enterprises. Most are based on the vertical integration of the technological cycle, which combines suppliers of inputs with producers of final products. Such groups often include R&D institutions developing new technologies, and these R&D institutions are financed by the production enterprises. For example, the Research Institute of Vacuum Electronic Machine Building is included in the FIG Urals Plants and the State Research Institute of Chemistry and Technology of Polymers is part of the FIG RUSKHIM. Many FIGs declare that one of their goals is the implementation of R&D in new products and processes. Under current conditions of difficult financing and organizational problems, however, the groups have so far tended to invest little in R&D projects with a long-run payoff.

In accordance with the Program to Promote the Creation of Financial Industrial Groups in the Russian Federation approved by the government of Russia in 1995, several FIGs will be established to bring R&D-intensive products such as aviation and space technologies, petroleum chemistry, communications equipment, lasers, and armaments to world markets. In the defense sector the FIG Russian Aviation Consortium has been established, and includes large privatized R&D institutions like the United Design Bureau of Sukhoy and units named after Ilyushin and Yakovlev, famous aircraft designers.

Another related organization form is the large joint-stock company, which owns and controls its units, in contrast to groups in which the enterprise members remain independent organizations. Gazprom, in the fuel sector, is the most prominent example of such a company. Some of the 20 research institutes owned by Gazprom perform large-scale, long-term R&D; others provide more immediate technical services. Some R&D units are fully owned subsidiaries of Gazprom working on a contract basis, and others are considered integrated departments of the parent company; however, all are mostly financed by Gazprom.

Although there are many obstacles to the creation of efficient financial industrial groups and large concerns such as Gazprom, these kinds of organizations may be the best way of concentrating capital on R&D and innovation. Although relatively small in number, the large and stable financial industrial groups and large corporations in different sectors of the economy could be a significant factor in Russia's recovery. An important point is that these organizations decide which sectors and projects are promising and invest accordingly.

Table 3.3. Small enterprises in the Science and Scientific Services sector.

	1991	1992	1993	1994
Number of small enterprises	10,600	35,900	64,800	51,700

Source: CSRS, 1996b, p. 12.

3.2.5 Small businesses

The development of small business in the Soviet Union started in 1988 with the adoption of the law on Cooperation in the USSR. In 1990, joint-stock companies and private businesses were also legalized. In their registration new and existing enterprises can declare S&T as the main sphere of their activities. In these cases they are automatically listed in the so-called Science and Scientific Services sector. If S&T constitute more than 70 percent of their total activities, the enterprises are exempt from the profit tax during the first two years after registration. Small R&D enterprises, as well as some other R&D institutions, have tax concessions with respect to value-added tax (VAT), land tax, and customs duties.

By the end of 1994, there were 52,000 enterprises in the Science and Scientific Services sector of which about 80 percent were private (*Table 3.3*). They employ more than 200,000 workers and, together with those working under contract and on a part-time basis, 1.2 million individuals were estimated to be involved in these small businesses in 1994.

Small enterprises were often created as spin-offs from large research institutes. The entrepreneurial individuals in these institutes established their own small enterprises to raise their incomes and to be free of bureaucratic supervision. In many cases small enterprises were used as instruments to avoid taxes and overhead expenses. Some of the small enterprises leased property and equipment from the main institutes, and others used the facilities unofficially. Many individuals involved in these small enterprises continued as employees of the large institute, working only part-time in the new small enterprise. In 1994, more than 70 percent of small enterprises in the Science and Scientific Services sector had fewer than five full-time employees. According to some estimates only 3 percent of small enterprises in the Science and Scientific Services sector performed R&D. Others simply listed R&D as a major activity in their registration to obtain tax breaks.

In a recent CSRS survey, some 16 percent of R&D personnel did not know whether there were small enterprises based on their institutes and less than 50 percent of those who knew of their existence assessed them positively. A common view held by more than half of the respondents was that most small enterprises served the financial interests of the administration of the research institutes rather than the researchers.

Many private small R&D enterprises could not have survived under the conditions of low demand for R&D without help from the large research institutes with which their founders were affiliated. In 1991 and 1992 many small firms specialized in software, but intense competition and the lack of protection of intellectual property rights forced them to switch to other activities, frequently computer hardware retail. Most of those that continued with the software business either merged with affiliates of foreign companies or mastered specific markets (banking, accounting, etc.). The few small enterprises that were able to survive as S&T organizations found niches in Western markets that they could serve profitably. Among them there were several small companies developing software for telecommunications systems (for an American company), software for municipal information systems (for a Dutch city government), and biological preparations for race-horse testing (for Portugal).

Another way small enterprises survived was to perform intersectoral R&D. Without strict administrative control by an industrial ministry, small enterprises could apply their R&D to many spheres of activity. An example of such an enterprise is the Intersectoral Research and Production Laboratory created by researchers who were previously developing new metals for motor vehicles. By widening the applications for their R&D, the researchers obtained contracts from the Ministry of Railways and the Department of Chemical Industry. They developed a rail lubricant that significantly increased the life of railway rails; several Russian railways now use this lubricant. Small enterprises, however, cannot develop large-scale intersectoral projects that need substantial financing. For such projects, it is necessary to attract state investments or to find private capital, perhaps from financial and industrial groups.

State support of small business in Russia is still in its infancy. The main instrument has been tax exemptions to small enterprises for the first years of existence. In 1993, the Foundation for Promotion of Small Enterprises in S&T was established. It gives financial assistance on a competitive basis to research teams for the most promising S&T projects proposed by small enterprises. The work of the Foundation is discussed in Chapter 7.

3.3 An Example: Transformation of R&D in the Metallurgy Sector

In this section we illustrate the changes that have occurred in the metallurgy sector. Ferrous and nonferrous industries enjoyed a high priority in the USSR. Industrial enterprises were established particularly during the interwar "industrialization" period and after World War II. The metallurgy sector, especially ferrous metallurgy, developed extremely rapidly. By the beginning of the 1930s, a number of R&D institutes dealing with metals were established.

During World War II, new R&D institutes were created to work on the development of metals for military use. In 1944, the Central Research Institute for Ferrous Metallurgy, the main R&D institute for the industry, was created. The R&D institutes in nonferrous metallurgy were mainly devoted to the development of individual metals: the Central Research Institute for Tin; the Urals Research Institute for Aluminum; the Urals Research Institute for Copper; and the State Research and Project Institute for Nickel.

In the postwar years (1945–1955) many metallurgical research institutes were established in Moscow, Leningrad, and elsewhere. New R&D units, as well as all other sectoral R&D institutes, design bureaus, and experimental plants, were administratively directed by the science and technology departments of the Ministry for Ferrous Metallurgy and the Ministry for Nonferrous Metallurgy.

By 1991, there were 104 institutions performing applied R&D in Russia under the control of the two metallurgical ministries. Applied R&D related to metallurgy was also performed by higher education institutes as well as in institutes of the Academy of Sciences.

The structural transformation of the economy since 1991 has led to major changes in the metallurgy sectors. The disintegration of the USSR resulted in Russia's loss of some sources of manganese, chromium, titanium, silver, rare metals, and uranium since the large ore deposits are located in other republics. Sharp declines in industrial production in the major industries that were the main customers for metals have led to an abrupt decrease in the demand for metals. Production capacity of lead, copper, aluminum, and zinc is underutilized. Production of metals has fallen for manufacturing of forges and presses, metal-cutting machine tools, and excavators by 50 percent and for tractors and bulldozers by more than a factor of three. Meanwhile, the exports of metals have sharply increased. According to the Russian State Committee for Metallurgy most aluminum output and almost half of refined copper output were exported in 1994.

Because of these conditions, the R&D institutions must face some complicated problems. The number of sectoral R&D institutions declined from 104 in 1991 to 66 in 1994 (*Table 3.4*). The decline in the number of industrial enterprises performing R&D shown in *Table 3.4* is due to the fact that the managers of privatized enterprises have chosen to forgo R&D.

With the lack of funding and the decline in demand for their services, R&D institutes have been looking for ways to survive. Many small enterprises, established by personnel from R&D institutes, have implemented the R&D results from

Table 3.4. Number of R&D institutions of the State Committee for Metallurgy.

	1991	1992	1993	1994
Research institutes	43	43	43	43
Design organizations	10	9	7	4
Construction and exploration organizations	16	13	8	5
Experimental enterprises	1	1	1	1
Industrial enterprises	29	15	14	13
Others	5	1	0	0
Total	104	82	73	66

Source: Authors' estimate.

previous years. Research institutes have begun producing consumer goods, using their experimental equipment, and selling these goods through small enterprises. Many institutes have leased their premises to commercial enterprises. The lack of financing for R&D has led some institutions to keep their employees on the payroll for only part of the year.

According to a sample survey by the MSTP, two-thirds of R&D institutions in the metallurgy sector were privatized by July 1995. As with privatization generally, it is difficult to estimate the impact of this privatization on R&D activity, but some negative effects are apparent. For example, several large research institutes were purchased by commercial enterprises interested only in their premises, not in their research capabilities.

R&D institutes have also sought government financing, particularly as state research centers described in Section 3.2.2. Three such centers are under the umbrella of the Committee of Metallurgy (*Table 3.5*): the State Research Institute of Nonferrous Metals (GNIITsvetMet), the State Research Institute of Rare Metals (GIRedMet), and the Central Research Institute of Ferrous Metallurgy (TsNIICherMet). All are located in Moscow.

The new centers represent reorganization rather than simply a change in status. The GNIITsvetMet is a good example. It has 420 employees specializing in the study of heavy nonferrous metals and the purification of metallurgic gases. The institute owns FOLGA, a research and production enterprise, which is developing technologies to produce copper electrolytic foil, mainly for the radio electronics industry. The TsNIICherMet unites 11 organizations among which there are 7 research, testing, certification, and computer centers. The state research centers are financed primarily by the government R&D budget, so they are in a better financial position than other R&D institutes.

Table 3.5. State research centers (SRC) belonging to the State Committee for Metallurgy in 1994.

	No. of organizations in SRC	R&D personnel	Applied R&D in volume of budget financing
GNIITsvetMet	2	469	79%
GIRedMet	1	1,080	95%
TsNIICherMet	11	1,118	82%

Source: Authors' estimate.

After the dramatic output decline in metals between 1991 and 1993, some revival of demand occurred in 1994. In 1995, the decline in the demand for most metals ceased, and in a few cases even grew, mainly because of increased exports. Nevertheless, investment activity of the relevant enterprises is limited because of financial difficulties; therefore, government support of R&D remains crucial.

The revival of demand, the improvements in overall economic conditions, and the prospect of increased governmental support give some hope that Russia's metallurgical R&D will be able to overcome its current crisis and provide an impetus for progress in developing new products and processes.

3.4 Science and Technology Legislation

3.4.1 The legal environment

The institutional structure of applied R&D is shaped by the legal environment of a nation. There are three kinds of relevant laws: general laws relating to property, enterprises, and contracts; science and technology policy laws; and laws on intellectual property.

The Soviet system of central planning and state ownership did not require the complex legal structure of a market economy. With centralized direction and one owner – the state – there was no need for detailed legislation for market contracts or to carefully define property rights. The transition to a market system created a drastic and immediate need for a complex legal structure. The difficulties were compounded by Russia's new status as an independent state. The Russian Constitution, adopted in December 1993, further complicated the adoption of new laws for it identified two levels of legislation (federal and regional legislation). It was noted earlier that regional authorities now have an important role in S&T and other policies.

3.4.2 General laws

The Civil Code, adopted in January 1995, regulates civil and property rights of individuals and organizations. The law sets out the general procedures for registration, reorganization, and dissolution of all organizations including those in S&T. Similarly, general privatization laws applies to the S&T sector unless the state chooses to exempt an R&D institution under the procedures described earlier. The 1995 law on State Support to Small Enterprises also applies to small science-oriented businesses but gives special support to commercial organizations in the Science and Scientific Services sector.

The law on Conversion of Defense Industry states the legal basis for activities of defense enterprises and R&D institutions and gives two general principles of conversion of military facilities to civilian facilities:

- Utilization of high technologies, developed in the military sector, for production of internationally competitive products.
- Utilization of production facilities for state programs to ensure socioeconomic development.

This law applies to both production and R&D activities. The legislation has some significant omissions for it leaves uncertain the status of international activities of former military sector enterprises, the provision for national security, the use of classified technologies, and the legal mechanisms for transferring technologies applicable to both military and civilian uses to the civilian sector.

General laws on standardization, certification, and tax legislation have had a major impact on the R&D sector. These topics are discussed in Chapter 7.

3.4.3 Laws on science and technology policy

General laws are insufficient to encompass the special features of science and technology. In July 1995 the State Duma passed the law on Science and State Science and Technology Policy to deal with this insufficiency. The law was in preparation for three years.

The law defines the strategy for developing state S&T policy; the place of S&T activities in the state, society and economy; and the legal status of researchers and R&D institutions. It also spells out sources of R&D financing; a system of tax, credit, and customs incentives; and provisions for international S&T cooperation. The law contains a number of completely new measures, including the following:

- Regulations for state certification of R&D institutions.
- Rules for undertaking state orders for R&D on the basis of agreements (contracts).

- Licensing provisions of individual S&T activities.
- Basic principles of state S&T policy.
- Responsibilities of different levels of state authorities for S&T activities.
- Budget and non-budget funds for promoting S&T in Russia.
- Priorities for basic research.
- Provisions for a fixed share of R&D expenditure in the government budget.

Unfortunately, the law has some shortcomings. For example, there is no mechanism for certification of R&D institutions nor are certified institutions given any special incentives. The principles for certification are to be developed, but it seems likely that all existing R&D institutions will be certified thereby reducing the significance of the procedure. The law does not address state support to small business engaged in S&T. Nevertheless, the new law provides a basis for further development of S&T policy as social and economic conditions change.

3.4.4 Legislation on intellectual property

Legislation for the protection of intellectual property was enacted in the Soviet Union as early as 1931. At that time it was acknowledged that recognition must be given to new inventions and "other technical improvements." Inventors received certificates and remuneration from organizations using their inventions. This system of legal protections remained in place until 1992. During this 60-year period, two systems of legal protection of inventions were in existence: the copyright certificate on invention and the system of patenting. The copyright certificate was the most widely used device. Soviet citizens seeking to patent their invention abroad were required to receive permission from the Committee on Inventions established in 1931.

The new Patent Law of the Russian Federation was adopted in September 1992. This law protects a wider spectrum of intellectual property than the old Soviet certificates and includes provisions for industrial design and utility models. This law regulates certain relations between the inventor and his or her employer. To protect the employer's right to commercial secrecy the Patent Law allows the employer to forgo submitting a patent application. If the patent is granted in the inventor's name (according to an agreement between inventor and employer), the employer has the right to use the invention in his or her enterprise without a license agreement but with payment of proper compensation to the inventor. A Russian inventor may apply to foreign patent offices three months after an application has been submitted to the Russian Patent Office.

In 1992 the law on Trademarks, Service Marks and Names of Place of Goods' Origin was also adopted. This law provides trademark protection. After obtaining a certificate for a trademark, its owner has the exclusive right to its use for 10 years. Trademarks have become increasingly important in recent years. Between 1980 and 1988, 5,000 to 7,000 trademarks were applied for annually; the number increased to 12,000 in 1989 and to 29,000 in 1992.

Along with laws on patents and trademarks, legislation regulating intellectual property rights includes laws on Legal Protection of Software and Databases, Legal Protection of Integrated Circuits Topology, and Copyright and Adjacent Rights. Acts under preparation include laws on In-duty Inventions, Utility Models and Industrial Prototypes, and the Patent Court.

The implementation of patent legislation is assigned to the Committee of the Russian Federation for Patents and Trademarks (Rospatent). This federal executive agency, established by a 1993 presidential decree, performs the duties of a state patent office. It carries out state policy on industrial property protection, including the protection of inventions, utility models, industrial designs, and trademarks and identification of places of origin of goods, as well as legally protects computer software, databases, and integrated circuit design.

In August 1993 a government resolution approved a list of organizations that are to be supervised by Rospatent; these organizations perform individual patent functions. Together they form the State Patent Service. The list includes the Russian Research Institute for State Patent Expertise, the Board of Appeals, the Russian State Patent Library, the Russian Institute of Industrial Property and Innovations, the Administration of Industrial Property Rights, the Russian Research Institute for Patent Information, the Center of Patent Information Services (Informpatent), the Domodedovo Production Complex, and the Production Enterprise (Patent).

Even with these institutions in place, Russia still does not have an effective patent system. The necessary legislation has not been approved. The Patent Court has not yet been established, and the civil and arbitration courts do not have enough experience or enough qualified specialists to deal with S&T issues or to make patent legislation effective. Supervision by a patent procurator also does not exist.

An unresolved problem is the financing of patenting and licensing abroad. In 1990 the USSR Council of Ministers stopped the central financing of patenting and licensing. Since then applications for patents in other countries have been obtained at the expense of individual institutions. Budgetary allocations by ministries and governmental committees to institutions to recover patent expenses incurred abroad have either stopped or considerably decreased. The failure to pay renewal fees has caused three-quarters of the patents filed abroad in 1990 to lapse (OECD, 1994a, p. 64). There are few instances of Russians obtaining new foreign patents.

3.4.5 Proposed legislation

The State Program on Protection of the S&T Output in Russia has had some impact on intellectual property rights. This program aims at creating the conditions for innovation by providing a clear definition of rights on S&T output being financed by the federal budget; a control system for monitoring rights on S&T output; a control system for transferring dual-use technologies to the civilian sector; and support and control of international S&T cooperation.

The details of these provisions are to be resolved jointly by federal and local authorities with the MSTP supervising the process. The program envisages the development of laws to bridge the gaps in legislation on intellectual property protection, the creation of a federal database on inventions, and the promotion of technologies applicable to both defense and civilian industries.

Urgent issues in S&T are now being settled by presidential and governmental decrees. Presidential decrees have been ratified on the following: Urgent Measures for Preservation of the S&T Potential of the Russian Federation, State Research Centers, Measures for Material Support of Russia's Scientists, and the Board on S&T Policy Attached to the President of the Russian Federation. The government has enacted decrees on the establishment of the Russian Foundation for Basic Research, the Russian Humanities Research Foundation, and the Foundation for Promotion of Small Enterprises in S&T; on the procedure and use of sectoral and intersectoral non-budget funds for R&D; on privatization of R&D institutions; on the establishment of the Governmental Commission on S&T Policy; and on governmental support of R&D. In addition, a number of governmental decisions have been made concerning the Russian Academy of Sciences.

Even though numerous, the various laws are fragmentary, sometimes insufficiently coordinated with one another, and have major gaps. There is no law to regulate the relations between the state, participants of S&T activities, and consumers of their results; nor have many of the principles of the state's S&T policy been determined.

A doctrine on the development of Russian science was prepared by the MSTP and approved by the president in June 1996. As a basis for policy-making, this document is extremely important, not only for the country's scientific community, but also for the development of future governmental decisions and the prospects for political and economic reforms. The document states general policies whose realization at the federal level will secure a stable, goal-oriented transformation of the R&D sector.

Development of detailed legislation to regulate the status and activities of R&D institutions and to determine the procedure of giving preferences and privileges to some of them has started; the government is preparing a law on the status of the Russian Academy of Sciences. Draft legislation is about to be proposed to develop government support for innovation in enterprises. Legislative work continues on the development of intellectual property protection; on a draft law on non-budget funds in science, culture, and education; and on changes in the taxation and customs codes to provide more incentive for R&D and innovation. A federal contract system for financing R&D projects from government sources and a system of repayable financing of applied R&D are also in preparation.

3.5 Conclusions

The policymakers in Russia have attempted to transform the R&D sector by adopting new legislation and introducing tax incentives. These attempts, however, are being made within the old centralized system of S&T management with all its principal components such as intersectoral barriers and centralized financing. Most government R&D funds are still distributed through old industrial ministries or departments which control specific programs. The share of government R&D funds distributed on a competitive basis remains small. There is a long way to go to create an efficient and internationally competitive S&T system. As time passes, federal agencies will become less able to carry out a top-to-bottom transformation of the S&T activity. Many R&D institutions are being privatized, so that highly qualified research teams are no longer under governmental control. The share of the government budget in the nation's expenditure on R&D is declining. The necessity of transition to a new S&T policy is becoming more widely recognized. Direct management by the state should be replaced by indirect measures, and state support should be limited to the most promising activities.

The strategic objective is to rearrange R&D institutions according to the types of customers served. This approach would create a diversity in the R&D sector: some organizations would be integrated into production enterprises, some would be run by research consortia, some would be classified as government laboratories, and others would be largely independent. Some would eventually be privately financed; others would remain state financed. The diversity would be similar to that found in other major industrial economies. The system of governance and financing of the Russian Academy of Sciences must also be reviewed carefully.

Chapter 4

Sectoral Analysis of Russian R&D

Leonid Gokhberg

During the current transition to a market system, applied R&D must be ready to respond to short-run changes in the economic conditions of the various industrial sectors, as well as long-run changes in the economy. The interactive nature of innovation is complex in a market economy with many feedbacks. Currently, the macroeconomic disequilibrium dominates all other market developments; one consequence of this situation is that innovations contribute little to economic growth. It is hoped that macroeconomic conditions in Russia will improve so that some sectors of the economy will be in a position to introduce new products and processes. The conditions for and prospects of improvement vary by sector. Devising suitable public policy requires an analysis of structural changes in the economy, as they impact on the development of each industry. This chapter provides the sectoral analysis required for formulating S&T policy.

Developments in each sector have been determined, in part, by the economic recession that has hampered the country since 1990. The causes of the recession are complex, but clearly low effective demand, chaotic supply conditions, sluggish adjustment, and increased competition from higher-quality imported goods have played a role. From 1991 to 1995 industrial output declined by half and all industrial sectors suffered in varying degrees from the decline.

Since mid-1994 the output of some industries has stabilized, and in 1995 output in some sectors even began to increase. The financial conditions of enterprises remain difficult, though they are gradually adjusting to market conditions and to foreign trade liberalization. Investors are more willing to place their savings in safe profitable ventures abroad than to invest them in Russian production activities.

Table 4.1. Contributions to the production of gross domestic product by sector (%).

	1989	1990	1991	1992	1993	1994
Production of goods	62.8	60.7	59.8	59.0	49.5	43.5
Industry	35.9	35.2	37.6	42.7	33.3	28.3
Agriculture	15.5	15.3	11.9	8.5	8.4	6.3
Construction	10.5	8.9	9.0	6.7	7.5	8.5
Other	0.9	1.3	1.3	1.1	0.3	0.4
Services	30.0	32.4	36.3	32.2	44.4	50.0
Value-added taxes	7.2	6.9	3.9	8.8	6.1	6.5
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: *Voprosy statistiki*, 1995.

Given that industry demand for R&D is still weak, the level of applied R&D in the next few years will depend on a combination of government policy and economic conditions.

Currently, the production of goods is less important in the Russian economy than it was in past decades. In 1989 the output of goods was 63 percent of gross domestic product (GDP); in 1994 it was only 44 percent (*Table 4.1*). Sectors that were neglected in the past but are now important in a market system – trade, real estate, banking, insurance, and household and business services – have expanded significantly. Most striking, banking services expanded 180 times from 1991 to 1994.

In the production of goods major shifts have been experienced across sectors. Raw-materials industries maintained their output because of export opportunities and a sufficient level of domestic demand, whereas sectors producing capital and nonfood consumer goods suffered (*Table 4.2*). In manufacturing, output decline from 1991 to 1995 ranged from 61 percent in machinery production to 80 percent in textiles and clothing manufacturing; in contrast electricity generation experienced only 19 percent decline.

The natural-resource orientation of Russia's economy has increased significantly, and is now significantly different from that of major countries in the Organisation for Economic Co-operation and Development (OECD). The high shares of the electricity-generation and fuel industries in total industrial output (29.5 percent in Russia compared with 6.2 percent in the United States and between 12 and 14 percent in France, Germany, and Italy) and the large output of metallurgy (16.6 percent in Russia compared with 4.8 percent in the United States and 5.7 percent in Germany) indicate the increased natural-resource bias. Industries that manufacture complex products represent small and decreasing shares in total industrial output;

Table 4.2. Industrial production by industry (%).

	Annual growth rates (previous year = 100)				Distribution of industrial output			
	1992	1993	1994	1995[a]	1992	1993	1994	1995[a]
Electric-power engineering	96.6	94.7	91.2	97.0	6.6	7.1	13.5	13.8
Fuel	87.5	85.7	89.9	98.0	19.8	19.5	16.0	17.6
Metallurgy	78.7	82.0	86.8	106.1	17.8	17.5	16.6	17.1
Chemicals	77.6	78.2	71.1	108.0	8.5	8.0	7.5	7.9
Machinery	85.1	84.4	60.6	90.0	20.4	20.2	19.1	17.0
Wood, furniture, and paper	85.4	81.3	68.8	93.0	4.4	4.4	4.2	4.7
Stone, clay, and glass	78.0	82.7	71.1	92.0	2.7	2.7	3.8	3.5
Textiles, clothing, and leather	73.6	76.6	52.7	69.0	7.1	6.5	3.1	2.3
Food products	81.3	90.8	78.1	91.0	9.4	10.6	11.9	11.0
Total[b]	81.2	83.8	77.2	95.0	100.0	100.0	100.0	100.0

[a]Preliminary estimate.
[b]Discrepancies in totals are due to rounding.
Source: State Committee on Statistics, various years.

such branches include the chemical industry (7.5 percent compared with between 14 and 15 percent in the United Kingdom, the United States, Italy, and Germany) and machinery (19 percent in Russia, 35 percent in France, 41 percent in the United States, and 43 percent in Germany). (Data for Russia are given for 1994; for the OECD countries data, see State Committee on Statistics, 1994, p. 84.)

Several factors could favor Russian industries in the long run. First, the size of Russia's territory and the transportation systems which are inadequate for foreign suppliers will give many Russian enterprises a competitive advantage in the domestic market when demand increases. The availability of a large, relatively cheap, yet highly qualified labor force could help domestic enterprises become competitive, even in foreign markets. Russia's previous S&T achievements included many technologies and complicated technical devices and armaments that were much sought after in world markets. Restructuring and an improved financial situation will allow some domestic and foreign enterprises to invest in the development of new products and processes in Russia.

Russia has the finances available to develop its economy. Savings in Russia, however, are being used for working capital and in realizing profits from financial transactions. More than a half of the funds available for discretionary spending by

Russian households (approximately R42–44 trillion in 1994) was used to purchase convertible foreign currency, and much of the rest was used in financial speculation (*Ekonomist*, 1995). In other words, investments in fixed assets would be forthcoming to finance economic growth if manufacturing enterprises were to become profitable.

Industries, of course, have many special characteristics. The analysis of industry trends can be based on various traditional classification schemes according to such criteria as technology (R&D intensity) level, orientation, wages, and skills (OECD, 1995b). Five types of industries, with respect to primary economic factors affecting competitiveness, are appropriate for this study: (1) resource-intensive industries, (2) labor-intensive industries, (3) scale-intensive industries, (4) specialized suppliers (differentiated products), and (5) science-based industries (OECD, 1987). Each type of industry has a specific role in technology flows. Thus, resource- and labor-intensive sectors can be considered net technology recipients, whereas the science-based sectors can be considered exporters of technology to the rest of the economy. The differences are roughly measures by variations in the ratio of R&D expenditures to sales in which the science-based sectors have significantly higher ratios (*Table 4.3*).

The current Russian Classification of Branches of the National Economy still uses the obsolete administrative (ministerial) structure of economy in official statistics, and does not distinguish sectors into economic activities. This system is not compatible with the International Standard Industrial Classification (ISIC), which defines industrial activities that can be grouped into the five above-mentioned groups in a straightforward way. Therefore, the data used in this chapter refer to broad sectors of industry that are only loosely comparable with OECD categories.

In addition to classifying industries by technology characteristics and orientation, Russian industries can be classified by recent output trends and the financial condition of their enterprises. These short-run trends strongly affect R&D activities and through this have a long-run impact on the national economy. The R&D base in the key industries that create technology for much of the rest of the economy has recently eroded to such an extent as to raise the possibility of damage to future growth in all sectors, including the prosperous natural-resource sectors. The classification based on recent output trends and financial conditions of enterprises groups industries into four major groups (Institute of Economic Forecasting, 1995):

1. *Growth pockets* are distinguished by increases in output and improvements in financial conditions of the enterprises. Examples include the chemical and ferrous metals industries.
2. *Stability pockets* contain industries with improvements in the financial conditions of enterprises, on the one hand, and output stagnation or decline, on the

Table 4.3. Percentage distribution of R&D intensity by industry (value of R&D/production).

	1989	1990	1991	1992	1993	1994
Electric-power engineering and fuel	1.26	1.13	0.67	0.20	0.26	0.31
Metallurgy	0.80	0.81	0.38	0.14	0.11	0.11
Chemicals	2.46	2.42	1.32	0.48	0.58	0.60
Machinery	6.21	7.46	4.50	2.94	3.22	5.64
Heavy, power engineering, and transport machinery	5.66	5.71	2.05	0.87	1.06	1.01
Instrument-making and and electrical machinery	4.44	4.76	5.10	1.44	1.32	1.33
Chemical and petrol machinery	0.96	1.1	2.53	0.98	1.10	1.29
Machine tools	4.00	3.53	2.79	1.41	1.34	1.16
Motor vehicles, tractors, and agricultural machines	1.49	1.37	0.85	0.45	0.68	0.89
Machinery for construction and communal services	0.57	0.56	1.00	0.38	0.34	0.32
Defense industry	9.13	12.34	7.05	6.95	7.46	13.48
Wood, furniture, and paper	0.64	0.52	0.29	0.16	0.08	0.06
Stone, clay, and glass	0.49	0.64	0.38	0.12	0.06	0.03
Textiles, clothing, and leather	0.15	0.06	0.09	0.06	0.05	0.05
Food products	0.21	0.28	0.08	0.06	0.10	0.12
Total industry	2.23	2.48	1.27	0.67	0.72	1.08

Source: Author's calculations.

other. Examples include the resource-intensive nonferrous metals industry and the wood and paper industries.

3. *Stagnating sectors* include industries with a stable or slightly decreasing level of output and with enterprises in tolerable financial conditions. Examples include both resource-intensive sectors (fuel, electric power, food) and specialized suppliers (such as machine-building).
4. *Collapsing sectors* include industries with declining output and with enterprises in worsening financial conditions. Examples include labor-intensive light industry (textiles, clothing, and leather) and construction-materials production (stone, clay, and glass products).

In this chapter we provide a detailed review of the various major sectors and also consider the implications of the prospects for each sector's applied R&D.

Table 4.4. Composition of machinery output in Russia and the United States (%).

	Russia (1990)	United States (1982)
Investment equipment	54	59
of which for services	6	24
Defense products	29	15
Durable consumer goods	17	26
Total	100	100

Source: *Problems of Forecasting*, 1993.

4.1 The Machine-building Sector

4.1.1 Overall output trends

The machine-building sector produces a wide array of products from machine tools to automobiles and missiles. For decades, the industries in this sector played the leading role in the Soviet economy as measured by both output and the number of employees. Russia had about two-thirds of the Soviet machine-building capacity in its territory, so it inherited this large industry with the Soviet breakup.

The machine-building industry manufactured many products demanded by the military. Approximately 29% of the Russian machine-building sector was devoted to producing defense products. This share was nearly double the US share (15%) dedicated to defense products and more than the Russian combined share of consumer goods and equipment for services (*Table 4.4*). Because of this military orientation Russia's machine-building sector was not ready for an economy that emphasized the demand for civilian goods. The situation was further aggravated by the fact that an overwhelming part of technologically sophisticated durable goods (except for passenger cars) were produced by defense industry enterprises.

From 1990 to 1993, the decline in output was slower in the machine-building sector than in industry as a whole. The momentum of the machine-building development program introduced in the late 1980s continued into the 1990s, and was aided by a powerful lobby that supported the machine-building sector after the collapse of the USSR.

In late 1993, the decline in output drastically accelerated. This acceleration was associated with a considerable rise in the prices of domestic machinery products, making them comparable to the prices of imported items of higher quality. Simultaneously, demand by military and agricultural sectors decreased. Machinery manufacturers were slow to respond to changes in demand, so their products often did not meet the needs of consumers (for example, a surplus of heavy-duty trucks and a shortage of light-weight vehicles).

In addition, many low-quality Russian machinery products continued to be unattractive in export markets. The share of machinery products exported was 19 percent of the total output in 1991 and 10 percent in 1993. Imports of these items increased, and by 1994 the balance of trade in machinery was negative with a deficit of US$7.5 billion, making the Russian economy strongly dependent on imports for machinery. The quality of many domestic products which needed advanced technology was considerably lower than imported products (e.g., personal computers, consumer electronics, and pharmaceuticals).

Automobiles and Machine Tools

Some industries in this broad sector fared relatively well during the transition because these enterprises were manufacturing products that were in demand. The automobile industry is an example. From 1992 to 1994, the production of trucks decreased by 65 percent, but the output of passenger cars and buses fell by only 17 percent and 3 percent, respectively. From January to August 1995, the output of automotive parts was 2.7 percent above its 1994 level; this recovery was due to the fact that prices of domestic products were lower than prices of comparable imports. The production structure of the automobile industry is being changed to increase competitiveness. Production of light-duty trucks has increased and new engines have been introduced. Measures are being taken to add new passenger car and bus models (Khoroshilov, 1995). In the majority of the other machine-building sectors, however, output has continued to decline, mainly because of low levels of investment in many industries. Limited demand particularly affected machine tools because these products were intended to re-equip the machine-building sector itself.

Under centralized planning some types of technologically advanced equipment were produced and used in manufacturing even though they were more costly than alternatives. The higher costs were not reflected in prices, so the equipment was considered affordable. After the centralized system with its distorted prices was abolished, output of advanced equipment sharply declined. Less drastically affected were the output of universal machine tools and production of inexpensive equipment that was not linked to specific production methods. Still the declines were pronounced from 1991 to 1994: there were declines in output of metal-cutting machine tools from 74,000 to 19,000 (by 74 percent), forge and press machines from 27,000 to 3,000 (88.6 percent), digital-programmed machine tools from 16,700 to 500 (by a factor of 33), and automated lines from 556 to 49 units (by a factor of 11.3). The share of metal-cutting digital-programmed machine tools decreased from 22.6 percent to 2.8 percent of the total machine tool output; for comparison, current output of these types of tools ranges between 50 and 75 percent in the United States, Japan, and Germany (Centre for Economic Conjuncture, 1994). Manufacturing of rotor and rotor-conveyor lines and industrial robots has virtually stopped. Output of machine tools continued to decline in 1995 by 12 percent; this decline is a major factor hindering modernization of Russian industry.

Electrical and Construction Machinery

Output of heavy engineering and construction machinery has also decreased. From 1990 to 1994, declines were evident in the production of turbines (by a factor of two), excavators (by a factor of four), and bulldozers (by almost a factor of seven). In 1995, as demand stabilized or grew in some sectors (metallurgy, oil extraction, polymer, and paper production), the output of some enterprises in construction machinery increased. Increases in demand for these recovering industry sectors, as well as the projected rise of investments for modernization of agriculture, the food industry, and industrial construction, may result in the revival of the production of electrical machines, instruments, and automation equipment.

The Defense Sector

In this subsector, output decreased 2.6 times from 1992 to 1994. The decline in output was particularly sharp for military machine products, but this was offset by a rise in the share of civilian products in the total output of defense-industry enterprises reaching 64 percent. During 1994, there was a sharp reduction in orders and investments for the conversion of military enterprises to civilian industries. Of R1,400 billion earmarked in the preliminary federal budget for conversion programs in 1994, less than half were made available to enterprises (Volkov, 1995).

In spite of their difficult situation, defense-industry enterprises retained considerable potential as demonstrated by their exports of high-quality military and civilian products. A number of enterprises have mastered the manufacturing of new types of industrial products, including articles that earlier were imported such as equipment for the fuel industry and medical equipment (State Committee on Statistics, 1995a). The sale of these products is the reason for the output stabilization of civilian products from the defense industry in 1995.

All these changes led to greater specialization of defense-industry enterprises. On the one hand, 13 percent of former military enterprises manufactured only civilian products by 1996. On the other hand, the number of enterprises in which military products were more than a half of their output increased by 17 percent from 1993 to 1995 (Centre for Economic Conjuncture, 1995, p. 6).

4.1.2 Trends in applied R&D

By 1990 R&D effort in the machine-building sector accounted for three-quarters of total industry R&D, and since then it has gained even greater importance. A report of the Centre for Economic Conjuncture of the Russian government states that "domestic civil machine-building is to a considerable extent archaic and inefficient, has sufficiently lagged behind world standards, and given openness of the Russian economy . . . requires reproduction on a completely new technical and technological basis" (Centre for Economic Conjuncture, 1994, p. 6). It is impossible to accomplish this task without improving R&D and innovation activities. An ambitious R&D policy is crucial since R&D spending in machine-building declined by 80 percent in real terms from 1989 to 1994.

There are several reasons for the fall in R&D. The reduction in defense orders and the limited funds for conversion of the defense industry led to a reduction in R&D for military products. From 1990 to 1994, the number of R&D-performing institutions in the military sector decreased from 1,468 to 704 and R&D personnel declined by 32 percent. Even so, R&D in the defense-industry sector fared better than R&D in the civilian sector. The military sector's R&D units are the largest of all the industry sectors. From 1990 to 1994 the decline in R&D personnel in the defense sector was significantly smaller than that in the automobile sector (45 percent), machine-tool sector (78 percent), and electrical machinery sector (75 percent). The result has been an increase in the gap in R&D intensity between the military and civilian parts of the machine-building sector. Defense industry R&D now constitutes more than two-thirds of total industry R&D (*Tables 4.5* and *4.6*).

The shifts in applied R&D to the defense industry were based on the assumption that military R&D units must be reoriented to serve civilian branches rather than reduced in size. The redirection of defense R&D is reflected in the rise in the share of civilian R&D in former military R&D units from 46 percent in 1992 to 53 percent in 1994 (*Table 4.7*). The civilian orientation placed former military enterprises in direct competition with weaker civilian R&D units for government funding and for supplier contracts; as a result the latter units are gradually being replaced on the market. Given its continued large size, it is not surprising that the defense industry was one of the two sectors in machine-building in which the R&D intensity did not decrease (see *Table 4.3* above).

The decline in R&D expenditures in chemical machinery (by 77 percent) was also smaller than the decline in expenditures in machinery on the whole (82 percent) between 1989 and 1994. R&D institutes in this sector were split into smaller specialized profit centers closely connected with specific enterprises. Simultaneously, the share of development increased from 73 percent to 87 percent in the sector's R&D expenditure. Thus, the tactics of strengthening ties with

Table 4.5. Percentage distribution of R&D personnel by industry.

	1989	1990	1991	1992	1993	1994
Electric-power engineering and fuel	7.0	5.4	6.3	5.8	6.0	5.3
Metallurgy	4.0	3.6	3.5	2.7	2.0	1.7
Chemicals	7.8	6.7	7.3	6.0	5.3	4.7
Machinery	75.5	79.5	77.2	81.4	83.1	85.9
Heavy, power engineering, and transport machinery	5.8	5.0	4.0	2.8	2.8	2.3
Instrument-making and electrical machinery	8.4	7.6	12.7	6.2	4.9	3.8
Chemical and petrol machinery	0.4	0.3	1.5	1.2	1.0	0.8
Machine tools	1.8	1.6	1.7	1.2	1.1	0.7
Motor vehicles, tractors, and agricultural machines	4.6	4.1	4.9	4.3	4.9	4.6
Machinery for construction and communal services	0.2	0.2	0.5	0.4	0.4	0.2
Defense industry	54.1	60.6	51.8	65.4	68.0	73.6
Wood, furniture, and paper	1.4	1.4	1.4	1.1	0.8	0.5
Stone, clay, and glass	1.0	1.2	1.3	0.8	0.5	0.3
Textiles, clothing, and leather	1.2	0.4	1.1	0.7	0.5	0.3
Food products	1.2	1.0	0.9	0.8	0.8	0.8
Other sectors	0.9	0.8	1.0	0.8	1.1	0.4
Total industry	100.0	100.0	100.0	100.0	100.0	100.0

Source: CSRS, various years.

enterprises and reorientation to their needs (even to the detriment of long-term projects), combined with some institutional changes, enabled this sector to maintain some of its R&D base.

4.1.3 Innovation activity and financing

The subsectors differed from one another in their innovation activity; this is another manifestation of the direct dependence of S&T activities on the economic condition of an industry. In machinery branches oriented to manufacturing equipment for growing or stable sectors, innovation activity was high. For example, the share of enterprises introducing one or more innovations was 55 percent in chemical and petrol machinery and 62 percent in construction machinery. It should be noted that innovation is defined as introducing a product or process that is new to the enterprise, not necessarily new to the economy.

Table 4.6. Percentage distribution of the value of R&D activities performed within industry R&D institutions by industry.

	1989	1990	1991	1992	1993	1994
Electric-power engineering and fuel	6.5	5.0	6.1	7.4	9.1	8.1
Metallurgy	4.1	3.4	3.4	3.6	2.5	1.5
Chemicals	8.4	7.1	7.5	6.0	5.8	4.1
Machinery	75.3	80.0	77.1	79.1	78.8	84.0
Heavy, power engineering, and transport machinery	5.2	4.2	2.6	1.9	1.9	1.5
Instrument-making and electrical machinery	8.6	7.9	13.0	5.3	4.2	2.5
Chemical and petrol machinery	0.4	0.4	1.6	0.9	0.9	0.7
Machine tools	1.5	1.3	1.6	0.9	0.7	0.4
Motor vehicles, tractors, and agricultural machines	3.2	3.0	3.6	4.1	6.0	4.3
Machinery for construction and communal services	0.2	0.1	0.5	0.2	0.2	0.1
Defense industry	56.3	63.0	54.2	65.7	64.9	74.6
Wood, furniture, and paper	1.3	1.2	1.3	1.1	0.5	0.3
Stone, clay, and glass	0.8	0.9	1.2	0.6	0.3	0.1
Textiles, clothing, and leather	1.1	0.3	1.2	0.7	0.4	0.1
Food products	1.3	1.1	0.9	0.9	1.8	1.4
Other sectors of industry	1.1	1.0	1.2	0.6	0.9	0.3
Total industry	100.0	100.0	100.0	100.0	100.0	100.0

Source: CSRS, various years.

Technological re-equipment of a number of machinery branches and the introduction of new types of products, including those with the participation of foreign organizations, helped to maintain high levels of innovation activity in heavy and power engineering machinery and ship-building (50 percent of enterprises introduced innovations) and in manufacturing of motor vehicles, aircrafts, and radio and communications equipment (about 59 percent). However, in the stagnating components of the machine-building sector the innovation rates were lower; examples are machine-tools production (36 percent), agricultural machinery (33 percent), equipment for textiles (26 percent), and the food industry (25 percent).

Russian electronics, considered part of the machine-building sector, is a high-technology industry in serious trouble. Unable to compete with foreign companies, domestic personal computer output declined by more than a factor of three from 1990 to 1994. Innovation activity in electronics is at a level that is too low for

Table 4.7. Percentage distribution of R&D expenditure in R&D institutions of the Russian defense industry by objective.

	1992	1993	1994[a]
Defense R&D	54.3	47.6	46.6
Civilian R&D	45.7	52.4	53.4
Total	100.0	100.0	100.0

[a]Estimates.
Source: State Committee on Statistics, 1995c.

a branch that, by definition, belongs to the high-tech sector. Only 38 percent of enterprises introduced innovations in 1994, which is approximately equal to the average for machine-building as a whole. Innovations have mostly occurred in the production of household appliances, and many of these innovations are simple models of products based on licenses held by foreign firms (video cassette recorders, television sets, and audio recorders).

The links with applied R&D necessary for innovation are usually established either by contracts with R&D institutions or through in-house R&D units. Generally the sectors performing the most in-house R&D, such as electric-power and communications equipment, motor vehicles, and instruments, also had the most R&D contracted with independent R&D institutions. The positive correlation between in-house and contract R&D suggests that the two kinds of activities are complements to, rather than substitutes for, one another, a relationship that holds in other industrialized countries. In-house R&D apparently is a proxy for an enterprise's interest in innovation and leads to more contract R&D. There are, however, exceptions. Machinery for chemical, aircraft, and construction industries support a large amount of external R&D (between 24 and 29 percent of the enterprises contracted for R&D) and a small amount of internal R&D (between 9 and 16 percent). It should be noted that the terms large and small are relative to the average in Russia. In international comparisons, the Russian average is low. In 1994 only 12 percent of enterprises in the machine-building sectors were engaged in contract R&D and 13 percent in internal R&D.

Finally, the various parts of the machine-building sector differ in the relative roles of state and enterprise financing of R&D (*Table 4.8*). Overall only one-quarter of R&D financing for the sector is from government funds; the rest is largely from enterprises. Again, defense industries are the exception because aircraft, communications equipment, and electronics, all defense-oriented industries, obtained two-thirds of their R&D financing in 1994 from government funds. Foreign financing of machinery R&D is fairly insignificant for most subsectors, but it is substantial in heavy and chemical machinery and aircraft industries.

Table 4.8. Percentage distribution of R&D expenditure in machine-building by subsector and source of funding in 1994.

	Funds from enterprise R&D units	Budget funds	Non-budget funds	Funds of enterprises and R&D institutions	Foreign funds	Total
Heavy machinery	26.4	24.8	6.2	35.9	6.7	100.0
Chemical and petrol machinery	34.3	5.6	4.4	50.0	5.7	100.0
Electrical machinery	18.4	53.3	4.5	21.9	1.8	100.0
Instruments	14.4	18.5	3.0	63.7	0.4	100.0
Machine tools	33.9	23.3	0.6	42.2	0.1	100.0
Motor vehicles	84.0	5.6	1.3	8.5	0.6	100.0
Agricultural machinery	45.6	15.6	10.1	27.8	0.9	100.0
Aircraft	6.0	64.4	10.8	12.6	6.1	100.0
Communications equipment	4.9	70.8	1.7	21.7	0.9	100.0
Electronics	16.1	53.8	2.2	25.3	2.5	100.0

Source: Author's estimates; discrepancies in totals are due to rounding.

Changes in the structure of R&D financing have entailed shifts in the type of R&D activities carried out (basic research, applied research, development). Thus, science-based and specialized machinery branches, which continue to receive a high share of government support, had higher shares of basic research (defense industry, instrument making and electrical machinery, and machine tools) than industries in market-oriented sectors (such as construction and chemical machinery); in the latter sectors basic research was reduced to zero (*Table 4.9*). In response to enterprise pressure, the share of development in the overall R&D activity in the machine-building sector increased from 68 percent in 1990 to 76 percent in 1994. Applied research, which is notable for long-run returns, decreased over this period from 30 percent to 20 percent.

The increased emphasis on development supported from enterprise financing has already resulted in some increase in machinery R&D output measured in terms of the development of equipment prototypes (*Table 4.10*). As stated earlier, the changes taking place favor new types of machinery intended for stable sectors of industry (oil and gas, wood and paper industries), transportation (automobiles and rolling stock), communications, health care, and households. The reduction affected machinery development for declining sectors (textiles and food industries) as well as manufacturing of such products that cannot compete against imported items

Table 4.9. Percentage distribution of the value of R&D activities performed within industry R&D institutions by type of activity in 1994.

	Basic research	Applied research	Development	Total
Industry	3.6	24.5	71.9	100.0
Electric-power engineering and fuel	1.6	50.2	48.2	100.0
Metallurgy	3.4	42.4	54.2	100.0
Chemicals	5.5	34.7	59.7	100.0
Machinery	3.4	20.3	76.3	100.0
Heavy, power engineering, and transport machinery	1.3	16.4	82.4	100.0
Instrument-making and electrical machinery	3.7	13.0	83.3	100.0
Chemical and petrol machinery	0.3	13.1	86.6	100.0
Machine tools	4.3	30.1	65.6	100.0
Motor vehicles, tractors, and agricultural machines	2.0	12.4	85.6	100.0
Machinery for construction and communal services	0.0	34.2	65.8	100.0
Defense industry	3.6	21.1	75.3	100.0
Wood, furniture, and paper	17.5	33.2	49.3	100.0
Stone, clay, and glass	0.1	18.6	81.3	100.0
Textiles, clothing, and leather	3.5	38.5	58.0	100.0
Food products	13.6	75.0	11.4	100.0

Source: CSRS, various years.

(computers and equipment for trade). Demand decline from machine-building itself was reflected in a reduced number of new types of machines for use in this sector (machine tools, forge and press machines, automated lines, and industrial robots).

Government priorities shape the distribution of federal funds among various parts of the machine-building sector. The priorities are reflected in 18 federal S&T, innovation, and investment programs approved in 1994 for machine-building. All are intended to reorient the sector from the inherited production to domestic and export market demand. Major programs include development of the following:

- State-of-the-art equipment for the fuel and power-engineering complex.
- Internationally competitive machine tools.
- Power-saving equipment for electrical generators and transmissions.
- Improved railway locomotives and passenger cars.
- Better urban and suburban mass-transit vehicles.

Table 4.10. Number of prototypes of machines, equipment, instruments, and automation means by type.

	1990	1991	1992	1993	1994
Machines and equipment	963	742	795	858	984
Power engineering equipment, diesel engines	25	30	15	20	27
Equipment for ferrous and nonferrous metallurgy	9	9	4	5	9
Railway equipment and rolling stock	10	8	22	29	25
Electrical machines and equipment	146	100	79	107	112
Chemical, pumping, and compressor equipment	63	72	55	52	61
Equipment for oil and gas extracting and processing	18	20	35	29	32
Metal-cutting machine tools	40	57	37	33	26
Forge and press machines	39	44	49	27	20
Wood-processing, pulp, and paper equipment	20	17	38	28	24
Automated lines, manipulators, industrial robots	16	13	7	3	6
Automobiles and engines	35	20	40	41	66
Agricultural machines for cattle-breeding, poultry-farming, and fodder production	16	17	21	27	19
Earth-moving and road machines and construction machines and equipment	31	23	23	23	23
Technological equipment for textiles, clothing, and leather manufacture	68	39	17	26	17
Technological equipment for food manufacture	46	30	30	26	33
Trade and public-catering technological equipment, regulators	32	5	11	13	11
Communications equipment	58	25	54	63	75
Electronics equipment	73	69	52	78	86
Medical equipment	40	31	41	45	71
Equipment for cultural and social services	26	24	93	96	105
Others	187	109	112	87	136
Instruments and automation means	203	151	202	182	207
Technological process control and regulation instruments	70	56	76	55	89
Electric-measuring instruments	14	10	12	16	16
Computers	39	26	30	21	10
Machines and instruments for measuring mechanical values	23	18	20	24	19
Chronometers	5	8	25	4	8
Physical research instruments	19	7	1	11	16
Optical instruments and apparatuses	16	12	9	22	20
Others	17	14	29	29	29
Total	1,166	893	997	1,040	1,191

Source: CSRS, various years.

- New machines and equipment for housing and road construction.
- New agricultural equipment and better food storage and handling systems.
- Standards and certification system for Russian machine-building products.

In addition, two large-scale programs are to be completed in the framework of defense-industry conversion:

- Civilian aviation project to manufacture more than 10 types of multipurpose civilian airplanes and helicopters.
- Development of electronics equipment, particularly devices that monitor changes in the environment.

These two programs accounted for 10 percent of all budget appropriations for civilian R&D in 1995.

State research centers provide an additional source of R&D financing in the machine-building sector. The status of state research centers was granted to 25 of the most prominent research institutes carrying out machinery R&D, including R&D on aviation, robotics, ship-building, optics, instruments, and electronics. State support for R&D in machine-building is especially crucial since this sector is the source of technological progress in the industries that use its products as equipment. The proper selection and support of machine-building projects will have an impact on Russia's economic recovery far beyond its immediate impact on the machine-building sector itself.

4.2 The Chemical Sector

4.2.1 Overall output trends

The chemical industry is a medium-technology sector (except for the pharmaceuticals subsector) and ranks second after machine-building in R&D intensity (see *Table 4.3*). However, the chemical industry in Russia is considerably less R&D intensive than it is in industrialized OECD countries: 0.6 percent in Russia in 1994 compared with 3.3 percent on average in affluent OECD countries in 1992 (OECD, 1995b, p. 69).

Output declined by 57 percent in the chemical sector from 1991 to 1994. In 1995, growth in exports led to a rise in the output of basic chemical products such as synthetic resins and plastics, synthetic rubbers, and chemical fibers and threads. An increase in world prices made Russian products, whose prices had increased at a slower rate, more competitive. Output of the above-mentioned products grew by 8 percent, and production of synthetic ammonia, sulfuric acid, and fertilizers increased in a range of 11–17 percent. Production of polyethylene and polypropylene increased the most in this sector (by 32 and 62 percent, respectively). In the 1960s and 1970s there was an increase in the capacity to produce these new chemical products enabling the industry to capitalize on the increase in world demand for them. The economic prospects are good for a number of chemical companies that produce these products now in demand.

4.2.2 R&D and innovation

For decades, chemical R&D was oriented to the needs of the defense, fuel, and raw-materials industries. The sharp reduction in orders from the defense industry and the decline in the output of civilian products from 1991 to 1993 led to a decrease in R&D input, particularly in R&D employment, that had exceeded the industry average (*Table 4.5*).

Despite this situation, the chemical sector remained distinguished as the industry with the highest qualified researchers; 26 percent of them had advanced degrees compared with 10 percent in total industry and 8 percent in the machine-building sector.

Government and enterprise funding contributed to the revival of innovation activity in this sector. In 1993, 122 new raw materials, substances, and manufacturing materials were introduced into production, 93 of which were used for the first time in Russia. According to a Centre for Science Research and Statistics (CSRS) survey, 43 percent of chemical enterprises introduced new products or processes in 1994 (this percentage was 22 percent in industry as a whole). The share of enterprises that planned to develop or introduce innovations over the 1995–1997 period (37 percent) was also higher in the chemical industry than in the average for total industry (19 percent). Likewise a high percentage of chemical enterprises contracted out R&D: 24 percent of the enterprises in the sector compared with 5.7 percent for the total industry average. The chemical sector experienced a fall in R&D intensity from 2.5 percent in 1989 to 0.5 percent in 1992; however, since 1993, some growth has been noticed in this indicator because of the sector's efforts to maintain a high level of innovation.

R&D establishments in the chemical industry continue to rely on budget financing in the following priorities:

- Catalysts and their utilization.
- Membrane and other unconventional methods of separating, cleaning, and concentrating materials for use and processing.
- Safe production of low-tonnage chemical products.
- New manufacturing processes to reduce resource consumption and increase environmental safety.

- Chemistry and technology for water purification.

Chemistry-oriented programs are a high priority in the federal budget. They accounted for 16 percent of government S&T programs financing in 1994. This high priority helps to maintain basic research, whose share in the sector's R&D effort (nearly 6 percent in 1994) is higher than the industry average (less than 4 percent). Ten leading chemistry institutes have been designated as state research centers and consequently receive additional budgetary support.

The situation with non-budget sources of R&D financing in the chemical sector seems to be more favorable than in most industries, and their contribution to R&D expenditure is higher than the industry average. This makes the chemical industry less dependent on budgetary financing.

This favorable record, if it continues, will provide the basis for restructuring the sector's R&D base. The restructuring should include the 30 Academy institutes and 90 institutions of higher education that perform chemical R&D. Integration of industrial R&D units with the Academy institutes and better use of university facilities are important in improving R&D in this sector.

4.3 The Fuel and Electricity-Generation Sectors

4.3.1 Overall output trends

The fuel and electricity-generation industries provide essential inputs for every industry and almost every household. For this reason and because of high demand in export markets, the output decline in this sector has been smaller than elsewhere; production of primary energy products decreased by only 13 percent from 1991 to 1994, and currently accounts for almost one-third of total industry output.

The level of energy production achieved between 1993 and 1994 filled the domestic energy needs and allowed some increase in the export of oil and gas (State Committee on Statistics, 1995a). Simultaneously, the structure of fuel production changed: the share of natural gas increased from 45 percent in 1992 to 49 percent in 1994 with a decrease in oil (from 35 percent to 32 percent) and coal (14 percent to 12 percent).

Petroleum-refining output fell more sharply than the output of other energy products (a 25 percent decline from 1992 to 1994). There was a shift in the mix of exports to crude oil at the expense of more expensive refined products. In 1995 the composition of output began to shift back toward more refined products.

Most enterprises in this sector are still in a difficult financial situation despite relative stability in sales. Money receipts have lagged behind production, as enterprises in other sectors have failed to pay their fuel and electricity bills. As a result, solvency in the fuel industry (especially in oil extraction) has fallen drastically. Financial indicators in 1995 did not improve, showing that the sector has remained stagnant (Institute for Economic Forecasting, 1995). Many enterprises in the oil industry introduced limits on the extraction of crude oil in 1994 because customers were unable to pay. Oil production in 1994 was only 80 percent of the 1992 level.

The level of oil extraction was affected by the fall in exploration and the depletion of oil deposits. To address this problem, the oil industry needs more efficient technologies for both the extraction and production of its product. It must also renovate refining equipment. To increase the value of oil exports, as well as domestic consumption, there must be improvements in the quality of petroleum products and increases in the output of low-ethyl gasoline, low-sulfur diesel fuel, and motor fuels all of which are in demand.

The natural-gas industry is the most prosperous sector of Russian industry. Its exceptionally good natural-resource base has permitted stable levels of gas extraction. Yet even here, financial limitations have postponed the introduction of new extracting capacities and the construction of pipelines, compressor stations, gas-processing plants, and other facilities. A serious problem has been the loss of gas in transportation, a waste which is much greater in Russia than in the United States. Government support and private investments will be required for the creation of a system of sales, transportation, and processing of natural gas that meets world standards. The development and reclamation of a new gas-extracting region on the Yamal Peninsula will also require extensive investment (Vorontsov, 1995).

Coal output has declined by 20 percent from 1992 to 1994, reflecting a decrease in demand from domestic electricity-generating stations, ferrous metal production, and export markets. Rises in the price of transportation has forced up the price of coal. Revival of demand by the ferrous metallurgy sector in 1995 increased the demand for coal for coking, but this gain was largely offset by the decline in the demand for coal in electricity generation. Many coal fields have become unprofitable, yet coal extraction by strip mining, the cheapest source, is only about half of coal output. The measures undertaken to reconstruct the coal industry began in 1995, and involve the gradual reduction of deep mining in favor of strip mining and the shutdown of unprofitable mines.

In electricity output, Russia ranks second in the world after the United States. There was some reduction in electricity output (by 13 percent between 1992 and 1994 and an additional 2 percent from January to September 1995). The structure of the electricity-generation industry is changing. Electricity output from hydroelectric-power stations increased by 6 percent from January to August 1995,

Table 4.11. Percentage distribution of R&D expenditure in fuel and electricity-generation sector by industry and source of funding in 1994.

	Funds from enterprise R&D units	Budget funds	Non-budget funds	Enterprise funds	Private nonprofit funds	Foreign funds	Total
Electric power	7.7	37.5	27.0	27.6	0.1	0.1	100.0
Oil industry	7.8	17.2	22.5	51.4	–	1.2	100.0
Gas industry	6.4	1.1	28.1	63.9	–	0.5	100.0
Coal industry	4.4	38.4	40.9	16.1	0.3	–	100.0

Author's calculations; discrepancies in totals are due to rounding.

while output by nuclear and thermonuclear power stations decreased by 1 percent and 3 percent, respectively. Nuclear power stations in Russia provide 13 percent of electricity output compared with 22 percent in the United States, 24 percent in Japan, and 34 percent in Germany. A great deal of electricity in Russia is generated by natural gas, which is the cheapest source of energy.

4.3.2 R&D and innovation

The fuel and electricity industry ranks third among major sectors in total industry R&D, and its R&D intensity is higher than that of some branches of manufacturing. The sector's R&D personnel declined by 58 percent from 1990 to 1994.

Despite the personnel decline, powerful political and administrative support has enabled this sector to keep most of its research institutes intact; the number of R&D institutes declined from 188 in 1990 to 182 in 1994. The orientation of research institutes to meet the needs of enterprises has strengthened. Approximately 35 percent of enterprises in the oil and gas industries contracted out R&D during the 1992–1994 period; this was the highest level of this indicator in the Russian industry. R&D in the fuel and electricity-generation sectors is more dependent on enterprises' financing and less dependent on government support than R&D in other sectors. The share of financing from enterprises is very high in natural-gas (64 percent) and oil (51 percent) industries, while budgetary contributions to these enterprises are the lowest (*Table 4.11*).

The coal industry is the exception. Enterprises contributed only 16 percent of the coal industry's R&D funds, while the share of federal funds, both budgetary and non-budgetary, totaled 79 percent. The coal industry is the lowest among Russian industries in innovation activity, with only 12 percent of enterprises introducing innovations in 1994.

Enterprise financing increased the flexibility and productivity of research institutions, but also forced them to reduce their size. The average number of R&D personnel per unit decreased from 408 in 1990 to 235 in 1994. The sector's share in industry R&D expenditure increased from 7 percent in 1989 to 8 percent in 1994, while its share of R&D personnel fell from 7 percent to 5 percent (*Tables 4.5* and *4.6*).

In the sector as a whole the share of applied research increased from 43 percent in 1989 to 50 percent in 1994, a trend contrary to that in most other sectors. Applied research was financed both by federal sources and by R&D-performing institutions.

The Ministry of Fuel and Energy finances a considerable part of its R&D within the framework of the Fuel and Energy Program approved by the Russian government in 1994. Due to budget constraints, the program's R&D financing was small in 1994. In 1995 it was assigned the following R&D tasks:

- To develop a Russian energy strategy.
- To increase energy savings.
- To improve gas-power engineering.
- To create high-capacity electricity transmission between Siberia and European Russia.

Actual funds for the federal program on energy are much smaller than was requested by the Ministry of Fuel and Energy, and not enough to obtain substantial results. The Ministry on Science and Technology Policy (MSTP) also finances two government S&T programs devoted to fuel and energy. The objectives of the programs are to introduce ecologically clean power engineering and to promote technologies for development of complex fuel and energy resources in Russia. These two S&T programs are examples of joint public and private financing of industry-oriented R&D. In addition to nearly R3.5 billion allocated to them by the MSTP in 1994, associations of gas, coal, and oil industries and others spent R9.8 billion of their own funds. This pattern of public–private funding is an effective form of investment in industrial R&D in the transition period, and should be used in the future when the private sector becomes a significant source of financing for R&D.

4.4 The Metallurgy Sector

4.4.1 Overall output trends

The drastic reduction in defense-industry demands and the severing of cooperative ties with former Soviet republics caused a major decline in demand for ferrous metals between 1991 and 1994. Output declined by a factor of two from 1991 to

1994. In an effort to maintain trade, enterprises in this sector acted as net creditors to the machine-building sector and did not apply rigid sanctions to customers in arrears in their payments for shipments of metal. In some periods, arrears equaled one-third of the total nonferrous metallurgy output (Budanov, 1995).

The sector has gradually reoriented itself toward exports, and by 1994 50 percent of production was exported. In late 1994, output of all main types of ferrous metal products increased. In 1995, with some increase in domestic demand from the automobile and construction industries, output grew 6 percent for steel and 9 percent for cast iron and finished rolled ferrous metals products. In recent years metallurgical enterprises have displayed the best performance of most economic indicators – investment, profitability, stock prices, and wages.

Before 1991, the Russian metallurgical industries produced 60 percent of the former USSR total. These industries are still world leaders in production, except for some metals for which the United States and Japan rank first.

To maintain its leadership role, the sector must remain competitive. This will require reductions in energy and material consumption per unit of output. Some gains have been achieved by modernizing or even closing obsolete facilities. For example, the share of oxygen converter and electric steel in the steel output grew from 50 percent in 1992 to 61 percent in 1995 and the share produced with continuous casting technologies increased from 28 percent to 37 percent. The sector's leadership was also threatened by the considerable slump in output of products for the domestic market, especially high-quality and expensive products, such as alloy steel, rolled metals, and special steels for the defense industry.

Nonferrous metals experienced similar developments. The export market is even more important for these metals; in 1994 70 percent of production was exported. Production is almost totally dependent on developments in the world market and on changes in exchange rates (Institute for Economic Forecasting, 1995). Developments of nonferrous metals have varied significantly within the sector; the output of primary aluminum (including raw materials imported for tolling), refined copper, zinc, and other nonferrous metals and their concentrates is increasing, while the output of rolled bronze, brass, and titanium is declining.

The prospects for the metals industry depend, of course, on domestic demand, especially investment activity, and on export trends. Factors unique to the metals market may also be important. Competition from new high-technology metals will also affect the prospects for these industries as will the increased use of recycled materials and the development of metal-saving processes. Mini-mills may be built to use local raw materials (including secondary ones) and the newest technologies. The existing gigantic enterprises are likely to remain the main suppliers for the automobile and construction industries, but these large mills must adjust to new conditions by providing new products, lowering costs, and instituting after-sales services (Budanov, 1995, pp. 53–54).

4.4.2 R&D and innovation

The R&D intensity in Russian metallurgy was close to that in OECD countries until 1989. Since then, it has decreased drastically from 0.8 percent in 1989 to 0.1 percent in 1994 (*Table 4.3*); this rate of decline is larger than the total industry average. During the 1990–1994 period, R&D personnel decreased from 52,100 to 13,800, or by 74 percent. The curtailment of R&D in this sector has been partly offset by the fact that R&D projects targeted to metallurgy are carried out at approximately 160 institutes of the Academy and in other industry sectors that have received more government support than research institutes in the metallurgical sector.

Metallurgy currently receives a relatively high proportion of R&D and innovation financing from enterprises; this is probably a reflection of the good financial standing of the manufacturing companies in the sector. The share of non-budget and enterprise funds in R&D amounted to 12 percent and 32 percent in 1994, respectively; both sources allocate more funds to metallurgy than they do to industry as a whole. Enterprise initiative is especially intensive in nonferrous metallurgy: the share of enterprises that contracted out R&D remained 37 percent between 1992 and 1994. The contribution from foreign sources is negligible, 3.4 percent of R&D expenditure; in precious metals, however, foreign financing reached 22 percent in 1994.

Government support (24 percent of the government's R&D expenditure on the metallurgy sector in 1994) was oriented to R&D activity in the following priority areas:

- Improvements in the technologies for extraction, concentration, and agglomeration of ores.
- Creation and introduction of low-waste and conservation technologies.
- Development of new materials (refractory metals; hard, super-hard, light, and special alloys; ceramics) and technologies for their production.
- Creation of environmentally safe technologies, new methods of exhaust and sewage purification, and new ways to use solid wastes.

Three large research institutes were granted the status of state research centers. Federal support to metallurgy R&D institutions allowed them to increase the share of basic research in R&D expenditure from 2 percent in 1989 to 3.4 percent in 1994.

Innovation activity in metallurgy is characterized by the creation and introduction of new materials. Thus, 42 types of metallurgy materials were developed and

39 were introduced into production in 1993. Relatively favorable market conditions stimulated enterprises to introduce more innovations than the total industry average. Nearly 34 percent of ferrous metallurgy enterprises and 49 percent of nonferrous industries introduced at least one innovation in 1994. Given the favorable economic situation, this trend is expected to continue, resulting in the revival of R&D and innovation activity in the metallurgical sector.

4.5 The Food Industry

4.5.1 Overall output trends

Processed food output declined by 53 percent from 1991 to 1996; this decline is smaller than the total industry average. The most significant decreases were in the production of meat, milk products, butter, granulated sugar, flour, cereals, bread, fish products, confectionery, and vegetable oil. Most of the decline for these products reflected a shift in output to more expensive products demanded by high-income households. Furthermore, in the past these products received a very high subsidy from the federal government; when the subsidies were eliminated, industries producing these food staples were more severely affected than other industries. Price increases for agricultural raw materials lagged behind price increases for processed products, enabling food-processing industries to increase their profitability, particularly in 1995 (Institute for Economic Forecasting, 1995).

A rise of the population's income is expected to stimulate production in the food industry. To increase the quality of food products and the output per unit of raw materials, new technologies must be installed in the meat-, milk-, poultry-, and fish-processing industries. These technologies will increase the share of domestically produced foods in the domestic market.

4.5.2 R&D and innovation

The number of R&D personnel declined by 64 percent from 1989 to 1994, exceeding the average reduction in industry R&D employment, although the number of R&D units decreased only slightly from 47 in 1990 to 45 in 1994. The food industry, along with the fuel and electricity-generating industries, is the only sector that experienced a relative increase in industry R&D expenditure *and* a reduction in R&D personnel (*Tables 4.5* and *4.6*). In 1990 the food industry in Russia had approximately the same R&D intensity (0.3 percent) as OECD countries; now the Russian R&D intensity is about half that level, the result of relatively little interest by either the government or enterprises in financing R&D in this sector.

The low level of R&D in the food industry is matched by a low innovation activity of the enterprises. Only 18 percent of them introduced innovations in 1994, which is below the industry average (22 percent), and this percentage is expected to decline further. Most innovations are based on patent licenses and know-how agreements rather than on R&D obtained under contracts with R&D institutions or performed within enterprises. Only 1.7 percent of the enterprises contracted out R&D in 1994.

Currently, the government supplies most R&D financing in the food industry. The government's S&T program is primarily aimed at the creation of new technologies and equipment for the manufacture of high-quality, ecologically pure foodstuffs. The program comprises 36 projects working to develop environmentally safe and resource-saving technologies. The work is carried out by R&D units in the food sector and by the Russian Academy of Agricultural Sciences and engineering colleges. The program's principal projects are study of food albumen, improvements in dried foodstuffs, introduction of resource-saving technologies for baking bread, introduction of resource-saving technologies for processing meat, and development of technologies for obtaining fermentation and food antibiotics on the basis of membranous, biotechnological, and other progressive methods. This R&D program received R2.1 billion in 1994; this amount places it high on the government's list of S&T programs.

4.6 The Wood, Furniture, and Paper Products Sector

4.6.1 Overall output trends

Output in this sector fell by 56 percent from 1991 to 1994. In 1995, however, both domestic and export demand for paper increased sharply, leading to a recovery of 23 percent in paper output and 33 percent in commercial pulp. These increases led to a situation in which paper and pulp enterprises achieved higher profitability than any other industry sector. In contrast, the enterprises in the lumbering and woodworking branches fared poorly. They were unable to recover their higher costs for energy and transportation nor could they avoid raising export prices given the considerable rise in real exchange rates. Similar difficulties were experienced in the furniture-manufacturing industry, which also faced intense import competition.

One of the sector's most serious economic problems is how to increase output of finished products per physical unit of raw materials. In plywood, cardboard, paper, and pulp the same amount of timber yields four to seven times more finished products in the United States than in Russia. The lower output per raw-materials input is caused by the low quality of the equipment and the waste of timber and paper in production. It is also due to a low use of scrap materials. The manufacture of 1 ton of paper and cardboard consumes more than 250 kg of scrap paper in the United States and more the 450 kg in Japan and Germany. In Russia, such secondary raw materials are used on a considerably smaller scale (Centre for Economic Conjuncture, 1994).

4.6.2 R&D and innovation

Wood, furniture, and paper industries have a modest R&D intensity in all nations. In Russia, the level was low to begin with, and it has declined significantly in the transition period. R&D personnel fell from 19,700 in 1994 to 3,900 in 1994, and the sector's contributions to industry R&D totals are around 0.5 percent (*Tables 4.5* and *4.6*). A further decline in R&D personnel may completely destroy the industry's R&D base which would be detrimental to Russia given its exceptionally rich stock of raw materials.

One favorable development is the application of R&D results from other sectors to the wood industries, especially R&D in the university sector such as that at the St. Petersburg Academy of Forestry and the Moscow State Forestry University. Approximately two-thirds of budget funds available for R&D in this sector are channeled to universities and Academy research institutes. These institutions give priority to basic and high-level applied R&D related to wood. However, the share of basic research in R&D expenditure in this sector – 17.5 percent – as reported by respondents, seems to be overestimated (*Table 4.9*).

A major part of R&D expenditure in the industry in 1994 was from federal non-budget funds, including the Fund for Financial Regulation in the Timber Industry (31 percent), and from business enterprises (28 percent). In the number of enterprises contracting R&D (3 percent), wood and paper industries are at a level lower than the industry average (nearly 6 percent in 1994) and rank last among the seven sectors examined here. Innovation activity of its enterprises is also below average: 18 percent of enterprises introduced innovation in 1994, and only 17 percent intended to do so in the future.

4.7 Collapsing Branches

This category of industries is marked by declines in both output and financial results and includes textiles, clothing, and leather and construction-materials industries (stone, clay, and glass in the tables). These industries also have the smallest scales of R&D performance and the lowest R&D intensity among all the main sectors (*Tables 4.3*, *4.5*, and *4.6*).

4.7.1 Overall output trends

In the textiles, clothing, and leather sector, which in Russia has traditionally been called light industry, output declined by 80 percent from 1991 to 1995. The lower output was due to a decline in demand which, in turn, was due to a fall in real income per capita and competition from imported products. The output decline was the largest among industrial sectors.

In the cotton industry, the output decline in 1992 and 1993 was also caused by interruptions in supplies of raw materials from the Central Asian republics of the former USSR. Some plants were idle for several months because they were without raw materials. In 1994 the state offered loans to enterprises for purchases of raw materials, but cotton-manufacturing output still fell by 25 percent in 1995.

Despite the output decline in this sector, some enterprises successfully expanded production of goods that were in demand, such as outdoor clothing. Although the sector primarily serves the domestic market, some textile and clothing enterprises managed to export their products. The real appreciation of the ruble in 1995, however, hit the export end of the clothing industry hard.

Demand for construction materials (stone, clay, and glass) is determined by construction investments rather than, as in textiles and clothing, by current household consumption. Construction output began to decline in 1989 and, as expected in grave depressions, fell more rapidly than the industry as a whole. Rises in the relative prices for construction materials forced construction firms to undertake measures to reduce materials consumption in the construction process.

The one flourishing part of the construction sector is in small-scale individual housing in the countryside. As a result of this growth output increases were evident from 1994 to 1995 in asbestos and asbestos cement pipes (by between 11 percent and 17 percent), polished glass (by 8 percent), and so forth. In contrast, output of materials for large-scale construction, especially for industrial building, decreased by a factor of two to three from 1990 to 1995.

Due to a gradual revival in general investment activity in the Russian economy, the possibilities are good for obtaining external financing for the purchase of high-quality construction materials for housing and industrial construction (Vorontsov, 1995). There are also good prospects for manufacturing state-of-the-art components for construction of one- and two-story homes and farmhouses, as well as effective wall materials, and increasing the use of articles made from local raw materials (clay, sand, lime, and so on).

4.7.2 R&D and innovation

Innovation activity in light industries has been comparable to that in the food industry. Although 18 percent of the enterprises introduced innovations in 1994, only 13 percent of the enterprises plan to introduce innovations between 1995 and 1997, placing light industry, together with the coal and construction-materials industries, at the bottom of the list of industry sectors.

The small amount of innovation activity of light-industry enterprises and the reductions of budgetary appropriations caused a decline of 85 percent in the number of R&D personnel from 1989 to 1994. By the beginning of 1995, there were only 2,700 R&D personnel left in the light industry sector. Only 2 percent of light-industry enterprises contracted for R&D in 1994. There were, however, some new industry structures in which innovation was twice that of the sector average. For example, 22 percent of the enterprises of the Roslegprom joint-stock company and 30 percent of enterprises in the Rostekstil textile group introduced innovations. In R&D institutions attached to the governmental Department of Textile and Light Industry, the share of federal financing was 65 percent of R&D expenditure in 1994, but in industrial companies it was only 7 percent.

Government R&D financing in this sector has lacked specific goals, and most of the funds available have been used to finance the remaining R&D institutions rather than to carry out a coordinated program with clear objectives. The exceptions are small-scale projects financed by the MSTP directed at the creation of new technologies for new textile and cotton materials, including those with unconventional fibers.

The bleak financial outlook of the construction-materials sector negatively affects the innovation activity of its enterprises. On average, only 12 percent of enterprises introduced product or process innovations in 1994, the lowest among the main industry sectors. The share of enterprises that contracted out R&D was only 3 percent in 1994. The exception was the glass industry, where the share of innovative activity (21 percent of enterprise) approached the industry average.

Having neither sufficient enterprise demand nor serious budgetary support, the R&D effort of the construction-materials sector decreased markedly. R&D personnel declined sixfold from 1990 to 1994.

Budget funding of R&D is low for the construction-materials industry. The Federal Economic Program on Dwellings allocated little to R&D projects in this sector in 1995. Again, there was an exception for Rosstrom, an industrial association serving the construction-materials industry. In 1994 only 9 percent of the R&D carried out by the association was financed by the federal budget. The association received 49 percent of its financing from non-budget funds and 40 percent from enterprise contributions.

The analysis of budget-supported R&D projects in the construction-materials industry shows that the majority of the projects are oriented to the needs of housing construction, primarily individual houses (cellular concrete for low-level dwelling, fiberglass-reinforced plastic items based on thermoplastics, sanitary equipment of high reliability and duration, technology for manufacturing cement-fiber tiles, and so on). However, a number of projects are also aimed at the creation of technologies for manufacturing materials for large-scale industrial and public constructions (vulcanized roofing polymer film, prefabricated buildings made of thin monolithic concrete shells, and aggregates for light concrete).

The current policy considers housing construction one of the key sectors necessary to fill the future housing needs of the Russian population, and therefore could become a "money pump for the economy." R&D institutions in related fields should be more active in offering their services to enterprises in the sector.

4.8 Conclusions

The prospects of R&D in industry sectors vary from sector to sector and strongly depend on economic conditions. In principle, market research should be able to identify those segments of the market in which Russian products could be competitive. The federal government should then provide R&D funding to enterprises in these segments. The rationale for increased activity of the government is that currently even the most prospective industries are operating under difficult economic conditions and the enterprises are barely able to support R&D. Government support would enable R&D institutions to survive and maintain their research capabilities for the economic recovery and renewal of growth of the Russian economy.

Chapter 5

Innovation Activity of Russian Industrial Enterprises

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Applied R&D is only the early stage in the process that leads to a new product or new production process. A crucial later stage is that of innovation – the introduction of new products and processes into the economy. Such commercialization is the way R&D raises living standards and benefits the population.

This chapter focuses on innovation, particularly the role of the enterprises in the Russian setting. The chapter consists of three parts. The first provides a brief history of attempts to reform the Soviet innovation system since the early 1960s. The second part examines the empirical evidence of recent general trends in industrial innovation. The third part describes feasible policy initiatives that would promote enterprise innovation.

5.1 Innovation Activities in the USSR: Adjustment without Reform

5.1.1 Changes in the organizational structures of innovation: From the 1960s to the 1980s

Soviet policymakers spent several decades searching for efficient innovation policies. In the 1960s, it was widely recognized that bureaucratic costs outweighed the possible advantages of direct, top-down management, although the concept of socialist planning was not questioned. The command economy had already lost much of its steam and needed to progress technologically. The contrast between a powerful R&D potential and its insignificant utilization by industry was apparent. It was recognized that innovation in nondefense fields was important, so civilian R&D was given a higher priority than earlier in terms of financing, wages, equipment, buildings, and pilot and experimental facilities. Administrative command mechanisms were unable to combine the activities of separate research institutes, design bureaus, experimental pilot plants, and industrial enterprises to create new products and processes and introduce them into the economy. Such a separation of R&D institutions from industries was considered a source of inefficiency, as was the slow transfer of knowledge from the Academy and higher education institutions to enterprises; the limited application of mighty military R&D potential to civilian industries; the gap between the metropolises and provinces in the S&T level; and, finally, the almost complete autarky of the USSR with respect to innovation.

With the recognition of these problems, efforts were made to transform the organizational structures of innovation. Most important was the establishment of research and production associations and, later, intersectoral science and technology complexes (ISTCs) to strengthen ties between research and production and to achieve high efficiency in technology transfers (see also Chapter 3). These organizations were created within the framework of the centralized state management and had integrated plans and a high level of budget financing. Hopes were high that ISTCs would provide "realization of penetrative achievement of S&T progress, development of massive competitive products, transition to a new technological structure, modernization for the whole economy, and advancement in the world market with high-technology products."

However, the organizational changes were not backed by incentives for achieving such ambitious objectives. The ISTCs were shielded from market forces by lavish subsidies. Enterprises within ISTCs continued to follow the legislation and informal rules valid for organizations subordinate to industrial ministries. Although legal entities, ISTCs did not have their own finances and the leading organizations in an ISTC could influence its satellite members only during the formation of plans. The freedom and incentives necessary for the development of ISTCs were missing. As a result, goals were not accomplished and industrial ministries remained closed systems with minimum interactions with external organizations.

Important organizational changes were also made to help disseminate information about innovations. A state S&T information system (GSNTI) was created. GSNTI had a hierarchical structure (USSR, branch, territorial, and local levels). By 1990, GSNTI comprised 10,500 units and had a staff of 136,000 employees (CSRS, 1992, pp. 86–87). GSNTI disseminated information on S&T achievements and advanced production techniques, as well as the collection, systematization, and analysis of efficient methods for the introduction of innovations. It also organized domestic and international exhibitions of advanced machinery and technology.

In spite of the changes in the 1960s, 1970s, and 1980s, by the early 1990s the organizational structure for innovation had several inefficiencies. The innovation system did not have enough versatility and, as shown in previous chapters, had acquired an extremely inflexible structure. Organizational changes implemented within the framework of the administrative command system had not created an efficient way to bring technological ideas to commercial realization quickly. The military sector was the exception, for here the innovation process was well organized. The arms race and international competition demanded innovations and pushed the central authorities to establish a special mechanism for defense innovations and to allocate resources generously to the military sector. Incentives for the efficient integration of R&D and production were lacking in all other sectors. Innovation was stifled by the centrally planned economy despite the illusion of significant organizational change.

5.1.2 Changes in the central planning system

The central planning system for innovation survived with its major features intact until 1991 when the Soviet Union was replaced by the independent republics. Until this time major decisions in the USSR were made by the supreme party leadership and the central government. Drafts of decisions of national importance were prepared for party leaders by such central bodies as the State Planning Committee, the Ministry of Finance, and the USSR State Committee of Science and Technology. At the republic level, an analogous structure of decision-making prevailed. Regional and local authorities, however, had few chances to influence the development of innovation activity located within their boundaries for these decisions were made at the national level.

Resources needed for R&D innovations were estimated by the State Committee for Material and Technical Supplies. The point of departure for the estimations was the previous year's output, which secured stability of the economic structure. The State Planning Committee followed a similar approach, which also resulted in the reproduction of existing production patterns. The centralized distribution of financial resources through the state budget excluded the possibility of forming an innovation strategy that depended on the economic results of enterprises. Instead support for R&D was available to all industries roughly in proportion to their existing size. The pricing and distribution system guaranteed the sale of any increase in output. Financing for inefficient industries was available without provisions for the repayment of loans.

The development of S&T in the Soviet period was regulated by five- and one-year plans, which officially assigned tasks and priorities. Under this system of management, important intersectoral S&T problems were ignored because they did not match the departmental system of management.

Criticism of the performance of the R&D system focused on the actual management of S&T processes; however, only a few major attempts were made at improving the underlying system of management. Under pressure by prominent scientists and R&D administrators within the general paradigm of the administrative command system, the Communist Party of the Soviet Union (CPSU) Central Committee and the USSR Council of Ministers adopted a new system of S&T management in July 1979. The measure was entitled On Improvement of Planning and Reinforcement of the Impact of Economic Mechanism on Increase in the Efficiency of Production and Quality of Works and envisaged changes in both planning and incentives for R&D and innovation.

This document had the following provisions for S&T planning:

- The S&T program would be established for a twenty-year period with subdivisions into five-year stages. The S&T goals would be based on the socioeconomic objective defined by the Communist Party. After each five-year period, the program was to be supplemented by more precise objectives for the next five-year period.
- S&T programs would identify which areas to focus on and provide time tables for the completion of various stages, from research to the introduction of new technology into the economy.
- The five-year plans would guide the allocation of resources for S&T.

The leading role in developing S&T programs was assigned to the USSR Academy of Sciences and the USSR State Committee on Science and Technology. These two organizations reported to the USSR Council of Ministers and State Planning Committee. S&T programs were to be worked out both for the national economy as a whole and for separate branches and regions of the country. The responsibility for preparation of branch programs was placed on the corresponding ministries and departments, and regional programs were to be developed by republican governments. All this activity occurred under the guidance of the USSR State Planning Committee.

Another reform concerned economic incentives for R&D and innovation activities. In the late 1970s, there was an attempt to decentralize management of innovation to ministries and departments within ministries. In each branch, a fund for S&T development was established which was derived from payments by enterprises according to standards fixed by each ministry. The funds could be carried over from one period to another but could not be diverted to other purposes. Major uses of the fund were to finance R&D and to introduce new machinery. A portion of the ministry funds was at the disposal of the USSR State Committee on Science and Technology and was used for additional financing of projects carried out in accordance with national S&T programs. A further portion of the funds was retained by individual enterprises to give them an incentive to speed up innovations and raise their economic efficiency. The funds could be used at the discretion of the enterprise to design new processes or products or to buy new machinery to implement innovations.

Finally, the reform measures attempted to strengthen incentives for R&D and innovation. Previously, incomes of participants in the innovation process were strictly controlled by direct regulations. A Fund of Economic Incentives was established in each enterprise to pay bonuses to managers, researchers, and other personnel. Contribution to these funds was based on profits from the innovations.

Even with all these changes, the bureaucratic grip on R&D institutions and enterprises remained tight. The system of state procurement orders limited the possibility of accomplishing work on a contract basis. A ceiling on achievable profit rates neutralized the influence of demand on innovation. Even though the system envisaged the recovery of all costs, intangible investments were not included as an enterprise cost. Limits on the increase in personal income did not give incentives to innovators and researchers. Attempts to increase incentives by establishing sectoral funds, providing bonuses for successful innovation, granting special governmental and departmental awards, or introducing ranks for researchers had limited impact because the dominant bureaucratic structures kept the system from reflecting the wide variance in returns inherent in innovation.

5.1.3 Decentralization to enterprise

The 1987 law on state-owned enterprises was an important step in decentralizing decisions to enterprises. It was intended to give enterprises some economic independence and the responsibility for the results of their activities. It was hoped that, among other goals, new economic methods would accelerate S&T progress, secure maximum receptivity to innovation, and increase incentives to use the latest S&T achievements. Innovations to produce new and higher-quality products at low costs were recognized to be the most important way of increasing the income of an enterprise and providing for its self-financing.

The enterprise had to support its activities from the revenue realized from the sale of its output. The law granted enterprises the right to arrange their economic activity according to one of two economic models. The first was based on a system of profit distribution and input charges. After settlement with ministries for taxes, the repayment of credits, and payments to a wage fund determined by a fixed share of the value-added or some other measure of production, the enterprise could apply its net profit to any of the three funds: development of production, bonus payments for personnel, or social activities (health, training, recreation, or housing). The workers collective and the managers of the enterprise determined the distribution of income among these funds.

The second model of economic self-support was based on detailed regulations for distribution of income after payment for material inputs. Income was used first for the settlement of taxes and repayment of credits. The remaining income was then distributed among the funds mentioned above and then used for wages.

In both systems, enterprises could create a financial reserve and a fund of hard currency. The fund for development of production could be used by an enterprise to finance R&D and innovation and to purchase fixed assets. An enterprise was also granted the right to use the funds from amortization of fixed assets for the development of production or similar uses.

Through these reforms enterprises obtained freedom in financing innovations, but enterprises limited their use of this new freedom. This was because the law on state-owned enterprises created a conflict between the legal status and actual status of property in a state enterprise. Most managers of state-owned enterprises had little interest in the development and modernization of production that would increase profits in the long run. At the same time, having practically uncontrolled command of their enterprises' property, managers had an interest in increasing the revenue of enterprises in the short run by raising prices and using cheap credit. They used the resulting profits to reward themselves in direct and indirect ways and to maintain the real wages of employees whose support they needed.

R&D institutions were also subject to the law on state-owned enterprises. The transition of the industrial sector to a more decentralized system led R&D institutions to search for ways to be self-supporting. One way was to increase efficiency, and this did occur at the level of research teams. Arbitrary rule by managers became less common, and managers took more responsibility for their organizations' results. However, the effort to make R&D institutions self-supporting oriented them to short-term objectives that increased current revenue. The change also made R&D institutions more dependent on clients who were not yet always sufficiently competent in expressing their requests directly to the R&D institutions.

The intended goal of the new law was to retain the system of top-down control while enlisting the initiative and enthusiasm of managers, researchers, and workers. However, the reforms of the 1980s failed to achieve these goals.

5.1.4 Voluntary organizations to promote technical progress

Another development in the 1980s was the foundation of voluntary S&T associations. S&T societies (STSs) were voluntary public organizations that supported S&T to solve specific industrial problems. STSs operated under the guidance of trade unions and comprised voluntary research laboratories and schools involved in advanced studies. Also included were so-called technology houses and people's universities of technological progress (a kind of open university), where more than 1 million people studied annually.

The All-Union of Inventors and Rationalizers (VOIR) was also founded under the guidance of trade unions as a voluntary organization aimed at involving employees in innovation and organizing production in a more rational way. To improve the development of innovations and to solve the task of speeding up the country's socioeconomic development, VOIR, together with the All-Union Council of S&T Societies, carried out an experiment of combining efforts of scientists and enterprise managers. Contracts from enterprises financed the effort. The main goal of this endeavor was to accelerate implementation of S&T tasks in the five-year plan. As part of this effort an interdepartmental committee on the introduction of especially important inventions was established.

Still another initiative was the establishment of an S&T creative work program for young people in 1986. In early 1987, the responsibility for development of this program was placed with the respective All-Union Coordination Council headed by the Deputy Chairman of the USSR Council of Ministers and the Chairman of the USSR State Committee on Science and Technology. A regional system was also established. By the end of 1988, 500 centers existed with an average of more than 600 people (mostly employed on a part-time basis) at each center. Such centers arranged interaction between clients and temporary working groups including employees of public R&D institutions. This form of R&D organization proved to be efficient since it could complete contracts more quickly with smaller numbers of participants and at a lower expense than the established R&D institutions. Moreover, with their own financial resources, the centers were able to carry out self-initiated research, create and develop data banks, and help in the introduction of S&T achievements into enterprises.

The voluntary organizations were probably cost-effective ways of providing some flexibility in a rigid R&D–innovation system. However, small, innovation-oriented organizations could not compete for resources with the mighty ministries, giant branch research institutes, and industrial enterprises. In an environment where political importance and size were major factors in obtaining resources, young enthusiasts had little chance of gaining significant support.

5.2 Recent Trends in Innovation Activity

5.2.1 Transition difficulties

Partial reforms within the central planning system ended with the collapse of the USSR and Russia's sudden shift to a radical liberalization policy in 1991. This switch in policy was designed as a revolution against the central planning system. The idea was to remove the state from economic activity and to rely on private initiative and the market to tackle economic problems. In the rush to establish a market system, little attention was paid to legislation to regulate market activity, to encourage innovation, and to promote competition.

As the economy moved to a market system in 1991, innovation activity drastically decreased for a number of reasons:

- An unstable macroeconomic environment tremendously damaged innovation. Short-term and survival goals dominated enterprise behavior. High interest rates and unstable and unpredictable domestic demand made innovation economically unprofitable. Another obstacle to innovation was a shortage of working capital for enterprises, accompanied by decreased centralized financing.
- Russia's lag behind the West was finally and unconditionally acknowledged. Political pressures on the R&D sector to catch up now vanished along with most of the subsidies for R&D. Indeed, during the first years of post-Soviet reforms government policy was limited to maintaining R&D institutions, while support for industrial innovation declined sharply. Enterprises now were exposed to market pressures, and many recognized that in the long run they must innovate to survive. Still, market signals during the transitional period were misleading, and could not substitute for government guidance. A new national innovation system has not yet emerged.
- Large-scale privatization of state enterprises broke established partnerships between production enterprises and research institutes. Industrial ministries no longer coordinated the work of research and production units, which had to learn how to operate in a market environment.
- Brain-drain from the R&D sector had a strong negative effect on R&D and innovation activities. In the past both employers and employees were distressed by staff reductions. Restricted in their efforts to dismiss employees, troubled R&D institutions and enterprises adjusted to the decline in their funding by across-the-board cuts in real wages. Young, mobile, and talented employees had economic incentives to move to other sectors such as banking, trade, and other services, as well as to work abroad, leaving R&D institutions and enterprises with senior employees much less disposed to innovation than the younger ones who left.

The decline in innovation can be documented by several indicators of economic activity. A simple but comprehensive indicator is the level of innovation activity measured by the share of enterprises carrying out the introduction of innovations (for the survey methodology developed by the Centre for Science Research and Statistics see section A1 in Annex and also Gokhberg and Kuznetsova, 1996; the first survey results were published in CSRS, 1996c). According to CSRS (1996c), this measure fell from between 60 percent and 70 percent in the 1980s to the average of 22 percent for the 1992–1994 period (*Table 5.1*). The percentage of innovating enterprises varied by industry. The highest shares of enterprises implementing activities to introduce at least one innovation are found in the oil- and gas-extracting industry (48 percent), nonferrous metallurgy (49 percent), the medical industry including both instruments and pharmaceuticals (48 percent), and the chemical and petrochemical industry (43 percent). For the oil and gas industry and nonferrous metals industry, innovation activity was economically justified since the demand for these products was relatively stable in both domestic and foreign markets in comparison with other major industry sectors (State Committee on Statistics, 1994b, p. 13). All the sectors connected with extraction and processing raw materials and intermediate products had a smaller decline in output than the manufacturing sectors during the 1992–1994 period. By 1995 some of these raw-materials sectors had achieved an increase in output from the previous year (nonferrous and ferrous metallurgy and chemical and petrochemical industries).

Surprisingly, some industries suffering from a steep decline in output demonstrated relatively significant innovation activity. Examples include machinery and metal-working (38 percent of enterprises introduced innovations) and ferrous metallurgy (34 percent). These developments reflect the fact that the drastic decline in demand in their traditional products forced companies to make innovations in related fields in an effort to survive. Major innovation requires investment. Therefore, a revival of innovation activity, even in depressed sectors, has been demonstrated by the competition of enterprises for tenders for centralized investment. The Commission on Investment Tenders at the Ministry of Economy received an unexpectedly large number of proposals from the machine-building (17 percent of the total) and metallurgy (13 percent) sectors (Profile of Change, 1995).

The level of innovation activity has been low in industry sectors oriented to domestic-market needs such as light industry (18 percent of enterprises introduced innovations), the food industry (18 percent), and the construction-materials industry (12 percent). This reflects, in part, low overall demand for the products of these sectors and, in part, the fact that domestic consumer goods are not competitive with imports. Realistic forecasts of innovation activity in these industries, based on enterprise estimates, predict that in the 1995–1997 period there will be even less innovation activity than during 1992–1994 (13 percent in light industry; 16 percent

Table 5.1. Innovation activity of industrial enterprises during the 1992–1994 period.

	Enterprises surveyed A	Innovating enterprises B	Level of innovation activity (B/A), in %
Oil extracting and refining, gas extracting	135	65	48.1
Coal, slate, and peat	317	39	12.3
Ferrous metallurgy	240	82	34.2
Nonferrous metallurgy	76	37	48.7
Other metallurgy, n.e.c.	183	48	26.2
Chemicals (excluding pharmaceuticals)	515	219	42.5
Machinery and metal-working (excluding medical equipment)	3,348	1,259	37.6
Wood, pulp, and paper	1,374	251	18.3
Stone and clay products	2,142	270	12.6
Glass, porcelain, and faience products (excluding medical articles)	153	32	20.9
Textiles, clothing, and leather	2,162	380	17.6
Food products	4,957	877	17.7
Microbiological industry	42	17	40.5
Medical equipment and pharmaceuticals	119	57	47.9
Other sectors	1,216	170	14.0
Total	16,979	3,803	22.4

n.e.c. = not elsewhere classified.
Souce: CSRS, 1996c.

in the food industry; 10 percent in construction-materials industry). In spite of an obvious improvement in the economic situation (reductions in the rate of decline in output and the rate of inflation), a decrease in innovation activity is expected in the 1995–1997 period, not only in these industries but in practically all industrial sectors, including the most economically well-to-do branches such as the oil and gas and nonferrous metals industries.

Enterprise managers estimate that over the next three years the level of innovation activity will be only 19 percent on average. A division of enterprises into two categories with respect to innovations is apparent: more than 70 percent of the already innovating enterprises plan to continue innovation activities; those that did not support innovation in the past are not expected to introduce innovations in the future.

Table 5.2. Innovating industrial enterprises by type of activity during the 1992–1994 period, survey results.

	Introduced new or improved products	Introduced new or improved technological processes	Performed R&D
Oil extracting and refining, gas extracting	24	48	18
Coal, slate, and peat	13	22	1
Ferrous metallurgy	57	64	37
Nonferrous metallurgy	23	26	15
Other metallurgy, n.e.c.	31	33	24
Chemicals (excluding pharmaceuticals)	189	158	104
Machinery and metal-working (excluding medical equipment)	1,122	829	456
Wood, pulp, and paper	208	170	47
Stone and clay products	177	145	38
Glass, porcelain, and faience products (excluding medical articles)	23	22	5
Textiles, clothing, and leather	307	249	43
Food products	724	466	101
Microbiological industry	12	12	3
Medical equipment and pharmaceuticals	50	35	18
Other sectors	101	115	12
Total	3,061	2,394	922

n.e.c. = not elsewhere classified.
Source: CSRS, 1996c.

5.2.2 Types of innovation activity

Innovation activity encompasses a wide range of diverse activities such as R&D, design, testing, and, finally, the introduction of new or improved products and processes into production (*Table 5.2*). In the period from 1992 to 1994, innovations were made by fewer than 4,000 of the almost 17,000 enterprises surveyed; however, some of the enterprises were simultaneously engaged in different types of innovation activity. More than 80 percent of the 4,000 enterprises active in innovation were engaged in product introduction. This indicates that innovation activity was biased toward product innovation. A major factor in the innovation activity was the struggle by enterprises for shares in new and traditional markets. The most common tactic was for an enterprise to improve its products and to change its product lines, adding new ones and dropping obsolete ones.

Product innovations are very important at the trough of an economic cycle for they can lead to new markets and opportunities for growth. The indisputable leaders in product innovations were those connected with manufacturing equipment for light industry (95 percent of innovating enterprises carried out product innovation). In part, these innovations targeted import substitution. For example, imports of textile machinery from the West totaled $200 million annually in the early 1990s with additional imports from former Council for Mutual Economic Assistance (CMEA) member countries. These imports included 200 items of equipment which were also manufactured in Russia (Khimushkin, 1995). Innovations in this field were supported by the budget, although demand for equipment by textile manufacturers was bleak.

A high level of product innovations was also a characteristic of the medical industry (88 percent of innovating enterprises introduced product innovations) and the chemical and petrochemical industry (86 percent). Consumer goods industries had only an average rate of introduction of new products even though producing better products is one of the conditions for the survival of enterprises in this sector.

The other significant type of innovation activity is the introduction of new or improved production processes, primarily to reduce the costs and to improve product quality. In transition economies, such as Russia, enterprises are more concerned with immediate survival than with long-term profitability. Product innovations better serve the first goal since they can bring in more revenue, whereas process innovations have a long-term payoff.

Process innovations were introduced by 63 percent of innovating enterprises between 1992 and 1994. Under the special circumstances in Russia, labor-saving process innovations were of little value because managers were attempting to maintain employment levels. Managers, hence, were not interested in innovations that could reduce costs by reducing the size of their staff. In contrast, product innovations could raise the revenues of an enterprise while maintaining the employment level. Process innovations are most widespread in the raw-materials sectors, such as mining, chemical, and petrochemical industries because their export orientation makes lowering costs a significant factor. In these industries, sales are of standardized commodities in which product innovation is less significant. For the 1992–1994 period, the share of enterprises engaged in process innovations among the innovating enterprises was 74 percent in the fuel industry, 72 percent in the ferrous metallurgy, 70 percent in nonferrous metallurgy, and 72 percent in the chemical and petrochemical industries.

Process innovations focused on cost reductions in the energy, fuel, and materials sectors. These innovations were forced on Russian enterprises partly by the increase of relative prices of energy and materials and partly by the fierce competition in the domestic and foreign markets; this competition made enterprises realize that reductions in their relative costs were crucial for survival.

Improvements in product quality have been a priority with one-quarter of enterprises engaged in process innovations. Better product quality is the main factor in the recent increase in competitiveness of domestic products relative to imports in the Russian market.

There have been some innovations aimed at protecting the environment such as the reduction of dangerous wastes; these innovations were pursued primarily by enterprises with a high potential for damaging the environment. Improvements in working conditions ranked lowest in the objectives of innovation activities.

The pattern of innovation activity shows that R&D performance by enterprises is insignificant, as could be expected with economic conditions that discourage expenditures with a long-run payoff. Indeed, in the three years under examination (1992–1994), only 5 percent of the total number of enterprises or 24 percent of those active in innovation, performed in-house R&D. In G-7 countries, enterprise-financed R&D occurs in more than 90 percent of the large industrial enterprises.

The reasons for such low levels of R&D in the Russian enterprise sector lie in the Soviet past. As discussed earlier, industrial R&D was carried out by research institutes and design bureaus that were separate from the production enterprises. The privatization program did not help this situation; it broke even the weak links existing between industrial R&D and production units. Industrial enterprises, privatized separately from R&D institutions, do not significantly support R&D because it has only a long-term payoff, and they lack sufficient investment funds to introduce radical innovations.

5.2.3 Qualitative characteristics of innovation

Many of the innovations counted in the data cited above represent insignificant improvements of products and technologies already in use by other domestic or foreign enterprises. In the survey cited above industrial enterprises indicated that most of their innovations are the introduction of products that are new only to their enterprise. One might better classify such activity as the diffusion of innovation rather than innovation itself.

In practically all sectors of industry, the output of new products decreased at a greater rate than the output of all products. For example, the share of newly introduced products in the output of machine-building decreased from 6.5 percent in 1990 to 2.6 percent in 1994, and that of radically new products from 3.0 percent to 0.9 percent, respectively.

Another important aspect of innovation is its source. The technology for innovation has diverse origins. It can be the result of an enterprise's in-house or contractual R&D, or it may come from patent licenses or from reliance on unpatented technology. As mentioned in earlier chapters, technological progress in Russian enterprises depends almost completely on R&D performed outside the enterprise sector. Technology transfer thus has a major role in the innovation process as a link between R&D and production. In their innovation activity during the 1992–1994 period, enterprises relied mainly on new technologies and other S&T achievements acquired by technology transfer (*Table 5.3*).

The weakness of enterprise R&D is partly compensated by the use of R&D results obtained from other sectors: the industrial R&D institutions, academy organizations, and higher education. It should be noted, however, that enterprises with in-house R&D are also the most active in seeking R&D results elsewhere. These enterprises are in chemical and petrochemical industry (66 percent of innovating enterprises obtained contractual R&D), ferrous metallurgy (57 percent), nonferrous metallurgy (78 percent), the fuel industry (77 percent), and the medical industry (51 percent). This reconfirms the importance of enterprise R&D as a link to external S&T.

Transfer of technology occurs most often by contractual R&D (33 percent of innovating enterprises) and borrowing or imitation without patents (18 percent relied on know-how agreements and 23 percent on engineering and consulting services). These are the most accessible and the least costly sources. In contrast, acquiring patent licenses and rights for patents holds only a modest share in overall technology transfer. These two forms of transfer were used during the 1992–1994 period by no more than 16 percent of enterprises active in innovation. In the three years since the beginning of economic reforms, only 125 industrial enterprises of the 17,000 surveyed have bought patent licenses for the use of inventions. These enterprises were largely in the machinery and metal-working industry (45 enterprises) and the chemical and petrochemical industry (28 enterprises). Even the most economically successful sectors, such as nonferrous metallurgy (16 percent of innovating enterprises bought licenses for inventions) and the fuel industry (15 percent) are not using patents as a major source of innovation.

The weakness of the patent and license market reflects the decrease in the general innovation activity in Russia. The decrease is also apparent in the fact that only 7 percent of the R&D institutions produced patentable inventions. The high expenses of patenting intellectual property and the weak guarantees against imitation discourage patenting even those few inventions that are patentable. This is especially so for enterprises suffering from financial difficulties.

Thus, estimates of qualitative content of innovation indicate that most innovation activity in Russia involves modest technological progress or only imitation of innovations that have been introduced elsewhere. Innovations are characterized by little use of the most advanced S&T achievements. The innovation activities

Table 5.3. Technology exchange during the 1992–1994 period (number of industrial enterprises acquiring technology), survey results.

	Acquisition of patent rights	Acquisition of patent licenses (of which licenses on the use of inventions)	Acquisition of unpatented licenses	R&D results	Know-how	Other[a]
Oil extracting and refining, gas extracting	10	12 (10)	56	50	27	30
Coal, slate, and peat	1	4 (2)	19	15	6	8
Ferrous metallurgy	16	10 (8)	59	47	16	27
Nonferrous metallurgy	7	6 (6)	32	29	11	19
Other metallurgy, n.e.c.	6	8 (3)	43	36	16	21
Chemicals (excluding pharmaceuticals)	19	31 (28)	168	144	84	108
Machinery and metal-working (excluding medical equipment)	98	114 (45)	701	519	262	364
Wood, pulp, and paper	7	12 (1)	91	55	27	42
Stone and clay products	6	61 (3)	125	77	33	49
Glass, porcelain, and faience products (excluding medical articles)	2	1 –	15	9	8	8
Textiles, clothing, and leather	8	16 (6)	138	87	39	60
Food products	31	85 (9)	233	107	102	75
Microbiological industry	–	1 –	13	12	5	8
Medical equipment and pharmaceuticals	8	6 (4)	39	29	16	18
Other sectors	2	25 –	56	21	20	28
Total	221	392 (125)	1,788	1,237	672	865

[a]Engineering, consulting, and other technology-related services.
n.e.c. = not elsewhere classified.
Source: CSRS, various years.

recorded in enterprise surveys include mainly insignificant improvements in existing products and technologies or diversification of product lines to offset the limited demand for the enterprises' other products.

5.2.4 Investment and innovation

Innovations are closely connected with investment activity. Fluctuations in innovation activity and volume of investment are positively correlated; the introduction of innovations often requires investments and investments are often in response to the profit opportunities created by innovations.

Investment declined threefold from 1990 to 1994. The investment share in GDP was 17 percent in 1994 compared with 22 percent in 1990 (State Committee on Statistics, 1995, p. 13). The only reason the share remained as relatively high as it did is that GDP itself declined. The most significant decrease (by a factor of between three and four) in capital investments from 1991 to 1994 was in the chemical, wood, construction-materials, and light industries. The decline in investments was most limited in the fuel and power-generation sectors where demand for products changed little (State Committee on Statistics, 1994a).

Another view of the pattern of investment is provided by data that divide investment into that directed at restructuring of functioning enterprises and that for technological advancement (*Table 5.4*). The objective of investment in technological advancement is to raise the technological level of specific enterprises and workshops by introducing advanced machines and substituting new, more productive methods for outdated ones. The leaders in this form of capital investments are enterprises in the ferrous and nonferrous metallurgical industries, which are more active in innovation than enterprises in most other industry sectors.

The methodology of official Russian statistics limits innovation-related capital investment to that mainly connected with the acquisition of fixed assets such as the cost of machines, equipment, and other capital expenses used in introducing new or improved products or processes. This is, of course, only a small part of the expense of introducing an innovation. More significant is the R&D expense connected with innovation; given the data available, R&D expenditure is perhaps the best indicator of innovation costs. Another part of innovation costs related to technology transfer is represented in Russian statistics by exports and imports of S&T services (for data, see Chapter 6). Innovation requires, however, more than R&D efforts and investment in new equipment. It also needs marketing and personnel training. All these expenditures must be made prior to the realization of returns on the innovation, although they are, as a rule, charged by enterprises to accounts that include both routine and innovation activities; so they are difficult to measure.

Table 5.4. Structure of capital investment in 1994 (%).

	Share of investment outlays for reconstruction and technological re-equipment in capital investment	Distribution of the total investment for reconstruction and technological re-equipment	
		Reconstruction[a]	Technological re-equipment[b]
Industry	54	32	68
Electric-power engineering	27	45	55
Fuel	47	19	81
Ferrous metallurgy	74	40	60
Nonferrous metallurgy	71	38	62
Stone, clay, and glass products	38	41	59
Food products	59	30	70
Agriculture	40	33	67
Transportation	51	46	54
Construction	48	44	56
Total for Russia	51	36	64

[a]Reconstruction is defined as a comprehensive re-equipment of the enterprise aimed at increasing output and product quality.
[b]Technological re-equipment is considered less comprehensive and refers to particular production units only.
Source: State Committee on Statistics, 1995e.

Russian enterprises have not been active in creating marketing units sufficient to research and influence market demand. Therefore, most enterprises are ill-informed about prices, costs, and their market – a major disadvantage in introducing new products. The exceptions are enterprises active in innovation. A Centre for Science Research and Statistics (CSRS) survey of machinery-building enterprises shows a close connection between marketing and innovation activities. All the enterprises engaged in innovations had their own sales and marketing services.

Despite the limited data, we have attempted to estimate the overall innovation expenditures in Russia in 1994. The estimation is based on data on R&D expenditures, capital investment in machines and equipment, as well as exports and imports of technologies. The calculations suggest a value of all innovation expenses at R10 trillion or 1.6 percent of gross domestic product (GDP). These are very low numbers. Using the same methods of calculating general innovation expenditures, the percentage of innovation activities in GDP in Russia was 4.9 percent in 1990 or three times higher than the estimates given for 1994. The share of innovation expenditure in GDP then is not only low but have decreased during the transition to a market economy.

Table 5.5. Capital investment by source of funding (%).

	1993	1994
Individual funds	2.6	4.1
Enterprises' own funds	59.8	64.5
Centralized non-budget investment funds	3.3	5.9
Privileged state investment credits	1.7	1.4
Local budgets	15.1	10.5
Federal budget	17.5	13.6
Total	100.0	100.0

Source: State Committee on Statistics, 1994a.

5.2.5 Factors hindering innovation activity

Several surveys conducted in 1993 and 1994 asked enterprise managers to indicate the principal factors limiting innovation. They ranked the high level of inflation first (mentioned by more than 40 percent of enterprise managers) and the accompanying high interest rates on loans second. Inflation changes the price of inputs and products in an unsystematic way, making the profitability of an innovation difficult to calculate. The resulting uncertainty dampens the long-term investment in innovation. Most loans are available for only two to three months, which is a vastly insufficient duration for innovation to occur. Banks are ready to arrange loans mostly to enterprises in export-oriented natural-resources sectors that can pay back debts quicker than manufacturing enterprises.

Insufficient budget financing as a factor hindering innovations was ranked third; approximately 20 percent of enterprise managers listed this factor. Only 3 percent of enterprises received state financing for the acquisitions of fixed assets. Thus, enterprises have had to rely largely on self-financing for their investments in plants and equipment and the share of their funds in the capital investment total is growing (*Table 5.5*). This pattern is also reflected in the financing of innovations (not contained in *Table 5.5*: 46 percent of enterprises surveyed used mainly their own resources to finance innovations, whereas loans were used by only 18 percent of them.

Other hindrances to innovation were difficulties obtaining materials, fuel, and electricity. These difficulties were reported most by enterprises in the light- and food-industry sectors, but also affected the chemical and petrochemical and nonferrous metals industries. Some of the shortages were created by the disruption of ties between consumers and manufacturers in other countries in the CIS and Russia. Increases in prices of electricity, raw and other materials, and rail transport created additional difficulties. An insignificant share of enterprises reported a shortage of qualified specialists for innovation activity as a problem. The importance of this factor may increase in the future, given the movement of professionals away from R&D.

Besides the factors within the enterprise, innovation activity is noticeably influenced by factors of demand: more than 40 percent of enterprises reported insolvent customers as a problem and about 20 percent listed a sharp drop in demand. Clearly least important to limiting innovation is the lack of need for technological innovations; only 1 percent of surveyed enterprises mentioned it.

5.3 Innovation Policies for Economic Growth

Technological change is considered the primary source of growth in almost all studies in the literature of economic growth. Analyses have shown that technological progress contributes between 70 and 90 percent to GDP growth per capita in industrialized countries. The process of technological progress in turn consists of the introduction and diffusion of innovations.

Recovery of innovation activity and economic growth in Russia requires a more comprehensive stabilization policy than the one currently in force. A switch to a reliable and growth-oriented macroeconomic policy is necessary but not a sufficient condition for promoting innovation activity. With a decline in investments and R&D expenditures by a factor of four, with the collapse of production of consumer durables that embody advanced technology, and with the brain drain from R&D-intensive industries, special measures are required for innovation. The government must use well-known instruments of industrial and S&T policy that include the following:

- Increased government financing of R&D.
- State procurement of innovative products.
- Restructuring programs supported by a mix of private and public financing.
- Formation of development institutions providing long-term credits for investment projects.
- Tariff and nontariff regulations on foreign trade, particularly for domestic innovations.
- Elimination of the tax on profits used for investment and R&D expenditures.
- Promotion of cooperation among production enterprises, financial organizations, and R&D institutions.
- Legal protection for intellectual property.
- Creation of an efficient information infrastructure including a network of consulting companies.

In its efforts to promote R&D the state should not substitute for the market but rather help enterprises to adjust to market competition. For instance, state purchases of new products is most important at the earliest phases of their introduction to bring down unit costs. This policy is actively used in virtually all industrialized countries. The objective of state programs is to support the initial phases in the life cycle of new products to create favorable conditions for the restructuring of production facilities. Private funding should be involved in financing innovations, for experience in other nations has shown the efficiency of mixed financing and risk sharing by the state and private organizations. Government guarantees for financing high-risk projects may also promote innovation.

Public policy is needed to improve the infrastructure and financial conditions so that small enterprises can focus on developing innovation. In spite of the role of large firms, companies owned by individuals risking their own capital remain an important force in a market economy. Small firms have been the source of many radical innovations.

Also important in financing basic research and promoting applied R&D are state subsidies and tax breaks, as well as other services whose usefulness is characterized by important externalities (for example, communications, transportation, information, engineering, and other business services). Any taxation scheme must recognize that the possibility of high profits provides incentives to innovate. It is necessary to gradually shift to a new taxation system that transfers a major taxation burden from current revenues to accumulated wealth. Along with the existing investment tax credit it would be worthwhile to introduce a tax credit for R&D. The undeveloped market relations and the necessity to overcome the structural disproportions in Russia make it necessary to have special tax exemptions differentiated by industries during the transition period. As the economic situation stabilizes and the government budget condition improves, the use of tax concessions can become more limited.

An information infrastructure is also needed to provide the country's research centers and enterprises with state-of-the-art means of telecommunications and data banks incorporated into the global information networks. This program can be developed using domestic satellite communications in the way that other global networks of commercial and scientific and technical information have been created.

Under conditions of galloping inflation and a deep slump in investment activity, the formation of long-term lending institutions becomes important. Provision of special credit lines by the government through commercial banks or through the creation of special financial institutions is important in promoting innovation. Reliance on commercial banks, however, requires complicated controls to be effective. Financing from commercial banks is very inflationary in the Russian context. The use of special institutions is more in accord with world practice. Examples include the World Bank, the European Bank for Reconstruction and Development, the Japanese Bank of Development, and Brazil's Bank of Reconstruction and

Development. Significant experience with project financing has been accumulated which can guide new Russian institutions.

World experience suggests various methods for the mobilization of domestic savings to support investment activity. In Russia, household savings have decreased in real value because of hyperinflation. This problem could be solved with a special program of personal savings that includes indexation of personal savings in savings banks.

The objective of state promotion of innovation and investment activity is to stimulate but not substitute for private activity. It is widely accepted that private activity largely depends on industrial organization and the industrial-financial structure of the economy. Large corporations closely connected with banks form an important base for industrial organization under conditions of a modern market economy. Controlling a major part of industrial production, such financial and industrial groups ensure stable industrial growth and are the foundation of the economic power in industrialized market economies. Financial and industrial groups can play a significant role in securing economic growth under the turbulent conditions in the Russian economy. Relying on their own sources of capital accumulation, these groups of interdependent industrial enterprise, banking, and trade organizations can finance innovation in key industries. The concentration of resources in financial and industrial groups ensured the rapid economic growth in the postwar Japan and West Germany and from the mid-1960s in Korea and other countries where the conditions of transition to the market were similar to those now present in Russia. This is the reason why one of the key objectives of the national industrial policy should be to promote the formation of independent financial and industrial organizations. This is particularly a necessary precondition for successful restructuring and conversion of the defense industry.

For the first time in decades enterprises are once again interested in promoting and implementing innovation activities. They now know that their products' competitiveness is linked to the technological level of production. Therefore, the stage is set for an innovation-promotion policy that will lead to growth in productivity.

Chapter 6

The Integration of Russian R&D into the International Economy

Levan Mindeli

The Soviet Union's isolation from the international R&D system was largely its own doing. Russia, however, from the very beginning of its independence, adopted an economic policy of openness and established the objective of joining in world S&T activities. This chapter explores the initial consequences of that policy. It begins with a description of the general internationalization of S&T and continues with a discussion of Russia's strategies for international participation in ways that protect its national interests. The chapter then reports on Russia's international transactions in the early years of the transition (1991–1995) and provides examples of the diversity of international activities that have occurred. It concludes with a discussion of current policy related to international activity.

6.1 The Internationalization of S&T

The international economic system has expanded dramatically since the end of World War II and in the process it has become more technological in two ways. First, the goods that are traded embody more R&D in their production. Second, there is increasing exchange of technological knowledge in the form of licenses, know-how, and research alliances of firms across national boundaries.

Both developments reflect the impact of several factors. Some new products and processes require large expenditures which, in turn, require the worldwide application of a technological advance to be profitable. At the same time, the costs of global integration of innovation activity have decreased. Dramatic improvements in transportation have reduced costs for trade in goods while new international communication networks permit the inexpensive and fast exchange of information. Further, the spread of global financial institutions and the greater convertibility of currencies have facilitated the raising of capital on a multilateral scale. Finally, the relaxation of many international tensions and the disappearance of military confrontations between two competing social systems has increased cooperation.

Even though national S&T policies remain significant, their role has been reduced by the increasing importance of multinational corporations. These organizations operate across national borders with production, distribution, and R&D carried out in different nations. Technology-intensive products frequently cannot be identified with any one country of origin. For the multinational corporation, technology is often the most significant dimension of corporate rivalry and R&D policy becomes a key corporate decision. In addition, there are small companies that operate internationally in highly specialized niches of a broader product market. The government was also active setting up new institutions: they have established new international research centers that are internationally oriented in their projects.

Increasing internationalization of S&T provides the following important lessons for Russia:

1. The economic potential and political influence of a country are determined in part by the level of its technological development. New nations have quickly emerged in international competition and dramatically increased their standards of living.
2. Some nations are increasingly concerned with environmental issues.
3. Assistance to developing countries includes technological aid.
4. S&T activities have become increasingly important to international organizations, and there is more coordination of national S&T efforts.
5. Organizational structures have become considerably more flexible with international R&D carried out by temporary teams of researchers from different countries.

The USSR had little experience with systematic international cooperation in S&T activities. The exception was the Council for Mutual Economic Assistance (CMEA), involving the centrally planned economies of Central and Eastern Europe. In the last decade of its existence from 1980 to 1991, the CMEA attempted to combine the innovation efforts of its member states to enhance economic growth. It was assumed that such cooperation would symbolize a qualitatively new stage of cooperation and exchange of S&T results, leading to the integration of national S&T potentials. One of the most important ways of cooperation was the development of specialization among the member nations.

CMEA policies had a number of positive results: national S&T programs were coordinated within the framework of the so-called CMEA Complex Program of S&T Progress, direct international links between research institutes and industrial enterprises were created, and the exchange of researchers among CMEA countries was promoted. These were clearly progressive steps. Even so, the CMEA S&T programs were largely failures. They were highly politicized and centrally controlled. Participating organizations could not obtain sufficient financing for joint activities from their national governments. The isolation from world S&T activity reduced the efficiency of various projects. There was little involvement of Soviet military R&D – the largest and most advanced part of the USSR R&D activity. Formalism was excessive in the drawing up of research plans, the production of elaborate reports, the maintenance of a large bureaucracy, and the distribution of resources to activities on insignificant topics. Most joint projects failed to produce world-level research results or innovative products and processes. The question of competitiveness in the world market was seldom considered.

Perhaps the fundamental problem, however, was departmental barriers. The chain of science–technology–production diffusion within national industrial ministries interfered with potential international links. To sum up, the CMEA experience was another demonstration of the incompatibility of innovation with an administrative command system.

6.2 Russia's Strategy for International S&T Cooperation

A dominant part of economic growth depends on technological advances. These advances come from many countries, so by participating in international R&D activities, a country gains from inventions achieved in other parts of the world. If it pursues a policy of isolation, its economic growth is limited to the technological advances achieved only with its own resources. Russian R&D resources are now in disarray. Therefore, the transition to a market economy and democratic society requires international participation. Increased participation in world activities may reduce the lag in technology that Russia has in many fields. A level of technology equal to that in industrialized countries is essential for the success of Russia's manufacturing industries and to enable Russia to shift away from its current natural-resource orientation.

Imports of advanced production equipment and know-how are also an essential element of international activity. Experience in other parts of the world, particularly in Japan, shows that the effective use of such imports requires substantial domestic R&D to adapt imported technology. This is especially true for Russia, given the variety of its climate and environmental conditions, labor skills, and population's educational level. New products must also be modified to conform to local consumer preferences. International activity also allows Russian defense R&D to be the basis of exports of both military and civilian goods.

As pointed out in earlier chapters, the Russian R&D sector is large in absolute size. Earnings from abroad help support the sector and its large staff and improvements in equipment. Increased international S&T links may help institutional transformations, in particular allowing financial and industrial groups and corporations currently emerging in Russia to become international organizations. Likewise, it can contribute to the rise of small and medium-sized enterprises. Finally, technology can increase productivity, raising wages without inflation and creating more highly skilled jobs.

Even though it is unclear which model of market economy will prevail in Russia, it is possible to identify nine basic principles that should guide Russian policies in international S&T cooperation:

- *Balance*. Involvement in international R&D on a reciprocal basis requires a certain amount of domestic S&T activity so that there is interest abroad in domestic results that can be used in technology exchanges. It is naive to rely on another nation's altruism; rather the country should be able to offer technology in exchange for S&T results. Russia's influence in international affairs depends on its own S&T activity. The right approach is to secure technological independence while taking advantage of the international division of intellectual labor.
- *Advancement*. Raising Russian R&D to international standards means adjustment to future trends, not to the current level of S&T activity. This advancement will help to form a new model of the Russian R&D establishment. Without a new model Russia risks finding itself in a state of always trying to catch up. A particular valuable tactic is to establish positions in certain niches in the world market and to export science-intensive products from these niches.
- *Efficiency*. International cooperation must be cost-efficient. A general method for determining efficiency consists of comparing expenses of domestic activities with the value of the R&D received from international efforts. For international R&D, however, this method of evaluation is limited because many aspects of both costs and results cannot be measured. Furthermore, national efficiency is not limited to immediate economic results, but also includes the effects of the intangible and long-run gains to a nation from S&T cooperation. A more comprehensive accounting of the impact of international S&T transactions should also recognize the gains from increasing the stock of knowledge available to a nation and from diffusion of R&D results to neighboring

industries, since externalities are pervasive in R&D. Social, environmental, and other impacts must also be taken into account.

- *Flexibility*. One-sided approaches to complicated problems must be avoided. Thus, while in the most developed fields in Russia (e.g., nuclear physics and space exploration) a policy of national independence is possible, in others, with smaller domestic potential (chemistry and electricity generation), the emphasis should be on the consolidation of research efforts in frameworks of joint studies and projects. In still others (such as agriculture) it is important to stimulate technology imports.
- *Differentiation by country*. Relations with specific countries, international organizations, and individual companies must be maintained. It is important to remove long-ingrained stereotypes of a uniform world capitalist system. Every participant has strategic and tactical interests which influence his or her behavior in S&T transactions.
- *Coordination*. It is desirable to avoid uncoordinated actions of different Russian participants in international R&D activity. In so doing, efforts should be made to prevent restrictive features of the previous regime from reappearing, and avoid infringement on the rights and interests of independent organizations trying to maintain international connections. Coordination should take into account both domestic and foreign interests.
- *Improvement*. International R&D activity should not be a short-term campaign as it was, for example, with the establishment of joint ventures during the *perestroika* period. Long-term relationships and a stable public policy are necessary. There should be provisions, however, for dismantling organizational structures that have completed their tasks and for discontinuing public policies that are no longer desirable.
- *Protection of national interests*. Reasonable participation should be combined with protection of national security interests, including restrictions on the transfer of strategic technologies and products.
- *Participation in international scientific and research organizations*. These organizations are increasingly important in S&T activity. By joining these groups, Russia can obtain access to information and the ability to influence activities and protect its particular interests.

These principles should be followed in many aspects of S&T policy such as financing, legislation, product standardization, intellectual property rights, and the development of information and other infrastructures. These elements are discussed in other chapters, but their international dimensions must be emphasized.

6.3 International Cooperation in Russian Applied R&D in the 1990s

6.3.1 Limitations on international cooperation

The collapse of the USSR eliminated the rigid state control over international R&D contracts. Russia's introduction to the world scene of applied R&D has been difficult for several reasons:

- Industrial R&D lost much of its budget appropriations, the main sources of its financing. Governmental appropriations for defense R&D were also sharply reduced.
- The demand by enterprises for the results of applied R&D fell and the innovation activity of the institutions formerly active in innovations decreased.
- As mentioned in Chapter 5, in the unstable macroeconomic environment the new financial institutions were interested only in short-term gains. They were not ready to provide long-term financing for R&D and innovation.
- With the disintegration of the USSR, many scientific, technological, and production links between republic boundaries were broken.
- In contrast to basic research, which had developed international contacts during the Soviet period, international ties in applied R&D were weak, especially with industrialized countries.
- The sharp reduction in Russian technical aid to former socialist countries and developing nations curtailed the demand for applied R&D in aid programs.
- Governments of leading Western countries were selective in distributing aid and limited its amount even though, according to available estimates, approximately 15 and 20 percent of Russian R&D institutions are internationally competitive in their research (Kuznetsova and Dagaev, 1995, p. 20).
- Emigration of scientists and engineers abroad and the flight of specialists to other domestic activities damaged Russia's own S&T potential.

Despite these difficulties, Russia has been able to partially integrate into the world's international R&D system. These positive results provide reasons for increasing the scale of international activity. The establishment in Russia of offices and research centers by foreign companies and organizations is encouraging, as is the involvement of such giants as IBM, Siemens, General Electric, and Boeing in R&D activity with Russian enterprises. Foreign government offices are also involved in cooperative activities with Russia.

In some cases, however, Russian participants have benefited only to a limited extent because they have signed agreements that are disadvantageous to them. Russian managers have lacked the appropriate expertise in negotiating contracts with intellectual property clauses. Obviously the limited expertise in the world market for patents and licenses results from the paucity of such transactions during the Soviet era. In the past the Soviet Union bought about 100 licenses annually whereas Japan purchased between 3,000 and 5,000 and the United States between 2,000 and 3,000 yearly. Recently, licenses have often been bought for low level technology that violates environmental regulations. Under financial distress many R&D institutions and enterprises have eliminated their patenting, marketing, and foreign economic services to reduce expenses, but the absence of such expertise makes bargaining with foreign partners one-sided. For example, one condition for obtaining a foreign contract often calls for full transfer of intellectual property rights which deprives the Russian side of royalties. Patent rights are often lost to foreign companies, and the commercial use of products invented independently in Russia is sometimes blocked even after the contract has expired. A further problem is that Russian participants sometimes fail to obtain rights for improvement on patents. Dumping (sale of Russian technologies at below market prices and low reimbursement to Russian specialists) has occurred, spoiling the general reputation of Russian technology experts. Private firms and individuals often sell results obtained by state-owned organizations at the expense of government financing. In most cases no provision is made for repayment to the state. For example, a Canadian company bought a technology for the creation and exploitation for self-contained environmental systems from the Institute of Biophysics (Krasnoyarsk) for next to nothing (Kuznetsova and Dagaev, 1995, p. 20). There also are cases of outright deception. For example, the German company Pearl Agency illegally disseminated an operational system developed by the Russian company Phystech-soft (*Isvestiya*, 20 September 1995).

To improve the practice in international S&T contracts for Russian organizations, the Ministry on Science and Technological Policy (MSTP), together with other interested departments, has worked out recommendations for R&D institutions. The recommendations cover all aspects of intellectual property rights which must be taken into account before signing an agreement with a foreign partner. It is expected that this document, together with increased legal knowledge of executives and employees of R&D institutions about intellectual property rights, will provide the basis for mutually profitable transactions with foreign partners.

International involvement also occurs through foreign direct investment in Russian S&T activities. This activity, however, has been strongly limited by political and economic instability as well as by social and ethnic conflicts. Investment has been hurt by the lack of clear tax rules and laws protecting foreign property and profits of joint ventures. The assignment of powers and responsibilities is unclear within the government, and the level of bureaucracy is still high. For example, many potential foreign investors are scared off by the requirement for approval by a large number of authorities.

The difficulties may decrease in the long run, allowing Russia's advantages in the international setting to become apparent. In various fields Russia is likely to be competitive in the world market. Laser technologies, pharmaceuticals, medical devices, and computer software are some of the promising sectors. The Russian defense industry, aerospace and shipbuilding sectors, and a number of others are also promising fields for S&T cooperation. Moreover, the demand for Russian S&T may increase as marketing services for technology are developed and packaging and advertisement of consumer products achieve world standards.

The prospect of greater international involvement has led to a public debate on whether such participation will best serve Russia's interests. It is difficult to find any serious report calling for complete autarky in S&T. Still there are different opinions concerning the scale, form, and direction of such international involvement. Two main concepts of international relations have been discussed: the neoliberal and the neorealist (Sandholtz, 1992, pp. 11–12). The first is based on a high estimate of the Russian S&T potential and the favorable experiences of newly industrialized states (Kochetov, 1994). The second, more pessimistic view, is connected with doubts about the possibilities of Russian R&D and its high-technology products to succeed in international competition and to overcome the barriers of protectionism (Kuzin, 1993). There are also differences of opinion on the role of international activity in particular industries and fields. Several authors emphasize cooperation in high-technology sectors (Bubennikov and Mamrykin, 1995; Firsov, 1993). Some think that it is also important to involve foreign partners in the basic branches of the Russian economy (Khalevinskaya, 1995, p. 15). There is considerable discussion about the international involvement of defense R&D; the discussions include statements on the possibilities of the role of defense industry in international R&D activity (Gavrilov, 1993), certain doubts about it (Tolkachev, 1995), and apprehensions concerning foreign secret service activities in international contacts (Arkhipov *et al.*, 1994).

The current government policy favors liberalization of foreign economic contacts, including those in S&T (Program of the Russian Federation, 1995, p. 127). Perhaps as a consequence, questions of safeguarding national security have frequently been raised lately (Obolensky, 1995; Porokhovsky, 1995). Most attention has been given to technology export controls (Presnyakov and Sokolov, 1994).

6.3.2 The size of international S&T transactions

Currently measures that capture Russia's participation in international R&D do not exist. The primary data are dispersed over hundreds of organizations participating in international technological activity. Statistics of international S&T transactions are often missing even at the level of ministries and departments, and regional data are

Table 6.1. Exports and imports of machines and chemicals in Russia.

	1990		1991		1992		1993		1994	
	Billion $	% of total	Billion $	% of total	Billion $	% of total	Billion $	% of total	Billion $	% of total
Exports										
Machines & equipment	12.5	17.6	5.2	10.2	3.8	8.9	2.9	6.5	2.5	5.0
Chemicals	3.3	4.6	3.4	6.6	2.6	6.1	2.6	6.0	3.9	7.7
Imports										
Machines & equipment	36.3	44.3	15.8	35.6	13.9	37.7	9.1	33.8	10.0	35.8
Chemicals	8.9	10.9	5.5	12.4	2.5	9.3	1.7	6.2	3.0	10.6

Source: State Committee on Statistics, 1994d, p. 435.

even scarcer. As a rule institutions and specialists involved in international activities prefer not to make such information public to avoid attention from competitors, tax authorities, and even the mafia.

Some indirect measures are available for the scale and orientation of Russia's international activity in applied R&D. One of the most useful indicators is the level of export and import of technology-intensive products as shown in *Table 6.1*. The table shows a steady decline in the export and import of machinery. In exports of chemicals volumes have changed little although imports show a sharp decline. The shares of exports of machinery listed in *Table 6.1* are remarkably small for a major industrial country.

The low or decreasing shares in *Table 6.1* date back to the Soviet period. In 1980 the share of machines and equipment was 16 percent of total exports and 35 percent of total imports, and that of chemical products was 3 percent and 6 percent, respectively (*National Economy of the USSR in 1990*, 1991, pp. 659–661).

Another measure of international links is provided by data on the export and import of technology that is not embodied in products. (I am grateful to Irina Kuznetsova for material in this section.) For exports, the measure includes receipts for engineering services, patent licenses, and know-how (unpatented technological knowledge) sold abroad by Russian organizations. Imports here include payment for these same items by domestic organizations to foreign ones.

In 1994, Russia was a net exporter of technology (S&T services), valued at $295 million, but this net amount was reflected mainly in sales of engineering services, which were 91 percent of all the technology exports (*Table 6.2*). Sales of R&D services were 8 percent of technology exports in 1994 and sales of licenses and know-how were each less than 1 percent. Besides tough foreign competition, Russian science must deal with a lack of funds to maintain patents abroad.

Table 6.2. Structure of exports and imports of S&T services, in percent.

	Export		Import	
	1993	1994	1993	1994
R&D services	5.0	7.7	2.0	5.7
Engineering services	94.5	91.0	46.0	18.0
Licenses	0.02	0.3	26.0	57.0
Know-how	0.4	0.9	26.0	19.3
Total	100.0	100.0	100.0	100.0

Source: CSRS, 1996c, p. 23.

Nevertheless, in comparison with 1993, the value of licenses sold increased significantly in 1994.

In 1994, imports of S&T services were a modest $46 million, which was 12 percent lower than in 1993. Patent licenses made up 57 percent of S&T service imports.

The volume of imports and exports of technology items was very low for an economy of Russia's size. Among the Organisation for Economic Co-operation and Development (OECD) countries only the small economies of Finland and Norway have a comparable volume of these trade items. This comparison suggests that Russia is still not completely integrated into the international market for intangible S&T transactions. Decreases in technology imports further isolate Russia from the countries with the most advanced world innovations and continue to aggravate technological backwardness of some of its industrial sectors.

The largest volumes in S&T services trade were with the United States and Germany. Their shares in exports of Russian R&D services made up 24 and 40 percent, respectively; in Russian imports of such services their shares were 63 percent and 11 percent. In Russian imports of engineering services and intellectual and industrial property (patents, licenses, and expertise), the shares of the United States and Germany are also considerable, but substantial shares in this category also belong to the United Kingdom and Italy. Export of Russian engineering services are also high to China and developing countries – Iran, Pakistan, and Egypt.

Some 545 international S&T projects were implemented in 1994, many with MSTP support. Americans were involved in 120 projects and Germans participated in 111 projects. *Table 6.3* presents the main fields of R&D where projects were implemented.

Prospects for trade in technology should improve. Registration and purchases of patents and patent licenses by Russian organizations should be helped by the recent provision of government funds for obtaining patents abroad and for promoting

Table 6.3. International R&D projects by field of research in 1994 with MSTP support, by S&T field.

S&T field	Number of projects
Future information technologies	42
Modern bioengineering methods	38
Technologies, machinery, and production for the future	33
Complex exploration of oceans and seas, the Arctic and Antarctic	24
Global environmental and climate changes	24
Future processes of agricultural production	23
New materials	22
Controlled thermonuclear fusion and plasma processes	21
High-temperature superconductivity	18
National priorities in medicine and health services	15
High-energy physics	11
Telecommunications	9
Human genome	9
Optics, laser physics	8
Environmentally safe power engineering	8

Source: MSTP.

their registration (Government of the Russian Federation, 1995). Over time, participation in international transactions should make Russian managers more aware than they are today of the profits that can be realized from patents and patent licenses. They should begin to learn that buying technology is an effective way to improve products and processes, valuable even with extensive R&D of one's own. Thus the United States, with the largest domestic R&D activity in the world still imported $5 billion worth of technology items, almost 100 times the amount purchased by Russia. Of course, the low level of technology imports corresponds to the current low level of innovation. When innovation picks up, so should the import of technology.

6.4 The Spectrum of International S&T Cooperation

6.4.1 Classification of international S&T links in Russia and diversity of partner countries

Several elements distinguish R&D partnerships with commercial objectives from those with noncommercial goals. The commercial category includes S&T components of direct foreign investments; the execution by Russian organizations of applied R&D for foreign customers; investments in R&D by foreign companies; export and import of R&D-intensive products; foreign sales and purchases of S&T

intangibles rendering S&T services such as patents, licenses, and know-how; and the leasing of R&D installations and equipment. The common factor in these diverse transactions is the search for profits by both domestic and foreign participants.

The noncommercial category includes joint nonprofit research projects; the exchange of S&T information at international exhibitions, fairs, conferences, congresses, symposia, seminars, and courses; exchange of specialists and students; publication of S&T results in books and periodicals; and S&T assistance in aid programs. Profit is not the objective in these activities. Most activities are supported by national governments, international organizations, or philanthropic foundations, and seek to provide good will, to achieve prestige, or to serve the public interest.

Another distinction is between activities aimed at the commercialization of completed developments and those directed at obtaining new S&T results. There is also a distinction between activities to create new products or processes embodying the results of R&D and activities to achieve intangible knowledge, be it R&D services or patents. R&D contacts may be implemented through direct links between partner institutions or in the framework of intergovernmental agreements, both bilateral or multilateral. Such classifications are certainly not exhaustive, but nevertheless help to systematize the variety of current international R&D links in Russia.

Another way of classifying international S&T activity is by the country involved. There are several distinct groups:

- G-7 and smaller industrialized countries with highly developed technologies.
- Countries in the Commonwealth of Independent States (CIS) whose S&T activity since the collapse of the USSR has been artificially isolated from Russia.
- Countries from the former CMEA with technological bases similar to Russia's (Hungary, Poland, the Czech Republic, and the Slovak Republic); these countries are influenced by their past interactions with Russia.
- Newly industrialized countries of Asia that are approaching the economic level of the most developed countries.
- Large developing economies including China, India, and Brazil, which have had success in some R&D high-technology sectors, but which are confronted with difficult problems of commercialization.
- Some states in Latin America, Asia, and Africa (Argentina, Mexico, South Africa, Egypt, Turkey, and others) that have created an R&D base focused on technologies for mining and processing natural resources; in this respect they are similar to Russia.
- Oil-exporting countries (Saudi Arabia, Kuwait, and so on) that use receipts from natural-resources exports to introduce new technologies.

S&T transactions with particular countries are influenced by past bilateral relations and geographic proximity. Transactions with G-7 countries and with highly developed smaller European nations are catalysts in the transition to a more innovative economy. These nations are the technological leaders, and by joining the *train* of the countries with extensive international R&D links, Russia can more quickly move toward increasing the competitiveness of its economy. Nevertheless, given Russia's long isolation from the world community and the considerable technological lag in the majority of civilian sectors, attaining competitiveness vis-à-vis these countries will be a lengthy process.

Russia's role in the S&T activities of the CIS merits special attention. Chances are good that in the coming years Russia will be a major source of technology for CIS member countries. To facilitate relations with CIS countries the financial and legal details of the transfer of S&T results must be worked out. Other aspects of Russia's S&T policy with CIS countries include maintenance or restoration of relations between research institutes, exchange of S&T information, mutual certification of diplomas and certificates, coordination of patenting and licensing activities, and guarantees of access to scientific installations in other states.

Russia may have some competitive advantages in former CMEA countries owing to collaborations prior to 1990. Researchers and managers in these countries know their Russian counterparts, and this may secure business and research ties. Consumers and businesses in these countries are familiar with Russian products, and in the past there were common standards that should facilitate future sales of some products.

Some R&D cooperation has already been restored with East European partners. For example, the Kaluga Road Repair and Mechanical Plant, in cooperation with the "Roads Mechanization, Prague" joint-stock company, manufactures state-of-the-art machinery for Russian railroads, based on Czech developments and know-how. These machines are 2.5–3 times lower in price than comparable Austrian products (*Ekonomika i Zhizn*, 1995). In the field of biotechnology, the Inbio joint venture, based on cooperation between the Russian Institute for Albumen Synthesis and the University of Sofia (Bulgaria), has developed a procedure for processing microorganisms to obtain biologically active compounds for medicine and foodstuff.

Cooperation is developing with both new and traditional Asian partners. The Center for Physical Instrument-building of the Institute of General Physics is developing an industrial laser with the financing, equipment, and materials provided by the Korean Institute of Science and Technology. In the Republic of Korea, a company specializing in imports of Russian technologies has been established with state funding and private capital. On the basis of the Bach Institute of Biochemistry and the Vietnam Institute of Tropical Medicine, a laboratory has been established to develop fermentation technologies for Vietnam's food industry as well as soil microorganisms and regulators of plant growth. The Skochinsky Institute of Mining and the Central Research Coal Institute of China are cooperating in a project to provide the Chinese market with Russian developments in cleaning and drifting combines, cutting tools, hydrotransport, and underground coal gasification. An important condition for increasing S&T cooperation with the Asian countries is exchange of information. The Russian House for International S&T Cooperation has joined the computer networks of the UN Asian-Pacific Center on Technology Transfer to facilitate information exchange with Asian countries.

Russia has attempted to achieve more contacts with countries and regions that are second in line in the world S&T arena. Business in these countries, as a rule, is riskier than business with industrialized countries, yet Russia may confront less competition in these areas than in industrialized countries.

6.4.2 R&D projects with foreign partners

Despite its currently limited scale, the participation of foreign partners in Russia's applied R&D organizations is very important. There are several prominent examples of its importance.

A large-scale partnership exists between the American firm Pratt and Whitney and the Russian Ilyushin Aviation Complex and Perm Engines Joint-Stock Company (JSC) to develop aircraft engines. Another example of an applied R&D project is the cooperation between Rosneftegazstroj JSC and Turboizoljatsija Production Association and the French CIF-IZOPIPE company to create technology and equipment for manufacturing polyethylene gas pipelines from Russian raw materials. The new pipelines last two to three times longer than steel pipes, weigh a third less, and do not require electrochemical protection.

Some joint projects are active in import substitution. The Research Institute for Aviation Technology and Production Management (NIAT) is working with companies from Italy and Canada to develop equipment for electrochemical and ultrasonic punching and pressing molds. This equipment will reduce imports of expensive equipment from Switzerland and Japan, saving up to $90 million annually.

International projects also help solve acute social and environmental problems. The joint project of the Russian Lota company with several American companies (ADM Protein Specialties, Protein Technology International, and the American Soya Association), and the companies from Italy (Bertuzzi) and France (Magra), will develop medicine and food supplements for children. The Chernobyl Nuclear Power Station project, implemented by the Russian Research and Construction

Project Institute for Nuclear and Power Machine-building and the Oxford Polytechnic company (United Kingdom), is attempting to make all objects of the Chernobyl nuclear power plant into an environmentally safe zone. The Russian scientific center MEI-VEI, together with Masuda Research of Japan, is implementing a project on development of an ozone-absorption installation to ensure safe drinking water.

6.4.3 Foreign orders for R&D

In recent years the Russian S&T sector has benefited from contracts to perform R&D for foreign enterprises. Some projects are technically advanced. An example is the Research and Production Association for Machine-building Technology (TSNIITMASH) which has contracts from German, Italian, and French companies to determine the possibilities of using various materials and equipment in the construction of electric power stations.

For a number of Russian research institutes, foreign R&D contracts provide an opportunity for improving their technical facilities. For example, the Institute of Biochemical Chemistry of the Russian Academy of Medical Sciences obtained the equipment and reagents necessary for research in connection with a contract with the American Proctor and Gamble Company. In some cases foreign orders have served to maintain research capacities of Russian institutes. Managers at the Research Institute for High-Frequency Currents in St. Petersburg speculate that the institute has survived only because of shipments to foreign customers of prototypes of high-frequency current and ultrasound technologies.

Foreign enterprises have been particularly attracted by the S&T capabilities of the Russian defense industry where an overwhelming part of the Soviet Union's applied R&D effort had been performed (see Chapter 4). By late 1994, the Russian defense complex was developing more than 1,200 projects with partners in 18 countries (*Inzhenernaya Gazeta*, 1994, No. 131). Examples of the unique developments of Russian defense enterprises include a rotary-drawing method of punching, an electron-beam welding process, technologies to manufacture pure materials on the basis of centrifugal refinement, and sorption-extraction and fluoride technologies. The Izhevsky Zavod JSC cooperates with several large American and German enterprises in the production of satellite communication, medical equipment, and consumer products.

6.4.4 Higher education institutions

Cooperation between Russian higher education institutions and foreign firms is a promising route for international S&T links. The introduction of Russian R&D-intensive products to world markets could take place simultaneously with the provision of educational services. The Russian State Committee for Higher Education supports special programs to involve Russian universities in international S&T cooperation. Between 1993 and 1995, 350 international S&T projects involving the participation of more than 80 universities and higher education institutes were selected to receive government support; most of these projects were for applied research. Foreign partners contributed a total of $33 million to the projects (Higher Education R&D, 1995, p. 5).

Several projects have already demonstrated success. The Altai State Technical University, together with IBM, has created the Barnaul-based Center for Integrated Computer Technologies. IBM provided the computer and information technologies at a considerable discount. This university has also launched efforts to promote Russian technologies in the Chinese market. The Moscow Automobile Mechanical Institute together with the Boolan Industries Company has organized the production of punched pistons for automobile engines based on the isothermal-punching technology developed by the institute. The Siberian Physico-Technical Institute at the Tomsk Sate University established an engineering commercial center specializing in marketing, advertising, patenting products, and personnel exchanges to support international S&T cooperation.

6.4.5 Technology transfer through patents, licenses, and expertise

Another form of collaboration is the transfer of existing technology by a company to a joint activity. For example, in establishing Mechatron, a joint venture for manufacturing electric drives, the Italian partners Poletta & Osti and Izoflux (the world leaders in general-purpose industrial and robo-technical electric drives) contributed their know-how in engines production. In the creation of the Mechatronica Research and Production Group, a joint venture with the South Korean company DARIM, the Russian partners contributed the know-how. However, the most promising contacts are those encouraging mutual exchange of know-how. An illustration is the Isopress inter-metallurgy project of the Russian institute VNII-metallurgija and the Israeli company El-plazma. The Russian partner is providing its Israeli partner with hydro-pressing, hydrostatic, and gas-static processing technologies and receiving in exchange know-how about metal purification and other technological processes.

In some cases, enterprises in Russia have successfully licensed their technologies. The Russian joint-stock company Central Research Institute for the Sewing

Industry concluded five license agreements with companies from Germany, Sweden, and Italy.

Technology-based partnerships may speed up the introduction of innovations. The average duration of development of new types of machines and equipment was estimated at 2.2 years in Russia in 1993 (CSRS, 1995a, p. 168); this period of time is much longer than in G-7 countries.

There are promising examples of successful S&T links in different areas and regions. At the machine-building plant in Tosno (in the Leningrad region) a joint venture, Rekon, has been established for manufacturing Russian-made carriages on the basis of Spanish technology. The Urals Electrical Engineering Plant in Yekaterinburg has started manufacturing new current transfers with a technology developed by ABB. The Japanese firm Yamaguchi has helped to set up production of a special gastrointestinal drug called dinol at Belvitamin a Belgorod pharmaceutical enterprise. Such contacts are not one-way streets. For instance, specialists of the Zelenograd Doka JSC have established a plant in Canada for production of potato mini-tubers using its unique hydroponic technology (*Izvestiya*, 1996, 7 March).

6.4.6 Joint ventures and small businesses

By 1995, the Russian Science and Scientific Services sector was involved in 510 joint ventures employing about 8,900 persons. Exports of their products and services totaled $94 million in 1993, and domestic sales were $23 million (CSRS, 1995a, p. 185; 1996, p. 12). Some 70 percent of the foreign joint ventures are located in Moscow or St. Petersburg.

Some joint ventures successfully combine Western capital and technologies with Russian intellectual resources. In these partnerships foreign companies supply high-tech products and technologies, while their Russian counterparts provide adaptation, software, and after-sale and other services. However, the scale of these activities is very modest if we take into account the size of the Russian economy.

Many small firms have made distinctive contributions to international S&T activity. These firms require financial support and expert advice to offset the disadvantages of their small size. The St. Petersburg city government, with financing from the European Union and the Russian–German investment fund, Invest Consulting Company, has tried to deal with these disadvantages by providing consulting services to small businesses. Yet, according to a survey, small enterprises in innovative areas such as information technologies and engineering services are more interested in direct investment and partnership with firms from the West than in advice (*Izvestiya*, 1995, 6 October).

6.4.7 Foreign direct investment in Russian R&D

Foreign direct investment may be the catalyst to speed up Russia's S&T developments. In 1994, the value of foreign investments in the Science and Scientific Services sector was $26 million or 2.5 percent of the total value of foreign direct investments Russia (State Committee on Statistics, 1995, p. 301). This is a modest amount but great hopes have been raised by the participation of foreign capital in the establishment of Russian technoparks, such as that in St. Petersburg and the biotechnological center in Pushchino near Moscow. The research and production capability of a huge military plant in Kursk with unique technologies for synthetic and quartz article production has been successfully preserved because the US Computerland corporation bought almost 50 percent of the shares of the enterprise (*Delovye Liudi*, 1993, p. 38).

Foreign direct investment is also promoted by the expanding practice of tenders for state procurement in which foreign companies can compete.

6.4.8 Development of infrastructure for international transactions

An ever-growing number of Russian R&D institutions are switching to such information systems as Internet, RELCOM, PEER REVIEW, and STN International. Information interaction is also developing in specific areas. In particular, the Russian Center for Pharmaceutical and Medico-Technical Information, with financial support from the IMS (United States), created a dialogue system of information retrieval and exchange on domestic and foreign pharmaceuticals named METAPHARM. The Russian Institute for Economic Problems of Nature Management, with the assistance of Frisenius-Consult (Germany) and partial financing from the Hessen regional government, has established the Federal Data Bank on Nature Protection Technologies of EU countries and the United States.

An important contribution to the dissemination of information on options for R&D cooperation will be provided by the Russian Dealers and Distributors Network, which has more than 300 regional offices and a center of international commercial information implementing the program Interpartner. The search for partners in applied R&D will also be facilitated by joint publications, such as *Business Russia* magazine founded in Chicago by the *Ekonomika i Zhizn* weekly, and the Russian Chamber for Trade and Industry. The Russian S&T Information Centers of the MSTP and Academy of Sciences and Optistora company (Netherlands) have jointly developed an English-language database on results of R&D in Russia.

Participation of Russian R&D institutions and specialists in international exhibitions and trade fairs is expanding. For example, many Russian and other CIS researchers participate in the Leipzig Innovation Fair and the annual world inventions salon Brussels-EUREKA; both provide valuable information. In 1993 and 1994 the MSTP supported 10 exhibitions of new Russian technologies, 4 S&T seminars, and 2 presentations of Russian research centers. In the course of these events 47 contracts were signed, totaling about $10 million. Russian expositions were organized at international exhibitions and fairs where 36 contracts were signed, amounting to approximately $3.5 million.

Mediatorial services have become increasingly important as they help to link potential S&T partners. The company Informtechnology Service was established in 1991 for this purpose. The American firm Dworkovic & Associates provides a selection of licensees and licenses, calculates the costs of licenses, concludes licensing agreements, and assists in obtaining credits for investments. Through this company more than 2,000 sellers and buyers have found each other. The company's data bank contains 35,000 clients from 60 countries. At present, the company is attempting to standardize the technology databases available in Russia (Nikitina, 1995, pp. 17–18).

6.4.9 Noncommercial international activities

While much of the international activity for applied R&D has been on a commercial basis, noncommercial activities are also relevant to applied R&D. Participants in these activities recognizes that Russian R&D is valuable to the entire world. Numerous international organizations, national governments, private companies, and foundations have rallied to preserve the core of Russian R&D. In 1993, the European Union established the International Association for the Promotion of Cooperation with Scientists of the Independent States of the Former Soviet Union (INTAS), a nongovernmental organization uniting science representatives from the West with their CIS counterparts. Another example of help from Western colleagues is the activities of the Technological Center of the German Guild of Engineers. The center examined Russian projects in laser technologies and, as a result of this examination, 15 projects received financing from the Federal Ministry of Education, Science, Research, and Technology of Germany (*Inzhenernaya Gazeta*, 1995, No. 65).

Two European Union research programs are particularly important for Russian R&D: EUREKA and COPERNICUS. At present, Russian R&D institutions and enterprises are participating in 19 projects of these two EU programs. At the MSTP four working groups have been established to improve cooperation with EUREKA's umbrella projects: FAMOS, EUROENVIRON, EUROLASER, and EUROSURF. Several Russian R&D institutions with a long history together have participated in these projects. For example, the Russian Polus Research Institute, together with partners from Germany, the Netherlands, Italy, and Spain, has developed a safe technology for surgical treatment by high-temperature laser radiation under the auspices of the EUREKA project. In the COPERNICUS program, the Institute of Radio Engineering and Electronics of the Russian Academy of Sciences, together with the Polytechnic Institute of Bari (Italy) is creating systems of mobile communication based on solid-state electronics elements that perform better than existing cellular systems.

Personnel exchanges have become increasingly popular; more and more Russian scientists are actively participating in research and training programs abroad. One illustration is the recently established International Institute of Industrial Cooperation in southern California; the objective of this institute is to establish permanent collaboration between American oil and gas experts and their colleagues from CIS countries. In Moscow, at the Academy of National Economy, an international incubator of technologies has been established with a grant of the American Agency for International Development and Cooperation to help qualified specialists bring their projects from R&D to commercialization.

6.5 Government Support to International S&T Links

As the political and economic situations stabilize in Russia, the attention given to S&T issues will increase. In all probability, the state will have the main burden of organizing, maintaining, and regulating Russia's international S&T activities. Governmental policy for international cooperation must capitalize on the decades of experience of other nations. However, simple imitation must be avoided, and foreign schemes must be adjusted to Russian conditions.

In addition to the political, economic, and socio-cultural features of Russia, public policy must take into account the differences in the technological level of particular sectors and fields of S&T. A policy of cooperation in vanguard fields (such as aerospace and defense branches) must be established; this policy can be based on the experience of the most advanced countries. Many high-technology and basic sectors should also study the policies pursued by newly industrialized nations. Finally, in some cases (particularly mining branches, light industries, and food sectors) public policy should study the approaches that have been successful in developing countries.

Russia's technology policy has several features in common with international S&T policy of market economies. First, national security concerns have led to the control of technology exports. There has been a change from unilateral to multilateral control, from the control of immediate products and technologies to control over their national destination and from centralization to decentralization (creation of intercompany units). In view of these developments the Russian system of regulation must implement a clear system for controlling technology exports that are oriented to strategic national interests. Better controls will allow Russia to join international control systems which, in turn, will provide opportunities for more exchanges of applied R&D results.

Second, applied R&D is better promoted by government efforts to create a favorable climate for international cooperation than by direct government subsidies for international projects. The government should work on ensuring large-scale orders for Russian products and services. Such activity is particularly important in government procurement, large construction projects, and commercial aviation. Financing of exports at below-market interest rates is also important, particularly for large orders for products produced by sectors that have received government assistance. Russia has not yet developed a system of export regulation and promotion. Export control activities are dispersed among the Ministry on Science and Technological Policy, the Ministry of Economy, the Ministry of Foreign Economic Relations, the State Committee for Industrial Policy, the Ministry of Defense Industry, as well as other agencies.

Two important areas requiring government support are infrastructure improvements and information dissemination. Abundant data enabling business circles to watch world trends in technology development, to search for partners, and to examine the competition should be collected in data banks on advanced technologies. These data banks should be established, maintained, and accessible to interested companies. Many nations also have S&T attachés in diplomatic missions to monitor foreign S&T progress; Russia should do the same.

Tasks have been assigned to the Russian government through international agreements in the field of science and technology as well as by bilateral and multilateral intergovernmental bodies on the issues of R&D cooperation. These arrangements provide a legal framework for international contacts at different levels. Russia urgently needs to establish international agreements on protection of investments and double taxation and to join international efforts against piracy of intellectual property rights. Russia must also undertake the task of setting up a legal framework for foreign direct investments in S&T. The model law on foreign investments, currently under development by the OECD with experts from CIS nations, may provide a significant contribution. Coordination of efforts to attract foreign investments has been assigned to the Russian Center for Assistance to Foreign Investments, recently founded at the Russian Federation Ministry of Economy. At the same Ministry, an Information Center for Foreign Investments has been organized to create data banks on specific investment projects for potential foreign partners.

Another task is to increase the budget financing of large intersectoral and sectoral international applied R&D projects. A prototype of such a structure may be found in the activities of the Russian House of International R&D Cooperation established by the MSTP with the aim of investing in international applied R&D projects.

Considerable value has been attributed to indirect methods of governmental control of international S&T transactions. A system of taxation and customs regulations must be established for both Russian R&D institutions and their foreign partners. The status and privileges of free economic zones are yet to be formulated; such zones could disseminate information on advanced foreign technologies.

The state is also responsible for providing standards for certification of products and procedures. These standards must be rigorous yet favorable to international transactions. The government must also develop the human resources of S&T including training researchers in international transactions. Management training for S&T international transactions should be introduced.

Russia must establish membership in the most important international economic, science, and technology organizations. Membership in these organizations will not only provide benefits to researchers but also protect Russia's national interests.

The prospects for greater Russian participation in international R&D activities are favorable. The world is about to take a qualitative technological leap, and currently much effort is devoted to ensure sustainable development. In the transitional periods, favorable conditions are being created for involvement of new participants in international R&D activities of which Russia will be the largest. The Russian government should actively promote S&T cooperation with foreign partners using a variety of policy tools.

Chapter 7

Government Policy for Applied R&D

Andrey Fonotov and Lioudmila Pipiia

From 1992 to 1994 Russia faced the possibility of total disintegration of its R&D sector. By 1995 the crises had passed, but problems remained such as insufficient financing, unsatisfactory research facilities, and the outflow of young promising researchers from the R&D sector. The current problem is how to create an integrated strategy for S&T development to avoid the need for emergency measures. To solve this problem Russian R&D policy must recognize the value of institutions inherited from the Soviet Union and redesign them to serve the market economy. This chapter describes the policy emerging and proposes additional measures.

7.1 Strategic Goals and Factors of S&T Policy

The R&D sector has passed through two stages in the evolution of market reforms: liberalization of the economy occurred in the first stage (1992–1993); financial stabilization took place in the second stage (1993–1995). By 1996 the principal tasks had become stimulating investment, improving production efficiency, and restructuring industry. The main problem has been to determine ways of reforming Russian society that would lead to social progress and economic development on the basis of democratic principles. Achievement of this objective would enable Russia to become one of the world's most prosperous countries, but it requires a comprehensive approach that includes many changes in business, government policy, education, and S&T resources (Fonotov, 1993).

The prospects are good for realizing Russia's goal of economic growth. In the period from 1996 to 2000, the most internationally competitive industries will be in the natural-resource sectors. These sectors are also crucial in the Russian economic policy as their revenues can be used to finance structural changes that promote the development of technology-intensive industries. Over the long run technology holds the greatest promise for a prosperous Russia. Some forecasts project that by between 2001 and 2005 Russia will already be able to produce competitive high-tech products that will ensure the diversification of Russian exports and supplant natural-resource sectors as the leading sectors of the national economy.

Russia already possesses a number of high-technology sectors capable of producing internationally competitive products, and the government intends to pursue a policy to support these sectors, such as aerospace, nuclear-power industries, and power machine-engineering. To implement this economic strategy, S&T policy should pursue three long-term goals:

1. Steadily increase support of R&D from public and private sources.
2. Create a stable demand for S&T results.
3. Provide support for innovations.

These principal directions require concrete measures from the state. The process of implementation must also recognize the socioeconomic reality and take into account the different and often conflicting factors and interests of many groups in Russia that influence S&T policy. These factors include demands from the scientific community, the economic interests of the public and private sectors of the economy, social policy requirements, and the consequences of restructuring state institutions. Under these conditions, every S&T measure is a compromise among interested parties. It is important to recognize that the R&D sector is competing with other groups for governmental support, tax concessions, and preferential regulations. Increasing government expenditures for R&D may reduce the budgets for health, education, and social security. Similarly, subsidies for state-owned enterprises may reduce budget funds for R&D and social services. Tax concessions in one field increase the pressure to grant tax concessions in other fields.

S&T policy is also the result of legislative compromises often reached after intense struggles. At the beginning of market reforms, it became clear that the S&T system inherited from the Soviet Union would not be able to function with the changes occurring in the economy. The shift from central planning to a market system made it necessary to quickly adopt a myriad of laws to support the reforms, including legislation on intellectual property that would promote R&D and innovation (see Chapter 3). Some matters were regulated by decrees from the president and the government and others by legislation passed by the Duma. Often the laws from one branch contradicted those of another. Under these conditions, lobbying groups representing different sectors of society had considerable influence on legislation. In the 1992–1993 Parliament, the strongest lobbies represented the military-industrial complex, the managers of collective farms, and the directors of state-owned enterprises. In the competition between lobbies, the interests of the R&D sector without a strong political base were given little attention.

The sociopolitical conditions in Russia in early 1992 did not permit reformers to develop and implement a coordinated program of market reforms. Governmental policy was influenced by political pressures, the sharp deterioration of the macroeconomic situation, and the subsequent reduction in the state budget. Subsidies were given to state-owned enterprises for fear that the collapse of these enterprises would destabilize the country. There was no governmental concept of a strategy of socioeconomic development, and the contribution of R&D to economic growth was ignored. A host of new problems emerged as Russia entered international S&T markets (see Chapter 6).

S&T policy between 1992 and 1993 was formulated under conditions of unprecedented reductions of governmental expenditures for R&D. Inadequate financing of R&D severely harmed the operations of government-supported R&D institutes and created tension in the scientific community.

Simultaneously with these developments the government has stated that R&D is to be a priority activity. For instance, in 1993 a government decree On the Selective Structural Policy of the State (No. 306, 12 April 1993) was enacted. It identified five priorities in national restructuring:

1. The fuel and power complex including oil processing and petrochemistry.
2. Support for low-income households.
3. Stabilization of transportation and communications systems.
4. The conversion of military industry to civilian uses.
5. R&D participation in the transformation of industry.

It is obvious that the last two objectives have not yet been realized. In practice R&D does not have a higher priority than many other activities. Government appropriations for R&D have been grossly inadequate.

Many different governmental departments have policies that affect S&T – for example, the Ministry of Economy, the Ministry on Science and Technological Policy, the State Committee on Industrial Policy, the Ministry of Finance, and the Ministry of Defense Industry. Coordination between ministries has been limited, but a governmental commission on S&T policy, chaired by the prime minister, was established in 1995 to improve coordination of S&T policies among the ministries.

To deal with the coordination problem and other S&T issues, a 1995 draft law was prepared, On Science and the State Science and Technology Policy. This draft law is one of the most important documents on R&D policy; it defines the role of

R&D in the national economy and is intended to ensure that S&T decisions are consistent at different levels. The draft law defines the procedure for elaborating government S&T policy, addresses the legal status of researchers, identifies the sources of financing for R&D, sets out taxation, credit, and customs concessions for R&D, and prescribes rules for international R&D collaboration. The draft law also contains a number of radically new concepts such as state certification of R&D institutions and a federal contract system for state orders. The adoption of this law will be a major step in addressing the main problems of S&T regulation.

7.2 Government Financing of R&D

7.2.1 Current financing problems

The most important indicator of a state's actual S&T policy, as opposed to its rhetoric, is the budget allocations to R&D. The policy for governmental support for basic and applied research has been much disputed. Two extreme positions are often expressed. One has been taken by a number of experts who have insisted on eliminating governmental financing of applied R&D and concentrating budgetary support solely on basic research. Their argument is that under market conditions applied R&D should be carried out and financed by enterprises. Thus the scale of financing would reflect the demand by enterprises for applied R&D. The current industrial R&D sector should be transformed into company R&D (Lakhtin, 1990). Such rose-colored expectations reflected the pre-reform period when people in the country were contemplating a market without really knowing what it was.

The other extreme view is applied R&D should be completely supported by funds from the state budget, because in the coming years enterprises in Russia will not be capable of financing an adequate level of applied research. This viewpoint was frequently held in 1994 and 1995 (see, for example, Varshavsky and Varshavsky, 1995).

The actual adjustment of R&D to new conditions shows that the experience has been somewhere between these two positions. Enterprises have invested little in R&D and innovation, but this reluctance reflects the macroeconomic instability of the economy in the first years of reform. The extremely unfavorable investment climate hindered innovation activity and made financing of R&D unattractive to private capital.

To prevent a major disintegration of the country's S&T potential, the government has shouldered the main role of financing applied R&D along with supporting basic research. This is a transitional solution. In the long run, private capital must be involved in financing applied R&D and innovation. Whether this can be achieved depends on the macroeconomic situation and the S&T development strategy.

Under the new conditions, it is also necessary to adjust applied R&D to the requirements of Russian industry, as well as to develop capabilities to market intellectual products of R&D for both domestic and foreign markets. Research institutes are becoming increasingly interested in drawing attention to their achievements and are making efforts to search for customers among domestic industrial enterprises, foreign companies, banks, and others ready to invest in R&D.

To sum up, in the first years of the transition government support served to preserve the R&D base; this role dominated the restructuring of the R&D sector. In 1995, however, the government adopted the position that "the main task of today is to stabilize the situation, to put the level of governmental support of R&D in correspondence with the needs of its reorganization without destructive consequences" (MSTP, 1996). Officials and researchers now recognize that the state cannot maintain all the research institutes at the pre-reform level.

7.2.2 Selectivity and competition in R&D programs

The new policy clearly requires the state to be selective in its support of R&D. It also states that government funds for R&D should be distributed as much as possible on the basis of competition. Simultaneously, efforts must be made to develop a system for objectively evaluating R&D proposals.

These principles have been implemented by shifting to tender-based R&D financing. In this method individual scientists or groups submit competitive proposals for specified research tasks. This contrasts with the previous system in which R&D institutes were given funds on the basis of their budget requirements. Tender-based financing allows budget funds to be channeled to creative groups and individuals and ensures that applied R&D focuses on topics important to the national economy. Competition for financing among researchers also increases their interest in achieving results that are up to world standards. It may lessen the brain drain from the R&D sector since the best researchers can be better supported in a competitive system. In the long run, the efficiency of budget funds will increase in a competitive environment.

The first steps in this direction have already been made. Several budgetary and extra-budgetary funds allocate support through competition. Some of these foundations are listed in *Table 7.1*. The funds for these foundations were established by the government to strengthen the selectivity of financing S&T projects, to increase financing of R&D, to stimulate initiative by researchers, and to involve industry-supported applied R&D. Non-budgetary funds draw support from industrial enterprises through a procedure established by the state. These funds are

Table 7.1. Foundations promoting R&D in Russia.

Budgetary foundations	Non-budgetary foundations
Russian Foundation for Basic Research	Russian Foundation for Technology Development
Russian Foundation for Research in Humanities	Russian Foundation for Conversion
Russian Foundation for Promotion of S&T in Small Enterprises	
Russian Foundation for Support to Young Scientists	
Federal Foundation for Industrial Innovations	

Source: MSTP, various years.

considered a transitional form in the process of moving from government to private funding of R&D.

Among the foundations listed in *Table 7.1*, the activities of the Russian Foundation for Technology Development (RFTD) and the Russian Foundation for Promotion of Small Enterprise in S&T (FPSE) are directly associated with applied R&D. The RFTD, established in May 1992, is a centralized non-budget foundation which, along with 71 sectoral non-budget funds attached to sectoral ministries or industrial associations, is financed by contributions of 1.5 percent of sales of revenue of industrial enterprises. The contributions are divided as follows: three-quarters of the amount collected support sectoral non-budget funds and the remaining one-quarter goes to the RFTD. Initially it was assumed that these funds would be used to maintain existing industrial R&D institutions. Over time, however, the emphasis has shifted to projects that introduce innovations. *Table 7.2* contains data on the number and field of projects approved for financing by the RFTD in 1994.

In 1995, spending from sectoral non-budget funds was equal to about 9 percent of the government budget for civil R&D planned for 1995. The funds are growing rapidly, increasing nearly tenfold in the last six months of 1995.

Unfortunately, the government's current S&T policy in Russia cannot be called consistent. For instance, on 19 January 1996, the president's decree On Measures for Securing Timely Payment of Wages, at the Expense of Budget at all Levels, Pensions, and Other Social Payments questioned the need for the RFTD. The decree directed that all previously established non-budgetary foundations must be liquidated within two weeks and their funds must be used to pay wages in budget organizations. The decree indiscriminately lumped together the activities of all non-budgetary foundations, ignoring individual achievements in long-term

Table 7.2. R&D projects approved for financing by the RFTD in 1994, by R&D objective.[a]

Objective of R&D	Number of projects
Informatics, instrument-making, and conversion of defense R&D	23
Fuel and power generation	3
Chemistry and new materials	21
Machine-building and transport	30
Agroindustrial complex	5
Biotechnology and forestry industrial complex	5
Mining, metallurgy, and construction	5
Social sphere	11
Economics and law	1
Total	104

[a] The objectives of R&D are presented in correspondence with the names of sectoral departments at the Ministry on Science and Technological Policy of the Russian Federation.
Source: MSTP, 1995.

development and stressing only the single short-term goal of obtaining additional money for the budget. After the publication of this decree, the government was forced to reconsider its decision to abolish some of the non-budgetary foundations including the RFTD. It decided to retain the RFTD and restored most of the accumulated amounts to the foundations.

7.2.3 Repayable financing and the contract system

In February 1994, the Foundation for Promotion of Small Enterprise in S&T (FPSE) was established to support innovative projects of small businesses. The foundation is financed by allocations from the MSTP. In 1996 the allocation was 1 percent of the federal budget for civilian R&D. The FPSE also receives voluntary contributions from domestic and foreign enterprises, organizations, and individuals. The FPSE not only examines research and production projects proposed by enterprises but also allocates grants for development of the innovation infrastructure – training specialists, patenting inventions, certifying products, arranging conferences and meetings, and producing publications.

At present, FPSE experts find that the most profitable lines of innovations are in medical technologies, civilian and industrial ecological activities, environmental monitoring, personal safety, computer technologies, shipping, office equipment, and energy-saving devices. The foundation examines approximately 150 applications every three months and chooses about 30 projects to receive between R200 and 250 million on privileged terms (interest rates of 25–30 percent, much less than the 90–100 percent annual interest rates charged by commercial banks). Projects are examined for their future usefulness to enterprises. Nearly 1,000 experts are involved in the review process, and the final decisions are made by a 12-member foundation commission (*Poisk*, 1995).

The FPSE embodies an important concept for R&D policy – repayment by the enterprises of financing from the budget and non-budgetary funds once an innovation is realizing revenue. The requirement of repayment financing should force enterprises to carefully select R&D projects, paying close attention to the projects' economic viability. It also makes the foundation partially self-financing as revenue from old projects finance new ones. Financing repayment should also provide additional resources to supplement budget funds. After some time repayable financing should provide a steady source of funds to support RFTD and FPSE activities and to offset interruptions in budget financing. The MSTP also plans to apply the principles of repayable financing to R&D projects performed by federal S&T programs, international S&T projects, regional programs, and other activities supported directly by the budget. It is hoped that repayable financing will eventually be applied for most of the applied R&D financed by the federal budget.

Draft regulations envisage that half of the funds that will be repaid by the contractor will be deposited in a special account of the MSTP. These funds will be used to fund new projects and for arranging exhibitions, seminars, and conferences and publishing information materials. According to the draft, intellectual products obtained from research performed on the repayable basis would be the property of the MSTP until the funds advanced to the project have been completely repaid.

The new methods of research financing reflect the necessity of creating a mechanism of government support for R&D that conforms to the principles of a market economy. In our opinion, one important additional measure would be the introduction of a federal contract system for R&D. The contract system would regulate relations between organizations carrying out R&D projects and recognize the need to respect intellectual property rights. These changes would lower barriers to industrial use of S&T results obtained from federal projects.

Contracts protecting intellectual property rights should be broken down into three levels: between the employee and the research institute; between the research institute and the industrial enterprise; and between the research institute and the state. Legal documents securing relations at the first and second levels have already been completed. Documents regulating the relationship between the state and the research institution are under development.

In the autumn of 1995, the MSTP submitted to the government a draft decree on the introduction of the federal contract system for financing R&D projects from both budgetary sources and non-budgetary funds. Its adoption has been delayed by the unresolved issue of ownership of R&D results obtained under contract. Despite this delay, the government plans to use the contract system in the framework of current legislation to gain experience with the contract system. This sort of financing is to be introduced in stages. It is expected that expansion of such a system will increase the flexibility for financing R&D projects and improve the investment and innovation climate.

7.2.4 S&T priorities

The new forms of government financing reflect S&T priorities. At present, the list of priorities is long. It consists of 14 subjects and encompasses almost all fields of science and technology. Its contents are almost identical to the priorities of the world's most developed countries, and does not always acknowledge the special conditions in Russia (*Table 7.3*, left column). During the first four years of reforms the priorities were widely criticized. The limited size of the government budget ruled out financing all R&D inherited from the Soviet system. The task was to carefully select R&D projects that should receive support. Experts from the Organisation for Economic Co-operation and Development (OECD) pointed out that the process of setting priorities at a more detailed level, as well as the criteria used in the selection process, was unclear. OECD experts further noted: "There was, unquestionably, an inclination to distribute small amounts of money to a large number of teams, and there is still a tendency to select frontier technology programs without giving sufficient attention to their applicability" (OECD, 1994a, p. 36).

In 1994, at the behest of the MSTP, the Republican Research and Consulting Expertise Center prepared proposals on the priorities of S&T development and a list of critical technologies. The proposals were based on a two-stage expert poll using the Delphi method. In the first phase 107 representatives were polled from the Academy, higher education, and the industrial R&D sectors, as well as industrial management. In the next stage the results were reviewed by MSTP specialists who relied on consultations with scientists, particularly members of the scientific boards for federal S&T programs.

In August 1995, the list of priorities for S&T development and the list of critical technologies prepared by the MSTP were sent to ministries and departments responsible for a considerable share of the government's allocations to R&D (the Russian Academy of Sciences; academies of medical and agricultural sciences; the state committees on industrial policy, higher education, and the defense industry; the ministries of the economy, atomic energy, transport, fuel and energy, health and medical industry, agriculture, and environmental protection, among others). On the basis of comments and proposals made by ministries and committees, a list of priorities for S&T development was prepared (see *Table 7.3*, right column).

Table 7.3. Actual and proposed S&T priorities in Russia.[a]

Actual priorities	Proposed priorities
1. New production technologies	1. Information technologies and electronics
2. Informatics and communications	2. Industrial technologies
3. New materials	3. New materials and chemicals
4. Chemical products and technologies	4. Technologies of living systems
5. Fuel and power engineering	5. Transportation
6. Transportation	6. Fuel and power engineering
7. Forestry	7. Ecology and environmental management
8. Food production and processing	8. Priority directions of basic research
9. Life sciences and biotechnology	
10. Ecology and environmental management	
11. Space	
12. Technologies for medical research and social services	
13. Fundamental properties of matter research	
14. Fundamental problems of Russia's social and cultural development	

[a]The table presents a complete list of priorities, comprising both applied R&D and basic research.
Source: MSTP, various years.

In spite of the great amount of work and the sophisticated methods, there are limitations to setting priorities this way. First, the priorities proposed in *Table 7.3* are merely an enlarged list of previous priorities, although the categories are more precisely defined. Second, the Delphi method is oriented toward a search for a consensus among a number of possible choices; it does not provide an effective search for S&T policy based on the goals set out. Third, economic agents – industrialists, bankers, owners of small business – were not sufficiently represented; implementation of innovations depends on the participation of these agents. Representatives of industry took part only in the initial stages. A more active involvement of business circles was difficult because under present-day conditions managers are primarily interested in short-term investments with a quick return of capital. They react negatively to activities that yield only long-run returns.

Thus, only one phase of the choice of priorities for S&T development has been completed. The results have clarified and harmonized the position of the ministries and departments influencing the country's S&T development, yet the interests of the government are quite different from those of businessmen. Informal discussions with politicians and representatives of business circles should be valuable in overcoming the limitations of this survey, particularly in recognizing economic criteria for applied R&D support.

In the process of developing priorities, a list of 76 critical technologies was also compiled. Critical technologies were defined as "technologies that have an inter-branch nature, provide the prerequisites for the development of many technological fields or directions of R&D and solutions to key problems of . . . S&T priorities" (MSTP, 1995a). The problems in developing a list of priorities for S&T activities apply equally to creating a list of national critical technologies. Despite the absence of a clearly formulated overall state strategy for long-term economic development, the inclusion of the economic factor in the definition of critical technologies would make the concept more useful.

7.2.5 The future of government financing of S&T programs

In 1994, government financing was organized into 41 government S&T programs, 16 federal goal-oriented programs with an R&D element, and 4 interdepartmental programs. The list of government programs includes practically all fields of science and technology. Under conditions of limited financing, this means the funds are dispersed over several projects in each program. A serious issue in S&T policy is to increase selectivity and to shorten the list of government S&T programs.

Another important problem is the formation and implementation of federal goal-oriented programs (for data, see *Exhibit A3.13*). Often the government decides to finance programs and for this it addresses specific items in the federal budget. Examples are the Federal Space Program and the Program of Civil Aviation Development. Financing of other programs is decided on the basis of proposals from ministries and departments. The approval procedures are rudimentary. Funds allocated to programs largely support the general upkeep of institutions rather than R&D activity essential to a program's objectives.

To increase the effectiveness of federal R&D expenditures, the government must clarify the procedure for forming and implementing federal goal-oriented programs. According to MSTP data, 55 percent of the 1995 federal budget appropriated to civilian R&D was allocated to these goal-oriented programs.

Another method of government support for R&D is provided by state research centers (SRCs). At present, the status of SRC has been granted to 61 R&D institutions which perform R&D in such advanced fields as nuclear physics and power engineering, chemistry and new materials, aircraft development, ship-building, navigation and hydrophysics, medicine and biology, biotechnology, computer science and instrument making, engineering, optoelectronics, laser systems, and robot engineering (see *Exhibit A1.6*). SRC status was given to the largest institutes in the industrial R&D sector, and 17 SRCs are institutes associated with defense industries. SRCs are concentrated in regions that were active in R&D during the Soviet era. Thirty-three centers are in Moscow, and another six are in the region surrounding Moscow, eleven are in St. Petersburg; and the regions of Novosibirsk and Tomsk have four each. Some of the centers are located in the former closed science cities. Research institutes with SRC status are given priority in budget financing for approved activities. Between 40 and 70 percent of the total funds obtained by state research centers are provided by government programs (MSTP, 1996).

An evaluation of the two-year experience with SRCs shows that the key question is whether the centers are worth their costs. Would a selection procedure for financing based on competition produce better results at cheaper costs than one based on SRC status? Could this selection process be biased toward supporting large institutes inherited from the centralized planning system?

To answer these questions we must take into account the conditions of the economy in transition and the urgency of preservation of the country's R&D potential. The program of SRC development started in 1992, and its large-scale implementation began in 1993, when the amounts of governmental R&D financing were dramatically reduced and survival of R&D institutions was the dominant consideration for policymakers. Therefore, the program was intended to minimize the destruction of the largest and best-known research institutes possessing state-of-the-art equipment rather than to introduce market principles into applied R&D.

In the first two years the program supporting SRCs was not backed with sufficient financing. Government funds allocated to them were hardly enough to pay salaries and maintain the facilities; little was available for renovation and improvement of equipment.

The meager financing notwithstanding, an SRC exhibition in Moscow in November 1995 demonstrated a high standard of S&T achievements; institutes which had earlier been working solely for military needs managed to reorient their operations to civilian purposes. For example, the Obninsk branch of the Karpov Physico-Chemical Research Institute developed and introduced into production various pharmaceuticals. The Research Institute for Organic Semiproducts and Dyes introduced into use radically new pharmaceuticals for cancer diagnosis and therapy. The Applied Chemistry Institute worked out a technology for industrial production of ozone-safe freons. The Bochvar Research Institute for Inorganic Materials is completing certification tests of a new zirconium alloy with a high threshold of radiation resistance for manufacturing envelopes for heat-emissive elements of nuclear reactors' active zones; use of this alloy will increase the efficiency of nuclear fuels by 20 to 30 percent.

The 1995 Moscow exhibition had two objectives: first, displaying achievements of SRCs; second, drawing the attention of business circles to S&T results with the goal of obtaining support for commercialization. In mid-1996, a similar exhibition took place in St. Petersburg.

The results of the SRC program are currently under review. It is expected that some centers will lose their SRC designation; others will have their status renewed; and some additional institutes will be given SRC status. Despite the drawbacks of the program of SRC development revealed in its implementation, many research institutes continue to seek SRC status. By the end of 1995, the MSTP received more than 200 applications.

SRC development must be improved by establishing more reliable links between applied R&D institutes and industry and by creating more favorable conditions for commercialization. Emphasis must be on enhancing the Russian industry's positions in domestic and international high-tech markets. Activities should be introduced that encourage competition in R&D financing. Furthermore, R&D goals should determine the acquisition of equipment rather than equipment determining the research conducted.

Finally, the program of governmental support to scientific schools should be reassessed. In September 1995, the government enacted a decree aimed at reducing the brain drain from the country and raising the prestige of scientists. In the budget of the Russian Foundation for Basic Research, R34 billion were appropriated directly to leading scientists and scientific schools, while another R100 billion were distributed to these scientists on a competitive basis.

The effectiveness of this program is questionable. Any scientist with a professor's title may claim support under this decree, though it is obvious that the number of leading scientific schools is limited and one can name all their leaders. It is unclear what a "leading scientific school" means in this context. This expression has been used by the scientific community to designate a specific theoretical direction headed by a prominent scientist who has attracted a group of talented disciples. However, there is no strict definition which could be used in the implementation of this decree. In some publications, scientific schools means any type of research team (Tretyakov and Melikhov, 1995).

Any effort to distribute government funds must define clear and concrete rules. Criteria must be developed to determine leading scientific schools. Their presence must be confirmed in certain scientific areas. Lists of leaders in the respective schools must be available. These criteria will provide a rationale for financing projects of leading scientific schools and the question of whether they are suitable for budgetary support can be reconsidered.

7.3 Government Support of Innovation Activity

7.3.1 Budget financing of industrial innovation

Innovation activity was recognized as the weakest part of the Soviet S&T system. In the reform era innovation was to be directed and financed by enterprises, but in the difficult times of transition many proposals were made for government support. In 1994, Russia's MSTP, together with 11 other ministries and departments, agreed on a draft entitled the Complex Program of the Development and Governmental Support of Innovative Entrepreneurship in the Russian Federation for the Period 1994–1996. The measures in this program were aimed at creating legal, organizational, and economic conditions for developing enterprise innovations; forming a market infrastructure for innovation activity (including establishment and development of technopark structures); and involving researchers in innovation. The program was financed by participating ministries and local authorities and by funds from private investors.

The most critical issue was financing availability. Where the resources were sufficient, good results were achieved. For example, with funds allocated by the MSTP and the Lomonosov Moscow State University, an exemplary scientific park was established with up-to-date equipment. It is operating successfully. Unfortunately, other projects were not as adequately supported.

The outcome is not surprising. To make a program of innovation support effective, it is necessary, first, to make the measures proposed consistent with the available resources and, second, to make the government's support to innovation-related investments a major element of the program. This was not the case with the innovation program, so improvements are clearly necessary.

7.3.2 Infrastructure support

Infrastructure was and still is a weak point in Russia's economy. Since successful results in R&D will be increasingly determined by cooperation, the development of links between research institutes and businesses are essential. Furthermore, the country's innovation potential cannot be realized without capable personnel. The government must provide appropriate support for training personnel for R&D and innovation with the active involvement of entrepreneurs interested in the development of human resources.

In today's world, effective R&D and innovation activity is impossible without extensive use of information technologies. Recently, some important improvements have been made. In 1996, 28 telecommunications networks were operating in Russia; electronic mail is becoming increasingly available. The MSTP has contributed to the establishment of the InfoScience experimental telecommunications system, which is popular among Russian researchers. Despite these improvements, Russia lags behind world standards. Researchers still do not have access to unrestricted exchange of scientific information with colleagues or to various databases both within the country and abroad. The information revolution is well under way in other industrialized nations; in Russia it has barely begun. Russia must radically improve the availability of information to scientists and engineers using advanced technologies to collect, transfer, process, and analyze the information. Investment of government funds in the field may be one of the most important elements of the state's innovation policy.

Some steps have been taken. In 1995, the interdepartmental program of the National Network of Computer Communications for Science and Higher Education was established. This network will provide leading research and education centers with access to domestic and international S&T information resources. Approximately 1 percent of the federal R&D budget was channeled to this program in 1996.

7.3.3 Applying R&D results to innovations

In August 1995, the government of Russia established the Federal Foundation for Industrial Innovations (FFII). The financing of this foundation is planned to be 1.5 percent of the government's centralized capital investments. In practice, the foundation is to be a tool to pursue the government's S&T and industrial policy. It is to early to determine whether the FFII will function efficiently. However, based on the experience of previous foundations (the RFTD and FPSE) it can be stated that, to be effective, the foundation must accumulate considerable resources in its budget account, adhere to the S&T priorities it establishes, observe the principle of repayable financing of innovation projects during at least the first several years of its operation, and obtain legal support from the state.

Another way of moving R&D into production is the establishment of investment groups. About 20 elite scientific institutions in the field of chemistry and material science, including 10 SRCs, have started an investment group whose objective is to sell completed R&D. The government, through the MSTP, is assisting in the creation and operation of this investment group.

To fulfill its tasks, an investment group must obtain private investments and complete the technology cycle from the R&D project to the final use in mass production. These groups may advertise their research results to create a demand for their services, and help the commercial use of innovations with the issuance of company securities and broker operations.

Table 7.4. Distribution of the most important R&D projects supported by the MSTP, by field of S&T.

Field	Number of projects	Investment required (in million $)	Average duration of projects (in years)
Machinery	25	363.8	2.0
Metallurgy	15	372.2	2.7
Construction	29	67.6	1.3
Power generation	30	78.7	2.0
Development of fuel and energy resources	7	18.2	2.0
Chemistry and new materials	26	93.0	1.7
Forestry-industrial complex	4	99.0	1.8
Informatics and instrument-making	83	235.1	2.2
Agriculture and agro-industrial complex	29	651.6	2.5
Medicine and health services	15	101.8	3.6
Light industry	17	69.1	1.7
Total	280	2,150.1	2.1

Source: MSTP, 1995b.

Still another activity to promote innovation was initiated by the MSTP in 1995. The MSTP has selected a number of the most important finalized R&D projects for use in industrial production. A total of 280 projects were chosen from more than 500 applications (see *Table 7.4*). A majority of the projects had business strategies that were close to implementation. The Ministry offered to act as a broker between research institutes that had failed to find customers for their R&D results and industrial enterprises that might commercialize the results. In spite of favorable economic evaluations of this effort, entrepreneurs were in no hurry to invest their money in the commercialization of R&D results. Part of the problem was that R&D institutions did not have sufficient experience in promoting technologies in the market. More important, the basic factors favoring innovations have yet to be established – a macroeconomic equilibrium, a legal base for intellectual property, marketing institutions, and so forth. As a result, most of the projects selected by MSTP have yet to be implemented.

7.4 Indirect Support to R&D and Innovation

7.4.1 Tax concessions

Most industrialized countries, including Russia, provide various tax exemptions for R&D expenditures. By early 1996, a number of tax and other exemptions existed for institutions and enterprises performing R&D, as well as for organizations introducing new equipment and technologies. The tax exemptions and concessions are as follows:

- The value-added tax (VAT) does not apply to the R&D performed in educational institutions or to R&D financed by the budget or by foundations such as the Russian Foundation for Basic Research, the Russian Foundation for Technology Development, and sectoral non-budget funds.
- Purchases of equipment to be used for R&D are also exempt from VAT; these include goods and equipment imported through programs of foreign technical assistance or under contracts with foreign organizations performing joint R&D. Imports of R&D equipment are exempt from customs duties.
- As much as 10 percent of total profit spent by enterprises and organizations on R&D is exempt from the profit tax.
- Profit tax does not apply to profits realized on R&D-related activities by educational institutions and educational services.
- Profits that are spent on construction, renovation of industrial fixed assets, and new equipment and technologies are exempt from profit tax.
- New small enterprises in the Science and Scientific Services sector are exempt from profit tax for the first two years after formation if S&T projects constitute over 70 percent of their total activity.
- Grants from foreign philanthropic organizations to budget-supported institutions and nonprofit R&D organizations are exempt from profit tax.
- The personal income tax does not apply to grants given to Russian residents by foreign nonprofit organizations.
- Property and land tax exemptions are given to public research and higher education institutions, R&D institutions of the Academy of Sciences, state research centers, and other R&D institutions listed annually by the government.

Many of these tax exemptions are in effect in industrialized countries. In these countries R&D is given special treatment because of its externalities and its importance in economic growth. In estimating the size of tax rebates, it is necessary to note that they are intended for enterprises and institutions that are at the stage of investing in R&D, new technologies, and technical re-equipment. Tax exemptions should also be available during the introduction of R&D results. For example, there could be tax vacations for profits acquired through the operation of high-technology products for 3 to 5 years after the innovation's introduction. It is also advisable to enact tax exemptions for dividends received by investors from innovation projects over the first three years.

Real-estate and land tax exemptions for research institutes were intended to compensate for insufficient budgetary financing. Some R&D institutes have become, in effect, tax-exempt real-estate organizations. Tax exemptions should be repealed on non-R&D activities of research institutions.

7.4.2 Product standards

The government has a decisive role in setting product and certification standards. This issue is especially urgent in Russia since, in a number of cases, technical re-equipment of industry has been accomplished with obsolete technologies and consequently the new products do not meet current environmental and technical standards. Some obsolete technologies and products have been imported into Russia; others are from domestic sources.

Russia inherited a system of state standards (GOST); these standards were valid both in the entire Soviet territory and in the member countries of Council for Mutual Economic Assistance (CMEA), but many times they were different from international standards. Nevertheless, the OECD (1994a, p. 71) reports that "the former Soviet Union had developed a remarkable infrastructure for the standardization and normalization of technology." The centralized network of the State Committee on Standardization, Metrology, and Certification of the Russian Federation (Gosstandart) has been preserved, and continues its activities.

In 1993, laws on standardization, uniformity of measurements, and certification of goods and services were adopted. The Gosstandart participates in the International Standards Organization (ISO), developing about 60 new international standards and executing the examination of another 400 international standards.

The transition from GOST to international standards has been very expensive. It is extremely important, however, that Russia adopts only those international standards that are equal to or exceed the level of current GOST standards. It is completely unacceptable to adopt quality standards for goods and services that are lower than GOST.

Government activity with respect to standards is limited in several ways. First, less than a half of goods and services have compulsory certificates. It would be desirable to speed up the process of certification by allocating the necessary funds to this process. Second, it has become necessary to subject technologies imported into Russia, as well as technologies used in the re-equipment of enterprises partially or completely owned by the state, to compulsory official examination. The state must use all necessary economic levers to erect barriers to the import of obsolete technologies into Russia. Third, technological developments and new machinery prototypes originating in R&D institutions must be checked for compliance with domestic and world requirements. This measure will prevent the reproduction of outdated products under the pretext of introducing new ones.

7.5 Regional Aspects of S&T Policy

The problem of regional development is especially urgent because of Russia's size and its variety of natural, climatic, and socioeconomic conditions. Each region of the country participates, to some extent, in the performance of applied research. However, as mentioned earlier, regional aspects of R&D were neglected in the Soviet era and the distribution of R&D potential over the country's territory has been uneven (see Chapter 2). The departmental rivalry also present in R&D led some sectors to dominate in certain regions. The needs of regional development were largely ignored in the decision-making process if they conflicted with the interests of central departments.

The current reforms in Russia have moved an important part of economic decision-making from the central government to regional administrations. The regions no longer wish to be merely customers of S&T activity and instead are striving to become participants in R&D and innovation activities directed at their economic and social problems. Industrial enterprises have already eliminated their dependence on R&D performed by institutions belonging to corresponding branch ministries and have become increasingly interested in searching for R&D partnerships in local markets.

Regional S&T policy can be pursued in different forms and by a variety of methods, such as founding technoparks or establishing funds to promote small research-oriented enterprises. Regional measures can be introduced to encourage international R&D cooperation, including arranging local exhibitions of S&T achievements.

Between 1992 and 1993, it became obvious that regions wished to participate in the selection and implementation of regional and interregional S&T programs that would be financed in part from the federal budget. Such programs have been adopted and account for about 1 percent of the federal budget allocations to civilian R&D in 1994 (CSRS, 1995a , p. 107). The share of federal budget funds in the programs varies from 18 to 55 percent.

The programs in the regulation On the Procedure of Financing Regional S&T Programs and Projects from the Federal Budget of the Russian Federation provide funding of regional S&T activities and ensure the distribution of results of

Table 7.5. Regional S&T programs and their financing considered by the interdepartmental board on regional S&T policy in 1993 and 1994.

	1993	1994
Number of projects in programs	1,266	1,421
Recommended for federal budget financing	715	896
Not recommended for federal budget financing	551	525
Financing requested from the federal budget (in million rubles):	8,826.71	30,511.27
Recommended for financing	3,509.85	16,299.20
Not recommended for financing	5,316.86	14,212.07

Source: Center Renatekhs, 1995, pp. 7, 9.

interregional and national importance. R&D that will be beneficial to regions will also be performed by research institutes of the Russian Academy of Sciences, regional research and education institutions, and research centers established by local authorities. Finally, funding is available for the development of a market infrastructure for R&D and innovation activities in Russia's regions. The federal funds are allocated to regional S&T programs and projects only on the basis of cost-sharing. After a project is completed, the ministry, the regional administration, and the project's participants become co-owners of the intellectual property.

The selection of projects is done by independent experts at the Center for Regional S&T Cooperation (Renatekhs). Data for the number and financing of regional S&T programs and projects are given in *Table 7.5*.

The experience between 1993 and 1994 shows that the main reasons for the rejection of regional proposals were the following:

- Duplication of work performed in the framework of federal S&T programs or regional programs financed by the Russian Federation Committee on Higher Education.
- Use of budget funds for unauthorized purposes such as recovering enterprises' current assets, re-equipment of enterprises for new types of production, and arrangement of sale of products.
- Absence of potential users in a specific area of R&D.
- Absence of the finance sharing.
- Lack of novelty elements in R&D offered and the availability of ready-made developments in other regions (Center Renatekhs, 1995).

A total of 59 of the 89 regional authorities of the Russian Federation participate in regional S&T programs which include interregional economic associations, such as the Association for Economic Interaction of Regions of the Central Black Earth Area Chernozemye, the Association Siberian Treaty, and the Association for Economic Interaction of Regions and Republics of the Urals Area. The Krasnodar, Irkutsk, Saratov, Kemerovo, Tomsk, and Tula regions are among the most active participants in regional S&T programs.

In spite of the fact that financing of regional programs is an insignificant part of the federal budget, these programs are a radically new form of cooperation between the federal government and the regional governments. The program takes into account local needs or preferences. Shared financing and the necessity of funds from local budgets, industrial enterprises, and other sources increase the responsibilities of local administrators and R&D participants in the projects.

Improvements in governmental S&T policy in the regions are connected with the implementation of cooperation agreements between MSTP and regional administrators. They also depend on the capability of regional science centers coordinating federal and regional S&T policies.

The so-called technopolises present another aspect of regional S&T policy. Many of these cities were established exclusively for R&D activities; many were formerly very active in military R&D. There are about 60 municipal technopolises in the country; more than 20 are close to Moscow. These towns had acute problems in 1992 and 1993 when demand for their S&T products, previously supported with government funds, sharply decreased. The military specialization of the majority of technopolises restricted the possibility of their performing civilian R&D. The financial crisis caused critical situations in maintaining the industrial safety of some of the experimental facilities in these towns. Moreover, the average age of researchers is over 50 in some towns which reduces the chances of launching new activities.

At least two national tasks can be identified that would help reduce the crisis of the technopolises. The first is establishing a steady base for the development of innovation. The idea is to reorient the creative potential in these towns from an armaments race to a technology race. The highly qualified personnel and high-quality equipment in these regions make this shift possible. The second task must address the destruction of nuclear, chemical, and biological weapons in accordance with international agreements signed by the Russian Federation. New technologies must be created for the safe and economic disposal of stocks of these weapons. The knowledge and skills of specialists who participated in creating such weapons are likely to be valuable for devising ways of destroying them.

The program for the development of technopolises requires recognition of their specializations and locations. In this connection we should single out a group of technopolises whose R&D institutions are located near Moscow and St. Petersburg. Programs for these technopolises should be linked to the development programs of these two megalopolises. The development of other technopolises should be dealt with in agreements between federal and local authorities.

The conversion of dying technopolises into centers of innovation will require large expenditures. Federal budget allocations will not be enough. It is necessary to combine federal and local resources and to transfer part of the budget originally targeted for the economic development of technopolises to social expenditures. These towns should also receive funds allocated in international disarmament treaties.

7.6 Conclusions

The S&T policy pursued between 1992 and 1995 gradually shifted from budgetary support of R&D institutions to goal-oriented activities and the development of non-state financing. The emphasis on competition in allocating funds reduced the monopolistic character inherited from the Soviet era, and promises to raise the efficiency of S&T activities.

The basic elements of government policy have been formed, and the contract system of intellectual property is being introduced. Repayable financing for applied research and innovation projects has already spread to many programs.

Still, S&T public policy is burdened with unsolved problems. The innovation component of the S&T policy is hesitantly being pursued, reflecting uncertainty on how to proceed. The gap between R&D institutions and industrial operations remains large despite various government measures. For this reason it is crucial to combine government and business efforts in the innovation process. Understanding and then meeting the needs of industries is the most important task of applied R&D. Entrepreneurs must help scientists and innovators understand the intricacies of industrial demand for R&D. The creation of a more definite innovation policy remains an important task of governmental policy.

Chapter 8

Concluding Comments

Leonid Gokhberg, Merton J. Peck, and János Gács

In this chapter we comment on selected points made earlier in this report and attempt to answer directly the three questions raised in the introduction:

1. Was the decline in applied R&D from 1991 to 1995 too steep or too modest for the welfare of the Russian economy?
2. How should the organization and structure of Russian applied R&D develop over the long run?
3. What role should public policy play in applied R&D?

8.1 The Decline of Russian Applied R&D

Chapters 2 (Gokhberg) and 3 (Alimpiev and Sokolov) clearly describe the dramatic fall in Russian applied R&D from 1991 to 1995. There was a steep fall in real terms of government funding for research institutes. The institutes responded to the decrease in their budgets by sharply reducing the salaries of researchers. The reduction led to an exodus of researchers; employment of researchers in the research sector fell from 1.22 million in 1990 to 542,000 in 1995, largely in applied R&D. The process of downsizing was largely a decentralized one, depending on each researcher's decision to leave or stay and depending on the outcome of the struggle of institutes to survive. Many institutes initiated activities far from research and development such as leasing their buildings or retailing personal computers. Staff members often took additional jobs.

All the chapter authors have concluded that the decline in applied R&D was too sharp. The size of the Russian applied R&D sector is regarded as inadequate to support Russian manufacturing, particularly its high-technology sectors.

Comparisons of the size of the Russian R&D sector with those in other countries tend to confirm this conclusion. One of the most striking comparisons is in terms of gross expenditures on research and development (GERD) as a percentage of gross domestic product (GDP). In 1994 Russia tied with Greece and Portugal for last place among the 23 nations for which data are available (see Table 8.1 in CSRS, 1995b). There are problems in making these comparisons since they depend on purchasing power parity exchange rates and calculations of GDP; all measures are subject to error.

Other indicators for 1994 show that Russia ranks high in absolute volume of R&D and the ratio of researchers to all workers. In total absolute R&D expenditures Russia places immediately after the G-7 countries. In the category of researchers per 10,000 individuals in the labor force, Russia ranked second after Japan. The editors put less emphasis on the size of the R&D sector and more emphasis on the effectiveness of the R&D sector than the chapter authors. In Chapter 2 Gokhberg reports that facilities and materials are inadequate for effective research. Even though some researchers may exist on paper and not in reality (like the serfs in Gogol's *Dead Souls*), the high ratio of personnel to expenditures suggests that Russian R&D may have too many researchers chasing too little money.

Less spending on salaries and more on materials and equipment would improve efficiency. Further, several chapters find that the links between R&D and production are weak. This is a significant difficulty for the payoff to R&D comes primarily in selling technologically advanced products that meet world standards. Achieving that goal requires manufacturing and marketing expertise along with effective R&D. Russian enterprises lack the skills necessary to realize the payoff from R&D.

8.2 The Organization and Structure of Applied R&D

8.2.1 The need for enterprise R&D

Earlier work at IIASA concluded that most applied R&D should be performed by enterprises rather than carried out by separate R&D institutes, as is still the Russian practice. Manufacturing enterprises should finance applied R&D, determine its direction, and perform R&D within their own organizations. An alternative emerging in Russia is for enterprises to hire independent R&D institutes to carry out R&D; in this option enterprises would still finance R&D and determine its general direction, but they would rely on an R&D institute to actually carry out the R&D activity.

Experience in industrialized countries shows that contractual R&D is not carried out as efficiently as R&D in facilities directly owned by manufacturing enterprises (Mowery, 1993). There are several reasons for this. First, applied R&D benefits from interactions with other activities of the firm, particularly manufacturing and marketing. These interactions between researchers and others occur more easily when all are employed by the same firm. Informal contacts are much more difficult across organizational boundaries than within them. This is sometimes a problem even for departments in the same firm, and the barriers increase when the organizations are separate.

Second, it is difficult to draw up effective contracts for applied R&D. A good contract specifies the tasks to be accomplished. In this case, however, clarity may be difficult because R&D tasks by nature involve considerable uncertainty. One can enforce a contract that requires the delivery of five tons of coal by the first of next month; one cannot enforce a contract that requires an improvement in integrated circuits by the first of next month. Managers are better able to monitor and evaluate R&D within organizations than outside them. R&D requires feedback. Alimpiev and Sokolov in Chapter 3 recognize the importance of feedback; they point out that in the linear model of R&D during the Soviet era much failed without it.

Third, an enterprise cannot be an effective buyer of R&D if it relies primarily on contractual R&D. Purchasing R&D requires knowledge about current technology, about R&D results that fit well into the productive process, and about costs. Such expertise usually comes from engaging in R&D within the organization and developing a core of researchers loyal to an enterprise.

These three factors have been used to explain why enterprises in industrialized countries rely primarily on in-house R&D. The American computer firm IBM, the German electric and electronics firm Siemens, the British chemical firm ICI, and the Japanese automotive giant Toyota make relatively limited use of contractual R&D.

Nevertheless, independent R&D organizations have a modest role in industrialized economies. They are useful at carrying out applied R&D when interactions with other activities of the enterprise is unnecessary and when the task can be clearly specified. Independent research units are also an efficient organizational form when there are significant economies of scale in carrying out R&D. For this last case, the most efficient organization is the research center serving many firms.

Major users of independent research organizations are enterprises that are also conducting significant in-house research activities. Gokhberg in Chapter 4 finds this is also true in Russia; enterprises in industries with considerable in-house R&D are likely to be the ones with considerable contractual R&D. These facts support the proposition that carrying out in-house research enables a buyer to use contractual

R&D effectively. Thus contractual R&D does not substitute for in-house R&D but rather complements it.

The implications of these organizational considerations are that Russia must promote R&D performed by manufacturing enterprises. In Russia enterprises are considered requesters for applied R&D from institutes rather than performers of it. The current low demand for R&D by enterprises is explained primarily by macroeconomic conditions that are external to the R&D sector. There is no doubt that general economic conditions have precluded enterprises from playing a major role in financing R&D. However, organizational factors within the sector have also discouraged R&D activity. Alimpiev and Sokolov point out in Chapter 3 that the Soviet experience with research production associations largely failed to overcome the problems presented by the independent research institutes. The associations lacked the power to direct research or control finances. The newly established financial-industrial groups described by the authors may also suffer from the loose coupling of R&D institutes to production enterprises. It should be recalled that members of Japanese *keiretsu* such as Mitsubishi Electric look not to the group but to their in-house research organizations for new products and processes.

We suggest consideration be given to promoting enterprise takeovers of research institutes to create enterprise-owned research activity. This type of policy is described by Fonotov and Pipiia in Chapter 7; the authors propose that R&D institutes serving primarily one enterprise should be taken over by them. They also suggest consortium organizations for R&D institutes serving several enterprises. Research centers remaining independent would correspond roughly to organizations with economies of scale that are sometimes independent in industrialized countries. We endorse such plans, particularly if emphasis is given to the creation of in-house R&D – the organizational form that has great promise of improving the efficiency of Russian R&D activity.

8.2.2 Intellectual property rights and competition

R&D activity in a market economy requires that inventors or those who finance them realize a profit from new products or processes that succeed in the market. If competitors can quickly imitate new products or processes they will eat away the profits. On the one hand, those who have invested time or money into an invention must have exclusive use of the innovation as a reward for their efforts. On the other hand, there must be widespread diffusion of an invention if society is to reap the maximum benefits. Patents that allow innovators to monopolize inventions for a limited number of years fulfill the requirement for exclusivity and still encourage inventions and diffusion of their benefits.

Russia has instituted patent laws but, as Alimpiev and Sokolov state, it does not yet have an effective patent system. The government has been unable to implement patent laws, so there are few sanctions for patent infringement. We join the two chapter authors in urging for the early establishment of an effective patent system as it is essential for an effective applied R&D. Alimpiev and Sokolov also point out that there are analogous issues with respect to trademarks and copyrights.

The Russian patent law specifies that the individual inventor must receive reasonable compensation from his or her employer. This provision is not in patent laws in other countries; arrangements between employer and researchers are left unregulated. The provision reflects the time when state-financed research institutes dominated R&D activities, and there was little concern about the incentives to finance research and more concern about creating incentives for individual researchers. In a market economy, however, if the necessary intellectual base is available a major problem is ensuring incentives to finance R&D. State regulations in relations between an inventor and his or her employer create uncertainty about what is "reasonable compensation." Furthermore, financing inventions is a process that requires very high returns from a successful invention to offset the costs of inevitable failures. At present the Russian patent provision, along with many measures in the patent law, is not in effect. In the future, however, the provision may discourage enterprises, including foreign ones, from financing R&D.

Patent laws are important, yet most innovations are not patented. Many do not meet the standards of novelty and most discoveries of science are unpatentable. Trade secrecy is used as an alternative way to allow innovators to realize profits although most trade secrets eventually become known. The most significant way returns from innovation are realized is by the head start that the innovator obtains by placing a new product on the market first or by using a new process before others (Levin *et al.*, 1987). This advantage has been shown to be even more significant than patents in yielding temporary profits in many industries such as electronics and transportation equipment. A head start, in turn, requires knowledge of the market, expertise in advertisement, and efficient pricing and distribution mechanisms.

Innovation activity, however, is not solely or perhaps even primarily a question of positive incentives. Much innovation activity in the current global economy is determined by the character and pace of competition. Enterprises in industrialized economies innovate largely because the failure to do so will mean a loss of sales to the innovative rivals. Ultimately the failure to innovate in most industries means the firm will not survive. In this environment, enterprises regularly set aside a percentage of their revenue for R&D activity. Innovation, as the great Austrian economist Schumpeter stated, has become routinized. For example, the firm that introduces a 16K RAM integrated circuit immediately sets to work to develop a 64K RAM circuit, the next step in what has been called a technical trajectory, or the path in the evolution of technology. The firm launches the next step, costly as it is, because it knows that its competitors will be at work on the next stage, and it cannot risk falling behind.

Most Russian enterprises are not accustomed to thinking of product and process improvement as an ongoing activity. Innovation in the Soviet system was a distinct event of applying R&D results – not an everyday activity. The threat of competition was not as important as it was, and is, for firms in industrialized economies.

The chapter authors, particularly Glaziev, Karimov, and Kuznetsova in Chapter 5, report on the low level of innovation in the Soviet system. They stress that innovation has declined in the past five years primarily because of the adverse macroeconomic situation. We would add that Russian enterprises have yet to consider innovation a requirement for survival, even though they face intense competition from foreign enterprises. They still think innovation is an infrequent event, as it was in the Soviet system. They are unlikely to be successful in competing with firms that regard continual innovation as a necessity even if it requires sacrificing other activities.

8.2.3 International transactions

Mindeli in Chapter 6 provides a very complete account of Russia's entry into the international S&T system, which has taken many forms, and which has resulted in many promising initiatives. Still the overall impression is that the integration of Russian R&D is modest, given its size and industrialized character.

A comparison of the postwar economies of Japan and Russia identifies some of the problems. Japan, somewhat like the Soviet Union, was isolated from world technology developments by the depression of the 1930s and World War II. By 1945, its technology level was significantly below Europe's and particularly the US's. An opportunity existed for increasing economic growth by importing technology and realizing the gains of a catch-up. The Japanese were not content with buying know-how; they used domestic R&D to adapt and improve their technology imports.

No similar development has occurred yet in Russia. There has been no catch-up or Japan-style double-digit economic growth. There has been limited import of technology; rather, the emphasis has been on exporting technological services to raise money for the research institutes. Yet many studies have shown that a major factor in Japanese economic growth was the combination of imported technology and domestic adaptation and improvement. The importance of importing technology has not been recognized in Russia.

A closely related point is that trade in know-how tends to be greatest between nations that are strong in the same industries. Thus Japan and the USA both have large electronics industries and both carry out substantial R&D in this field.

Yet, along with being major competitors, they are also major trading partners in know-how. The reason is that as already mentioned; enterprises that conduct in-house R&D are also effective buyers of R&D results from external sources. Thus Du Pont is a big purchaser of patent rights despite its large in-house R&D; some of its best-known inventions such as rayon were acquired abroad. Just as domestic contract R&D is bought by those with in-house R&D, so is international know-how bought by enterprises that are themselves active in research. And what is true for enterprises is mostly true for nations.

This is not widely recognized in Russia. As Mindeli reports, there is still a tendency to think of international activity of all sorts as a way to acquire what is not produced or developed at home. There is little need, it is thought, for participation in international activity in areas in which Russia is strong. Such a view runs counter to the view that trade is valuable when it involves the same group of products because trade gives consumers choices and promotes competition. As with products, so it is with technology. Only a fraction of inventions occur in any one nation, even when it is strong in a field.

One final comment. Mindeli's chapter is largely devoted to government policy. Yet in all the market economies technological activity in applied R&D across international borders represents largely unilateral moves of transnational corporations to export and to locate production and research in various countries. The other major forms of international transactions is joint activity between companies of different national origin. The pattern of international activity that emerges represents enterprises' responses to market factors. Governments have a minor role. There are exceptions that attract media attention such as US trade sanctions against some countries. And many governments do provide tax and other concessions to attract foreign direct investment. Still most economists view the process as an enterprise activity with governments in a supporting role. Chapter 6 stresses the need to place governments in a leading role and enterprises in a supporting one. This is probably the case for Russia today, given the weakness of Russian enterprises. In the future, however, enterprises must be recognized as a central institution in international aspects of applied R&D.

8.3 Public Policy

To the final question – what role should public policy play in applied R&D – it is relatively easy to give a general answer to: enterprises should finance, direct, and perform applied R&D. Applied R&D should be closely linked to innovation.

The problem is how to achieve this outcome. Russian enterprises are not typical market economy enterprises. The reason is not just the lack of macroeconomic stability. Russian enterprises have no effective systems for controlling managers or applying rules for corporate governance. Enterprises have little experience in marketing and related activities such as advertising, packaging, and product design. The tax burden is heavy, and the rules frequently change. Labor relations combine paternalism with worker resistance to lay-offs and efforts aimed at higher productivity. Suppliers, workers, and taxes may frequently be left unpaid, and the opportunities to obtain special deals for loans are also often utilized. Such advantages taken by an enterprise may drastically hurt the system. In this economic environment, the gains from innovation are insignificant compared with those from exploiting the market imperfections that abound in Russia. These conditions reduce demand for innovations.

This situation makes the creation of an effective S&T policy extremely difficult. Clearly S&T policy alone cannot remedy all these defects. S&T policy, however, can recognize that supporting applied R&D alone is unlikely to contribute to the development of high-technology exports or to economic growth. We have stressed, and the chapter authors have recognized, that applied R&D is only one element in an enterprise's innovation activities. Applied R&D alone is of little value; it must be combined with all the enterprise activities mentioned in Chapter 5 by Glaziev, Karimov, and Kuznetsova, such as investment in equipment, worker training, and marketing.

Given the central role of enterprises we support the use of sectoral R&D funds to assist innovation in enterprises as described by Fonotov and Pipiia in Chapter 7. This program, initiated in 1992, recognizes that enterprises are important and represents a shift away from almost exclusive support of industrial research institutes. Since the funds are collected by a levy on enterprises and since representatives of enterprises play a role in the selection process, the funds can be considered one part of the measures toward private financing. We know, however, that partial efforts in the Russian context, if sustained, can mean the death of promising initiatives.

The sectoral program is one element in an essentially new governmental policy for applied R&D. Fonotov and Pipiia describe the history of the first years of the transition as a period in which "a preservation role [for the R&D sector] dominated restructuring." Since 1995 the government has been considering steps for restructuring the R&D sector to free itself of the preservation role. This shift has allowed government policy to play a more decisive role in shaping S&T organization. The key words in the policy shift are selectivity, competition, and repayment. Selectivity means funding will no longer be determined by the financial requirements of existing institutes. Instead financing will be associated with projects selected for their technical merits and relevance to the problems of Russian society. Competition means that the allocation process will utilize competition among research teams and projects with the hope of improving efficiency. Repayment means that financial support will be regarded as loans to be recouped by the government when the R&D project makes a profit.

These are admirable principles, consistent with tested practice of governmental R&D financing in other countries. It is regrettable that the opposition from some R&D institutes will slow down the introduction of this approach.

8.4 Conclusions

It is easy to develop a long list of the problems in Russian applied R&D. This has been done in the chapters in this report. It was shown, particularly in Chapter 2, that many of the characteristics from Soviet era persist. Our title is "Russian Applied R&D: Its Problems and Its Promise." We think the title is apt because we found many problems.

It is easy to take a skeptical view of the word "promise" in our title. The chapters have shown that the problem of applied R&D cannot be separated from those of the enterprises and the problems of the enterprises from those of the economy. Applied R&D by itself will have its impact limited by the economic conditions. Even though in 1996 there are many hopeful signs that the economy is improving, the performance falls well short of that needed to create a market system that will sustain a technologically advanced R&D sector.

Yet R&D reorganization need not wait for a full recovery. R&D activities can become a factor promoting the restructuring of enterprises, and R&D institutes can be organized centers for change. To encourage that development requires moving from widespread support of the numerous R&D institutions inherited from the Soviet era to a system more consistent with a market economy. The shift is occurring, albeit slowly; in Chapter 7 Fonotov and Pipiia describe the many measures in public policy that focus on selectivity and economic payoff. Enterprises are slowly adjusting to a market economy, and are providing greater support for applied R&D. Russian enterprises are taking the first steps toward participation in international activity. Slow progress, but Rome was not built in a day, and neither will the applied R&D sector necessary for a prosperous market economy.

Annex: Methodological Notes and Statistical Tables

Natalia Gorodnikova

A1 R&D Indicators: 1989–1993

Basic classifications

The national industrial classification – namely, the so-called All-Russian Classification of Branches of the National Economy – was based on the material product concept. It was designed to meet requirements of the centralized planning system and was not similar to other international classifications. Therefore, only few indicators on R&D were derived from this classification, particularly labor statistics that were related to the Science and Scientific Services sector of this classification. Up to 1992 the Science and Scientific Services sector had included the following types of institutions:

1. Establishments performing R&D: academies (other than the educational institutions), research institutes, independent research laboratories, observatories; design organizations; experimental and research stations, experimental bases performing R&D; state archives performing research; environmental research institutions; and museums and libraries.
2. Independent design bureaus, excluding those for construction and forestry research.
3. Nonmanufacturing experimental enterprises.
4. Hydrometeorological service organizations.
5. Geological prospecting organizations.
6. Organizations researching marine life; experimental and technical laboratories; research and testing stations; central technical information bureaus; computer

centers of research organizations; and other organizations serving research institutions.

Higher education institutions, industrial enterprises, construction industries, and exploration organizations were not incorporated in the Science and Scientific Services sector regardless of whether or not they performed R&D. Due to the deficiencies data on the employment in the Science and Scientific Services sector were of minor use in R&D statistics and analysis. A new national industrial classification compatible with ISIC, Rev. 3, and Eurostat NACE, Rev. 1, is currently being introduced.

The sectoral classification accepted in Russian R&D statistics (i.e., not in the national industrial classification) also did not reflect the sectoring recommendations of the *Frascati Manual*, the major document of the OECD for measurement and survey of R&D activities (see OECD, 1994c). The peculiarities of this classification could be explained by the following institutional reasons:

- There was strong administrative subordination of R&D units to ministries and other governmental bodies under the centrally planned economy. Ministries were only interested in the data on affiliated R&D units, and the official statistics had to satisfy such requirements.
- The existence of the Academy of Sciences and branch academies as the bodies administering a network of R&D institutes was separated from industry and higher education.
- In the institutional structure of the R&D system in the former USSR, a large number of R&D institutions were separated from industry and higher education.

As a result, the national industrial classification was based on criteria such as administrative subordination, type of institution, and function of R&D units. For analytical purposes the R&D resources (personnel, expenditure, fixed assets) were traditionally grouped into four sectors. The academy sector included research institutes of the Russian Academy of Sciences and the branch academies (the Russian Academy of Agricultural Sciences and the Russian Academy of Medical Sciences). The higher education sector comprised R&D units of universities and equal higher education institutes. The industrial R&D sector covered the research, projecting, design, technological, experimental organizations that served industry but worked independently of industrial enterprises and such organizations that served the government. Other R&D units, not elsewhere classified, for example, hospitals and medical centers that performed R&D, were also included under this heading. The enterprise sector consisted of R&D units of industrial enterprises (research, design, technological, experimental units, etc.).

Major groups of R&D indicators

Until 1989, there were two primary indicators of R&D statistics in Russia: number of scientific workers and expenditure on S&T. The category of scientific workers included those employed at research institutes, but formally also included (on the basis of a scientific degree, place of employment, etc.) the teaching staff of higher education institutions notwithstanding their actual participation in R&D and advanced degree holders not necessarily engaged in R&D (administrative and management personnel in industry, agriculture, and other sectors; artists teaching in higher education institutions). However, postgraduate students as well as R&D personnel employed in many design organizations and industrial enterprises were not included.

Expenditure on S&T included the total value of work performed by independent R&D institutions, units of enterprises, research production and production associations, higher education institutions, and other legal entities, as well as the capital investment in construction of installations connected with the development of science.

Contracted project expenditures were reported by both performers and funders – that is, they were counted twice. The part counted twice reached, according to our estimates, almost one-third of the overall S&T expenditure registered. This indicator included not only expenditure but also profits obtained by reporting units and expenses for R&D, S&T services, and other activities. Due to the data collection procedures, data were not available for the Russian Federation and other ex-USSR republics; they were only recorded for the whole of USSR.

In 1989 Russian R&D data were collected separately for the first time. The main groups of R&D indicators collected and calculated in 1989–1993 were the following:

R&D Input	R&D Output
Personnel	Inventions, patents, licenses
Expenditure	Prototypes of new machines and equipment
Fixed assets	Uses of inventions and new prototypes of machines and equipment
	Production of new products

R&D Personnel

Data on personnel are for the end of the year. Employment in R&D institutions comprised personnel employed in the main activity of R&D institutes, e.g., those engaged in R&D or in direct service to R&D activity, including:

- Personnel engaged in activity in independent research institutes and design organizations.
- Personnel of R&D units in higher education institutes.
- Personnel of R&D units of enterprises and other organizations.

R&D specialists included personnel with higher or secondary special education (including postgraduate students) directly engaged in R&D. Administrators and staff of the planning, economic, financial, material-and-technical supply, and scientific information units were not included in this category.

Indicators of R&D personnel were based on the mixed occupation/qualification concept. Thus, R&D specialists who were graduates of higher education institutes with four to five years training were defined as researchers. Classification of researchers by field of S&T corresponded to the national Nomenclature of Occupations of Scientific Workers. It included 24 fields of S&T that incorporated more than 600 detailed specialities. On the whole, they could be grouped into major fields of S&T stipulated by the *Frascati Manual*.

R&D specialists with secondary special education with three to four years training were usually classified as technicians. The two-level postgraduate training system in Russia comprised candidates of science and doctors of science. The support staff comprised employees carrying out the auxiliary functions connected with performing R&D and with S&T services. Other staff included employees in accounting services, material supply units, and so on.

Data on teachers working as part-time researchers, i.e., those engaged in R&D along with their pedagogical activities, were gathered from higher education institutions. These researchers were not staff members of R&D units, but they were engaged in R&D in these units or in departments of higher education institutes and were working according to the approved research plans or on a contractual basis. This indicator had been included in the statistics since 1990.

Data on distribution of researchers by field of science and discipline were collected in 1990, 1991, and 1993. Information on distribution of R&D specialists by position, scientific degree, age, and gender was collected in 1993. All personnel data were usually expressed as head counts without estimation of their full-time equivalence.

R&D Expenditure

The primary source of financing was budget funds, centralized (non-budget) funds, and own funds of enterprises.

When estimating the indicators of R&D financing and actual expenditures, the category of financial appropriations were considered, i.e., the monetary funds intended for R&D. Data on budget appropriations on R&D for Russia have existed only since 1991.

The value of projects of R&D institutions included the value of all types of projects performed by R&D institutions during the year. Along with S&T projects, which comprised R&D and S&T services, the value of projects of the R&D institutions included all products, work, and services that were intended for other enterprises and institutions, as well as services provided to the population. The value of projects of R&D institutions was measured at contract prices (including calculated profit) and at actual costs. The value of R&D was defined as the value of S&T projects minus S&T services. R&D included basic research, applied research, and development.

Since 1989 the definitions of types of activity have been in line with the *Frascati Manual* recommendations. Basic research comprises the experimental and theoretical research aimed at obtaining new knowledge that is not oriented to any concrete objective connected with its practical use. The results of basic research are hypotheses, theories, methods, and recommendations for arrangement of applied research. Applied research is aimed at obtaining new knowledge with the view of its practical use for development of technological innovations. Development includes carrying out the following activities: design and technological projects, production of prototypes, and construction projects. Design and technological projects focus on the development of new types of materials, products, and processes; devices, documents, techniques, and the creation of their prototypes; and major modifications of available technology.

Construction projects include projects on development and location of branches of the national economy and branches of industry, feasibility studies of design and construction of enterprises (facilities), experimental designs; elaboration of new standardized documents and state standards for design, construction, and architecture; plans for regional designs; and projects aimed at improving processes, machinery, and equipment in production, mechanization, and automation of production processes.

Along with research and development, the activities of R&D institutions also include scientific and technological services, i.e., the activity in the field of S&T information, patents, licenses, S&T consulting, introduction, and other activities encouraging creation, dissemination and application of scientific knowledge.

As a summary we conclude that international comparisons of indicators of R&D expenditure are limited for the following reasons:

1. Breakdowns of R&D expenditure by source of funds, socioeconomic objective, field of science, and types of costs were not provided in the Russian national R&D survey.

2. The industrial classification used in the Russian R&D statistics was not compatible with the *Frascati Manual* recommendations.
3. According to the Russian system, current R&D expenditure included the depreciation of fixed assets, whereas according to the *Frascati Manual* it should have been excluded from R&D expenditure. At the same time, the Russian national R&D survey did not cover capital expenditure because this survey was organized in the framework of investment statistics.

R&D Fixed Assets

The R&D fixed assets comprised those directly intended for R&D performance. Statistics on R&D fixed assets were collected from three samples of R&D institutions:

1. R&D institutions of the academy, industrial, higher education, and enterprise sectors.
2. Organizations in the Science and Scientific Services sector.
3. R&D institutions of the academy, industrial, and higher education sectors (excluding enterprises). For this group the most complete information was collected in ad hoc surveys in 1989 and 1992.

The absence of detailed primary accounting and statistics resulted in two shortcomings in the indicators of distribution of R&D fixed assets by field of science. First, the distribution of equipment by field of science was performed not according to its real destination, but by name of R&D institutions. Second, only research institutes and design organizations were considered; higher education institutes were not taken into account due to the multi-profile character of R&D.

Inventions, Patents, Innovations

R&D output indicators are related to inventions, patents, and prototypes of equipment.

An invention is defined legally as R&D and production activity that results in a new and positive technical solution of a problem in the economy, society, or national defense. The result of innovation can be protected by law.

The registration of inventions, i.e., the registration in the State Register, involves the issuance of a protection document, which prior to 1991 was represented by an author certificate, stating the application of an invention, its priority, and authorship and the exclusive right of the state to use and take charge of the invention, as well as securing the rights and privileges of the author as specified by legislation.

In contrast, a patent certifies the exclusive right of the author (the patent owner) to the invention. The patentability is the juridical property of an object expressing that it can be protected by a document of an exclusive right (patent) on the territory of the concrete country at a given time. In the former USSR, the term “protection potentiality” had been used instead of the term “patentability” since author certificate was the main form of protective document rather than patent for a number of objects (e.g., for methods of diagnostics and treatment of diseases, for chemical substances, etc.) until 1991.

New prototypes of machines, equipment, apparatuses, instruments and devices that were developed in the country for the first time and that are essentially different from previously manufactured devices. This description provides information on the data included in innovation statistics, which in the former USSR were mainly limited to product innovations, notably to machinery products. Currently innovation statistics give information on indicators that are divided into the following groups:

1. Utilization of inventions: their use in a manufactured or consumed product or in the technological processes; transfer of inventions (by license) abroad in accordance with the established procedure; and use of inventions in prototypes to be transferred to exploitation.
2. Production of new machinery products by type, industry, and region (expressed in units and rubles).

New types of machinery products were regarded as introduced if the design and technological documentation have been developed; the technological equipment, tools, fixtures, press tools, and other machine-tool attachments necessary to manufacture those kinds of products were prepared for use; the regular production had been organized according to the technological process developed; and technical characteristics of products fully met the requirements specified.

According to the degree of novelty, both prototypes and products introduced were classified as new, modernized, or modified ones.

Reporting on innovations established under conditions of centralized planning is still mandatory for enterprises. Data series have been available since the early 1970s, and provide a large information basis for the analysis.

However, this system was designed many years ago and is not similar to international standards; it does not satisfy international requirements. First, the concept of an innovation process has not been introduced into the old Russian statistics. As a result, the data available do not allow us to analyze the structure of the innovation activities by type (R&D, patenting, etc.). Related input cannot be measured. The objectives of innovation, hampering factors, and the forms of technology transfer have not been investigated statistically.

A2 Implementation of International Standards in Russian R&D Statistics since 1994

Transformation of R&D statistics in Russia has resulted in new national surveys developed by the CSRS and aimed at applying international statistical standards to the national system. Nowadays the revised system of annual R&D surveys consists of the national R&D survey, the survey of government R&D funding, and the national innovation survey.

The annual national R&D survey was launched in 1995. It is designed in accordance with both the OECD standards and national characteristics. The statistical data cover R&D institutions (units) regardless of sector of the national economy. R&D data are gathered on both civilian and defense institutions.

Following the *Frascati Manual* recommendations (OECD, 1994c), an internationally accepted sectoral classification has been developed; it includes the government, business enterprise, higher education, and private nonprofit sectors. The government sector comprises institutions subordinated to ministries and departments responsible for state administration of public needs in general, nonprofit institutions completely or mainly financed and controlled by the government. The business enterprise sector comprises all organizations and enterprises whose main activity is the production of goods and services for sale, including those owned by the state; private nonprofit institutions serving the above-mentioned organizations are also included. The private nonprofit sector consists of nonprofit private institutions (professional societies, voluntary associations, etc.) and private individual organizations. The higher education sector is made up of universities and other educational institutions irrespective of sources of financing and legal status, as well as research institutes, experimental stations, and clinics controlled by or associated with them.

Data are collected for the natural sciences and engineering as well as social sciences and humanities.

R&D Expenditure

Gross expenditure on R&D (GERD) is the expenditure on R&D performed within R&D institutions, including both current and capital expenses. Value-added tax is not included in R&D expenditure. GERD data are available for different subclassifications. GERD includes intramural and extramural expenditures. Intramural expenditures are all expenditures (current and capital) for R&D performed within a statistical unit or sector of the economy, regardless of the source.

GERD sources include an R&D institution's own funds, budget funds (federal budget, local budgets), general university funds (higher education sector), non-budget funds (non-budget funds are established under industrial groups and associations from the levies paid by enterprises of 1.5 percent of sales for financing important sectoral and intersectoral R&D), higher education sector, private nonprofit sector, and foreign funds.

The classification of socioeconomic objectives is applied to total intramural expenditure. This classification of socioeconomic objectives is based on the NABS (Nomenclature for the Analysis and Comparison of Scientific Programs and Budgets) of Eurostat and also reflects national traditions.

If it is impossible to assign a concrete objective to the research project the general Advancement of Research objective is used. This category comprises usually basic research projects intended for the general development of natural sciences and humanities. Research in economics, policy, and management of science is also included in this group.

R&D Personnel

R&D personnel include all persons employed directly in R&D, as well as those providing direct services such as R&D managers, administrators, and clerical staff. Researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods, and systems, and in the management of the projects. Researchers usually have university or equivalent degrees. Technicians and equivalent staff are persons whose main tasks require technical knowledge and experience in one or more fields of engineering, physical and life sciences, or social sciences and humanities. They participate in R&D by performing scientific and technical tasks normally under the supervision of researchers. Other support staff includes skilled and unskilled artisans, secretaries, and clerks.

The classification of R&D personnel by formal qualification is based on categories related to the Russian educational system. Personnel size is counted annually. Data for age and sex, inflows and outflows of R&D personnel are collected biannually. On the base of the national R&D survey full-time equivalents are to be calculated.

Statistics of R&D Funding from Government Budget

Along with the new national R&D survey, special importance is given to statistics of government budget funding of R&D, which is still a major source of the national R&D base. Several principal requirements for estimating government R&D funding are taken into consideration:

1. To meet the current practice of R&D budget planning and analysis. The procedure of R&D budget analysis includes accounting of actual expenditures of the previous year, development of a plan, and estimation of outlays required for the year. In the framework of the federal budget R&D-related capital investments are separated from plans for current outlays.
2. To provide information for detailed comprehensive analysis of budget R&D funding. This supposes available data on budget R&D expenditure by type of expenditure, type of activity, discipline, and socioeconomic objective.
3. To agree with the general revision of concepts, definitions, and classifications of R&D statistics in Russia in accordance with the international standards, and with the national R&D survey.
4. To reflect national characteristics of R&D management, accounting, and statistics in Russia. It is important to combine the Eurostat NABS and *Frascati* recommendations with specific elements of national classifications, e.g., socioeconomic objectives and types of expenditures. These classifications allow comparisons to be made with international data.

The overall survey consists of four particular surveys: R&D funding in ministries and governmental agencies from the federal budget; R&D funding of state science and technology programs from the federal budget; funding of R&D in the federal goal programs from the federal budget; and funding of state research centers from the federal budget.

Innovation Statistics

The CSRS has also established new types of innovation statistics. The medium-term objective is to develop and implement an innovation survey in industry compatible with the Community Innovation Survey (CIS) and based on the OECD standards (OECD, 1992). (The new innovation survey is being developed in the framework of the Project on R&D and Innovation Statistics in the Russian Federation by Eurostat and CSRS under the TACIS Program.) This survey has two stages (Gokhberg and Kuznetsova, 1996). The first stage is the so-called *introductory survey*. It was implemented in 1995 for enterprises that respond to industrial censuses.

In line with the Oslo manual the basic objectives of the introductory survey are to focus on technological innovations; to consider an enterprise as a statistical unit; and to distinguish between product and process innovations.

Taking into account the current economic situation in Russia the set of types of innovation activities has been broadened for the survey in order to include all types of innovation activity. Thus, the enterprises contributing to innovation include those engaged in R&D, as well as those introducing new or improved products, new or improved technological processes, and that have purchased disembodied technological developments. These disembodied innovations include:

- Acquisition of rights for patents – patents on inventions, industrial prototypes, certificates on utility models the rights for which are ceded by the patent holder to an enterprise according to a contract on patent cession, registered at the Committee of the Russian Federation for Patents and Trademarks (Rospatent).
- Acquisition of patent licenses – licenses for the same items as above.
- Acquisition of unpatented licenses – contracts signed with organizations, enterprises, individuals on acquisition of works, services, or other information not protected with patents connected with enterprise-based development and introduction of new or improved products and new or improved technological processes. Generally, two types of unpatented licenses are distinguished – contracts for external R&D and contracts with enterprises or organizations for acquisition of know-how connected with introduction of new or improved products or new or improved technological process.

The survey covered 17,000 medium-size and large industrial enterprises of all types and forms of property. Small enterprises employing fewer than 200 persons constituted only 6.5 percent of the surveyed population due to official restrictions on surveying small enterprises.

Annex 1 Exhibits: Institutions

Exhibit A1.1. R&D institutions by type (and percentage distribution in 1994).

	1990	1991	1992	1993	1994	
Research institutes	1,762	1,831	2,077	2,150	2,166	(54.6)
Design organizations	937	930	865	709	545	(13.7)
Construction design and exploration organizations	593	559	495	395	297	(7.5)
Experimental enterprises	28	15	29	17	19	(0.5)
Higher education institutions	453	450	446	456	424	(10.7)
Industrial enterprises	449	400	340	299	276	(7.0)
Others	424	379	303	243	241	(6.0)
Total	4,646	4,564	4,555	4,269	3,968	(100.0)

Exhibit A1.2. R&D institutions (and percentage distribution) by sector in 1994.

	R&D institutions	
Government sector	1,150	(29.0)
Business enterprise sector	2,300	(58.0)
Higher education sector	511	(12.9)
Private non-profit sector	7	(0.1)
Total	3,968	(100.0)

Exhibit A1.3. R&D institutions by type of ownership in 1993 and 1994 (and percentage distribution in 1994).

	1993	1994	
Russian property	4,267	3,968	
Public property	3,597	2,999	(75.6)
Federal	3,385	2,801	
Regional	212	198	
Municipal property	21	10	
Property of voluntary associations	8	13	
Private property	116	150	(3.8)
Joint property (w/o foreign participation)	525	796	(20.1)
Foreign and joint property (Russian and foreign participation)	2	–	
Total	4,269	3,968	(100.0)

Exhibit A1.4. Academy R&D institutions (and percentage distribution in 1994).

	1990	1991	1992	1993	1994
Russian Academy of Sciences	297	321	369	396	409 (53.5)
Russian Academy of Agricultural Sciences	188	213	296	291	295 (38.6)
Russian Academy of Medical Sciences	50	52	64	59	60 (7.9)
Total	535	586	729	746	764(100.0)

Exhibit A1.5. State research centers (SRCs) of the Russian Federation.

	1993	1994	1995[a]
State research centers	42	61	61
Budget funds for SRC programs (in million rubles)	57,920	202,302	339,000
Basic research	–	118,034	209,163
Applied R&D	–	84,268	129,837
R&D personnel	92,361	96,904	108,533

[a] Projected.
Source: CSRS, various years.

Exhibit A1.6. State research centers (SRCs) by field of science and technology.

Field of science and technology	Number of SRCs
Nuclear physics and atomic power engineering	10
Chemistry and new materials	10
Aviation	4
Ship-building, navigation, and hydrophysics	6
Medicine and biology	3
Biotechnology	4
Oceanology, meteorology, and engineering hydrotechnology	3
Informatics and instrument-making	5
Machine-building	4
Optical electronics, laser systems, robot technology, and special chemistry	5
Agro-industrial complex	2
Mining and metallurgy	3
Construction	1
Astronomy	1
Total	61

Source: Ministry of Science and Technological Policy of the Russian Federation.

Annex 2 Exhibits: Personnel

Exhibit A2.1. Russian R&D personnel.

	Researchers	Technicians	Support staff and others	Total
1989	1,118,800	270,500	826,300	2,215,600
1990	992,600	234,800	716,000	1,943,400
1991	878,500	200,600	598,700	1,677,800
1992	804,000	180,700	547,900	1,532,600
1993	644,900	133,900	536,200	1,315,000
1994	525,300	115,500	465,400	1,106,200

Source: CSRS, various years.

Exhibit A2.2. Percentage distribution of R&D personnel by occupation.

	Researchers	Doctors of science	Candidates of science	Technicians	Support staff and others	Total
1989	50.5	0.7	6.3	12.2	37.3	100
1990	51.1	0.8	6.5	12.1	36.8	100
1991	52.3	1.0	7.0	12.0	35.7	100
1992	52.5	1.1	7.3	11.8	35.7	100
1993	49.0	1.4	8.0	10.2	40.8	100
1994	47.5	1.6	8.8	10.4	42.1	100

Source: CSRS, various years.

Exhibit A2.3. R&D personnel by occupation, qualification, and sector of performance (and percentage distribution) in 1994.

	University degrees	Other postgraduate degrees	Others	Total R&D personnel
Government sector				
Researchers	143,685,000	–	–	143,685,000 (49.6)
Technicians	10,287,000	16,308,000	5,111,000	31,706,000 (11.0)
Supporting staff	16,154,000	14,826,000	39,371,000	70,351,000 (24.3)
Others	9,803,000	9,831,000	24,048,000	43,682,000 (15.1)
Total	179,929,000	40,965,000	68,530,000	289,424,000(100.0)
Business enterprise sector				
Researchers	343,346,000	–	–	343,346,000 (45.2)
Technicians	12,394,000	57,197,000	9,780,000	79,371,000 (10.4)
Supporting staff	45,128,000	50,738,000	116,630,000	212,496,000 (28.0)
Others	22,662,000	27,896,000	74,039,000	124,597,000 (16.4)
Total	423,530,000	135,831,000	200,449,000	759,810,000(100.0)
Higher education sector				
Researchers	38,190,000	–	–	38,190,000 (67.2)
Technicians	959,000	2,989,000	437,000	4,385,000 (7.7)
Supporting staff	2,828,000	2,019,000	3,600,000	8,447,000 (14.9)
Others	1,012,000	795,000	3,989,000	5,796,000 (10.2)
Total	42,989,000	5,803,000	8,026,000	56,818,000(100.0)
Private nonprofit sector				
Researchers	98,000	–	–	98,000 (49.5)
Technicians	8,000	4,000	–	12,000 (6.1)
Supporting staff	9,000	14,000	10,000	33,000 (16.6)
Others	8,000	13,000	34,000	55,000 (27.8)
Total	123,000	31,000	44,000	198,000(100.0)
Total	646,571,000	182,630,000	277,049,000	1,106,250,000

Source: CSRS, various years.

Exhibit A2.4. Percentage distribution of R&D personnel by qualification and sector in 1994.

	Government	Business enterprise	Higher education	Private nonprofit	Total
Candidate of science	62.2	55.7	75.7	62.1	58.4
Doctor of science	14.1	17.9	14.1	15.7	16.9
Other	23.7	26.4	10.2	22.2	25.1
Total	100.0	100.0	100.0	100.0	100.0

Source: CSRS, various years.

Exhibit A2.5. Percentage distribution of business enterprise R&D personnel by type of institution in 1994.

Sectoral R&D	Design & technology	Construction & exploration	Industrial	Experimental	Others	Total
62.1	21.7	4.2	7.9	0.4	3.7	100.0

Exhibit A2.6. Researchers and technicians by qualifications (and percentage distribution in 1994).

	1989	1990	1991	1992	1993	1994
Candidate of science	1,118,800	992,600	878,500	804,000	644,900	549,000(85.7)
Doctor of science	270,500	234,800	200,600	180,700	133,900	76,500(11.9)

Source: CSRS, various years.

Exhibit A2.7. Researchers with scientific degrees (and percentage distribution in 1994).

	1989	1990	1991	1992	1993	1994
Candidate of science	139,086	126,975	118,011	111,422	105,221	97,384(84.3)
Doctor of science	15,612	15,475	16,165	17,422	18,184	18,140(15.7)

Exhibit A2.8. Researchers by sector (and percentage distribution) in 1994.

	Government	Business enterprise	Higher education	Private nonprofit	Total
Researchers	143,685(27.3)	343,346(65.4)	38,190 (7.3)	98	525,319(100.0)
Doctor of science	12,586(69.4)	3,920(21.6)	1,624 (9.0)	10	18,140(100.0)
Candidate of science	47,350(48.7)	36,345(37.3)	13,588(14.0)	23	97,306(100.0)

Exhibit A2.9. Researchers by field of S&T (and percentage distribution) in 1994.

	Researchers	Doctor of science	Candidate of science
Natural sciences	116,391	8,743 (48.2)	40,694 (41.8)
Engineering	345,921	3,441 (19.0)	34,341 (35.3)
Medical sciences	18,866	2,638 (14.5)	7,287 (7.5)
Agricultural sciences	18,228	852 (4.7)	6,139 (6.3)
Social sciences	17,917	994 (5.5)	5,270 (5.4)
Humanities	7,996	1,472 (8.1)	3,575 (3.7)
Total	525,319	18,140(100.0)	97,306(100.0)

Exhibit A2.10. R&D personnel by occupation and by type of property of R&D institutions in 1994.

Type	R&D personnel	Researchers	Technicians	Support staff	Others
Public	883,356	427,856	86,479	227,436	141,585
Federal	860,515	418,135	83,798	220,869	137,713
Regional	22,841	9,721	2,681	6,567	3,872
Municipal	910	480	105	144	181
Voluntary associations	416	231	28	47	110
Private	24,541	10,737	3,777	6,549	3,478
Joint (w/o foreign participation)	197,027	86,015	25,085	57,151	28,776
Total	1,106,250	525,319	115,474	291,327	174,130

Source: CSRS, various years.

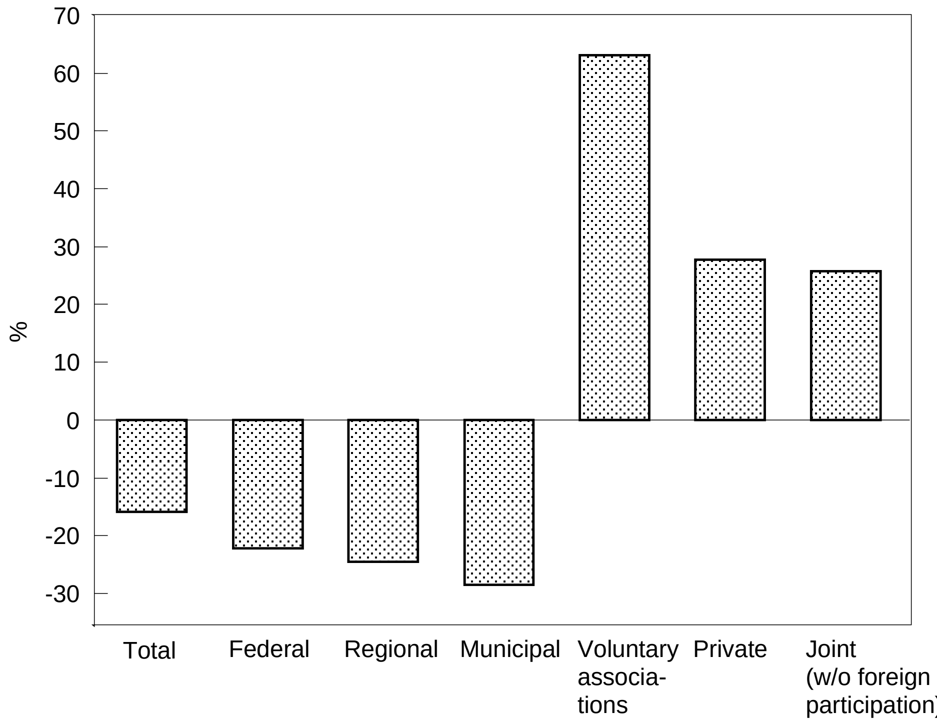

Exhibit A2.11. Annual growth rate of R&D personnel by property type of R&D institution in 1993–1994 period (1993 equals 100%).

Exhibit A2.12. Number of employees in the science and scientific services sector emigrating from Russia.

1980	1989	1990	1991	1992	1993	1994
140	950	2,100	1,800	2,100	2,300	2,100

Source: CSRS, 1996b, p. 31.

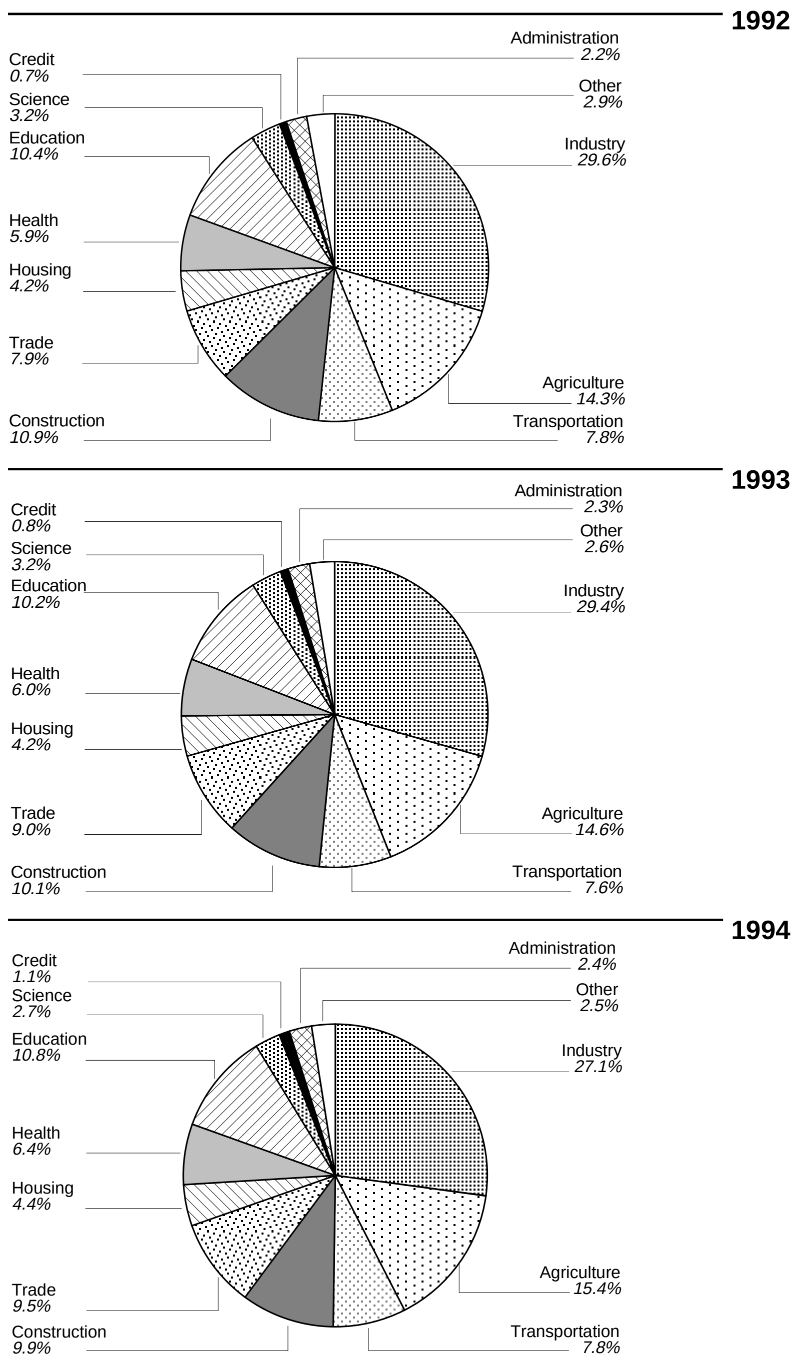

Exhibit A2.13. Percentage distribution of employment by sector. (Source: CSRS, various years.)

Annex 3 Exhibits: R&D Expenditures

Exhibit A3.1. Russian GERD (in million rubles).

	1989	1990	1991	1992	1993	1994
At current prices	10,903.7	13,077.8	19,991.3	140,590.7	1,317,199.5	5,146,102.0
At constant 1989 prices	10,903.7	10,898.2	7,243.2	3,203.7	3,031.9	2,517.2
As % GDP	1.90	2.03	1.43	0.74	0.77	0.82

Source: CSRS, various years.

Exhibit A3.2. Russian GERD by socioeconomic objective and sector in 1994 (in million rubles).

Socioeconomic objective	Government	Business enterprise	Higher education	Private nonprofit	Total
Economic development	417,060.1	1,940,404.3	167,109.4	140.0	2,524,713.8
Social development	177,195.4	68,286.9	39,653.8	268.1	285,404.2
General advancement	460,965.4	102,367.6	77,931.8	–	641,264.8
Exploration of the earth and atmosphere	93,338.9	55,995.7	8,224.2	–	157,558.8
Civilian space exploration	67,510.6	143,632.5	3,552.2	31.0	214,726.3
Defense	229,057.2	1,086,038.2	7,338.7	–	1,322,434.1
Total	1,445,127.6	3,396,725.2	303,810.1	439.1	5,146,102.0

Source: CSRS, 1996b.

Exhibit A3.3. Russian GERD by sector and source in 1994 (in million rubles).

	Government	Business enterprise	Higher education	Private nonprofit	Total
Own funds	68,152.5	463,504.0	11,356.9	–	543,013.4
Government budget	1,186,114.3	1,746,770.0	175,794.7	184.0	3,108,863.0
Priority objectives	277,327.7	474,457.8	59,727.6	31.0	811,544.1
General university funds	2,297.0	1,054.2	26,265.1	–	29,616.3
Nonbudget funds	40,565.4	266,191.9	18,389.3	–	325,146.6
Business enterprise	110,238.8	850,472.6	63,688.2	255.1	1,024,654.7
Higher education	771.6	1,621.6	6,017.3	–	8,410.5
Private nonprofit	1,213.3	4,172.1	197.7	–	5,583.1
Foreign funds	35,774.7	62,938.8	2,100.9	–	100,814.4
Total	1,445,127.6	3,396,725.2	303,810.1	439.1	5,146,102.0

Source: CSRS, various years.

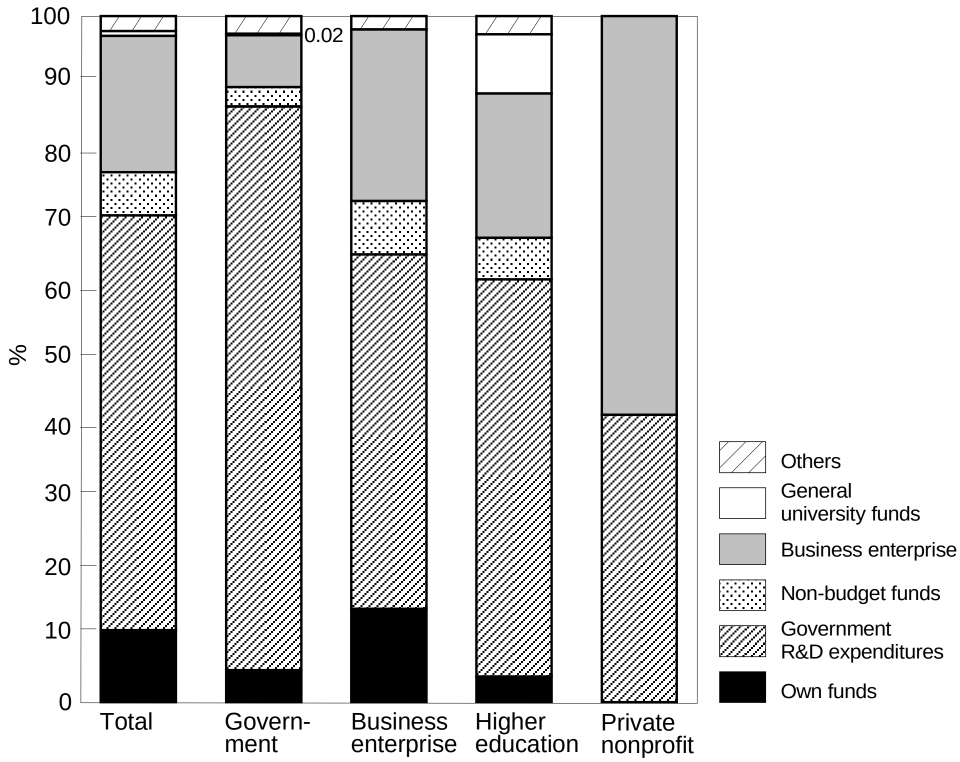

Exhibit A3.4. Percentage distribution of GERD by source of funds and sector of performance in 1994. (Source: CSRS, 1996b.)

Exhibit A3.5. Intramural current expenditures on (and percentage distribution of) R&D by type of activity and sector in 1994 (in million rubles).

	Basic research	Applied research	Development	Total
Government	560,065.4(40.8)	314,528.2(22.9)	497,350.9(36.3)	1,371,944.5(100.0)
Business enterprise	149,218.6 (4.5)	599,407.7(18.0)	2,575,009.5(77.5)	3,323,635.8(100.0)
Higher education	132,712.2(44.1)	107,588.9(35.8)	60,612.0(20.1)	300,913.1(100.0)
Private nonprofit	34.1 (8.1)	386.3(91.5)	1.8 (0.4)	422.2(100.0)
Total	842,030.3(16.9)	1,021,911.1(20.4)	3,132,974.2(62.7)	4,996,915.6(100.0)

Exhibit A3.6. Intramural current expenditures on R&D by the Academy institutes by type of activity (in million rubles).

	Basic research	Applied research	Development	Total
Academy of Sciences				
1990	884.5	384.2	169.4	1,438.2
1991	1,148.6	596.6	169.4	1,914.6
1992	9,001.3	4,221.1	979.3	14,201.7
1993	69,251.4	42,045.9	6,707.1	118,004.5
1994	409,547.3	87,931.9	47,401.9	544,881.1
Academy of Agricultural Sciences				
1990	43.6	155.1	41.9	240.6
1991	53.1	302.1	47.7	402.9
1992	856.8	2,210.9	548.6	3,616.3
1993	6,800.1	17,380.3	3,912.9	28,093.3
1994	34,894.8	63,986.1	24,482.5	123,363.4
Academy of Medical Sciences				
1990	47.2	63.0	0.9	111.2
1991	77.3	98.8	1.6	177.7
1992	529.7	1,098.5	10.7	1,638.9
1993	5,877.7	6,658.0	1,057.8	13,593.5
1994	39,144.5	15,585.2	3,276.0	58,005.7

Source: CSRS, various years.

Exhibit A3.7. Intramural current expenditures on (and percentage distribution of) R&D by type of activity and field of S&T in 1994.

	Basic research	Applied research	Development	Total
Natural sciences	486,747.1(55.4)	237,610.0(27.0)	155,101.7(17.6)	879,458.8(100.0)
Engineering	181,385.2 (5.0)	581,548.8(16.0)	2,862,844.5(79.0)	3,625,778.5(100.0)
Medical sciences	58,089.1(38.4)	69,181.5(45.8)	23,896.4(15.8)	151,167.0(100.0)
Agricultural sciences	39,873.9(22.2)	86,232.0(48.0)	53,551.9(29.8)	179,657.8(100.0)
Social sciences	38,185.2(35.0)	35,452.0(32.4)	35,670.3(32.6)	109,307.5(100.0)
Humanities	37,749.8(73.2)	11,886.8(23.1)	1,909.4 (3.7)	51,546.0(100.0)
Total	842,030.3(16.9)	1,021,911.1(20.4)	3,132,974.2(62.7)	4,996,915.6(100.0)

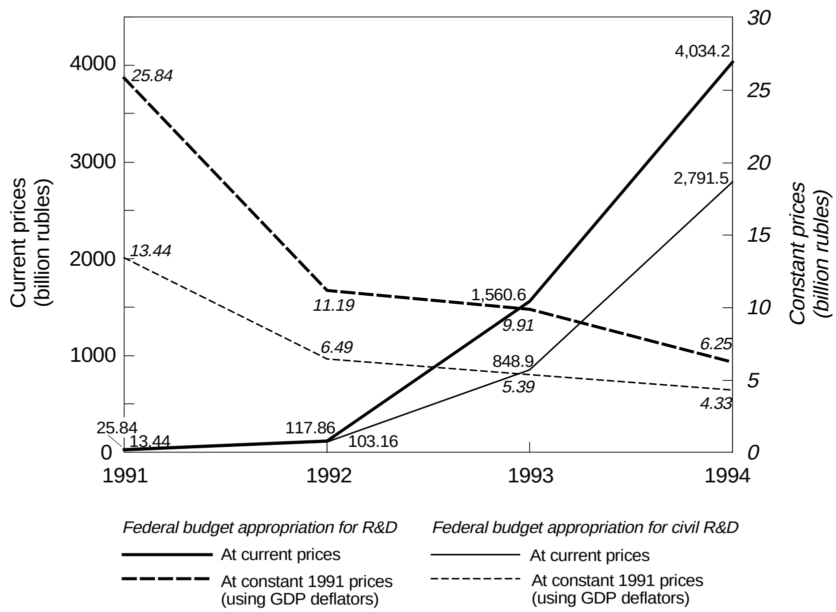

Exhibit A3.8. Federal budget appropriations for R&D.

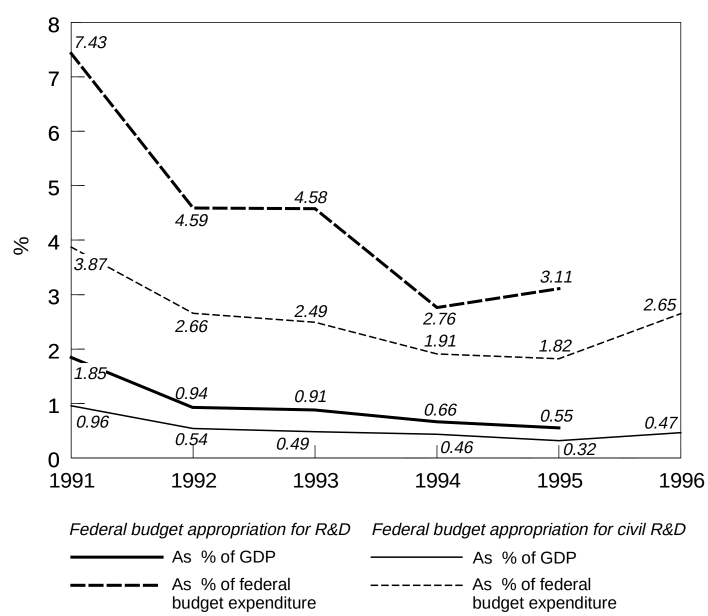

Exhibit A3.9. Federal budget appropriations for R&D as a percentage of GDP and a percentage of federal budget expenditures.

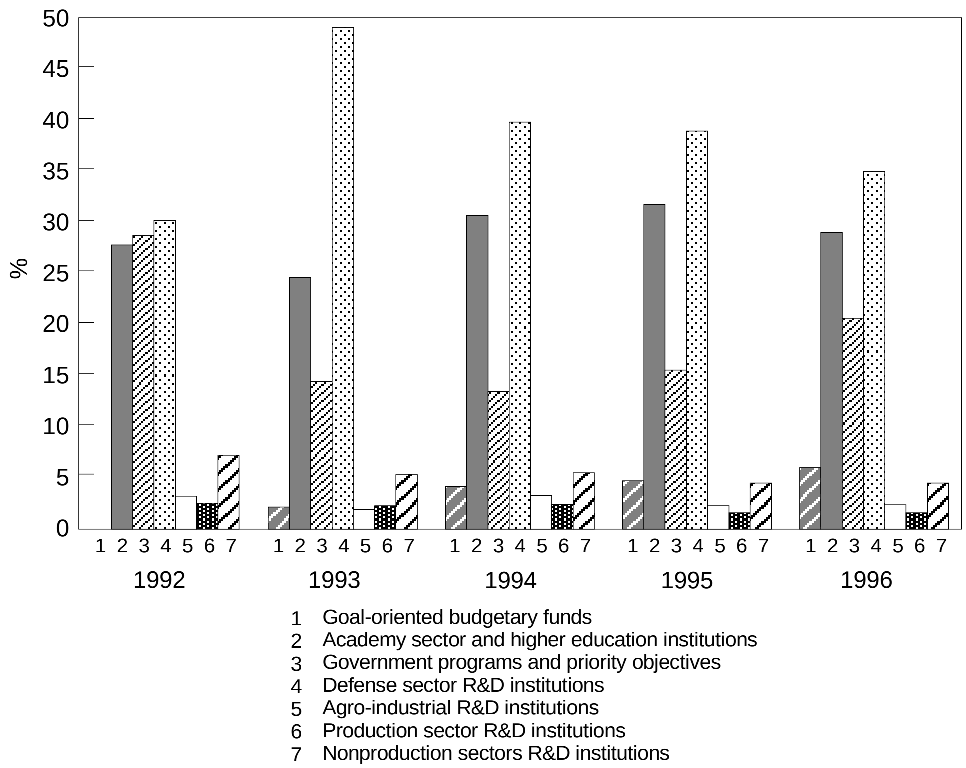

Exhibit A3.10. Percentage distribution of the federal budget appropriations for civilian R&D: 1992–1996.

Exhibit A3.11. Federal budget appropriations for civilian R&D (in billion rubles).

	1991	1992	1993	1994	1995[a]
Russian Fund for Fundamental Research	0.27	3.07	18.1	102.2	196.4
Fund for Promotion of Small Enterprises in Science and Technology	–	–	–	10.8	23.4
Russian Academy of Sciences	2.28	16.18	119.6	515.0	1,088.1
Siberian branch	0.28	3.30	27.0	110.4	300.7
Urals branch	0.08	0.99	8.0	37.3	61.9
Far Eastern branch	0.11	1.24	11.1	51.2	86.7
Russian Academy of Agricultural Sciences	0.30	2.45	18.4	94.6	173.6
Russian Academy of Medical Sciences[b]	–	1.76	12.6	41.0	99.9
Siberian Branch	0.03	0.28	2.1	7.3	17.8
Russian Academy of Education	0.02	0.40	2.6	9.8	17.1
Russian Academy of Arts	–	0.06	0.6	4.0	6.6
Russian Academy of Architecture and Civil Engineering	–	–	–	1.8	3.1
Government S&T programs	1.33	7.50	23.3	64.2	162.4
Major programs and projects of the national economy	0.46	8.58	17.9	28.4	44.9
International programs and projects	0.21	1.09	6.6	20.5	40.1
SRCs	–	–	57.9	202.3	321.1
Development of universities in Russia	0.21	1.50	7.4	n.a.	n.a.
S&T innovative infrastructure development (technoparks, technopolises, business incubators)	–	–	1.7	1.6	4.5
Funds for regional centers and programs	–	–	4.2	6.7	13.9
R&D performed in defense industry	n.a.	31.30	418.3	1,121.8	2,056.8
Civilian Aviation Development Program	–	10.64	73.8	249.9	504.9
Federal Space Program	0.04	8.72	148.8	425.2	899.6
Program of Development of the “Kurtchatov Institute” SRC	–	–	6.5	23.6	48.3
Reserve of the Ministry of Science and Technological Policy	0.18	1.20	8.4	17.5	51.9
Total[c]	13.44	103.16	848.9	2,791.5	5,228.6

[a] Estimation.
[b] Financed by the USSR Ministry of Health.
[c] Includes elements not listed.

Exhibit A3.12. Budget funding of R&D in the federal economic programs (in million rubles).

	1991	1992	1993
Power engineering strategy	–	–	248.8
Soil fertility improvement (“Fertility”)	–	–	–
Development of machine building for agro-industrial complex (including the “Farmer” program)	–	–	–
Development of medical industry and provisions for medicines and medical equipment	–	–	6,395.4
Development and production of new medical equipment	–	–	4,804.8
Federal space program	40.0	8,720.0	105,140.0[a]
Housing	–	–	350.0
International thermonuclear reactor	–	–	9,969.1
Development of nutrition industry	–	–	2,200.0
Development, production, and supply of technical rehabilitation for the disabled	–	–	960.8
Improvement of funeral services	–	–	–
Development of electronics	–	–	–
Civil aviation development	–	10,641.0	97,998.4
Technology for North Russia	–	–	–
Environmental protection	–	–	5,839.5

[a] Includes appropriations for the Russian Space Agency (except the Program of Basic Space Research).

Exhibit A3.13. Federal budget R&D appropriations for S&T programs (in million rubles).

	1991	1992	1993	1994
Agricultural technologies	158.0	449.6	1,240.1	2,828.5
Technologies for processing industries of agro-industrial complex	–	363.6	945.3	2,130.4
Information technologies	60.0	210.4	560.3	1,261.0
Telecommunications and integrated communications systems	30.0	104.9	430.5	962.7
Distribution of information	60.0	210.5	484.8	1,034.3
Microelectronics, computers, and automation means	–	60.3	–	–
Micro- and nanoelectronics technologies	–	120.5	442.8	898.5
Human genome	32.0	130.5	360.8	812.6
Priority genetics objectives	–	119.8	360.8	830.7
Bioengineering methods	40.0	207.8	640.4	1,491.1
Research in physico-chemical biology and biotechnology	–	56.2	168.4	400.9
New materials	58.0	535.4	1,461.8	3,377.5
Clean power engineering	66.6	400.6	1,078.1	2,459.4
Resources-saving and clean technologies in mining and metallurgy	–	125.2	357.6	929.9
Technologies for fuel and energy exploration	–	70.4	424.2	950.6
Zeolites of Russia	–	29.8	–	–
Social revival and progress	–	79.2	253.9	573.3
Educational information	–	50.1	–	–
Higher education	–	20.3	–	–
Educational progress	–	98.2	306.0	689.9
Ecologically safe and resources-saving chemical technologies	43.4	347.4	855.4	1,926.0
Chemical research and technology objectives	–	70.4	–	–
Research-intensive chemical technologies	–	70.4	–	–
Secondary processing of polymers	–	20.3	–	–
Methods for obtaining chemicals and materials	–	140.8	372.2	831.8
High-energy physics	100.0	422.6	1,269.8	3,455.0
Basic space research	40.0	200.4	2,163.9	–
Basic nuclear physics	–	158.6	501.9	1,525.9
Synchrotron radiation, radiation applications	–	125.2	356.4	1,516.4
High-temperature superconductivity	130.0	455.4	1,084.3	2,146.0
Controlled thermonuclear synthesis and plasma processes	30.0	120.0	285.7	1,226.6
Medicine and health services	71.0	306.4	829.2	1,582.1
Health	–	66.5	469.0	1,054.7

Exhibit A3.13. Continued.

	1991	1992	1993	1994
New medicines from chemical and biological syntheses	–	7.1	460.3	1,307.5
Environment and climate changes	50.0	220.7	631.9	1,420.3
Plans in case of natural and technological catastrophes	40.0	180.0	473.6	1,032.0
Exploration of oceans and seas	–	381.2	1,072.2	2,414.3
Construction	50.0	295.0	968.8	2,048.8
Utilization and reproduction of wood	–	143.1	508.2	1,154.8
Future technologies, and machinery	75.0	421.1	1,035.7	2,329.1
Research-intensive technologies	–	39.9	838.9	1,813.7
High-speed ecologically clean transport	50.0	200.4	529.5	1,135.4
High-efficient technologies in the social sphere	–	55.2	326.2	730.5
Federal fund for S&T information	–	–	233.1	526.4
Physics of solid nanostructures	–	–	303.2	926.8
Astronomy	–	–	75.0	1,164.9
Basic metrology	–	–	180.0	1,106.9
Optics, laser physics	–	–	72.6	1,080.4

Source: CSRS, various years.

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