

CHAPTER 1. INTRODUCTION

More than any other country, the Soviet Union was committed to science. The number of scientists per capita and the prestige they enjoyed exceeded that of any other country. Marxist-Leninist ideology viewed science and scientific methods as key to the development and management of the economy. In support of scientific advance, a huge infrastructure of educational, research and development, and production institutions was established.

Achievements in “big science” and advanced technologies in particular were used to validate the Soviet centralized directive form of management of science and the economy in the eyes of the domestic population and the international community. Soviet scientists and policy-makers frequently boasted of the advantages of such a system in marshaling huge resources and focusing them on priority programs such as space exploration, nuclear power, military systems, oil and gas development, computing and others.

Advanced technologies are characterized by their complexity in design and/or manufacture, and a rapid evolution which often establishes the state-of-the-art in the field. Their development depends on a vast infrastructure of supporting industries. Thanks to national security concerns and controls in both the Soviet Union and the Western members of the Coordinating Committee for Multilateral Export Controls (CoCom),¹ complete infrastructures for advanced technologies with military applications in the Soviet Union had to be developed independently of the corresponding Western industries, even when those technologies—so-called dual use technologies like computers—had significant and widespread civilian applications.

¹ CoCom includes Japan and all the member nations of the North Atlantic Treaty Organization (NATO) except Iceland.

In spite of some successes, Soviet achievements in advanced technologies and science more generally have lagged behind those of the West when measured by the level and quantity of results, number of Nobel Prizes earned, etc. From the 1960s through the mid 1980s, the Soviet economy as a whole “stagnated,” experiencing declining growth rates and growing inefficiencies, and an increasing technological lag behind the Western capitalist countries. Against this backdrop, Mikhail Gorbachev launched a program of economic restructuring (*perestroika*) in 1985 in an effort to revitalize the USSR economy. Above all, the economy was to be reformed through the acceleration of scientific and technical progress in a new stage of the scientific-technical revolution (NTR). This stage was to be characterized by accelerated development and assimilation of new technologies, including advances in microelectronics and computing, computer-aided manufacturing, materials, etc. in an effort to increase the output and efficiency of the economy without dramatically increasing inputs.

In the eight years since the start of *perestroika*, the Soviet Union and its successor states have experienced profound economic, political, and social change far exceeding the intentions of Gorbachev and other leaders. Indicators such as the rapidly falling gross domestic product, crime rates, and runaway inflation paint a picture of catastrophe. However, such indicators do not help us understand the underlying phenomena and processes which have led to these results. They do little to help us understand the degree to which, within the chaos, the foundation is being laid (or not being laid) for the future rejuvenation of the economies of the former Soviet republics and, in particular, their scientific and technical base. To understand these transformations one must look not only at macro-level indicators, but also at the processes at work at the micro-level—in individual technologies, research teams and institutes, and within various branches of the economy.

In this study we seek to contribute to an understanding of the development and transformation of Soviet advanced technologies and their organizational and environmental context, both prior to *perestroika* and during the reform period from 1985 through December, 1992, approximately one year after the dissolution of the Soviet Union. Our vehicle will be a detailed examination of research and development (R&D) facilities and projects within the Soviet high-performance computing (HPC) sector. We wish to document the development of HPC systems within these organizations, identify the factors which have shaped their development, and analyze the impact of the social, political, economic and technical changes since 1985 on these technologies and the organizations within which they have been carried out. Through such an analysis, we hope to cast light on the prospects for HPC in particular, and advanced technologies more generally in the Soviet Union's successor states.

Since the dissolution of the Soviet Union in December, 1991, terminology has become particularly problematic. The Soviet Union has been replaced as a political entity by fifteen independent countries, some of which have formed a loose confederation called the Commonwealth of Independent States. All of them have sought to distance themselves from the Communist legacy and have removed the words "Soviet" and frequently "socialist" from official names. At the same time, it is impossible for any of these states or the organizations and people within them to wipe the slate of history clean. They are bound to and influenced by their history in the Soviet Union. They share many problems, features, and trends precisely because they once were part of the Soviet Union. For this reason, we will use the terms "Soviet" and "Soviets" to refer to institutions and individuals which had their origins in the Soviet Union and which still exhibit the influence of the Soviet economic, political, technological, and social systems, even when we refer to events after the Soviet Union's breakup. We will refer to the Soviet Union's suc-

cessor states as “Soviet states,” and the republics of the Soviet Union as “Soviet republics.” Only when the distinction is important will we use “Russian,” “Ukrainian,” etc. We are also likely to use the latter when referring to institutions which originated (rather than metamorphised) after December, 1991 and are closely associated with one particular state.

High-performance computing provides an excellent vehicle for studying advanced technology in the Soviet Union and its successor states because of the nature of the technology itself, the nature of the infrastructure which supports this sector, and the importance of this particular technology to many critical spheres of activity in the military and civilian sectors, and its geo-political implications. Its study can cast light on a broad spectrum of issues, from technological innovation, organizational transformation, the Soviet reform process, the conduct of research and development, military and economic competitiveness, technology transfer of dual-use technologies and export control policies, and others.

High-performance computing represents one of the Soviets’ “best shots” in computing. In a tradition stretching back to Lenin, Soviet leaders have viewed technological advance as a key to economic development. The acceleration of scientific-technical progress and the wide-spread introduction of new generations of technologies was proclaimed a “key lever in the intensification of the national economy” [Vasi88]. They were a prominent feature of the ambitious international Comprehensive Program for Scientific-Technical Progress of the CMEA² Countries to the Year 2000 (Program to the Year 2000). In this program and for many year prior, high performance computing has

²The Council for Mutual Economic Assistance (CMEA) included members of the Warsaw Pact plus Cuba, Mongolia, and Viet Nam. The latter three played an insignificant role in CMEA computing. Those having the greatest impact on computing in the Eastern Bloc were Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, and the USSR.

been a high-profile, high-priority advanced technology. Not only are powerful computers tools to be used in scientific, economic, and military activity. They are symbols, often viewed as indicators of a nation's technological capability. The Soviet high-performance computing sector has drawn considerable financial, material, and human resources over many years. Because it has been one of the most innovative sectors of Soviet computing, providing rich research opportunities, high-performance computing has attracted some of the leading computer scientists and engineers in the country. A study of Soviet high-performance computing can shed light on what Soviet science has been capable of in a very important field.

High-performance computers are highly complex systems. They typically consist of thousands of components and subsystems, each of which can be considered a system with hundreds or thousands of elements. Hardware is highly complex, but does not reflect the full extent of a system's complexity. Basic hardware units such as gate arrays are altered to reflect a highly complex logical design. Software can be even more complex, since software designers tend to avoid duplicating code which serves the same, or similar functions. Computers are highly dependent on miniaturization. The ability to place thousands, or even millions of transistors on a single chip measuring only a centimeter or two on a side requires complex, high-precision manufacturing tools and extraordinarily pure input materials and processing conditions; such components cannot be created manually by skilled craftsmen with "golden fingers." As a result, computers have greater complexity per unit volume than any other device created by man. Through a study of these systems, we can identify strengths and weaknesses of the Soviets' ability to design, construct, and manufacture complex technologies.

The final product is dependent on a long chain of activities and products such as fundamental research, applied research, materials production, component and subsystem de-

velopment, machine architecture design, unit assembly, design and production technologies, and systems support services. Weaknesses in any link of the infrastructure can have serious consequences in the final product. Because HPC systems and their infrastructure are so dependent on each other, an examination of the end products can cast much light on the nature of the infrastructure and the changes that it might be undergoing. HPC systems can contribute much to our understanding of Soviets' ability to develop and manufacture advanced technologies which are also complex and highly sensitive to a wide range of inputs and upstream products and processes, both prior to 1985 and after. The study of high-performance computers is further important because they not only are an output of this infrastructure, but also help shape its nature. They are critical tools for the development of next generation systems and components, and in both the East and the West traditionally have been among the most advanced systems, creating demands which have caused the entire infrastructure to raise its technological level.

The Soviet high-performance computing sector is inter-administrative. To a greater degree than other parts of the computing and electronics sectors, high-performance computing involves the participation of a range of administrative entities. Nearly all projects include significant research at Academy of Sciences or VUZ (Institutions of Higher Education) institutes. Research, development, and production were carried out in industrial ministries such as the Ministry of the Radio Industry and the Ministry of Instrument-Building, Means of Automation, and Control Systems (Minpribor). Inputs such as integrated circuits, materials, and selected subsystems come from other ministries. The military also has played a significant role as a key customer and project sponsor. Decisions about HPC involved policy makers at the highest levels of the Academy of Sciences, branch ministries, the USSR Council of Ministers, state agencies, and the Military-Industrial Commission (VPK). Successful HPC development required the coordination

and cooperation of multiple administrative entities. As a result, Soviet high-performance computing provides a lens into basic decision making from the highest levels of government down, R&D processes within many industrial and academic branches of the economy, and the nature of the relationships between them. HPC is therefore also a useful vehicle for examining the changing roles of these organizations and their interaction.

High-performance computers are important enabling technologies in many areas of science and industry. Increasingly, supercomputers are becoming an essential tool in the development of advanced technologies in aerospace, computing, weapons design, materials and others. These industries rely on supercomputers for design, analysis, simulation, and visualization to improve product quality and functionality, shorten development cycles, and reduce labor and material costs. Computational methods have emerged as a third pillar of scientific advance, together with analytical and experimental methods. Numerical analysis and visualization have emerged as basic tools in a growing number of fields such as weather prediction, hydrodynamics, plasma physics, atomic and molecular structure, etc. If the Soviet states are to be broadly competitive internationally in these and other disciplines, their researchers and engineers must have access to high-performance computing systems.

High-performance computers are also useful for examining geo-political aspects of advanced technology. HPC systems are an excellent example of a dual use technology with broad applicability to both military and civilian applications. Few dual use technologies have been as consistently and tightly controlled by the CoCom nations as HPC. At the same time, HPC underscores the issues and difficulties surrounding export control regimes during the post-Cold War era. Thanks to rapid technological developments, high-performance technologies are becoming much more difficult to control. Western high-end supercomputers, still manufactured in small quantities and requiring consider-

able on-site support, remain relatively controllable. Advances have been so rapid, however, that today's workstations and mid-range systems offer functionality and performance available only on supercomputers a decade ago. These systems are often manufactured in large, uncontrollable quantities (100,000 or more) and are small enough that transporting them is trivial. Leading-edge technologies move into the commercial mainstream only a few years after introduction, and many Western massively parallel high-performance computers contain a very high percentage of off-the-shelf parts. At the same time, the relationship between the West and the Soviet states has become much less adversarial, but the latter's future stability and sensitivity to the former's national security concerns are by no means assured. These factors are forcing a reconsideration of Western and Russian export control policies [Nrc93].

Because the Soviet high-performance computers have for decades been developed independently of the West in a rather closed sector with limited transfer of technology from outside the Soviet Union, they provide a microcosm in which to study issues of technological innovation and the nature of technological advance within a specific set of social, economic, and political systems. Prior to the *perestroika* reforms, these systems were rather stable. Since 1985, they have experienced drastic changes, and the isolation of this sector from the West has eased considerably. Under these conditions, Soviet HPC technologies should help us learn more about technological innovation during highly dynamic periods which create drastically new opportunities and constraints.

Similarly, Soviet HPC provides a microcosm in which to study organizational development and transformation under changing conditions. Traditionally, organizational structures in the Soviet Union were very stable and given types of organizations throughout the country had very similar structures. The reforms have created great pressures on organizations and radically new opportunities for transformation.

Besides the reasons mentioned above, the Soviet HPC sector provides a useful vehicle for studying these issues because it is relatively small. It is possible to study nearly all the major projects and R&D centers in the entire sector. In doing so, we avoid many of the methodological problems associated with selecting a study sample and generalizing to the entire sector.

We will investigate HPC-related activities within one component of the Soviet high-performance computing sector—research and development facilities in industry, the Academy of Sciences, and the institutions of higher learning (VUZ). As pointed out in [Meye90], a study of the activities of individual firms should not be equated with the study of an industry or industrial sector as a whole. But a study of research and development facilities and their products provides an important piece of the over-all picture. R&D facilities are crucial to the health of advanced technology industrial sectors. In them the ideas, abstractions, and theorizing meet the realities of the physical world. Innovation is strongly shaped by not only the theoretical ideas generated, but also the opportunities and constraints imposed upon the process by a host of material, technical, social, and political factors. The results of R&D strongly affect the quality, performance, and innovativeness of products manufactured within an industrial sector. While improvements in R&D do not necessarily lead to improvements in the output of an industrial sector as a whole, a deterioration within R&D facilities will almost certainly have a negative impact on the sector's output. R&D facilities are also a critical point of interaction between sponsors, planners, developers, manufacturers, and users. While this study focuses on HPC R&D facilities and the technologies developed within them, we will necessarily touch on these other elements as well.

In chapter 2 we discuss several bodies of related research and the contribution a study of Soviet HPC can make to each. We also present the specific research questions and the

case study methodology used to address them. Chapter 3 gives an overview of the HPC sector. We present some of the sector's history, and place the numerous industrial and academic systems in the context of the sector as a whole. This sets the stage for three detailed case studies, covered in chapters 4, 5, and 6. Chapter 7 contains sections that discuss HPC projects (or sets of projects) not covered in the detailed studies. This chapter "rounds out the field," making our study quite comprehensive in its coverage. It also illustrates that the processes at work in projects discussed in earlier chapters are not unique, but apply more broadly throughout the sector. Chapter 8 provides a cross-cutting analysis of the individual projects and conclusions drawn from this study. In chapter 9, we discuss the implications of our study for Soviet HPC developers and users, and Western and Russian policy-makers, and suggest directions for future research.