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No 101

Economic Intelligence Report

ECONOMIC MAGNITUDE OF SOVIET ELECTRONIC RESEARCH AND DEVELOPMENT 1956–62

CIA/RR ER 62–38

November 1962

CENTRAL INTELLIGENCE AGENCY

Office of Research and Reports

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FOREWORD

Presented in this report is an estimate of the economic magnitude of electronic research and development in the USSR. The estimate is provided primarily in order to supply a quantitative frame of reference for the assessment of the substantive content of Soviet electronic research and development. In addition, the estimate may be useful in measuring the priority of this activity in terms of input requirements for manpower and materials.

Also in this report is compared the economic effort expended in the USSR on electronic research and development with that in the US during 1956-62.

Although estimates of the expenditures on Soviet electronic research and development were derived for each individual year during the period covered in this report, the estimates for the base year (1957) and for the entire period (1956-62) merit greater confidence than the estimates for the other individual years.

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ECONOMIC MAGNITUDE OF SOVIET ELECTRONIC RESEARCH AND DEVELOPMENT* 1956-62

Summary

Soviet expenditures for electronic research and development (R and D) are nearly as large as those in the US, and they are increasing as rapidly. A comparison of the two programs in 1961 may be summarized as follows:

	USSR	US
Total expenditures for electronic R and D	$2.2 billion**	$2.8 billion
Expenditures for military electronic R and D	$1.6 billion	$2.0 billion
Total employment in electronic R and D	218,000 persons	124,000 persons
Scientists and engineers employed in electronic R and D	80,000 persons	83,000 persons

Estimated expenditures on Soviet electronic R and D have increased at an average annual rate of 15 percent since 1956. During the same period, about 52,000 scientists and engineers and about 90,000 technicians were

* The estimates and conclusions in this report represent the best judgment of this Office as of 1 November 1962.

** For Soviet R and D, ruble values (old rubles) and dollar values are in 1955 prices. For US R and D, dollar values are in current prices. Because ruble prices for electronic R and D have not been affected by inflation, there is no problem of divergence between the two series for individual years. A deflator for US R and D prices is not available, because the product mix is continually changing and is quite complex.

The ruble-dollar ratios used in this report are as follows: for electronic R and D, 4.9 to 1; for equipment, 10 to 1; and for building construction, 6 to 1. These ratios all are based on studies for the respective categories.

added to the Soviet labor force engaged in electronic R and D -- an average annual increment of about 8,700 scientists and engineers and about 15,000 technicians.

Since 1956, Soviet expenditures for military electronic R and D have been about 72 percent of the total expenditures for electronic R and D. In the US, comparable expenditures exceed 80 percent of the total. It is estimated that, in 1961, 54,200 scientists and engineers, or about 70 percent of the total engaged in Soviet electronic R and D, were allocated to military electronic R and D.

The estimated allocation of expenditures on Soviet electronic R and D to the various categories of electronic R and D are as follows for the period since 1956: basic electronics, 18 percent; techniques, 5 percent; components, 14 percent; functional elements, 4 percent; and electronic end equipment and systems, 59 percent. The share of electronic R and D allocated to basic electronics (which involves phenomena basic to all electronic R and D) appears to be smaller in the USSR than in the US, where the percentage probably is about 25 percent. This ratio of allocations could be important in determining the relative rates of growth of electronic technology in the two countries in the future. The specific activities receiving the most attention in Soviet electronic R and D include electromagnetic wave propagation, automation, semiconductors, measuring instruments, radar, guided missile electronics, and computers.

The estimated Soviet outlay for facilities used in electronic R and D since 1956 is $331 million, and approximately 61 percent of this amount was allocated to military electronic R and D. The total undepreciated value of the facilities used in Soviet electronic R and D in 1961 was about $720 million.

I. Definitions of Terms

A. General

1. Electronics

Electronics is the science and technology that deals primarily with devices that collect, process, and transmit information in the form of electrical (and electromagnetic) signals and either control machines or present the processed information to human beings for their direct use.

2. Electronic Research and Development (R and D)

Electronic research is an activity of exploration and discovery leading to new information; its end product is usually a published report or monograph. Electronic development differs in that its end product is a material device or product. In the US, expenditures for tests and evaluations are usually distinguished from those for R and D. In this report, however, expenditures for testing and evaluating a product under development are included in the estimated expenditures for R and D and, although not specifically identified, are included with expenditures for labor and materials (primarily those allocated to electronic systems and end equipment).

3. Substantive Categories of Electronic R and D

a. R and D in Basic Electronics

R and D in basic electronics is that electronic R and D which yields information of broad utility -- that is, information that is applicable to many specific projects rather than that required to solve a problem peculiar to one project. Subject areas comprehended by R and D in basic electronics include electron emission, electron optics, electromagnetic propagation, information theory, network theory, solid state theory, interaction of radiation and material, gases and plasmas, physical effects (electrical), properties of materials, environmental effects, system theory, human factors, signal detection, reliability theory, electronic measurements, and magnetohydrodynamics.

b. R and D in Electronic Techniques

R and D in electronic techniques includes elements of electronic R and D such as mechanical design, printed circuitry, miniaturization and subminiaturization, molecular electronics, bionics, construction, automation, heat-transfer design, maintenance and repair

methods, assembly, inspection techniques, reliability, and tropicalization. In general, R and D in electronic techniques is concerned with the methods of producing electronic devices and the method of utilizing electronic devices or subsystems in nonelectronic systems.

c. R and D in Electronic Parts and Components

R and D in electronic parts and components is the area of electronic R and D which develops and improves the various elements that are combined to construct electronic devices. Electronic parts and components are made up of electronic tubes, semiconductors, electromechanical devices, magnetic devices, piezoelectric devices, capacitors, inductors, resistors, waveguides and transmission cables, switches, connectors, frequency-control devices, electronic materials,* miscellaneous hardware, batteries, thermoelectric devices, delay lines, and the like.

d. R and D in Electronic Functional Elements

R and D in electronic functional elements is concerned with electronic units that perform specific electronic functions such as acquisition of an electronic signal, modification of an electronic signal, generation of a carrier for an electronic signal, and the conversion of an electronic signal into a nonelectronic form for display, recording, or control actuation. Specific electronic functions included in this category are amplification, transmission, generation, modulation, demodulation, power supply, waveform control, signal attenuation, logical operations, coding and decoding, recording, signal display, signal analysis, transduction, counting, calibration, filtering, function generation, radiation of electromagnetic waves, frequency control, voltage and current regulation, and signal delay.

e. R and D in Electronic End Equipment and Systems

R and D in electronic end equipment and systems is the end product of electronic R and D. In this area the results of work in the other four categories of electronic R and D are combined to produce electronic end equipment such as radar sets, computers, direction finders, display units, and communications units. The electronic end equipment in turn is combined into electronic systems or incorporated into nonelectronic systems. R and D in electronic systems examines, develops, and improves the interaction or interdependence among the elements that make up the system. Electronic systems include systems

* The term electronic materials includes special forms of certain materials that are used to fabricate electronic components, although such materials do not themselves perform electronic functions. Examples are ceramics, tantalum, barium titanite, tungsten, gallium arsenide, cobalt, and phosphors.

for communications, detection and location, countermeasures, data processing, simulation, testing instrumentation, guidance, research instrumentation, medical diagnosis, fire control, and general control.

B. Economic Terms

1. Labor Force Engaged in Electronic R and D

The labor force engaged in electronic R and D consists of scientists, engineers, technicians, and management personnel who are concerned with research on electronic phenomena and the development of electronic equipment and should be interpreted in this report to mean direct labor force. Not included in this definition are persons in the indirect labor force, who are engaged in such duties as accounting, maintenance, custodial work, filing, and general logistic support. Only the size of the direct labor force itself is estimated in this report in terms of the number of workers, although a cost allocation is made for indirect labor.

Scientists, engineers, and technicians are included in the labor force on the basis of the position occupied and not on the basis of formal schooling or the academic degree attained. Several scientific and engineering disciplines are represented in the labor force, including mathematics, physics, chemistry, metallurgy, and electronic and mechanical engineering. Technicians are primarily machinists, mechanics, draftsmen, and persons engaged in electronic assembly and testing.

2. Expenditures on Electronic R and D

Expenditures on electronic R and D denote the economic value attached to the various physical inputs to the activities that comprise electronic R and D. These expenditures are expressed in this report in either rubles or US dollars.* Expenditures on electronic R and D have two components -- direct labor and overhead. Overhead expenditures are expressed as a percentage of expenditures for direct labor and consist of expenditures for depreciation of equipment, depreciation of buildings, indirect labor, and materials. Overhead expenditures, therefore, include all costs of performing electronic R and D other than the cost of the direct labor force.

3. Facilities Used in Electronic R and D

The facilities used in electronic R and D consist of the buildings and equipment of the research institutes, educational institutions, plant laboratories, and design bureaus that are performing electronic R and D in the USSR. In this report the term building applies

* See the second footnote on p. 1, above.

strictly to the edifice itself and the term equipment to all other physical components, ranging from central heating and airconditioning to voltmeters, oscilloscopes, and lathes. The term facilities does not include the electronic prototypes and associated facilities at field installations such as Mytishchi or Sary Shagan. Expenditures on these prototypes are included as expenditures on labor and material.

4. Military Electronic R and D

Military electronic R and D is that part of the total electronic R and D effort which is performed for the primary benefit of the military establishment. (Nonmilitary electronic R and D consists almost entirely of industrial electronics, including civil communications equipment, rather than consumer electronics such as radio and television broadcast receivers. In this report, therefore, the term industrial electronics will be used interchangeably with nonmilitary electronics.)

II. Size of the Labor Force and Expenditures

The estimated labor force employed in Soviet electronic R and D during 1956-62 is shown in the following tabulation (see the chart, Figure 1*):

	Thousand Persons						
	1956	1957	1958	1959	1960	1961	1962
Scientists and engineers	39.5	45.5	52.3	60.1	69.2	79.5	91.4
Technicians	68.9	79.2	91.1	104.7	120.4	138.5	159.3
Total**	108.4	124.6	143.4	164.8	189.6	218.0	250.7

During this period, about 52,000 scientists and engineers and about 90,000 technicians were added to the labor force, or an average annual increment of about 8,700 scientists and engineers and about 15,000 technicians.

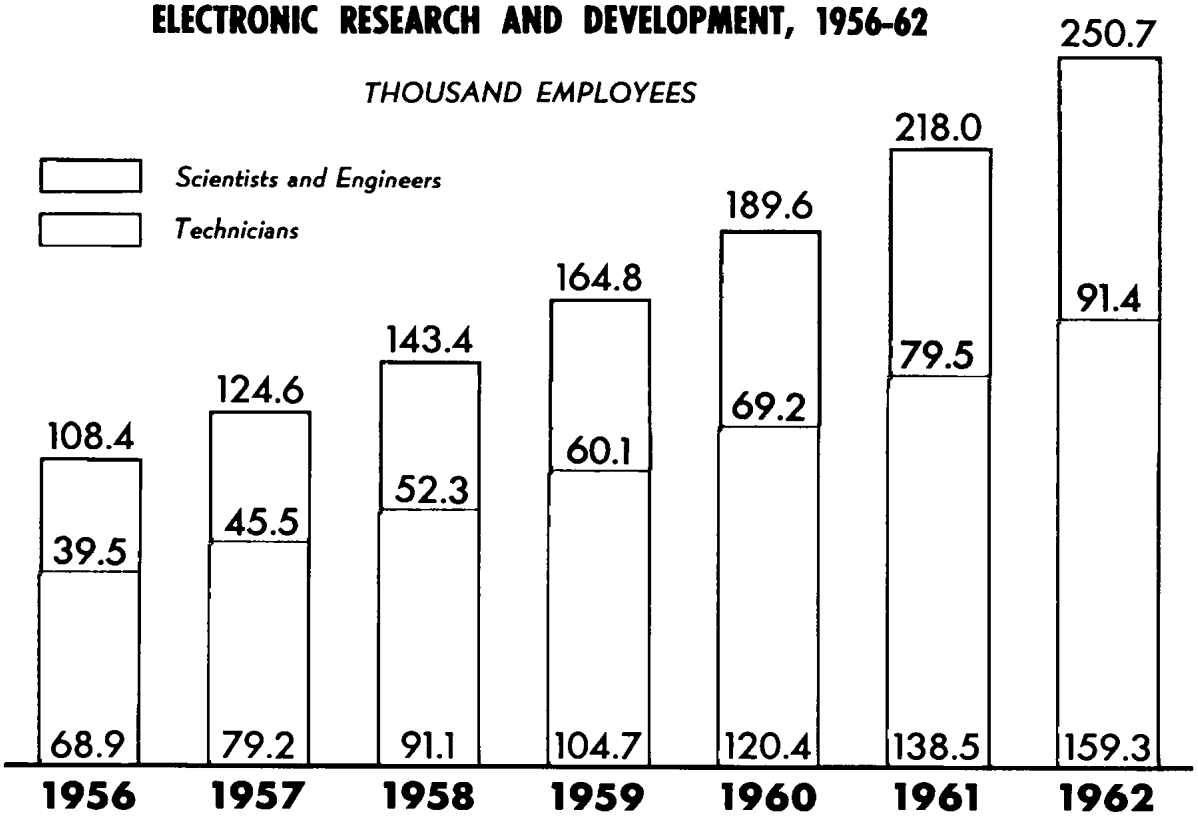
Approximately 70 percent of the scientists and engineers are estimated to have been employed primarily in military electronic R and D during the period. A slightly higher proportion of the technicians, about 72 percent, is estimated to be primarily engaged in military electronic R and D.

* Following p. 6.

** Because of rounding, components may not add to the totals shown.

Figure 1 50X1

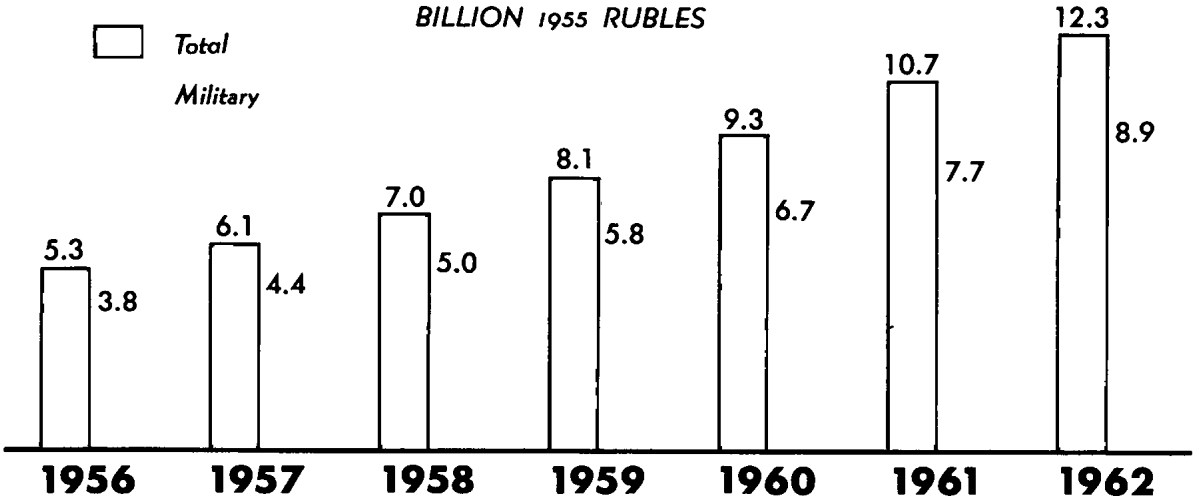
ESTIMATED LABOR FORCE EMPLOYED IN SOVIET ELECTRONIC RESEARCH AND DEVELOPMENT, 1956-62



Components may not add to totals because of rounding.

Figure 2

ESTIMATED SOVIET EXPENDITURES ON ELECTRONIC RESEARCH AND DEVELOPMENT, 1956-62



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Soviet expenditures on electronic R and D for the period 1956-62 are estimated to have been as follows (see the chart, Figure 2*):

	Billion 1955 Rubles						
	1956	1957	1958	1959	1960	1961	1962
Expenditures	5.3	6.1	7.0	8.1	9.3	10.7	12.3

The USSR, therefore, is estimated to have allocated 2.3 times as much economic effort to electronic R and D in 1962 as in 1956. The estimated average annual rate of growth of Soviet expenditures on electronic R and D was 15 percent during 1957-62. It should be noted that because of the methodology employed** all statements concerning the rate of growth of Soviet expenditures on electronic R and D also are applicable to the rate of growth of the labor force employed in Soviet electronic R and D.

Soviet expenditures on military electronic R and D are estimated to have comprised about 72 percent of expenditures on Soviet electronic R and D in each year of the estimate period. On this basis, estimated expenditures on Soviet military electronic R and D are as follows:

	Billion 1955 Rubles						
	1956	1957	1958	1959	1960	1961	1962
Expenditures	3.8	4.4	5.0	5.8	6.7	7.7	8.9

The total Soviet expenditures on electronic R and D and the Soviet expenditures on military electronic R and D are shown in US dollars*** in the following tabulation:

	Billion 1955 US $						
	1956	1957	1958	1959	1960	1961	1962
Total	1.1	1.2	1.4	1.6	1.9	2.2	2.5
Military	0.8	0.9	1.0	1.2	1.4	1.6	1.8

* Following p. 6.
** See Appendix A, 3, a, p. 24, below.
*** For the derivation of the ruble-dollar ratio for electronic R and D, see Appendix A, pp. 19 through 28, below.

Annual Soviet expenditures per scientist and engineer engaged in electronic R and D during 1956-62 are estimated to have been 134,000 rubles, or $27,400. Annual Soviet expenditures per employee in the labor force engaged in electronic R and D are estimated to have been 49,000 rubles, or $10,000 during the same period.

III. Categories* of Electronic Research and Development

A. Allocation of Expenditures

Soviet expenditures on electronic R and D are estimated to have been allocated during the period 1956-62 to the various categories of electronic R and D in the following proportions (see the chart, Figure 3**):

Categories of Electronic R and D	Percent of Ruble Values	Value in 1961: Billion 1955 Rubles	Value in 1961: Billion 1955 US Dollars
Basic electronics	18	1.9	0.4
Techniques	5	0.5	0.1
Components	14	1.5	0.3
Functional elements	4	0.4	0.1
Electronic end equipment and systems	59	6.4	1.3
Total	100	10.7	2.2

The military portion of Soviet expenditures during the same period on electronic R and D was allocated as follows (see the chart, Figure 4**):

Categories of Military Electronic R and D	Percent of Ruble Values	Value in 1961: Billion 1955 Rubles	Value in 1961: Billion 1955 US Dollars
Basic electronics	10	0.8	0.2
Techniques	3	0.2	Negl.
Components	13	1.0	0.2
Functional elements	4	0.3	0.1
Electronic end equipment and systems	70	5.4	1.1
Total	100	7.7	1.6

* See I, A, 3, p. 3, above.
** Following p. 8.

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Figure 3

ESTIMATED ALLOCATION OF SOVIET EXPENDITURES ON ELECTRONIC RESEARCH AND DEVELOPMENT, 1956-62

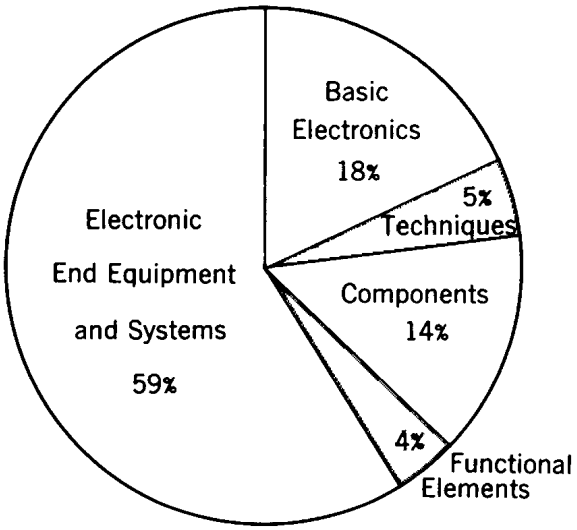
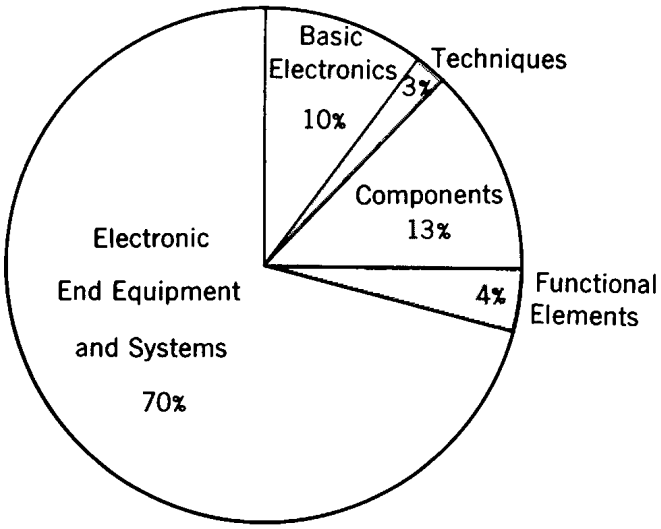


Figure 4

ESTIMATED ALLOCATION OF SOVIET EXPENDITURES ON MILITARY ELECTRONIC RESEARCH AND DEVELOPMENT, 1956-62



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The observed differences in allocation between the total and the military portion of Soviet expenditures on electronic R and D are explained by the proportion of the total expenditures in each category of electronic R and D devoted to military electronic R and D. The proportions devoted to military electronic R and D are basic electronics, 42 percent; techniques, 40 percent; components, 67 percent; functional elements, 75 percent; and electronic end equipment and systems, 84 percent. The proportion of the total expenditures devoted to military electronics is 72 percent.

B. Allocation of the Labor Force

In 1961, employees engaged in electronic R and D are estimated to have been allocated to the various categories of electronic R and D as shown in Table 1.

Table 1

Allocation of Employees Engaged
in Soviet Electronic Research and Development
1961

Thousand Persons

Categories of Electronic R and D	Scientists and Engineers		Technicians		Total	
	Total	Military	Total	Military	Total	Military
Basic electronics	20.7	8.1	20.8	8.1	41.5	16.2
Techniques	4.0	1.1	7.9	2.1	11.9	3.2
Components	10.8	7.3	21.6	14.6	32.4	21.9
Functional elements	3.4	2.3	6.8	4.5	10.2	6.8
Electronic end equipment and systems	40.6	35.4	81.4	70.9	122.0	106.3
Total	79.5	54.2	138.5	100.2	218.0	154.4

It is apparent that both military and industrial electronic R and D are oriented strongly toward electronic end equipment and systems. Basic electronic R and D is in second place in the total allocation of personnel, and only third in the ranking of military electronic R and D. Components, of course, receive a great deal of attention. The apparently small allocations of manpower to techniques and functional elements may be due to some extent to the lack of detail in the available information. R and D in these two categories could well be hidden in the categories of components and electronic end equipment and systems.

C. Expenditures on Facilities for Electronic Research and Development

The estimated Soviet outlays for facilities during 1956-62 totaled 2.7 billion rubles, or $331 million.* The annual expenditures were estimated as follows:

	1956	1957	1958	1959	1960	1961	1962	Total
Billion 1955 Rubles	0.3	0.3	0.4	0.4	0.4	0.4	0.5	2.7
Million 1955 Dollars	37	37	49	49	49	49	61	331

The estimated average annual rate of growth is about 8 to 9 percent, with the result that expenditures in 1962 for facilities will be about two-thirds higher than those in 1956.

During the period of the estimate the value of the inventory of facilities, neglecting depreciation allowances, grew from 3.8 billion rubles to 6.5 billion rubles, or about 70 percent. The undepreciated value of the inventory of facilities in 1961 was about $720 million. About 60 percent of the value of the inventory of facilities was allocated to Soviet military electronic R and D during 1956-62.

Forty-five percent of the value of the inventory of facilities was estimated to be in buildings and 55 percent in equipment.

IV. Comparison of the Economic Magnitude of Soviet and US Electronic Research and Development

A. Expenditures

A direct comparison of expenditures by the USSR and the US on the total electronic R and D and on military electronic R and D for 1956-62 is shown in Table 2** (see the chart, Figure 5***). This comparison shows that Soviet expenditures on both total and military electronic R and D were significantly less than those of the US during the same time period, even with the recognition that current US dollars are worth less than 1955 US dollars. Nevertheless, Soviet expenditures are relatively large, and if the apparent trend continues, Soviet expenditures will become an increasing proportion of US expenditures, although at a modest rate.

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* See the second footnote on p. 1, above.
** Table 2 follows on p. 11.
*** Following p. 10.

Figure 5

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COMPARISON OF ESTIMATED EXPENDITURES BY THE USSR AND THE US ON ELECTRONIC RESEARCH AND DEVELOPMENT, 1956-62

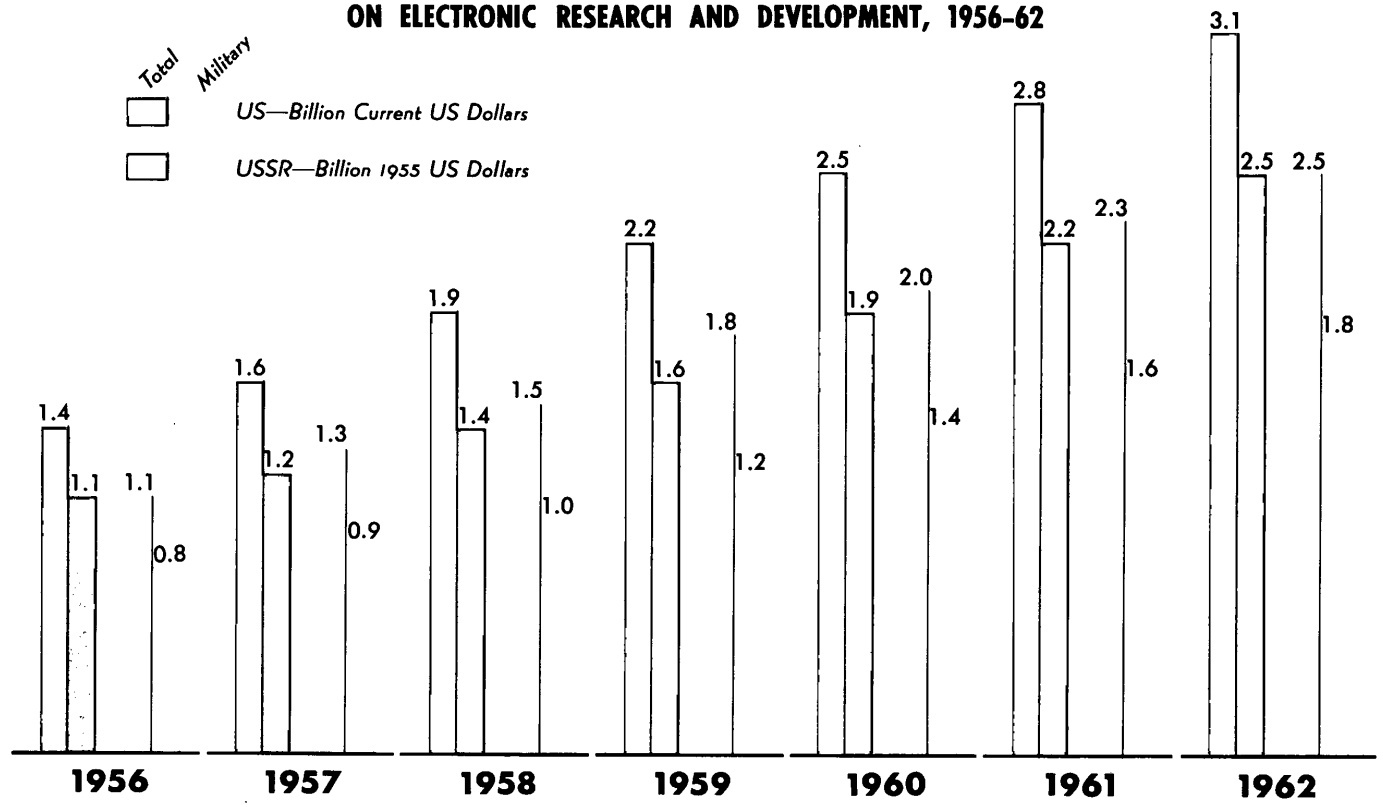

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Table 2

Comparison of Soviet and US Expenditures for Electronic Research and Development
1956-62

Year	Total Expenditures			Military Expenditures		
	USSR (Billion 1955 $)	US (Billion Current $)	USSR as a Percent of US	USSR (Billion 1955 $)	US (Billion Current $)	USSR as a Percent of US
1956	1.1	1.4	79	0.8	1.1	73
1957	1.2	1.6	75	0.9	1.3	69
1958	1.4	1.9	74	1.0	1.5	67
1959	1.6	2.2	73	1.2	1.8	67
1960	1.9	2.5	76	1.4	2.0	70
1961	2.2	2.8	79	1.6	2.3	70
1962	2.5	3.1	81	1.8	2.5	72
Total 1956-62	11.9	15.5	77	8.7	12.5	70

In 1960 and 1961, US expenditures on electronic R and D were about 20 percent of the total US expenditures on all types of R and D. 1/* A similar figure for the USSR was 28 percent, based on published figures for scientific research. 2/ It is believed, however, that the comparative figures used for the total expenditures on Soviet R and D of all types, called "appropriations for science," exclude the cost of much military and some industrial R and D. For this reason the share of the total Soviet R and D allocated to electronic R and D may well be considerably less than 28 percent.

This assumption seems to be borne out by other comparisons. The number of scientists and engineers estimated to have been employed in Soviet electronic R and D in 1960 is only about 13 percent of the total number of Soviet "specialists with higher education" employed in "scientific and scientific-research establishments" and "in technical planning, designing, and geological prospecting organizations" on 1 December 1960. 3/ This comparison, however, probably understates the percentage of all scientists and engineers in Soviet R and D who are engaged in electronic R and D, for the figure used to represent all scientists and engineers in Soviet R and D apparently includes many "specialists with higher education" who are not employed in R and D activities.

Another comparison indicates that the scientists and engineers estimated to have been employed in Soviet electronic R and D in 1960 were about 20 percent of the number of scientific personnel in the USSR on 1 October 1960. 4/ The Soviet definition of scientific personnel is as follows:

> Scientific personnel include: academicians, active and corresponding members of all academies; all persons with a degree of doctor of science, master of science or with the rank of professor, docent, associate professor, senior scientist and junior scientist, regardless of the place and nature of their work, as well as persons engaged in scientific-research work in scientific institutions and scientific-pedagogical work in higher institutions of learning regardless of whether they have academic degrees or title.** 5/

The Soviet definition of scientific personnel, therefore, apparently includes not only the scientists and engineers engaged in Soviet

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** The underlining is by the author of this report.

R and D but others who spend full time in other activities. Therefore, the above mentioned 20 percent of Soviet scientific personnel identified as scientists and engineers in Soviet electronic R and D may be understated also. This apparent understatement, however, may be more than compensated for by the number of Soviet scientists and engineers who are employed in R and D at facilities that are not included in the Soviet term "scientific institutions," such as plant laboratories and design bureaus. On balance the figure of 20 percent seems to be a reasonable estimate of the proportion of the total Soviet scientific and engineering personnel in R and D who are engaged in electronic R and D.

The percentage of electronic R and D allocated to basic electronics appears to be less in the USSR, about 18 percent, than in the US, where the proportion probably is about 25 percent. 6/ Absolute expenditures for basic electronics in 1961, consequently, are estimated to have been $700 million in the US and about $400 million in the USSR.

During 1956-62 the total Soviet expenditures on electronic R and D were equal to about 28 percent of the total value of the output of the Soviet electronics industry, 7/ and the expenditures were growing at about the same rate as the value of the output. In the US the total expenditures on electronic R and D were about 24 percent of the total value of the output of electronics, and expenditures on electronic R and D were growing faster than the value of the output of electronics. 8/ The US electronics industry, however, was growing at a significantly lower rate than that of the USSR during the period of the estimate.

B. Labor Force

A direct comparison of the Soviet and US labor forces employed in electronic R and D during 1956-62, as shown in Table 3,* indicates that the number of scientists and engineers engaged in electronic R and D is about equal in the two countries during the period of the estimate but that the USSR uses many more -- more than three times as many -- technicians in electronic R and D than does the US. The US added 53,000 scientists and engineers but only 26,000 technicians during 1957-62, whereas the USSR added 52,000 scientists and engineers and 90,000 technicians.

The rather startling difference between the comparison of expenditures and the comparison of labor forces can be accounted for by the vastly different relative prices of the inputs to electronic R and D in the two countries and the methodological assumption that the relationship of expenditures on labor and other inputs was the same in the two countries.** Thus the ruble estimate derived by this methodology, when converted to US dollars by estimated ruble-dollar ratios, results in

* Table 3 follows on p. 14.
** See Appendix A, 3, a, p. 24, below.

Table 3

Comparison of Soviet and US Labor Forces Engaged in Electronic Research and Development
1956-62

	Scientists and Engineers			Technicians			Total Labor Force		
	Thousand Persons		USSR as a Percent of US	Thousand Persons		USSR as a Percent of US	Thousand Persons a/		USSR as a Percent of US
Year	USSR	US		USSR	US		USSR	US	
1956	39.5	40.0	99	68.9	20.0	344	108.4	60.0	181
1957	45.5	46.9	97	79.2	23.5	337	124.6	70.4	177
1958	52.3	56.6	92	91.1	28.3	332	143.4	84.9	169
1959	60.1	65.8	91	104.7	32.9	318	164.8	98.7	167
1960	69.2	73.8	94	120.4	36.9	326	189.6	110.7	171
1961	79.5	82.8	96	138.5	41.4	335	218.0	124.2	176
1962	91.4	92.9	98	159.3	46.5	343	250.7	139.4	180

a. Because of rounding, components may not add to the totals shown.

fewer dollars than would have been the case if the Soviet labor input had been valued directly in dollars and the US overhead factors had been applied directly to the estimated Soviet labor cost to obtain the total dollar expenditures by the USSR on electronic R and D. In effect, the choice of the former methodology means that the USSR is estimated to associate fewer physical overhead inputs with its scientists, engineers, and technicians than does the US.

Although there is no direct evidence that bears on this relationship between labor force and other inputs to electronic R and D in the USSR, it is evident that the wage bill of the relatively large number of technicians used in Soviet electronic R and D is partly substituted for costs that are normally included in costs of material inputs in the US. For example, Soviet technicians might be required to construct a particular test apparatus in the laboratory from component parts, whereas the counterpart US program probably would purchase the test apparatus from a supplier of scientific equipment. Although the total costs might be comparable, the allocation of costs to labor and materials would be greatly different. In this example the wage bill of the Soviet technicians who constructed the apparatus would be allocated, of course, to the labor cost of electronic R and D. The labor cost of the US personnel who constructed the counterpart apparatus, on the other hand, would be allocated to the material cost of electronic R and D because the apparatus was constructed by personnel not allocated to electronic R and D.

V. Conclusions and Prospects

The major conclusions of this report are that Soviet expenditures on electronic R and D are relatively large, apparently support a comprehensive program, and are growing at least as rapidly as those in the US. These conclusions are stated in relation to US expenditures on electronic R and D, which are used as the standard of measure. But Soviet electronic R and D also is estimated to be large and growing rapidly in relation to the Soviet electronic industry in terms of magnitude of expenditures, number of highly trained personnel, and investment in plant and equipment required. In addition, expenditures on Soviet electronic R and D represent a significant share of the total expenditures on all R and D performed in the USSR.

Other things being equal, therefore, relatively rapid progress in electronic technology probably will be forthcoming in the USSR to the extent that substantial economic support contributes to such progress. Experience in the US has shown, however, that substantial economic support in itself does not guarantee rapid technical progress. 9/ The primary reason for this apparent discrepancy, apart from the competence of personnel, is the tremendous amount of unintentional duplication in electronic R and D. Although objective measurement is not possible, the

magnitude of such duplication of electronic R and D in the US is estimated to be between 30 and 85 percent of all electronic R and D performed. Another reason for a slowing of technological innovation in the face of impressive investment in R and D is the failure of industry and science to be aware of and use the latest technology.

These factors may or may not be present in the Soviet electronic R and D effort, but because they appear to be basic problems, they are likely to be present to a great degree. The USSR has recently reorganized its R and D effort to achieve a greater cooperation between the creators of technology and the users of technology, but there is no evidence concerning the amount of unintentional duplication of electronic R and D. One might speculate that such duplication might be less in the USSR than it is in the US because of the Soviet emphasis on central planning, in particular the planning of scientific research by the State Committee for Coordination of Scientific Research. Bureaucracy can be a formidable hurdle in any country, however, and many times it is almost as quick, although usually more expensive in the short run, to undertake a particular research task as it is to locate the results of a previous effort that is similar or identical to the one contemplated.

As examination of the problems in the advancement of electronic technology through R and D in the US indicates that the basic factor leading to duplication and nonadoption of new technology is simply the lack of communication among those creating and using electronic technology. Although it is beyond the scope of this report to investigate this problem, it is noted that creating and maintaining an effective means of communication in a large organization is a very complex and difficult undertaking. To the extent that the USSR is able to overcome the communication problem in electronic R and D, the rate of growth of technical achievement in this field has a greater probability of approaching the rate of growth of economic inputs.

The fact that the USSR is spending significantly less on basic electronics than the US could be important in determining the relative future rates of growth of electronic technology in the two countries. It should be pointed out that basic electronics includes research on the methods of measuring the physical parameters significant to electronics, such as frequency, phase and amplitude of electronic signals, electrical and magnetic properties of materials at radio frequencies, capacitance, inductance, resistance, impedance, and others. It is fundamental to the satisfactory performance of all types of electronic R and D to have the capability of performing these measurements satisfactorily.

The US spends more, absolutely and relatively, on military electronic R and D than does the USSR, although the Soviet expenditures on military electronic R and D may be increasing more rapidly. This lead in expenditures probably means, subject to the reservations discussed above, that

the US will maintain its lead in military electronic technology in most areas for the indefinite future. The allocation of Soviet expenditures on electronic R and D to the military sector, however, may have been understated because of Soviet secrecy on military information. Actually the numbers of scientists and engineers allocated to military electronic R and D in the USSR and the US appear to be fairly similar.

The pattern of allocation of Soviet electronic R and D to substantive activities within categories of electronic R and D is difficult to evaluate without more detailed information, but there appears to be no significant deviation from the pattern followed in the US. Perhaps the USSR is concentrating a bit more on electromagnetic propagation, acoustics as applied to underwater detection, warning, and tracking systems, radar, and computers than is the US. The US, on the other hand, probably is emphasizing communications, command and control systems, miniaturization and molecular electronics, laser research, and reliability more than is the USSR. Automation, semiconductors, magnetic materials, and guided missile and space electronics are strongly emphasized in both countries. These judgments are tentative in that magnitude cannot be precisely measured and emphasis changes over time more rapidly than indications of change become apparent in both the US and the USSR.

APPENDIX A

METHODOLOGY

1. Outline of Procedure

A study of facilities engaged in Soviet electronic R and D was made to establish a base-year estimate for the physical dimensions of buildings, for the size of the labor force, and for the allocation of the labor force to various categories of electronic R and D activities as indicated by the substantive content of the activities. Soviet wage rates and US analog factors were applied to the estimated labor force to obtain estimates of the total expenditures on electronic R and D and the allocation of these expenditures in the base year. The estimated value of facilities in the base year was derived by applying Soviet construction costs and US analog factors concerning relationships between building costs and equipment costs to the estimate of the physical dimensions of buildings at Soviet electronic R and D facilities. A distinction between military and industrial electronic R and D activity was made on the basis of information analyzed during the study of facilities.

The base-year estimates of the size of the labor force and of the value of electronic R and D were extrapolated backward and forward over the period of the estimate to form time series based on a rate of growth derived from a sample of electronic R and D facilities that afforded estimates of the rates of growth of their respective labor forces. The allocation of the labor force and the value of R and D to the various categories of electronic R and D activities and the division between military and industrial electronic R and D estimated for the base year were assumed to remain constant in every year during the period of the estimate.

The value of electronic R and D facilities estimated for the base year was extrapolated backward and forward over the period of the estimate at a rate of growth based on information concerning planned Soviet investment in electronic R and D during 1959-65.

2. Soviet Electronic Research and Development in 1957

a. Analysis of Facilities

Analysis* was made of 124 facilities used by the USSR to conduct electronic R and D, including scientific research institutes, educational

* For a summary of the results of the analysis, see Appendix B.

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institutions, design bureaus, and laboratories in manufacturing plants. Identification of these facilities was made on the basis of the substantive content of the activities carried on at the facilities.*

Estimates of the size of the labor force and of the physical dimensions of the buildings in a base year were available for the number of facilities shown in the following tabulation, and an allocation of labor force to categories of electronic R and D by substantive content of the activities was made for each facility, as follows:

Classification of Facility	Number of Facilities		
		Estimates Available	
	Total	Labor Force	Dimensions of Buildings
Numbered institutes	28	15	9
Institutes of the Academies of Science	24	11	2
Other research institutes	24	15	6
Educational institutions	30	16	3
Design bureaus and plant laboratories	18	14	3
Total	124	71	23

The estimates of the physical dimensions of buildings were translated into ruble costs of the buildings using Soviet cost factors.** Within each class of facility a factor expressing the ruble cost of building per employee was computed and used to complete estimates for those facilities that lacked only one of the two types of estimates -- building cost and size of labor force. From this expanded set of estimates, the arithmetic means of the labor force and the cost of buildings were computed for each class of facility and used to estimate the size of the labor force and the cost of buildings for those facilities that lacked independent estimates of both labor force and cost of buildings.

* For a listing of the activities that form the substantive content of electronic R and D, see Appendix C.

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After this procedure, each of the 124 facilities examined had an estimated labor force, an estimated cost of buildings, and an allocation of labor force to the categories of electronic R and D in a base year. By totaling these figures, estimates of the aggregate labor force, the aggregate cost of buildings, and the allocation of the aggregate labor force to categories of electronic R and D were obtained for a base year.

The base year associated with these aggregate estimates was obtained by taking the arithmetic mean of the base years of all facilities weighted by the estimated labor force of each facility. The weighted average year was computed to be 1957. In this base year the total labor force employed in Soviet electronic R and D was estimated to be 124,600 employees and the total value of buildings 2 billion rubles. The estimated allocation of the labor force to categories of electronic R and D is summarized in Table 4.*

The estimates thus obtained were divided into military and industrial electronic R and D by allocating each facility entirely to one or the other on the basis of subordination, substantive content of activity, and/or relationships with other facilities known to be devoted to military or industrial activities. A facility was presumed to be industrial until evidence indicated it to be primarily military. On this basis, 71 facilities were estimated to be devoted to military electronic R and D. The estimated labor force and the allocation of the labor force to categories of electronic R and D in 1957 are also shown in Table 4.

b. Value of Soviet Electronic Research and Development in 1957

The estimated wage bill for Soviet electronic R and D in 1957 also is shown in Table 4. The procedure illustrated in this table is simply to separate the total estimated labor force into scientists and engineers and technicians by the appropriate Soviet factors; to apply Soviet wage rates to the resulting subtotals; and to add the ruble products to obtain the total wage bill for Soviet electronic R and D and the wage bill for military electronic R and D in 1957.

As shown in Table 5,** the value of Soviet electronic R and D in 1957 was derived from the above wage bill by applying the overhead factors that obtain in electronic R and D in the US. Again the military portion of the total Soviet electronic R and D was calculated separately.***

* Table 4 follows on p. 22.
** Table 5 follows on p. 23.
*** Text continued on p. 24.

Table 4

Estimated Wage Bill for Scientists, Engineers, and Technicians
in Soviet Electronic Research and Development
1957

Category of Electronic Research and Development	Labor Force a/ (Thousand Persons)	Total Wage Bill a/ (Million 1955 Rubles)	Ratio of Scientists or Engineers to Technicians b/	Scientists and Engineers			Technicians		
				Thousand Persons	Annual Wage Rate c/ (Thousand 1955 Rubles)	Wage Bill (Million 1955 Rubles)	Thousand Persons	Annual Wage Rate c/ (Thousand 1955 Rubles)	Wage Bill (Million 1955 Rubles)
Basic electronics	23.7	545.6	1 to 1	11.9	30	355.8	11.9	16	189.8
Of which:									
Military	9.3	214.0	1 to 1	4.7	30	139.6	4.7	16	74.4
Techniques	6.8	140.7	1 to 2	2.3	30	68.0	4.5	16	72.7
Of which:									
Military	1.8	38.0	1 to 2	0.6	30	18.4	1.2	16	19.6
Components	18.5	382.3	1 to 2	6.2	30	184.9	12.3	16	197.5
Of which:									
Military	12.5	258.3	1 to 2	4.2	30	124.9	8.3	16	133.4
Functional elements	5.9	121.4	1 to 2	2.0	30	58.7	3.9	16	62.7
Of which:									
Military	3.9	80.5	1 to 2	1.3	30	38.9	2.6	16	41.6
Electronic end equipment and systems	69.7	1,441.0	1 to 2	23.2	30	696.7	46.5	16	744.3
Of which:									
Military	60.8	1,255.4	1 to 2	20.2	30	607.0	40.5	16	648.4
Total	124.6	2,631.0		45.5		1,364.1	79.2		1,266.9
Of which:									
Military	88.3	1,846.2		31.0		928.8	57.3		917.5

a. Because of rounding, components may not add to the totals shown.
b. 10/
c. 11/

Table 5

Estimated Total Expenditures
for Soviet Electronic Research and Development
1957

Category of Electronic Research and Development	Expenditures							
	Wage Bill (Million 1955 Rubles)		Overhead				Total (Million 1955 Rubles)	
			Factor a/ (Percent)		Expenditure (Million 1955 Rubles)			
	Total	Military	Total	Military	Total	Military	Total	Military
Basic electronics	545.6	214.0	100	100	545.6	214.0	1,091.1	428.0
Techniques	140.7	38.0	100	100	140.7	38.0	281.3	76.0
Components	382.3	258.3	125	125	477.9	322.9	860.3	581.1
Functional elements	121.4	80.5	125	125	151.7	100.6	273.1	181.1
Electronic end equipment and systems	1,441.0	1,255.4	150	150	2,161.5	1,883.1	3,602.5	3,138.6
Total b/	2,631.0	1,846.2			3,477.4	2,558.6	6,108.4	4,404.9

a. 12/. Wage bill multiplied by the overhead factor equals the overhead expenditures.
b. Because of rounding, components may not add to the totals shown.

c. Value of Facilities in 1957

As shown below in Table 6,* the total value of facilities employed in Soviet electronic R and D in 1957 and the value of facilities employed in Soviet military electronic R and D in 1957 were derived from the estimated value of buildings in these facilities using US analog information concerning the relationships between the value of buildings and the value of equipment. The value of facilities is shown at original cost -- that is, without allowances for depreciation.

3. Soviet Electronic Research and Development, 1956-62

a. Value of Soviet Electronic Research and Development, 1956-62

It was estimated that the rate of growth of the value of Soviet electronic R and D would be the same as the rate of growth of the labor force employed by Soviet electronic R and D, for the rates of growth were almost identical for the labor force employed in and for the expenditures on electronic R and D in the US during 1957-59. The US data specifically described R and D in the communication equipment and electronic components industry. 13/

To establish the rate of growth of the labor force employed by Soviet electronic R and D, a sample of 22 electronic R and D facilities was available for which the labor force could be established independently for 2 or more years. The average annual rate of growth of the labor force was computed for each of these facilities, and the span of years between labor force estimates for each facility was determined. This information is contained in Table 7.**

The growth was about 15 percent (computed using both the geometric and median values), and a median span of years from about 1955 to 1959 was selected to move the base-year estimates (1957) for the labor force and, consequently, expenditures throughout the period 1956-62. A weighted mean was not used as the measure of central tendency, because the use of the estimates of the labor force as weights would give excess weight to time periods that largely predate the base year, 1957, and would consequently distort the rate of growth during 1956-62. In addition, the large dispersion of the population of the sample dictated the use of the median or a geometric measure to avoid excessive influence of the higher extremes.

* Table 6 follows on p. 25.
** Table 7 follows on p. 26.

Table 6

Estimated Total Value of Facilities
Engaged in Soviet Electronic Research and Development
1957

Category of Electronic Research and Development	Value							
			Equipment					
	Buildings (Million 1955 Rubles)		Factor a/ (Percent)		Cost (Million 1955 Rubles)		Total b/ (Million 1955 Rubles)	
	Total	Military	Total	Military	Total	Military	Total	Military
Basic electronics	506.0	167.0	150	150	758.9	250.6	1,264.9	417.6
Techniques	113.8	32.7	150	150	170.7	49.0	284.5	81.7
Components	289.7	177.0	125	125	362.1	221.3	651.8	398.3
Functional elements	89.1	52.1	125	125	111.4	65.2	200.5	117.3
Electronic end equipment and systems	975.6	818.2	100	100	975.6	818.2	1,951.2	1,636.3
Total c/	1,974.1	1,247.0			2,378.7	1,404.2	4,352.9	2,651.2

a. 14/. Value of the buildings multiplied by the equipment factor equal the equipment cost.
b. At the original cost -- that is, excluding allowances for depreciation.
c. Because of rounding, components may not add to the totals shown.

Table 7

Estimated Average Annual Rate of Growth of the Labor Force Employed in Soviet Electronic Research and Development 1956-62

Facilities a/ Comprising the Sample							
		Initial		Terminal			
Number	Designation	Year	Labor Force	Year	Labor Force	Span of Years	Average Annual Rate of Growth
55	Radar Manufacturing and Testing Plant	1951	400	1956	500	5	4.6
42	Institute of Crystallography	1959	400	1961	450	2	6.1
13	NII 380 b/	1957	1,500	1961	2,000	4	7.5
37	Institute of Semiconductors	1957	400	1960	500	3	7.7
17	NII 2	1952	800	1955	1,000	3	7.7
21	NII 20	1950	2,000	1957	3,500	7	8.3
3	NII 11	1946	300	1951	450	5	8.5
50	Institute of Geomagnetics, Ionospherics, and Radiowave Propagation	1957	300	1960	400	3	10.1
66	Central Scientific Research Institute of Communications	1956	500	1959	700	3	11.9
48	Physics Institute imeni P.N. Lebedev	1958	1,200	1962	2,000	4	13.6
80	Polytechnic Institute imeni V.I. Lenin	1955	250	1960	500	5	14.9
9	NII 49	1953	2,000	1958	4,000	5	14.9
56	State Optical Institute imeni Vavilov	1952	700	1959	2,000	7	16.2
15	NII 619	1954	600	1957	1,000	3	18.6
2	NII 160	1950	600	1957	2,000	7	18.8
44	Institute of Physical Problems imeni S.I. Vavilov	1956	300	1961	750	5	20.1
33	Institute of Physics	1958	400	1960	600	2	22.5
54	Institute of Automation	1960	2,000	1965	6,000 c/	5	24.6
62	Leningradskoye Shosse Institute	1948	1,000	1954	5,000	6	30.8
38	Institute of Silicate Chemistry	1958	400	1960	750	2	36.9
25	NII 778	1952	1,000	1954	2,000	2	41.4
65	Central Scientific Research Institute of Cartography, Aerial Photography, and Geodesy	1954	100	1958	600	4	56.5
	Medians	1954-55		1959		5	14.9

a. For a complete identification of facilities, see Appendix B. The key number in this table refers to the number of the facility in the complete listing in Appendix B.
b. Nauchno-Issledovatel'skiy Institut (NII) -- Scientific Research Institute.
c. Based on a Soviet plan index.

b. Value of Facilities, 1956-62

The estimated value of facilities for Soviet electronic R and D for 1957 was extrapolated back to 1956 and forward to 1962 at an average annual rate of 8 to 9 percent. This percentage was selected because it approximates the rate of growth implied by a plan figure for investment in electronic R and D facilities during the period 1959-65 (3.0 billion to 3.5 billion comparable rubles). 15/

4. US Electronic Research and Development, 1956-62

a. Value of US Electronic Research and Development

The series for US expenditures on electronic R and D is based on estimates by components of the US Government for the years 1956, 16/ 1959, 17/ and 1962. 18/ The figure given [redacted] for 1962 was increased by 11.8 percent to make it comparable with the figures given for 1956 and 1959. The figure of 11.8 percent was derived from the relationship existing in 1959 between electronic R and D performed by private industry and that performed by all sources of electronic R and D. 19/ The figure in the original estimate for 1962 represented only the electronic R and D performed by industry. 50X1

The expenditures for the years 1957, 1958, 1960, and 1961 were estimated by interpolation between the figures given for the years 1956, 1959, and 1962. The series for expenditures for military electronic R and D was estimated by taking 81 percent of the total electronic R and D in each year. This percentage is the one reported by a US Government study for the year 1959. 20/

5. Ruble-Dollar Ratio

The aggregate ruble-dollar ratio used to convert 1955 rubles to 1955 US dollars was constructed by developing a ruble-dollar ratio for each category of electronic R and D. By taking their weighted arithmetic mean, these ratios were used to compute the aggregate ruble-dollar ratio. Expenditures within each category were allocated to labor, depreciation of equipment, depreciation of buildings, and materials. Expenditures for direct labor were determined by an analysis of the facilities. Expenditures for the depreciation of equipment were calculated by assuming a 5-year life for equipment, thus allocating one-fifth of the value of equipment as expenditures for depreciation of equipment. Similarly, expenditures for buildings were calculated by assuming a 20-year life for buildings and allocating one-twentieth of the value of buildings as expenditures for depreciation of buildings. The remaining expenditures were estimated to be divided between indirect labor and materials in the ratio of one part of indirect labor expenditures to two parts of materials expenditure.

The resulting allocation of expenditures based on the estimated expenditures for 1957 are as follows:

Category of Electronic R and D	Percent				
	Direct Labor	Indirect Labor	Depreciation of Equipment	Depreciation of Buildings	Materials
Basic electronics	50	10	15	3	22
Techniques	50	13	12	3	22
Components	44	14	8	3	31
Functional elements	44	14	8	3	31
Electronic end equipment and systems	40	18	6	2	34

The percentages calculated for the individual categories were weighted by the following ruble-dollar ratios in order to obtain a ruble-dollar ratio representative of aggregate expenditures on electronic R and D:

Input to Electronic R and D	Ruble-Dollar Weight $\frac{\text{1955 Ruble}}{\text{1955 US \$}}$
Labor (direct and indirect)	2.0*
Equipment	10.0**
Materials	9.0**
Buildings	6.0***

The aggregate ruble-dollar ratio derived from the above procedure was 4.9 1955 rubles per 1.0 1955 US dollar. This ratio was used for all conversions from rubles to dollars of aggregate estimates of Soviet expenditures on electronic R and D. The ruble-dollar ratios derived for the categories of electronic R and D were as follows: basic electronics, 4.88; techniques, 4.68; components, 4.92; functional elements, 4.92; and electronic end equipment and systems, 4.94. These ratios were weighted by the estimated expenditures on each category of electronic R and D in 1957 to obtain the aggregate ratio of 4.9.

* 21/
** 22/
*** 23/

APPENDIX B

FACILITIES ENGAGED IN ELECTRONIC RESEARCH AND DEVELOPMENT IN THE USSR

Number	City	Facility Designation	Estimated Labor Force	Year of Labor Force Estimate	Estimated Allocation	Estimated Type of Electronic Research and Development
Numbered Institutes						
1	Bolshevo		1,700	1957	Military	Electronic End Equipment and Systems: 100 percent (guided missile electronics [GM])
2	Fryazino		2,000	1957	Military	Basic Electronics: 10 percent (magnetic materials) Techniques: 10 percent (vacuum techniques) Components: 65 percent (electron tubes and semiconductors) Functional Elements: 15 percent (measuring instruments)
3	Gor'kiy		450	1951	Military	Components: 10 percent (crystals) Functional Elements: 40 percent (parametric and paramagnetic amplifiers) Electronic End Equipment and Systems: 50 percent (GM and navigational equipment)
4	Kaliningrad		1,000	1951	Military	Electronic End Equipment and Systems: 100 percent (GM)
5	Kunsevo		500	1952	Military	Electronic End Equipment and Systems: 100 percent (radar and GM)
6	Leningrad		1,700	1957	Military	Electronic End Equipment and Systems: 100 percent (underwater electronics)
7	Leningrad		1,700	1957	Military	Components: 25 percent (electron tubes) Functional Elements: 75 percent (microwave lines and transmitters)
8	Leningrad		1,500	1956	Military	Basic Electronics: 20 percent (magnetic materials) Techniques: 20 percent (tropicalization) Components: 20 percent (semiconductors) Functional Elements: 20 percent (amplifiers and measuring instruments) Electronic End Equipment and Systems: 20 percent (underwater electronics)
9	Leningrad		4,000	1958	Military	Electronic End Equipment and Systems: 100 percent (radar and GM)
10	Leningrad		1,700	1957	Military	Basic Electronics: 100 percent (carrier frequency techniques and acoustics)
11	Leningrad		1,500	1960	Military	Components: 100 percent (electron tubes and semiconductors)
12	Leningrad		1,700	1957	Military	Basic Electronics: 30 percent (propagation, antenna design, and gyroscopy) Electronic End Equipment and Systems: 70 percent (GM, computers, fire control systems, and navigational equipment)
13	Leningrad		2,000	1961	Military	Techniques: 10 percent (vacuum techniques) Components: 10 percent (electron tubes) Functional Elements: 10 percent (measuring instruments) Electronic End Equipment and Systems: 70 percent (GM, military TV, and radar)

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* Nauchno-Issledovatel'skiy Institut (NII) -- Scientific Research Institute.

Number	City	Facility Designation	Estimated Labor Force	Year of Labor Force Estimate	Estimated Allocation	Estimated Type of Electronic Research and Development
Numbered Institutes (Continued)						
14	Leningrad		2,500	1953	Military	Electronic End Equipment and Systems: 100 percent (underwater electronics)
15	Leningrad		1,000	1957	Military	Functional Elements: 20 percent (measuring instruments) Electronic End Equipment and Systems: 80 percent (navigational equipment and electronic countermeasures [ECM])
16	Leningrad		1,500	1958	Military	Electronic End Equipment and Systems: 100 percent (photofacsimile apparatus)
17	Marfino		1,000	1955	Military	Components: 50 percent (electron tubes) Electronic End Equipment and Systems: 50 percent (secure telephone systems)
18	Moscow		1,700	1957	Military	Electronic End Equipment and Systems: 100 percent (wire communications equipment)
19	Moscow		1,700	1957	Military	Electronic End Equipment and Systems: 100 percent (GM, infrared devices, radar, and navigation equipment)
20	Moscow		1,700	1957	Military	Components: 100 percent (electron tubes)
21	Moscow		3,500	1957	Military	Electronic End Equipment and Systems: 100 percent (radar, radio communications, and military TV)
22	Moscow		1,700	1957	Military	Electronic End Equipment and Systems: 100 percent (GM)
23	Moscow		1,700	1957	Military	Components: 100 percent (semiconductors)
24	Moscow		200	1950	Military	Electronic End Equipment and Systems: 100 percent (radar, ECM, and GM)
25	Moscow		2,000	1954	Military	Components: 10 percent (gyros) Functional Elements: 20 percent (measuring instruments) Electronic End Equipment and Systems: 70 percent (GM, radar, and telemetry equipment)
26	Novosibirsk		1,700	1957	Military	Electronic End Equipment and Systems: 100 percent (radar)
27	Novosibirsk		2,000	1958	Military	Components: 100 percent (electron tubes)
28	Pushkino		1,700	1957	Military	Electronic End Equipment and Systems: 100 percent (radio relay equipment)
Institutes of the Academies of Science						
29	Khar'kov	Institute of Radio Physics and Electronics	750	1961	Industrial	Basic Electronics: 100 percent (propagation, plasmas, magnetics, radio astronomy, physics of solids, and radio spectroscopy)
30	Khar'kov	Physical-Technical Institute of the Ukraine	500	1960	Industrial	Basic Electronics: 100 percent (crystallography)

50X1

Number	City	Facility Designation	Estimated Labor Force	Year of Labor Force Estimate	Estimated Allocation	Estimated Type of Electronic Research and Development
Institutes of the Academies of Science (Continued)						
31	Khar'kov	Physical-Technical Institute of Low Temperature	750	1961	Industrial	Basic Electronics: 100 percent (magnetic materials, crystallography, and low-temperature work)
32	Kiev	Institute of Electrical Engineering	750	1961	Industrial	Techniques: 30 percent (automation) Components: 30 percent (radio components and batteries) Functional Elements: 40 percent (paramagnetic and parametric amplifiers)
33	Kiev	Institute of Physics	600	1960	Industrial	Basic Electronics: 100 percent (physics of solids, nuclear physics, and high-vacuum techniques)
34	Kiev	Institute of Radio Engineering Problems	750	1961	Industrial	Basic Electronics: 100 percent (wireless transmission of power, rock crushing with radio frequencies, ultrasonic medical instruments, X-ray photography, and polymerization of plastics using radio frequencies)
35	Kiev	Computer Center	750	1961	Industrial	Techniques: 50 percent (automation) Electronic End Equipment and Systems: 50 percent (computers)
36	Kiev	Semiconductor Institute	750	1961	Industrial	Components: 100 percent (semiconductors)
37	Leningrad	Institute of Semiconductors	500	1960	Industrial	Basic Electronics: 30 percent (crystallography, infrared [IR], magnetic material, and photoelectrics) Techniques: 20 percent (frequency standards and miniaturization) Components: 50 percent (semiconductors)
38	Leningrad	Institute of Silicate Chemistry	750	1960	Industrial	Basic Electronics: 100 percent (investigation of silicon for semiconductors)
39	Leningrad	Physical-Technical Institute	1,000	1960	Military	Basic Electronics: 50 percent (dielectrics, crystallography, IR, maser, oscillography, optics, photoelectrics, and ultraviolet radiation) Techniques: 10 percent (miniaturization) Components: 20 percent (electron tubes, semiconductors, and batteries) Electronic End Equipment and Systems: 20 percent (space electronics)
40	Moscow	Acoustics Institute	750	1961	Industrial	Basic Electronics: 50 percent (acoustics and ultrasonics) Techniques: 10 percent (frequency standards) Components: 20 percent (waveguides, transducers, and cables) Functional Elements: 20 percent (oceanographic acoustical instruments)
41	Moscow	Computer Center	750	1961	Industrial	Electronic End Equipment and Systems: 100 percent (computers)
42	Moscow	Institute of Crystallography	450	1961	Industrial	Basic Electronics: 80 percent (crystallography, IR, nuclear physics, pulse techniques, synthetic mica and quartz, fine wires, and thin layers) Functional Elements: 20 percent (transmitters and receivers)
43	Moscow	Institute of Mathematics imeni Steklov	750	1961	Industrial	Techniques: 50 percent (machine translation) Electronic End Equipment and Systems: 50 percent (computers)

Number	City	Facility Designation	Estimated Labor Force	Year of Labor Force Estimate	Estimated Allocation	Estimated Type of Electronic Research and Development
Institutes of the Academies of Science (Continued)						
44	Moscow	Institute of Physical Problems imeni S.I. Vavilov	750	1961	Industrial	Basic Electronics: 100 percent (low temperature work and oscillography)
45	Moscow	Institute of Precision Mechanics and Computing Techniques	400	1960	Military	Basic Electronics: 20 percent (magnetic materials) Components: 20 percent (antennas) Electronic End Equipment and Systems: 60 percent (computers for machine translation, electron microscopes, and GM computers)
46	Moscow	Institute of Radio Engineering and Electronics	800	1959	Industrial	Basic Electronics: 50 percent (cathode emission, electrodynamics, propagation, masers, scatter, plasma, and pulse techniques) Techniques: 10 percent (coding and reliability of components) Components: 20 percent (semiconductors, electron tubes, waveguides, antennas, radio components, and cables) Functional Elements: 10 percent (measuring instruments, transmitters, and receivers) Electronic End Equipment and Systems: 10 percent (direction-finding equipment, space electronics, and telecommunications equipment)
47	Moscow	Laboratory of Information Transmission Systems	750	1961	Industrial	Basic Electronics: 10 percent (impedence measuring) Techniques: 20 percent (telegraph message coding and carrier techniques) Functional Elements: 10 percent (relay circuits) Electronic End Equipment and Systems: 60 percent (automatic telephone system equipment and multiplexing equipment)
48	Moscow	Physics Institute imeni P.N. Lebedev	2,000	1962	Military	Basic Electronics: 70 percent (acoustics, crystallography, dielectrics, IR, scatter, low temperature, maser, laser, optics, radio astronomy, propagation, and spectroscopy) Components: 15 percent (antennas, batteries, radio components, and semiconductors) Functional Elements: 5 percent (paramagnetic and parametric amplifiers) Electronic End Equipment and Systems: 10 percent (microwave equipment, navigational equipment, and underwater electronics)
49	Moscow	Radio Technical Institute	750	1961	Industrial	Basic Electronics: 10 percent (electronically controlled fusion) Components: 10 percent (wide-band double-cone transformers) Electronic End Equipment and Systems: 80 percent (high-speed electronic computer)
50	Moscow Oblast	Institute of Geomagnetics, Ionospherics, and Radiowave Propagation	400	1960	Industrial	Basic Electronics: 100 percent (ionospheric and tropospheric investigations, radio astronomy, and magnetic materials)
51	Novosibirsk	Institute of Radio Physics and Electronics	750	1961	Industrial	Basic Electronics: 100 percent (plasma and propagation)
52	Sverdlovsk	Institute of the Physics of Metals	750	1961	Industrial	Components: 100 percent (semiconductors)

Number	City	Facility Designation	Estimated Labor Force	Year of Labor Force Estimate	Estimated Allocation	Estimated Type of Electronic Research and Development
Other Research Institutes						
53	Baku	Unidentified Institute	2,000	1955	Military	Electronic End Equipment and Systems: 100 percent (fire-control systems)
54	Kiev	Institute of Automation	2,000	1960	Industrial	Basic Electronics: 20 percent (telemechanics) Techniques: 60 percent (automation) Components: 10 percent (semiconductors) Electronic End Equipment and Systems: 10 percent (telemetry equipment)
55	Kuchino	Radar Manufacturing and Testing Plant	500	1956	Military	Electronic End Equipment and Systems: 100 percent (clandestine devices)
56	Leningrad	State Optical Institute imeni Vavilov	2,000	1959	Military	Basic Electronics: 50 percent (optics, IR, and oscillography) Electronic End Equipment and Systems: 50 percent (IR devices and optical devices)
57	Leningrad	Central Scientific Research Institute of City and Rural Telephones	900	1959	Industrial	Techniques: 50 percent (code switching) Electronic End Equipment and Systems: 50 percent (telecommunications equipment)
58	Leningrad	"Forest Institute"	900	1959	Industrial	Components: 40 percent (electron tubes) Electronic End Equipment and Systems: 60 percent (TV equipment)
59	Leningrad	Institute of Electromechanics	900	1959	Industrial	Basic Electronics: 50 percent (optics and photoelectrics) Techniques: 30 percent (automation) Functional Elements: 10 percent (measuring instruments) Electronic End Equipment and Systems: 10 percent (direction-finding equipment)
60	Leningrad	Scientific Institute of Marine Communication	400	1952	Military	Electronic End Equipment and Systems: 100 percent (communications equipment, radar, and sonar)
61	Leningrad	Scientific Research Institute of Radio Broadcast Reception and Acoustics	600	1957	Industrial	Basic Electronics: 50 percent (acoustics, magnetic material, thermoelectrics, and ultrasonics) Components: 30 percent (radio components and semiconductors) Functional Elements: 20 percent (measuring instruments, receivers, and transmitters)
62	Moscow	Leningradskoye Shosse Institute	5,000	1954	Military	Electronic End Equipment and Systems: 100 percent (GM)
63	Moscow	Unidentified Institute	2,000	1955	Military	Electronic End Equipment and Systems: 100 percent (fire-control systems)
64	Moscow	All Union Electrical Engineering Institute imeni V.I. Lenin	500	1957	Military	Basic Electronics: 40 percent (magnetic materials and vacuum techniques) Techniques: 30 percent (automation and printed and synthetic circuits) Components: 10 percent (silicon power rectifiers) Electronic End Equipment and Systems: 20 percent (space electronics)
65	Moscow	Central Scientific Research Institute of Cartography, Aerial Photography, and Geodesy	600	1958	Industrial	Functional Elements: 100 percent (measuring instruments)

Number	City	Facility Designation	Estimated Labor Force	Year of Labor Force Estimate	Estimated Allocation	Estimated Type of Electronic Research and Development
Other Research Institutes (Continued)						
66	Moscow	Central Scientific Research Institute of Communications	700	1959	Industrial	Basic Electronics: 50 percent (acoustics, microwave, propagation, communications theory, radio noise, automatic control theory, reliability, and oscillography) Techniques: 10 percent (automation) Components: 20 percent (antennas, waveguides, cables, and radio components) Functional Elements: 10 percent (measuring instruments, transmitters, and receivers) Electronic End Equipment and Systems: 10 percent (telecommunications equipment and closed-circuit TV)
67	Moscow	Institute of Automatics and Telemechanics	800	1960	Military	Basic Electronics: 50 percent (theory of automatic control) Techniques: 10 percent (automation) Components: 10 percent (antennas) Electronic End Equipment and Systems: 30 percent (computers and GM)
68	Moscow	Metallurgical Institute imeni Baykov	1,300	1959	Industrial	Basic Electronics: 30 percent (crystallography) Techniques: 40 percent (automation) Components: 30 percent (semiconductors)
69	Moscow	Power Engineering Institute imeni Krzhizhanovskiy	700	1961	Military	Basic Electronics: 40 percent (ball-lightning phenomena) Components: 40 percent (electron tubes and semiconductors) Electronic End Equipment and Systems: 20 percent (computers)
70	Moscow	Scientific Research Institute for Computer Manufacture	900	1959	Industrial	Basic Electronics: 20 percent (magnetic materials) Techniques: 20 percent (automation) Components: 20 percent (radio components) Electronic End Equipment and Systems: 40 percent (computers)
71	Moscow	Scientific Research Institute of TV	900	1959	Industrial	Basic Electronics: 10 percent (optics) Functional Elements: 30 percent (measuring instruments, transmitters, and receivers) Electronic End Equipment and Systems: 60 percent (TV equipment)
72	Moscow	Scientific Research Institute of the Cable Industry	500	1960	Industrial	Components: 100 percent (waveguides and cables)
73	Mytishchi	Scientific Research Experimental Institute of Communications of the Ground Forces	600	1948	Military	Basic Electronics: 20 percent (scatter, pulse techniques, and propagation) Techniques: 10 percent (tropicalization) Components: 40 percent (antennas, batteries, radio components, and electron tubes) Functional Elements: 5 percent (measuring instruments) Electronic End Equipment and Systems: 25 percent (telecommunications equipment, buoys, recorders, radiosondes, and radar)
74	Novosibirsk	Unidentified Institute	2,000	1957	Military	Electronic End Equipment and Systems: 100 percent (radar)
75	Novosibirsk	Scientific Research Institute of High Frequency Telephony	900	1959	Industrial	Basic Electronics: 50 percent (propagation) Electronic End Equipment and Systems: 50 percent (telephone equipment)
76	Tomsk	Siberian Physical-Technical Institute	1,500	1960	Industrial	Basic Electronics: 50 percent (dielectrics, physics of the solid state, nuclear physics, propagation, IR, and scatter) Components: 20 percent (waveguides and semiconductors) Electronic End Equipment and Systems: 30 percent (radar)

Number	City	Facility Designation	Estimated Labor Force	Year of Labor Force Estimate	Estimated Allocation	Estimated Type of Electronic Research and Development
Educational Institutions						
77	Gor'kiy	Polytechnic Institute imeni A.A. Zhdanov	500	1957	Industrial	Components: 100 percent (electron tubes)
78	Gor'kiy	Gor'kiy State University	500	1957	Industrial	Basic Electronics: 100 percent (propagation)
79	Khar'kov	Artillery Radio Engineering Academy imeni Marshal Govorov	500	1957	Military	Electronic End Equipment and Systems: 100 percent (GM and EMC)
80	Khar'kov	Polytechnic Institute imeni V.I. Lenin	500	1960	Industrial	Basic Electronics: 100 percent (scatter, meteor trails, radio astronomy, and oscillographs)
81	Khar'kov	State University imeni A.M. Gor'kiy	200	1955	Industrial	Basic Electronics: 70 percent (oscillography, propagation, ultrasonics, and millimeter and submillimeter bands) Components: 20 percent (electron tubes, cables, and waveguides) Functional Elements: 10 percent (electron microscopes)
82	Kiev	Order of Lenin State University imeni T.G. Shevshenko	150	1954	Industrial	Basic Electronics: 70 percent (acoustics, dielectrics, luminescence, magnetic materials, physics of the solid state, IR, propagation, and thermoelectrics) Techniques: 15 percent (automation, correlation techniques, and reliability of components) Components: 10 percent (radio components and semiconductors) Electronic End Equipment and Systems: 5 percent (computers)
83	Kiev	Order of Lenin Polytechnic Institute	500	1957	Military	Basic Electronics: 60 percent (crystallography, dielectrics, pulse techniques, isotopes, thermoelectrics, physics of the solid state, and molecular electronics) Techniques: 10 percent (automation and radio broadcasting) Components: 15 percent (semiconductors) Electronic End Equipment and Systems: 15 percent (computers)
84	Leningrad	Red Banner Air Force Engineering Academy imeni A.F. Mozhayskiy	500	1957	Military	Components: 50 percent (semiconductors and gyros) Electronic End Equipment and Systems: 50 percent (ECM)
85	Leningrad	Military Red Banner Academy of Communications imeni Budenny	500	1957	Military	Basic Electronics: 40 percent (scatter, microwave, and propagation) Components: 20 percent (antennas and transmission lines) Electronic End Equipment and Systems: 40 percent (radar and telecommunications)
86	Leningrad	Electrotechnical Institute of Communications imeni M.A. Banch-Bruyevich	100	1958	Industrial	Basic Electronics: 40 percent (microwave, photoelectrics, pulse techniques, and propagation) Components: 10 percent (antennas and radio components) Functional Elements: 25 percent (paramagnetic and parametric amplifiers, measuring instruments, transmitters, and receivers) Electronic End Equipment and Systems: 25 percent (computers and TV equipment)

Number	City	Facility Designation	Estimated Labor Force	Year of Labor Force Estimate	Estimated Allocation	Estimated Type of Electronic Research and Development
Educational Institutions (Continued)						
87	Leningrad	Institute of Aviation Instrument Building	800	1949	Military	Basic Electronics: 30 percent (oscillography and pulse techniques) Components: 10 percent (electron tubes) Functional Elements: 30 percent (transmitters and receivers) Electronic End Equipment and Systems: 30 percent (radar and navigational equipment)
88	Leningrad	Institute of Electrical Engineering imeni V.I. Lenin	250	1960	Military	Basic Electronics: 30 percent (dielectrics, physics of the solid state, and photoelectrics) Components: 30 percent (semiconductors and cables) Electronic End Equipment and Systems: 40 percent (guidance and control equipment)
89	Leningrad	Institute of Electrical Engineering for Signaling and Communications	500	1957	Industrial	Basic Electronics: 100 percent (automatics and telemechanics)
90	Leningrad	Institute of Precision Mechanics and Optics	500	1957	Military	Basic Electronics: 50 percent (oscillography and optics) Techniques: 20 percent (automation) Electronic End Equipment and Systems: 30 percent (GM and computers)
91	Leningrad	Polytechnical Institute imeni M.I. Kalinin	1,000	1961	Military	Basic Electronics: 35 percent (dielectrics, nuclear physics, photoelectrics, and oscillography) Techniques: 15 percent (reliability of components) Components: 20 percent (electron tubes and semiconductors) Functional Elements: 10 percent (paramagnetic and parametric amplifiers and measuring instruments) Electronic End Equipment and Systems: 20 percent (radar and GM)
92	Leningrad	Leningrad State University imeni A.A. Zhdanov	1,000	1954	Military	Basic Electronics: 60 percent (acoustics, microwave, propagation, and ultrasonics) Components: 20 percent (electron tubes) Electronic End Equipment and Systems: 20 percent (radar)
93	L'vov	Polytechnical Institute	300	1954	Industrial	Basic Electronics: 70 percent (dielectrics and ceramics) Functional Elements: 30 percent (measuring instruments)
94	Moscow	Air Force Engineering Academy imeni N.E. Zhukovskiy	500	1957	Military	Electronic End Equipment and Systems: 100 percent (radar, direction-finding equipment, and GM)
95	Moscow	Military Artillery Engineering Academy imeni F.E. Dzerzhinskiy	500	1957	Military	Electronic End Equipment and Systems: 100 percent (GM)
96	Moscow	Aviation Institute imeni S. Ordzhonikidze	300	1958	Military	Basic Electronics: 40 percent (propagation and pulse techniques) Techniques: 10 percent (automation) Components: 40 percent (antennas, radio components, waveguides, and cables) Functional Elements: 10 percent (measuring instruments)

Number	City	Facility Designation	Estimated Labor Force	Year of Labor Force Estimate	Estimated Allocation	Estimated Type of Electronic Research and Development
Educational Institutions (Continued)						
97	Moscow	Electrical Engineering Institute of Communications	100	1958	Military	Functional Elements: 50 percent (transmitters and receivers) Electronic End Equipment and Systems: 50 percent (TV equipment)
98	Moscow	Electrotechnical Technicum imeni L.B. Krasin	500	1957	Military	Electronic End Equipment and Systems: 100 percent (radar)
99	Moscow	Higher Technical School imeni N.Ye. Bauman	400	1955	Military	Basic Electronics: 20 percent (ultrasonics) Techniques: 30 percent (automation) Functional Elements: 10 percent (measuring instruments) Electronic End Equipment and Systems: 40 percent (computers)
100	Moscow	Power Engineering Institute	1,000	1960	Military	Basic Electronics: 20 percent (laser research) Techniques: 30 percent (automation) Electronic End Equipment and Systems: 50 percent (computers and GM)
101	Moscow	Moscow State University imeni V.M. Lomonosov	1,000	1958	Military	Basic Electronics: 20 percent (crystallography) Components: 50 percent (semiconductors and antennas) Functional Elements: 15 percent (masers) Electronic End Equipment and Systems: 15 percent (computers)
102	Odessa	Electrical Engineering Institute of Communications	500	1957	Industrial	Electronic End Equipment and Systems: 100 percent (telecommunications equipment)
103	Saratov	State University imeni N.G. Chernyshevskiy	100	1958	Industrial	Basic Electronics: 50 percent (optics, oscillography, magnetics, and luminescence) Components: 50 percent (semiconductors and electron tubes)
104	Sverdlovsk	Ural State University imeni A.M. Gor'kiy	500	1957	Industrial	Basic Electronics: 100 percent (magnetics, materials, and crystallography)
105	Tomsk	Polytechnical Institute imeni S.M. Kirova	200	1958	Industrial	Basic Electronics: 100 percent (propagation)
106	Tomsk	State University imeni V.V. Kuybyshev	500	1957	Industrial	Basic Electronics: 100 percent (propagation, luminescence, dielectrics, photoelectrics, IR, and physics of the solid state)
Design Bureaus and Plant Laboratories						
107	Kazan	[redacted]	1,500	1949	Military	Electronic End Equipment and Systems: 100 percent (radar, underwater electronics, and intercept receivers)
108	Krasnogorsk		3,000	1959	Military	Electronic End Equipment and Systems: 100 percent (IR devices and optics)
109	Leningrad		400	1957	Military	Electronic End Equipment and Systems: 100 percent (radar, radio communications, and GM)

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Number	City	Facility Designation	Estimated Labor Force	Year of Labor Force Estimate	Estimated Allocation	Estimated Type of Electronic Research and Development
Design Bureaus and Plant Laboratories (Continued)						
110	Leningrad		1,000	1955	Military	Electronic End Equipment and Systems: 100 percent (radar, GM, underwater electronics, and mobile microwave [R-400])
111	Leningrad		900	1957	Military	Electronic End Equipment and Systems: 100 percent (navigational equipment, underwater electronics, direction-finding equipment, and beacons)
112	Moscow		600	1961	Industrial	Basic Electronics: 50 percent (materials for electron tubes) Components: 30 percent (electron tubes) Electronic End Equipment and Systems: 20 percent (IR devices)
113	Moscow		900	1957	Industrial	Techniques: 100 percent (standardization and coordination of specifications)
114	Moscow		1,000	1958	Military	Electronic End Equipment and Systems: 100 percent (radar)
115	Moscow		800	1956	Military	Electronic End Equipment and Systems: 100 percent (computers)
116	Moscow		500	1955	Military	Electronic End Equipment and Systems: 100 percent (military radio and GM)
117	Penza	"SAM" Plant, Laboratory of	1,500	1960	Industrial	Electronic End Equipment and Systems: 100 percent (computers)
118	Riga	"VEF" Plant, Laboratory of	1,000	1959	Industrial	Electronic End Equipment and Systems: 100 percent (radio, TV equipment, wire diffusion equipment, and telephones and telegraph)
119	Riga	Radio Plant imeni Popov, Laboratory of	100	1949	Industrial	Basic Electronics: 50 percent (communications theory and radio noise) Electronic End Equipment and Systems: 50 percent (broadcast radio and TV receivers)
120	Saratov		600	1956	Industrial	Components: 100 percent (electron tubes)
121	Saratov		900	1957	Military	Electronic End Equipment and Systems: 100 percent (radar)
122	Sverdlovsk		300	1957	Military	Electronic End Equipment and Systems: 100 percent (radio and TV equipment)
123	Taganrog		900	1957	Military	Electronic End Equipment and Systems: 100 percent (radar)
124	Vil'nyus		300	1957	Military	Functional Elements: 100 percent (measuring instruments for radar)

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APPENDIX C

ALLOCATION OF SUBSTANTIVE ACTIVITIES IN ELECTRONIC RESEARCH AND DEVELOPMENT IN THE USSR

Although it is not feasible to estimate the number of scientists, engineers, and technicians working in each substantive activity of Soviet electronic R and D, it is possible to rank the various substantive activities within each category of electronic R and D by estimating the number of research facilities participating in each activity. The terms used to describe the substantive activities are those found in the various sources reporting the activities. These terms are not altogether mutually exclusive and probably do not completely exhaust the substantive content that could be included in each category of electronic R and D. Nevertheless, the following estimated allocation is believed to indicate the main thrust of Soviet substantive activities in electronic R and D during 1956-62.

1. Basic Electronics

a. Ranking of All Substantive Activities

Substantive Activities	Number of Facilities Participating
Electromagnetic Wave Propagation	17
Magnetic Materials	14
Physics of Solids	11
Dielectrics	10
Crystallography	10
Acoustics	9
Infrared and Ultraviolet Radiation	9
Oscillography	9
Ionospheric and Tropospheric Investigation (for scatter techniques)	9
Photoelectrics	8
Nuclear Physics (for electronic applications only)	8
Carrier Frequency Techniques	7
Optics	7
Pulse Techniques	7
Radio Spectroscopy	7
Ultrasonics	6
Plasmas (magnetohydrodynamics)	4
Radio Astronomy (for electronic applications only)	4

1. Basic Electronics

a. Ranking of All Substantive Activities (Continued)	Number of Facilities Participating
Maser and Laser Research	4
Theory of Automatics and Telemechanics (automatic control)	4
Theory of Communications	4
Low-Temperature Investigations	3
Radio Noise	3
Luminescence	3
Thermoelectrics	3
High-Vacuum Techniques	2
Polymerization of Plastic Using Radio Waves	2
Materials for Electron Tubes	2
Theory and Design of Antennas	1
Gyroscopy	1
Wireless Transmission of Power	1
Rock Crushing with Radiofrequencies	1
X-Ray Photography	1
Synthetic Mica and Quartz	1
Fine Wires	1
Thin Films	1
Impedence Measuring	1
Meteor Trails	1
Ball Lightning	1
Cathode Emission	1
Electrodynamics	1
Isotopes	1
Reliability	1

b. Ranking of Military Substantive Activities	Number of Facilities Participating
Electromagnetic Wave Propagation	6
Dielectrics	6
Oscillography	5
Magnetic Materials	4
Photoelectrics	4
Acoustics	4
Optics	4
Infrared and Ultraviolet Radiation	4

1. Basic Electronics

b. Ranking of Military Substantive Activities (Continued)	Number of Facilities Participating
Pulse Techniques	4
Crystallography	4
Carrier Frequency Techniques	3
Ionospheric and Tropospheric Investigations (for scatter techniques)	3
Physics of Solids	3
Radio Spectroscopy	3
Maser and Laser Research	3
Nuclear Physics (for electronic applications only)	2
Ultrasonics	2
Theory and Design of Antennas	1
Gyroscopy	1
Radio Astronomy (for electronic applications only)	1
Low-Temperature Investigations	1
High-Vacuum Techniques	1
Theory of Automatics and Telemechanics (automatic control)	1
Ball Lightning	1
Thermoelectrics	1
Isotopes	1

2. Techniques

a. Ranking of All Substantive Activities	Number of Facilities Participating
Automation	15
Reliability of Components	3
Miniaturization (and subminiaturization?)	2
Vacuum Techniques	2
Tropicalization	2
Code Switching	2
Frequency Standards	1
Machine Translation	1
Coding of Telegraph Messages	1
Use of High-Voltage Lines for Telephone and Telegraph Carrier	1

2. Techniques

a. Ranking of All Substantive Activities (Continued)	Number of Facilities Participating
Standardization and Coordination of Specifications	1
Correlation Techniques	1
Printed and Synthetic Circuits (molecular electronics?)	1

b. Ranking of Military Substantive Activities	Number of Facilities Participating
Automation	9
Tropicalization	2
Vacuum Techniques	2
Miniaturization	1
Reliability of Components	1
Printed and Synthetic Circuits	1

3. Components

a. Ranking of All Substantive Activities	Number of Facilities Participating
Semiconductors	23
Electron Tubes	21
Antennas	11
Passive Components (resistors, capacitors, and coils)	11
Waveguides	8
Transmission Cable	8
Batteries	4
Crystals	1
Transducers	1
Transformers	1
Gyros	1

3. Components (Continued)

b. Ranking of Military Substantive Activities	Number of Facilities Participating
Semiconductors	13
Electron Tubes	12
Antennas	7
Passive Components	3
Transmission Cable	3
Batteries	3
Waveguides	1
Crystals	1
Gyros	1

4. Functional Elements

a. Ranking of All Substantive Activities	Number of Facilities Participating
Measuring Instruments	18
Amplifiers (including parametric and paramagnetic)	7
Transmitters	6
Receivers	6
Maser Devices	1
Relay Circuits	1
Electron Microscopes (electronic components)	1
Oceanographic Acoustical Instrumentation	1

b. Ranking of Military Substantive Activities	Number of Facilities Participating
Measuring Instruments	10
Amplifiers	6
Transmitters	1
Receivers	1
Maser Devices	1
Oceanographic Acoustical Instrumentation	1

5. Electronic End Equipment and Systems

a. Ranking of All Substantive Activities	Number of Facilities Participating
Radar	26
Guided Missile Electronics	23
Computers	17
Radio Communications Equipment	12
Television Equipment	10
Navigational Equipment	8
Wire Communications End Equipment and Systems	8
Underwater Electronics	7
Translation Machines	7
Infrared Devices	4
Radio Relay Equipment	4
Electronic Countermeasures	4
Direction-Finding Equipment	4
Multiplexing Equipment	3
Space Electronic End Equipment and Systems	3
Telemetry Equipment	2
Fire-Control Systems	2
Secure Communications Systems	1
Photofacsimile Equipment	1
Clandestine Devices	1
Optical Devices	1
Sonobuoys	1
Radiosondes	1
Radiotelescopes	1
Recording Equipment	1

b. Ranking of Military Substantive Activities	Number of Facilities Participating
Radar	26
Guided Missile Electronics	23
Computers	10
Radio Communications Equipment	10
Navigational Equipment	8
Underwater Electronics	7
Infrared Devices	4
Television Equipment	4
Radio Relay Equipment	4
Electronic Countermeasures	4

5. Electronic End Equipment and Systems

b. Ranking of Military Substantive Activities (Continued)	Number of Facilities Participating
Direction-Finding Equipment	4
Space Electronics	3
Translation Machines	3
Multiplexing Equipment	2
Fire-Control Systems	2
Secure Communications Systems	1
Wire Communications	1
Photofacsimile Equipment	1
Telemetry Equipment	1
Clandestine Devices	1
Optical Devices	1
Sonobuoys	1
Radiosondes	1
Recording Equipment	1

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