[redacted]

~~TOP SECRET~~
Controlled Dissem
Limited Distribution

NATIONAL INTELLIGENCE ESTIMATE

Soviet Military Research and Development

[ ]

~~TOP SECRET~~
NIE 11-12-72
19 September 1972
[redacted]

№ 176

THIS ESTIMATE IS SUBMITTED BY THE DIRECTOR OF CENTRAL INTELLIGENCE AND CONCURRED IN BY THE UNITED STATES INTELLIGENCE BOARD.

The following intelligence organizations participated in the preparation of the estimate:

The Central Intelligence Agency and the intelligence organizations of the Departments of State and Defense, and the NSA.

Concurring:

The Deputy Director of Central Intelligence

The Director of Intelligence and Research, Department of State

The Director, Defense Intelligence Agency

The Director, National Security Agency

The Director, Division of International Security Affairs, Atomic Energy Commission

Abstaining:

The Assistant Director, Federal Bureau of Investigation, and the Special Assistant to the Secretary of the Treasury, the subject being outside of their jurisdiction.

NIE 11-12-72

SOVIET MILITARY RESEARCH AND DEVELOPMENT

 [redacted]

CONTENTS

SOVIET MILITARY RESEARCH AND DEVELOPMENT

NOTE

This Estimate addresses the potential of Soviet military research and development. It first appraises the general magnitude and rate of growth of resources available for this purpose—i.e., the facilities, men, and money, and how efficiently these are used. It then assesses how effectively Soviet military research and development meets military requirements. It does not attempt to predict specific Soviet technological advances. This aspect of the problem is addressed in part in the series of NIEs on the various components of the Soviet military forces.

SUMMARY AND CONCLUSIONS

A. The USSR has long accorded high priority to research and development (R&D) on military weapon systems and related supporting technologies, including space programs. It has made substantial increases in the resources devoted to such R&D and has maintained a relatively satisfactory level of efficiency with which the resources are used. Comparable results have not been achieved in R&D related to civilian pursuits, but the Soviet leadership now appears to be giving it greater emphasis and attention.

B. Concerning resources, we have made estimates of what the Soviets are spending each year on their military R&D programs. But we recognize that such estimates cannot be compared, except very roughly, with estimates for similar expenditures in the US because of myriad problems including different currencies, price structures, economic priorities, and strategic goals. Paragraphs 15 to 26 of the text pages 7 to 10, present our approach to the estimates, which involves two complex and independent methodologies, and the results that it yields. The results could understate or overstate the true magnitudes by a wide margin. Nonetheless, the two independently-derived estimates are broadly consistent; they indicate that during the 1960s the growth in Soviet expenditures for military R&D plus space has been predominantly in support of the space effort. In this same period the estimated rates of increase in R&D facilities and manpower slowed; these rates of growth are now less than that for R&D expenditures as a whole.[1]

C. It is virtually impossible to measure the effectiveness of Soviet military R&D. Although the Soviets have demonstrated the ability to solve advanced technical problems, we do not know whether their end products reflect fully the original requirements for performance or not. We believe that the Soviets have established their own approach to military R&D which seems to emphasize the expeditious development of systems that will do a job simply and reliably.

---

[1] For the views of Vice Adm. Vincent P. de Poix, USN, the Director, Defense Intelligence Agency; Maj. Gen. Phillip B. Davidson, the Assistant Chief of Staff for Intelligence, Department of the Army; Rear Adm. Earl F. Rectanus, the Director of Naval Intelligence, Department of the Navy; and Maj. Gen. George J. Keegan, Jr., the Assistant Chief of Staff, Intelligence, USAF, on estimates of Soviet expenditures for military R&D, see their footnotes to paragraph 20, page 9 of the text, and to paragraph 65, Annex B, page 45.

D. This expeditious approach is followed within a vast R&D bureaucracy which tends toward conservatism. New ideas and concepts are subject to a variety of planning constraints and must be justified through numerous levels and agencies. And the Soviets often rely upon redundancy of effort, judging that the hedge against failure outweighs the greater expense involved.

E. We foresee little change in the way the Soviets go about carrying out their military R&D. The success that they have enjoyed will probably work against any major changes in procedures, at least in the near future. The various systems we expect them to introduce in the future will, for the most part, continue to represent improvements on present systems through subsystems upgrading or the continuation of established developmental trends. In general, the Soviets appear to favor this approach as contrasted with the search for radically new and untried concepts.

DISCUSSION

I. THE SOVIET VIEW OF RESEARCH AND DEVELOPMENT

1. The Soviet leadership views science and technology as fundamental to the growth of military power. They also see it as the key to a strong, modern economy and as a source of international prestige and influence. Accordingly, research and development[2] (R&D) enjoy a high national priority. The highest priority is given to military programs and some space programs, and to developments which contribute to an image of technological parity with, or superiority to, the US. Lesser, but growing, attention is paid to R&D related to civilian pursuits.

2. The Soviets are well aware of the importance of basic research in the sciences and support it generously. In many fields, researchers are free to pursue their work with few constraints. As a consequence, great strides have been made in key scientific areas. The USSR has also worked on building up industrial technology to support its R&D goals for the military and in space. But the Soviets are still weak in converting the results of their basic research into practical applications, especially in civilian R&D. In the past few years, Soviet leaders have attached increasing importance to closing this "technological gap."

3. The Soviets have decreased, but by no means have eliminated, their dependence on foreign technology in such key areas as in-

[2] Research and development as a whole includes basic and applied research in science and engineering, and in the design and development of prototypes and processes; *basic research* is original investigation for the advancement of scientific knowledge; *applied research* is directed toward discovery of new scientific knowledge with specific product objectives; *development* is actively concerned with problems encountered in translating research findings or other general scientific knowledge into specific products. The concept of R&D as used in this Estimate also includes testing and evaluation, and thus equates to the US concept of research, development, testing, and evaluation (R, D, T, & E).

strumentation and computers, which constitute supporting technology important to both military power and sustained economic growth. In these areas the Soviets continue to depend heavily on the acquisition of advanced Western equipment and technology. Development in these fields remains a priority goal, but progress has been slow, especially in nonmilitary applications, despite a substantial commitment of resources.

4. The Soviets have established three basic policy goals in civilian R&D which reflect concern with the low level of efficiency in this area. These are: to apply new technology more rapidly to the civilian economy; to improve the research environment with better equipment and a more effective scientific information system; and to find a better means of exercising control over the widely dispersed civilian R&D effort without weakening initiative. These goals, the subjects of various official government decrees, have been realized only on a small scale.

5. The extent and direction of Soviet military R&D will be influenced by the SALT agreements. The Soviets will certainly continue to pursue an active military R&D program under the agreements. Their willingness to limit the numbers of strategic weapons, while permitting qualitative improvements, indicates confidence that their R&D programs can meet competition with the US. In some instances, resources for this purpose could be shifted from additional deployment of present systems to R&D. For example, the Soviets probably will continue to develop more and better reconnaissance systems—i.e., "national means"—to ensure verification of US compliance with the SALT agreement. It is reasonable to assume that increased R&D on such improvements is already underway.

II. APPROACHES TO QUANTIFYING RESOURCES

6. The importance of R&D to the Soviet state is indicated by the rapid growth of resources—facilities, men, and money—that have been poured into these activities, especially into military R&D and space programs. The exact meaning of this effort is hard to define in more than general terms. It is especially difficult to relate this effort and its degree of success to similar US efforts. It is not clear just what activities are covered by expenditures for what the Soviets refer to as "science" (see Annex B). Moreover, neither the pattern of engineering employment, nor the level of efficiency of the operation is well understood. It is even more difficult to discuss these matters with regard to military R&D in particular. In this section we evaluate the resource inputs to Soviet military R&D. We later address the question of how effectively these resources are applied.

A. Research and Development Facilities

7. The number and size of facilities for research, development, and testing of Soviet weapon systems and space hardware have grown rapidly in the postwar years. Numerous scientific research and design institutes, experimental production plants, and major testing facilities were built—for example, the huge complexes at Tyuratam, Sary Shagan, and Kapustin Yar. If the Soviets saw a need for additional facilities to pursue a promising line of technological investigation, they undertook their construction with little hesitation. Construction of facilities, however, has not always resulted in development of operational systems. Thus, current and future construction of new facilities indicates additional R&D *potential*, and not necessarily production and deployment programs.

8. The resource base for R&D in support of the Soviet aircraft, missile, and space industries—measured in terms of the area of roof cover of identified facilities—grew rapidly in the early 1960s, at a rate of 15 to 20 percent a year, largely in support of new design programs. Since the mid-1960s it has continued to grow at 3 to 4 percent a year. From what little we know from the spotty data available, we believe that growth in other R&D facilities has been slower than that for the aerospace industries.

B. Scientific and Engineering Manpower [3]

9. The supply of highly trained and specialized scientific and engineering manpower has grown sharply over the past two decades. During this time substantial shifts have occurred in the occupational composition of this technical elite, reflecting shifts in demand since the mid-1950s, most notably for skills associated with military and space R&D. The average annual growth in numbers of engineers and natural scientists, which reached 11 to 13 percent a year during the period 1956-1963, has been 7 to 8 percent a year since then. Overall, the Soviets in 1970 had about 694,000 scientific workers in science and engineering and some 2.5 million engineers. Current enrollments in science and engineering indicate that this manpower pool will continue to grow at some 5 percent a year over the next five years to almost 1 million scientific workers and 3.4 million engineers in the mid-1970s. The advantage to the Soviets of this large body of trained manpower, particularly in engineering, has been neutralized somewhat by the assignment of trained personnel to non-technical jobs.

10. We estimate the total R&D work force in the USSR has grown from about 1.5 million in 1960 to close to 3.1 million in 1970 (about one-fifth of these are scientists and engineers with a college and university level education). The rate of growth has been 5 to 7 percent a year since 1963. Growth over the next 5 years could continue at about this rate, but more likely will decline slightly.

11. The Soviets attract the top scientific and engineering graduates to positions within the military R&D organizations which generally carry more prestige than civilian R&D organizations. Workers in the military R&D organizations are provided superior laboratories and other facilities, better opportunities for advancement, and housing preferences.

12. The quality of Soviet training of scientists and engineers is as good as it is in the West in many scientific and technological fields. One of the reasons may be early exposure of students to the scientific and technical disciplines. Physics is introduced in the fourth grade and one-third of the secondary curriculum is devoted to science and mathematics.

13. Nevertheless, a Soviet scientific and technical education has shortcomings. Until very recently, the aim was to develop special-

---

[3] The Soviets do not publish data on the number of workers actually engaged in either civilian or military R&D and we have not acquired any such data from classified sources. The Soviets do publish, however, many sets of statistics on manpower which bear directly on their overall R&D effort. For example, they regularly publish data on the number of Soviet workers holding degrees in engineering and on persons classified as "scientific workers" and as employed in "science and science services." Not all of this manpower is engaged in work in R&D. Many of these workers hold administrative, maintenance, or service positions and do not engage directly in R&D work. See Annex A, page 19 for additional details on this and other aspects of Soviet scientific and engineering manpower.

ized skills enabling the individual to perform efficiently only in specific areas, and the Soviet system has successfully fulfilled this aim. It has been less successful when the need arises for adaptability. The narrow specialties in which many Soviet scientists and engineers are trained produce limitations on their ability to integrate contributions from disciplines other than their own.

14. To add to their pool of scientific and engineering manpower, the Soviets have expanded part-time advanced training, but not without a penalty in the overall quality of training. Moreover, many part-time students are from older age groups and consequently do not have as long a period to use their acquired skills. In contrast to full-time students, graduates of part-time programs are not required to take assigned jobs. An indication of the quality of their training is the fact that those who manage, on a part-time basis, to receive engineering degrees and who seek engineering positions are usually hired only as a last resort. Most part-time graduates remain in jobs requiring only technician skills.

C. Outlays for Military Research and Development and Space Programs [4]

15. The conventional way to represent the resources available for military R&D and space programs—e.g., the research institutes, test facilities, manpower, and other inputs—is by means of the total expenditures involved. There are, however, no data that permit this to be done for the USSR in a reasonably straightforward fashion. Soviet financial data from official Soviet publications, and the detailed but incomplete information on Soviet facilities and programs observed in satellite photography, must be supplemented with a large amount of indirect data, subsidiary judgments, extrapolations, and assumptions to derive an estimate. There is no way of confidently telling how much error is introduced by each step in the process or whether, and to what extent, the errors offset one another or cumulate.

16. Even if an accurate estimate of expenditures for Soviet military R&D plus space programs could be derived, expressing it in terms permitting useful comparison with similar US expenditures is fraught with further problems. The US and the USSR have different currencies, economic priorities, price structures, institutional approaches, strategic goals, military tactics, and technical traditions—to mention only a few areas of difference. And even if R&D expenditure estimates in the US and the USSR were expressed in a common currency, the comparison could still only be used in the most general fashion as a gross measure of the relative effort. Moreover, an equal input of money does not imply an equal military achievement or capability. Used with other information, however, estimates of expenditures are helpful as one method—albeit imprecise—of assessing the relative R&D efforts and priorities of the US and the USSR.

17. We have made estimates—based on analysis of Soviet financial data—of Soviet expenditures for military R&D programs plus space programs in rubles. This analysis has been the principal basis for our past judgments. The ruble estimates have been converted to dollars by means of a ruble/dollar

---

[4] The derivation of the estimates of these expenditures, and a discussion of the inherent problems involved, are presented in Annex B, page 29.

conversion ratio. This ratio is based on available data on US and Soviet prices for complex, high technology equipment and represents a rough approximation of the comparative purchasing power of the ruble and the dollar in the area of R&D. The validity of the dollar estimates derived from Soviet financial data depends upon three factors: (a) the extent to which the coverage of "science" expenditures conforms to Western definitions of R&D; (b) the accuracy of our distribution of the Soviet expenditures between military and civilian programs; and (c) the extent to which the ratio used to convert the rubles to dollars represents the average purchasing power of the two currencies for R&D resources. The rate of growth of expenditures in rubles (1960-1970) is affected by the deflators used to convert currency units into constant units, and therefore by any inaccuracies in the deflators. Considerable uncertainty exists for each aspect of these calculations and it must be recognized that the estimate could overstate or understate the Soviet effort by a substantial margin.

18. As another approach, we have estimated directly what these Soviet R&D programs might have cost in dollars if they had been carried out in the US. A number of studies which attempt to cost particular aspects of the Soviet R&D effort directly in dollars have been done in the Intelligence Community, but no single study has presented comprehensive estimates of the cost in the US of all Soviet military R&D plus space programs. For purposes of this Estimate the work done in the Intelligence Community was collected and combined in order to develop for the first time this approach for estimating the magnitude of the Soviet military R&D plus space effort. We call this method the direct-costing method. The validity of the direct-dollar costs depends upon the precision with which the Soviet programs have been identified, defined, and projected both for past and future years, and upon the accuracy and relevance of the direct-costing relationships which have been applied. Again much uncertainty is present, and this approach could also overstate or understate by a substantial margin the true magnitude of the Soviet programs.

19. *Military R&D Plus Space Expenditures.* The Table below compares the estimates for Soviet expenditures on military R&D plus space derived from analysis of Soviet financial data with those developed by combining direct-cost estimates of individual programs.

ESTIMATED DOLLAR EQUIVALENTS OF SOVIET EXPENDITURES FOR MILITARY RESEARCH AND DEVELOPMENT PLUS SPACE PROGRAMS*

(Billion 1970 Dollars)

Year	Soviet Financial Data	Direct Costing
1960	5.4	6.9
1961	6.4	7.2
1962	7.4	7.7
1963	8.5	8.5
1964	9.7	10.0
1965	10.2	10.9
1966	11.0	12.1
1967	11.7	13.1
1968	12.2	13.8
1969	12.7–13.0	14.5
1970	13.8–14.6	13.6

*The figures in this Table are presented as single estimates rounded to one decimal place for reasons of ease of presentation, not because we have the confidence in them implied by such estimates. Because of the many sources of possible error in these figures, we have no basis for stating a range. The reader's attention is directed to the pertinent paragraphs of Annex B describing the methodologies and assumptions on which these figures are based.

20. The estimates derived from Soviet financial data are roughly of a similar magnitude and grow at about the same rate as those based on the direct-costing methodology, except for more recent years. There is no basis for considering one more accurate than the other, nor do the two series represent a likely range. Nevertheless, the two series are reasonably consistent despite the uncertainties of the task and the completely different approaches on which they are based. This consistency encourages the presumption that the general magnitudes which result are in accord with reality.[5]

21. *Military R&D Expenditures Alone.* These two approaches have been used to derive estimates of R&D expenditures directed at purely military goals. The first subtracts the costs of Soviet civilian space programs (e.g., unmanned lunar exploration and planetary probes) and military space programs already operational (e.g., satellite reconnaissance and communications) from the estimates based on Soviet financial data; these space costs have been estimated by direct costing. The second calculates costs of military R&D programs directly in dollars.

[5] Vice Adm. Vincent P. de Poix, USN, the Director, Defense Intelligence Agency; Maj. Gen. Phillip B. Davidson, the Assistant Chief of Staff for Intelligence, Department of the Army; Rear Adm. Earl F. Rectanus, the Director of Naval Intelligence, Department of the Navy; and Maj. Gen. George J. Keegan, Jr., the Assistant Chief of Staff, Intelligence, USAF, do not believe that the general consistency of results obtained from the two methodologies should encourage the presumption stated above. They believe that neither methodology produces very credible results, but they have considerably more confidence in the direct-costing approach. (For a further explanation of this view see their footnote to paragraph 65, Annex B, page 45.)

ESTIMATED
DOLLAR EQUIVALENTS OF
SOVIET EXPENDITURES FOR
MILITARY RESEARCH AND DEVELOPMENT[a, b]

(Billion 1970 Dollars)

Year	Soviet Financial Data (Less Space [c])	Direct Costing
1960	4.8	6.2
1961	5.6	6.4
1962	6.3	6.6
1963	6.7	6.6
1964	6.7	7.0
1965	6.1	6.8
1966	5.8	6.9
1967	5.6	7.0
1968	5.7	7.4
1969	5.7–6.0	7.5
1970	7.7–8.5	7.5

[a] The figures in this Table are presented as single estimates rounded to one decimal place for reasons of ease of presentation, not because we have the confidence in them implied by such estimates. Because of the many sources of possible error in these figures, we have no basis for stating a range. The reader's attention is directed to the pertinent paragraphs of Annex B describing the methodologies and assumptions on which these figures are based.

[b] Does not include National Aeronautical and Space Administration-type space programs, nor operational Department of Defense-type programs.

[c] Using a ratio of 1 ruble equals $2.

22. Of necessity, both series again appear roughly consistent, except in more recent years. The data imply that after the early 1960s, Soviet military R&D expenditures increased very little if at all, and that most of the growth in Soviet R&D came from the space programs. This conclusion is best understood in light of the fact that Soviet expenditures for military R&D were already high at the beginning of the 1960s. The relatively slow rate of growth during the 1960s—averaging only 2 percent a year—thus reflects

consistently high levels of activity throughout the 1960s. At the beginning of the 1960s more ballistic missiles, aerodynamic missiles, and military aircraft were under development than at the end. Although aircraft are now more advanced and more costly to develop, most of the missiles now in test are modifications of existing ones, rather than new systems, and consequently are less costly to develop.

23. In contrast, Soviet space programs were in their infancy at the beginning of the 1960s. During the decade (1960-1970) the number of space launches and estimated expenditures for space programs grew about nine-fold. We estimate that Soviet space programs of all types in 1970 cost the Soviets almost as much as military R&D programs.

24. We believe the resulting estimate—that the predominant growth element in Soviet R&D has been the space effort—is a true reflection of actual developments in the USSR, and not the result of attributing high costs to space programs and low costs to military ones. In both the US and the USSR the same plants and test facilities support missile and space development. Analogous, if not identical, methods have been used to estimate costs of the space and missile programs. They both, in turn, use methodologies similar to those developed to cost aircraft airframes. Thus we discern no reason for systematic upward bias in the estimates of the costs of Soviet space programs when compared to military R&D programs.

25. *Expenditures for Military R&D, 1971-1975.* The Ninth Five-Year Plan (1971-1975) calls for expenditures for "science" (i.e., for all R&D plus space) of 80 billion rubles, or an increase of 60 percent over the previous five-year period. This represents an average annual increase for the period of about 10 percent in current rubles. It is not unusual for actual expenditures to deviate from the planning figures, and it may well be that reported expenditures for the 1971-1975 period will fall below the planned levels. In any event, further inflation will probably make real growth less than 10 percent. If past rates of inflation continue, the projected rate of 10 percent in current rubles would equate to about 7 percent a year in constant rubles.

26. Military R&D alone may also increase by about 7 percent a year. There are, however, various considerations that could lead us to estimate slower or faster rates of growth. Supporting an estimate of a slower rate of growth is the apparent predominance of civilian R&D in recent growth and the fact that the expansion of facilities that carry out Soviet military R&D has slowed to about 3 percent a year. On the other hand, in the SALT context, Soviet leaders may wish to push military R&D programs more rapidly than in the past. An appropriate upper limit may be established by the following set of assumptions: if, (a) civilian R&D will grow at the same rate as the overall planned rate; (b) civilian space expenditures will not grow; and (c) the remaining growth will be for military R&D; then an arithmetic calculation indicates that military R&D could grow at a rate of 11 percent a year. These rates—a low of 3 percent a year, and a high of 11 percent—can be viewed as a reasonable assumed range for future possibilities. Under these assumptions, Soviet expenditures for military R&D may grow to the amounts as indicated below:

(Billion 1970 Dollars)

METHOD	1970	1972	1975
Soviet Financial Data	8–9	8–11	9–14
Direct Costing	8	8–9	9–13

III. EFFICIENCY IN USE OF RESOURCES

A. General

27. Estimates of the efficiency with which the resource inputs into Soviet military R&D and space programs are utilized have a bearing on our evaluation of these programs. Meaningful measures of efficiency of R&D activities, however, are difficult to develop even in the US where information is more complete. It is especially hazardous to compare the efficiency of R&D in different countries which have different priorities, price structures, and practices. But some insights can be obtained by comparing in a general way Soviet military R&D with civilian R&D in the USSR and with military R&D in the US, and relating these comparisons to institutional aspects of the Soviet military R&D establishment.

B. The Military Compared to the Civilian Sector in the USSR

28. Soviet R&D presents a clear split level in efficiency. Military R&D is more efficient than civilian for several reasons. It is efficient in that the customer is able to present his requirements to the R&D establishment and to participate in the development, testing, and production process through military-technical committees. Military R&D also traditionally has had first claim on resources, attracting the brightest scientists and engineers and the highest quality material and equipment. Its overriding priority has reduced the supply problems that plague civilian R&D. For example, the military sector absorbs most of the available computer capacity; numerous Soviet scientists working on civilian projects have complained about the handicap of inadequate access to computers. Workers in military R&D also receive higher wages because of extensive bonus supplements.

29. Of the two basic characteristics that distinguish military from civilian—better organization and higher priority—the former is often more important. For example, when high priority has been assigned to selected civilian projects, such as computers, the increased allocation of funds and materials has not produced good results quickly. Organizational, party, and bureaucratic barriers to coordination and communication, prevalent in civilian R&D, often have frustrated the effort. Military and civilian R&D differ significantly in the degree of interaction between the R&D organizations and their customers. Participation by the Ministry of Defense in the military R&D process is very great, while in civilian R&D researchers, designers, and customers are usually physically and administratively separate. There is no evidence that significant changes have been made recently in the management and planning of military R&D; the Soviets must find their general approach to be relatively satisfactory.

30. The Soviet leadership has been attempting to make civilian R&D more efficient and responsive to national needs, especially in areas which will contribute to economic growth. The Soviets in recent years have granted civilian R&D managers greater flexibility, have forced them to become economically accountable, have adopted monetary incentive schemes, and have tried to bridge the gap between research and production by establishing research organizations at a number of key industrial plants—techniques borrowed from military R&D.

31. Prospects for making civilian R&D more efficient are not outstanding; it is unlikely that there will be much "spinoff" from the classified military programs, or that resources will be shifted from military R&D, where they

probably can be utilized much more effectively than in civilian R&D. Nevertheless, pressures from the leadership for improvement in efficiency in production in general may lead to the allocation of a greater share of resources, to civilian R&D, but probably only if the total resources allocated to R&D continue to grow.

C. Soviet Compared to US Military Research and Development

32. It is difficult to compare the relative efficiency of Soviet and US military R&D. Part of this difficulty is a result of the different mix of resources used in the two countries. In the USSR manpower is relatively plentiful and capital equipment relatively scarce compared to the US. The Soviets therefore use more lower priced manpower and less higher priced equipment to do the same jobs. One Soviet R&D administrator has said that a US R&D worker produces twice as much as his Soviet counterpart. Our understanding is that this difference in productivity—whatever its magnitude—is due partly to the much greater array of equipment at the disposal of the US worker. But these judgments about R&D in general do not tell us much about military R&D in particular. We have no data that permit a direct measurement of the relative efficiency of Soviet and US military R&D in using resource inputs.[6]

[6] A ruble/dollar ratio for the output of Soviet military R&D and space programs would imply a specific relationship between the efficiencies of US and Soviet programs if compared with a ruble/dollar ratio for inputs to these programs. Ruble/dollar ratios *fully representative* of the relationship between the ruble and the dollar prices for the outputs of, and inputs to, Soviet programs would be necessary in order to attempt to measure relative efficiency this way. If more information becomes available in the future, such a measure could be undertaken.

IV. THE APPROACH AND PERFORMANCE OF SOVIET MILITARY RESEARCH AND DEVELOPMENT

33. While it is possible to make some general statements about the efficiency of military R&D in relation to its civilian counterpart, it is difficult, if not impossible, to measure the effectiveness of Soviet military R&D—i.e., the ability to solve the technical problems posed to it—by any absolute or objective standard. In order to do so we would have to assume that end products reflect fully the requirements levied on the R&D process and that our estimates of the performance of those end products are essentially correct. Neither of these assumptions can be demonstrated with confidence. What it is feasible to do, however, is to set forth what we know about how military R&D activities are managed and controlled within the USSR and to draw some inferences from this base.

A. Organizational Aspects[7]

34. Soviet R&D activities today enjoy a fair degree of latitude for cross fertilization and cooperation between their various components. This is unlike the situation that obtained under Stalin, when the best scientific minds were often forced to carry out their research under conditions of confinement and close scrutiny by state security organs—a situation that restricted the free exchange of ideas and concepts that is desirable for rapid scientific and technical advances. Nevertheless, scientists must still work within the confines of a vast and cumbersome bureaucracy which tends toward conservatism, and they still do not enjoy the freedom of exchange that characterizes the US scientific community.

[7] See Annex C, page 51 for a further discussion of the organization of Soviet military R&D.

35. In the US, the development and production of advanced weapon systems are performed mainly by private industry under contract to government agencies. In the Soviet economy, however, there is no private sector—all institutions having an R&D function are operated directly by one or another agency of the government. Overall R&D is controlled by the Politburo which receives advice on policy planning involving military R&D primarily from the staffs of the Central Committee, the Council of Ministers, and the Defense Council. Once a decision on a military R&D project has been made, the project is then turned over to the Military-Industrial Commission (VPK) of the Council of Ministers for implementation and supervision. From that point on, the VPK acts as the controlling peak of a pyramid of organizations, each having some element of the project to implement or on which to provide advice and guidance.

36. The bureaucratic relationships overseen by the VPK were already working before its establishment. Soviet military R&D on any one type of weapon system—such as fighter aircraft—has long enjoyed a high degree of ongoing cooperation between research and design, production, and military consumer. Representatives of design bureaus, production plants, and service users constitute ad hoc teams to follow the R&D program from conception to deployment. But this degree of multiple involvement also has its drawbacks. Any R&D project is subject to influence from a variety of organizations, each of which has its own ideas about what needs doing and how it should be done. Moreover, such cooperation requires standardization, and any new ideas or concepts must be justified through numerous echelons and agencies and are subject to a variety of technical, institutional, and planning constraints and biases.

B. Technical Considerations [8]

37. Soviet basic research in fields applicable to military developments probably is about equal in quality and scope to that of the West. Theoretical work is generally excellent. For example, Soviet theoretical work in aerodynamics is among the best in the world. Further, the Soviets have looked for theoretical solutions which would permit simple hardware designs using proven components. This approach seldom leads to optimum performances, but it does speed development and ease manufacturing, operational, and maintenance problems. And the Soviets have, where possible, taken advantage of advances in other countries to further their knowledge or to by-pass certain steps in their own developmental processes. In developing their missilery, they initially relied heavily on captured German equipment and documents as well as on the talents of many German scientists and engineers whom they took prisoner during World War II. In the early days of nuclear weaponry, they clandestinely obtained much data on US and other Western techniques. But the Soviets have also developed their own approaches and high technical competence, and their present military R&D in this field is, overall, a distinctly native product. In some fields they continue to rely heavily on a substantial effort for the acquisition of foreign technology.

38. In developing their own approaches to military R&D, the Soviets have generally shown a predisposition to keep the requirements of production and use in mind, to emphasize the essentials, and to develop that system which will most simply and reliably do the required job. Their early missile guid-

[8] See Annex D, page 57 for a discussion of technical achievements and considerations in specific technological areas.

 [redacted]

ance took advantage of their well-developed rocket-engine technology and avoided the need for lightweight digital computers which were then in a primitive state of development. Their Mig-21 was designed to do a specific job of interception and to be easy to manufacture, maintain, and fly. Once having established a design approach, they have then preferred to make many incremental changes, rather than a few quantum jumps. In this they prefer to use standardized, proven, off-the-shelf components rather than make major changes in subsystems with each new weapon system. They effectively use conventional materials and proven techniques to give military products the desired service life, and to decrease the time needed to develop them.

39. Their predisposition to put out relatively unsophisticated models early in the research effort, and then to upgrade them through subsequent model changes, permits the Soviets to field an operational model early, and to make improvements as a result of continued field experience and improvements in technology. Early surface-to-air missiles (SAMs) have been steadily improved by subsequent modifications; the mission flexibility of the Mig-21 has improved through the fielding of over 10 modifications; and the early Soviet nuclear submarines apparently met design specifications only years after their initial operations. The succession of incremental changes permits the most recently deployed weapons to be relatively up to date, but it also sometimes gives the forces a number of older models which do not represent the forefront of technology.

40. In several instances where they have departed from this philosophy, they have run into trouble. In the case of the SL-12 space booster they encountered numerous problems which resulted in a very poor record of success during the first three years of flight testing. Their largest space booster, the J-vehicle, has yet to be successfully flown. Their solid-propellant intercontinental ballistic missile (ICBM), the SS-13, apparently is having problems. These, and other troublesome ventures, may have tempered their willingness to take bold strides beyond proven concepts or techniques. We know of no deployed weapon system which fully used what we estimated was the state-of-the-art in their technology at the time of initial design.

41. This is not to say that they have never been successful in exploring new native technology. They have, for example, shown boldness in their approach to the development of antiballistic missile and antisatellite systems. The areas where the Soviets are likely to be venturesome are those where they believe the US, or some other Western nation, is making advances that could significantly affect the Soviet strategic position. There are, for example, indications that the Soviets have begun R&D on laser beam weapons. Such work may have been undertaken in the belief that the US had begun a similar program. Under such circumstances, we believe that Soviet decision-makers act swiftly to authorize R&D since they cannot afford to do otherwise.

42. One characteristic of the Soviet approach to military R&D which usually results in a reliable product in a relatively short time is that of competition between two or more design teams. This aspect has been most evident in the development of aircraft and missiles. It appears that when a decision is made to produce a new weapon system, the general specifications are handed to several designers with the understanding that final acceptance will depend on the evaluation of the product. Within the general guidelines laid down, each design team then examines the technology necessary to meet the requirement and pro-

ceeds to develop an experimental prototype. It probably is at this point that the individual designs are examined. Two or more are then chosen for further work, often with instructions from a central design bureau to incorporate whatever features were considered desirable in a design that was being dropped.

43. The process generally continues until the systems have reached the flight test stage and then the decision is made as to which to put into series production. In some instances one design clearly is favored and the other projects are abandoned. More often, the rejected system undergoes limited deployment. Regarding this competitive approach in the development of aircraft, five prototypes of Mach 2 interceptors were flown in 1956—three Migs and two Sukhoy types. One of the Migs was selected for use in Frontal Aviation as was one of the Sukhoy types. Another of the Sukhoy aircraft was selected for use in air defense. In the case of missiles, the SS-7 and SS-8 were developed concurrently as were the SS-9 and the SS-X-10. In each case the former was widely deployed while the other was deployed only in small numbers, or not at all. The SS-11 and SS-13 were probably also in competition with one another in a developmental program aimed at a small ICBM suitable for widespread deployment. One system, the SS-11, followed the off-the-shelf approach while the other, the SS-13, involved the new solid-propellant technology. The SS-11 obviously won but, even so, the SS-13 was deployed in limited numbers.

44. While the competitive approach has produced reliable, useful systems, it must be very costly, especially when even the clear loser is rewarded with a modicum of deployment. The Soviets apparently feel, however, that the rewards gained by this approach overshadow the expense involved.

C. Implications for the Future

45. Barring some major reorganization of their R&D establishment and its management, which we consider unlikely, we foresee little change in the way the Soviets go about carrying out their military R&D. The success that they have enjoyed in fielding a succession of new weapon systems will probably militate against any major changes in the procedures, at least in the near future. The various oncoming systems we expect them to introduce in the future (discussed in detail in the appropriate NIEs on the Soviet military forces) will, for the most part, represent improvements on present systems through subsystems upgrading or continuation of established developmental trends, rather than through the implementation of radically new concepts. The competitive approach in weapon system development will almost certainly continue, with heavy reliance on proven techniques and equipment. Bold innovative programs probably will only be undertaken when the stakes are great enough to justify the risks involved, and even then the chances of success will not be as great as those taken under their traditional competitive approach.

ANNEX A

SOVIET SCIENTIFIC AND ENGINEERING MANPOWER

SOVIET SCIENTIFIC AND ENGINEERING MANPOWER

A. Introduction

1. The Soviets do not publish data on the number of workers actually engaged in either civilian or military research and development (R&D), and we have not acquired any such data from classified sources. The Soviets do publish, however, many sets of statistics on manpower which bear directly on their overall R&D effort. For example, they provide data annually on the number of Soviets graduating in engineering and on persons classified as "scientific workers," and on the work force in "science and science services." We believe this information to be reasonably reliable and therefore use it as a basis for making our estimates on the level and rate of growth of this manpower. This Annex presents these estimates. We also provide some US-Soviet comparisons in these fields and, finally, we briefly examine the Soviet educational system which supplies this manpower.

B. Scientific Manpower

2. The Soviets annually publish extensive data on the total number of what they call "scientific workers" in the USSR. They break down this information by field of specialization, by geographical location, and even by national origin. In providing these data the Soviets use the term "scientific workers" which is much different in concept than the category known in the US as "scientists." The Soviets define this term as including all persons holding graduate degrees from universities in science and all persons engaged in research regardless of their educational background. Their definition[a] encompasses such fields as research on law and art which are not classified as "science" in the US.

3. R&D as used in the context of this paper draws manpower primarily from the fields of natural science and what the Soviets call "engineering sciences" (distinct from engineers, as such) and we therefore included these categories in discussing Soviet "scientific workers." In the decade of the 1960s this segment trebled (see Table A-I, page 20) while the total civilian labor force expanded by only 12 percent. Over a longer period (about the past 20 years) the rate of growth of this segment rose markedly during the late 1950s and early 1960s, followed by a decline in the rate of growth in the latter part of that decade:

Period	Average Annual Growth of Selected Categories of Scientific Workers	
	Percentage Rate	Thousands of Workers
1951-1955	6.7	9
1956-1963	13.5	34
1964-1970	7.0	38

[a] The complete Soviet definition for "scientific workers" reads as follows: (a) academicians who are full or corresponding members of an academy of science; (b) all persons who have an academic degree of doctor or candidate of science, or an academic title of professor, lecturer, senior or junior research associate, or assistant regardless of place or character of work; (c) persons conducting scientific research work and scientific pedagogical work in higher educational institutions, regardless of degree or academic title; and (d) other specialists who do not have an advanced degree or academic title but are doing research work in industrial enterprises, and design organizations.

TABLE A-I

SOVIET SCIENTIFIC WORKERS IN SCIENCE AND ENGINEERING BY SPECIALTY, 1960–1976 [a]
(Thousands)

	1960	1962	1964	1966	1968	1970	1972	1974	1976
Physics and Mathematics	29.0	48.3	58.2	70.8	83.0	95.3	101	113	125
Chemistry	26.2	25.4	31.6	36.7	41.7	45.8	49	54	59
Biology	15.1	21.6	25.7	29.8	34.1	37.3	41	45	49
Geology and Mineralogy	10.7	13.4	15.4	17.5	19.3	20.3	22	24	26
Agriculture and Veterinary Sciences	21.2	25.5	29.1	31.7	33.3	35.4	40	44	47
Medical and Pharmaceutical Sciences	32.2	33.5	35.1	39.3	44.6	50.0	51	55	58
Engineering Sciences [b]	129.8	201.3	269.3	319.6	363.0	409.5	479	532	597
Totals	264.2	369.0	464.4	545.4	619.0	693.6	783	867	961

[a] All statistics up to 1970 were obtained from official Soviet publications. Standard statistical methods were used to establish an average rate of growth up to 1970. This average rate was then projected to 1976.

[b] Includes only these engineers classified as "scientific workers", i.e., persons with graduate degrees in engineering, and engineers irrespective of degrees, working in scientific research organizations. They comprise about 16 percent of all persons classified by the USSR as engineers (see Table A-II, page 21).

This pattern of growth reflects the step-up in the Soviet strategic nuclear missile and space effort resulting from decisions probably made in the mid-1950s. The number of workers in the fields of physics, mathematics, and engineering—all essential to military R&D—has grown about eight-fold since 1950 (during this period the total civilian labor force expanded by only 30 percent). Since 1963, this total has grown only by some 60 percent, although during this recent period the share of those with advanced degrees has increased.

C. Engineering Manpower

4. Engineers are actually engaged in the direct performance of basic and applied research, and in the development and control of manufacturing technology. They design and build weapon and system prototypes, and maintain facilities and instrumentation. The term "engineer" as used by the Soviets, and therefore as used in this report, denotes a person who has received a diploma in engineering from a higher educational establishment. When compared roughly with US data, however, official Soviet figures which report the employment of such persons overstate substantially the number of persons actually employed as engineers. We base this judgment on an official past Soviet census [10] which indicated that as many as one-half of the persons with engineering degrees worked in managerial, administrative, or other essentially non-engineering occupations. (For example, Soviet Party leader Leonid Brezhnev holds a degree in metallurgical engineering and is therefore counted as an engineer in government and administrative institutions.) Moreover, certain Soviet categories of engineering (e.g., cartography, architecture, and hydrography) are not counted as such in the US. Nevertheless, we believe that the published

[10] The census of 1959—the last census which has included these data.

Soviet data provide a reasonably reliable indication of trends and areas of emphasis in allocating engineering manpower. These data show that the total number of employed engineers for certain years through 1971 [11] was as follows:

1950	400,000
1955	598,000
1960	1,110,000
1963	1,421,000
1965	1,631,000
1966	1,734,000
1967	1,960,000
1969	2,400,000
1970	2,486,000
1971	2,650,000

[11] The latest year for which official Soviet data are available.

We have projected these figures through 1976 by major engineering specialty on the basis of current university enrollments. Table A-II presents this projection for selected years.

5. The patterns of growth of Soviet engineers is similar to the growth of selected categories of "scientific workers," i.e., rapid growth since 1950 with the greatest increase in the 1955-1963 period, followed by a slowdown in the late 1960s:

Period	Average Annual Growth of Soviet Engineers	
	Percentage Rate	Thousands of Engineers
1951-1955	8.4	39
1956-1963	11.7	104
1964-1970	8.3	152

TABLE A-II

SOVIET ENGINEERS IN THE LABOR FORCE BY SPECIALTY, 1960–1970 [a]
(*Thousands*)

	1960	1966	1967	1970	1971	1972	1974	1976
Geology and Prospecting	51.3	64.0	69	81	85	87	95	104
Minerals Exploration	61.8	79.7	86	103	108	110	121	133
Power Engineering	82.1	95.6	101	117	122	125	133	142
Metallurgy	47.9	67.2	74	91	96	103	110	121
Machine Building and Instrument Construction	314.9 [b]	441.3	393	448	470	499	537	551
Electronics, Electrical Equipment Construction, and Automation	..	146.4	283	429	470	502	594	680
Radio and Communications	48.5	100.1	123	170	183	195	222	252
Chemical Technology	76.1	112.9	126	157	166	177	194	212
Construction	172.1	257.6	287	359	382	405	449	485
Transport	72.0	111.9	126	159	169	180	196	217
Other Specialties, Including Consumer Products, Geodesy, Meteorology, etc.	183.4	257.6	292	372	398	422	476	517
Total (Rounded) [c]	1,110	1,734	1,960	2,486	2,649	2,805	3,127	3,414

[a] Official Soviet data on the *total number* of engineers is published annually. Except for the years 1960 and 1966, however, this total has not been broken down by specialty. The figures for each specialty after 1966 are based upon average rates of growth in each field.

[b] This figure includes both machine building and electronics specialties.

[c] About 16 percent of the total number of engineers for each year is categorized as "scientific workers"—i.e., engineers working in scientific research and teaching organizations.

The most rapid growth was in the specialties on which military R&D is heavily dependent.

D. Employment in Research and Development

6. Numbers of scientists and engineers, however, do not equate to employment in R&D. Many of the scientific workers are employed as teachers, and are therefore not employed in R&D. Most of the engineers are employed in production, construction, transportation, and other non-R&D positions. Moreover, most employees in R&D do not have degrees in science or engineering.

7. An approximation of total full-time equivalent Soviet employment in R&D (excluding the social sciences and humanities) can be derived from reported Soviet employment in "science and science services." This employment is defined by the Soviets as numbers of administrators, professional staff, and non-professional staff in scientific research establishments; in design, experimental, and testing organizations; and in surveying, geological, and hydrometeorological work. By subtracting reported numbers of survey, geological, and hydrometeorological service workers and adding estimates of numbers of scientific workers employed in R&D at higher educational and industrial enterprises, we arrive at an approximation of numbers of R&D personnel in universities, enterprises, and at research, design, experimental, and test organizations. These numbers are set forth in Table A-III, page 23.

8. Employment in R&D is estimated to have grown from about 1.5 million in 1960 to 3.1 million in 1970 (some one-fifth of these are scientists and engineers with a college or university level education). The rate of growth has been 5 to 6 percent a year since the mid-1960s, compared to an average of 7 percent for scientific workers in science and engineering and 9 percent for engineers. If, as is estimated, the number of scientific workers and engineers grows at a rate of 5 percent a year through the mid-1970s, employment in R&D will probably grow no faster, and, most likely, will grow more slowly.

E. Some US-Soviet Comparisons

9. Because of conceptual differences in the statistical reporting of the two countries, it is difficult to make valid comparisons involving US and Soviet science and engineering manpower. The narrower concepts of "scientist" and "engineer" as used in the US generally will result in an overstatement of Soviet total numbers in each of these areas when direct comparisons are attempted. Keeping this limitation in mind, a comparison of the trend and size of scientific and engineering manpower nevertheless does provide an insight into Soviet strengths and relative priorities.

10. We can estimate with some confidence the total number of personnel holding college degrees and working the equivalent of full time in R&D in USSR. We compare this total with comparable US data in the Table below. As can be seen, growth in the USSR has been at a more rapid pace than in the US. But we

PERSONNEL WITH A COLLEGE DEGREE EMPLOYED FULL TIME IN RESEARCH AND DEVELOPMENT

(Thousands)

Year	US	USSR
1954	237	...
1955	...	141
1958	355	189
1961	425	288
1965	496	443
1968	551	534
1970	545	622

TABLE A-III

SOVIET EMPLOYMENT IN RESEARCH AND DEVELOPMENT

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Employed in Research Institutes Design Bureaus, Experimental Plants, and Test Establishments [a]	1,304	1,557	1,746	1,881	1,990	2,115	2,222	2,322	2,450	2,576	2,675
Employed in Universities [b]	31	33	37	41	42	46	57	62	60	58	57
Employed in Industrial Enterprises [c]	123	129	138	126	147	156	156	174	246	339	384
Total R&D Employment	1,458	1,719	1,921	2,048	2,179	2,317	2,435	2,558	2,774	2,973	3,116
With College Education [d]	249	288	349	374	406	443	454	490	534	585	622
With Advanced Degrees [e]	62	67	67	73	79	86	95	105	115	126	139

[a] Employment in "science and science services" (reported) less employment in geologic and hydrometeorological services (reported) gives employment in research institutes, design bureaus, experimental plants, and test establishments. Numbers of social scientists in research institutes (estimated to grow from 28,000 to 89,000) are subtracted from this number, and full-time graduate students engaged in R&D at research institutes (estimated to grow from 5,000 to 10,000) are added.

[b] "Scientific workers" at universities (reported) less social scientists at universities (reported total social scientists, less those at research institutes) gives total numbers of natural scientists, military scientists, and engineers at universities. One third of their time is reported to be devoted to R&D; the figures given here represent man-year equivalents.

[c] Total employment in R&D at industrial enterprises is assumed to be three times the number of scientific workers. This number was arrived at by subtracting scientific workers at research institutes (reported) and in universities from total scientific workers.

[d] Total of natural and military scientists and engineers employed by R&D enterprises, universities, and industrial enterprises, plus graduate students working on R&D at research institutes.

[e] It is assumed that the share of natural and military scientists and engineers with advanced degrees employed in R&D establishments (reported) represents the share for all such scientists and engineers in R&D.

are mindful that a smaller share of the total Soviet R&D employment is directly engaged in research than in the US. We also believe that Soviet R&D personnel are less efficient than are similar US personnel—i.e., each Soviet R&D professional has a larger number of support workers, while his US equivalent has more and better equipment. In view of these differences, we believe that the two series of figures cannot be used to make evaluative judgments regarding the relative R&D positions of the two countries.

11. In 1950, there were considerably more scientists in the US than there were scientific workers in the USSR.[12] Despite the superior Soviet pace of growth of natural scientific workers (see paragraph 3, page 19), the gap between the two countries has not narrowed greatly. In 1950 the number of US natural scientists in the military-oriented specialties—physics, math, and chemistry—exceeded that

[12] In the US, engineers are all persons *actually engaged* in engineering work at a level requiring knowledge of engineering, physical, life, or mathematical sciences equivalent to that acquired through completion of a four-year college course in one of these fields. Excluded are persons with such training but currently employed in positions that do not require it.

 [redacted]

of the Soviet Union by some four times. This margin has since been cut in half probably because of changing US national interests including reduced federal R&D support for defense and space.

F. Training of Soviet Scientists and Engineers

12. In the Soviet Union a high premium is placed upon technical and specialized, rather than liberal arts education. Science and technology are considered to be the foundation of national strength in modern times and consequently they receive unique emphasis at all levels of schooling. Secondary schooling provides the base for early (and mandatory) exposure to the sciences from which selected individuals are chosen for professional education. Moreover, the quality of professional training in scientific, engineering, and applied fields probably is comparable substantively to that offered in the West. One reason is the early exposure to scientific and technical subjects. Physics is introduced in fourth grade and one-third of the secondary curriculum is devoted to science and mathematics.

13. The USSR has 52 universities, where most scientists are educated, and over 200 technical institutes which provide much of the specialized engineering manpower. There is also a large part-time educational training program that provides higher education (including advanced degrees) in science and technology. The rate of increase in the enrollment in higher educational institutions has slowed somewhat in recent years, but an overall increase in enrollment through 1980 is forecast by Soviet leaders. In 1966, Premier Kosygin predicted an increase from 3.9 million to about 5.0 million students by 1970. Actual enrollment for the academic year 1967-1968 was 4.3 million indicating that the Soviets were well on the way toward that goal. The official target for 1980 is 8 million.

14. Emphasis on the training of manpower for industry and R&D is reflected in the sharp proportional and absolute increase in full-time enrollment in engineering since 1950. During the 1950-1951 school year, 346,000 of a total of 1.25 million students (about 25 percent) enrolled in higher education institutions were in engineering fields of study. By 1968, some 1.9 million students (43 percent) of a total enrollment of 4.3 million were in engineering. Over the same period, enrollment in the natural science fields trebled.

15. A scientific and technical education in the USSR has several shortcomings. Until very recently the aim was to develop specialized professional skills, enabling the individual to perform efficiently in specific areas. To this end, the Soviet system has been a success. But when the need is for adaptability of knowledge, then the success of their system is questionable. The narrow specialties in which many scientists and engineers are trained produce some limitations on their ability to integrate contributions from disciplines other than their own.

16. The quality of Soviet academic degrees since the mid-1950s is comparable to that in the West. First-degree (diploma) holders from university and other prestige institutions are somewhat ahead of holders of US bachelor degrees. In some cases they are comparable to a US master's degree. The Soviet "kandidat" degree is roughly equivalent to the US doctor of philosophy. The highest Soviet degree, "doktor," has no US equivalent.

17. In 1970—the latest year on which data are available—Soviet higher schools gradu-

ated nearly 203,000 students in fields considered in the US to be engineering, or nearly five times as many engineers as US colleges. The amount was up from three times as many in 1955. In the natural sciences, the US has maintained a consistent and wide lead graduating in 1970 well over twice as many scientists as the Soviets (88,000 compared with 36,500). Overall, in 1970 the USSR held roughly a two-to-one edge over the US in natural science and engineering graduates combined.

ANNEX B

ESTIMATING SOVIET EXPENDITURES FOR MILITARY RESEARCH AND DEVELOPMENT

ESTIMATING SOVIET EXPENDITURES FOR MILITARY RESEARCH AND DEVELOPMENT

I. INTRODUCTION

1. There are serious conceptual and practical problems in trying to measure resources used for research and development (R&D) within any large and complex national economy, and special problems for the analyst who tries to collect and interpret Soviet data. Even in the US, there is no clear line of demarcation between R&D and the preparatory stages of series production, nor between innovative design that results in the development of new products or processes, and production design directed at providing modified products or processes. Conceptually, military R&D cannot always be clearly differentiated from civilian R&D. Military R&D funding is defined in the US as outlays by the Department of Defense (DOD) for research, development, testing, and evaluation (RDT&E) activities—including military space R&D—and expenditures by the Atomic Energy Commission (AEC) for research directly related to military applications. This definition is bureaucratically workable, but somewhat deficient in conceptual terms—principally because it omits R&D financed in the private sector which may have important implications for military and space capabilities.

2. The problems are compounded in assessing Soviet military R&D. The data are incomplete and Soviet accounting practices and concepts cannot be matched with those used in the US. It is especially difficult to distinguish between military and non-military R&D and to determine just where the Soviets choose to draw the line between development and production. The conventional way to represent the resources available for R&D and space programs—e.g., the research institutes, test facilities, manpower, and other inputs—is by means of the total expenditures involved. There are, however, no data that permit this to be done for the USSR in a reasonably straightforward fashion.

3. Even if an accurate estimate of expenditures for Soviet military R&D plus space programs could be derived, expressing it in terms permitting useful comparison with similar US expenditures is fraught with further problems. The US and the USSR have different currencies, economic priorities, price structures, institutional approaches, strategic goals, military tactics, and technical traditions—to mention only a few areas of difference. And even if R&D expenditure estimates in the US and the USSR were expressed in a common currency, the comparison could still ony be used in the most general fashion as a gross measure of the relative effort. Moreover, an equal input of money does not imply an equal military achievement or capability. Used with other information, however, estimates of expenditures are helpful as one method—albeit imprecise—of assessing the relative R&D efforts and priorities of the US and the USSR.

4. Two basic approaches to estimating the cost of Soviet military R&D have been used in this NIE. Each is useful in its own way, but each has its own limitations. One deals with an analysis of published Soviet data—

primarily financial—and the other involves the direct costing of observed and estimated Soviet programs and facilities. The first starts with the derivation of Soviet military R&D plus space expenditures (expressed in rubles) from published Soviet financial data. The second applies US costs to known, estimated, and projected Soviet military R&D programs. This Annex discusses the complex problems encountered in these two approaches.

II. ANALYSIS OF SOVIET FINANCIAL DATA IN RUBLES

5. Analysis of the Soviet budget and other financial data has provided some insight into the total Soviet R&D effort, and that portion which is related to defense and space programs, but it does not supply the detail necessary to derive a figure for military R&D alone. The Soviets themselves say almost nothing specific about their military R&D or even about the total amounts spent for it. They do publish considerable general information—including expenditure data—about R&D as a whole, and these data have been used to develop approximations of the portion devoted to military R&D and space. So far, however, Soviet financial data has yielded no information about resources devoted to particular programs or missions.

6. *Soviet Expenditure Data.* The USSR provides little information regarding the concepts and methodology employed in the collection and presentation of their expenditure statistics. We believe that the Soviets report their financial support for R&D in terms of expenditures for "science." Although there are important institutional and procedural differences, the evidence indicates that the Soviet concept of "science" is compatible with Western definitions of R&D. The Soviets have provided expenditure data to the United Nations (UNESCO) for inclusion in studies of R&D. These data have been consistent with data published within the USSR under the rubric "science." They have used such Western terms as "basic research," "applied research," and "development" when discussing their science effort. They have shown themselves to be familiar with the expenditure figures for R&D in the US published by the National Science Foundation, and have discussed their "science" expenditures in a similar context.

7. The Soviets provide three important expenditure figures for R&D—or "science" as they call it. The most inclusive of these figures is described as "Expenditures for Science from the State Budget and Other Sources." We believe that this figure includes all important outlays for science in the USSR, and we use it as the control total in our overall budget analysis. It is referred to hereafter in this Annex simply as *total funds*. The Soviets issue two other official expenditure figures which they identify as components of *total funds*. One figure is the allocation labeled "Science" in the Social-Cultural category of the Consolidated State Budget. We refer to this account as *science budget funds*. The third figure reported in Soviet statistics is a record of expenditures for *capital investment* for science which, under Soviet accounting practice is grouped with other capital investments rather than included under "Science" in the budget.[13] When the *science budget funds* and *capital investment funds* are subtracted from *total funds* the result is another component, which we label *other funds*. The source and applications of the *other funds* are only partially explained in the Soviet literature. Until 1969, the distribution of *total funds* for science among these three components was relatively stable. *Science budget funds* represented about

[13] Although there are some funds for capital investment included in the science budget funds, these are in addition to those in capital investment funds.

60 percent, *capital investment* about 15 percent, and *other funds* about 25 percent of total funds. This breakdown—along with related economic data and subsidiary judgments on Soviet scientific activity—provides the framework for further analysis leading to estimates of expenditures for military R&D plus space programs.

Derivation of Military Research and Development Plus Space Expenditures

8. *Science Budget Funds.* This account is composed of two subaccounts, the All-Union budget and the budgets of the Union Republics. The All-Union portion typically accounts for about 90 percent of the *science budget funds.* According to the Soviets, it supports work "of a theoretical nature" and "other works of national importance." The budgets of the Union Republics support their subordinate academies of science and other scientific organizations that are concerned primarily with R&D of local interest. We believe that Republic budgets are not presently being applied to military or space activity.

9. The Soviets do not publish a breakdown of their *science budget funds* among civilian R&D, military RDT&E, and their space program. In 1958, however, they did publish a detailed *resource* breakdown—for example, wages and salaries, instruments, books, etc.—of expenditures for the 1950-1957 period under the All-Union and the Union Republics "science" budgets. In the case of the Union Republics—whose "science" budgets are devoted to local industry—itemized expenditures about equaled the announced totals.

10. The sum of the detailed costs did not, however, equal the announced totals in all the All-Union budgets. It left unexplained a large annual residual that grew steadily over the 1950-1957 period. Analysis of the official expenditure data and pertinent economic literature suggests that this residual is the major source of funds for those activities considered sensitive by the Soviets—i.e., military RDT&E, nuclear energy R&D, and the space program. Soviet publications, for example, have identified the All-Union budget allocation for "science" as a source of funds for "work of national importance," and they associate "science" expenditures with ballistic missile development and the space program.

11. The most recent budget handbooks, published in 1962 and 1966, have not repeated the detailed breakdown for *science budget funds*—quite possibly as a result of speculation by Western scholars in unclassified publications on the possible military significance of the residuals. Although the means of deriving details for the All-Union account are no longer available, the trend of the period 1950-1957 can be used for estimating the breakdown of the budget expenditures for science in the 1960s.[14]

12. In 1950, the unexplained residual amounted to 57 percent of *science budget funds* from all the All-Union budget. By 1957 it had increased three and one-half times and accounted for 75 percent of the All-Union budget. Also, by 1957 ***almost 90 percent*** of the annual increase in ***science budget funds*** from all the All-Union budget was being allocated to this residual. Although there were no signs of a slowdown in the late 1950s, we judge that the dramatic growth of the residual could not have continued much longer. We have

[14] For the views of Vice Adm. Vincent P. de Poix, USN, the Director, Defense Intelligence Agency; Maj. Gen. Phillip B. Davidson, the Assistant Chief of Staff for Intelligence, Department of the Army; Rear Adm. Earl F. Rectanus, the Director of Naval Intelligence, Department of the Navy; and Maj. Gen. George J. Keegan, Jr., the Assistant Chief of Staff, Intelligence, USAF, see their footnote to paragraph 65, page 46.

accordingly projected the share of the All-Union budget accounted for by the residual to grow at a declining rate to a maximum of 90 percent by 1964 and to remain at that level thereafter.[15] We believe that almost all, if not all, of this large portion of the All-Union component of *science budget funds* is applied to Soviet military R&D and space programs and that little or none of the remaining portion is so applied.

13. *Capital Investment.* The Soviets give no indication of the amount of *capital investment* funds used to construct or equip military R&D or space facilities. Presumably, however, *capital investment* supports all the R&D activities financed by the operating expenditures included in *science budget funds* and *other funds.* Therefore, *capital investment* has been apportioned between military R&D and space programs on the one hand, and civilian R&D programs on the other, to conform with the civilian-military split estimated for operating expenditures covered by these two funds.

14. *Other Funds.* There are few reliable data about the source or application of these funds. Other financial accounts that the Soviets call "enterprise funds" and "university research funds" are the source of about one-half of *other funds,* and these are the only sources of such funds that can be identified. Industrial enterprises and other commercial

[15] Even if 100 percent of the *science budget funds* from the All-Union budget were allocated to military R&D and space programs, the estimated expenditures for these programs presented for 1970 in Table B-I, below, would be increased by less than 10 percent.

TABLE B-I

ESTIMATED SOVIET EXPENDITURES FOR RESEARCH AND DEVELOPMENT AND SPACE, 1960–1970 BASED ON SOVIET FINANCIAL DATA

(Billion Current Rubles)[a]

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Science Budget Funds	2.3	2.7	3.0	3.4	4.0	4.3	4.6	5.0	5.5	5.9	6.5
For Military R&D Plus Space[b]	1.7	2.0	2.3	2.7	3.2	3.4	3.7	4.1	4.5	4.8	5.4
Capital Investment	.6	.7	.9	.9	1.0	1.1	1.2	1.2	1.3	1.3	1.4
For Military R&D Plus Space[b]	.4	.4	.6	.6	.7	.8	.8	.8	.9	.9	.9
Other Funds	1.0	1.2	1.3	1.5	1.4	1.5	1.8	2.0	2.2	2.8	3.8
For Military R&D Plus Space[b]	.3	.4	.4	.5	.5	.5	.6	.6	.7	.8–.9	.9–1.2
Total R&D Expenditures[c]	3.9	4.5	5.2	5.8	6.4	6.9	7.5	8.2	9.0	10.0	11.7
For Military R&D Plus Space[b]	2.4	2.8	3.3	3.8	4.4	4.6	5.1	5.6	6.1	6.5–6.6	7.2–7.6
Price Index (1968=100)	87	87	88	89	90	91	92	96	100	102	104
Military R&D Plus Space (Constant 1968 Rubles)[b]	2.7	3.2	3.7	4.2	4.8	5.1	5.5	5.8	6.1	6.4–6.5	6.9–7.3

[a] Except for bottom two lines.

[b] These figures in this Table are presented as single values rounded to one decimal place for reasons of ease of presentation, not because we have the confidence in them implied by such values. Because of the many sources of possible error in these figures, we have no good basis for stating a range. The reader's attention is directed to the pertinent paragraphs of this Annex describing the methodologies and assumptions on which these figures are based.

[redacted]

organizations normally withhold a small percent or their revenues to support R&D. The enterprise may enter a contract directly with a research institute, or it may pay the funds to its ministry and the ministry may then support research which is useful to the whole industry.

15. The amount deducted from enterprise revenue varies considerably among different ministries or production organizations. It is difficult to estimate the amount that may be deducted from revenues of enterprises engaged in military production and used to finance military related R&D. On the one hand, if the practice in the defense-related industrial sector were the same as in all other Soviet industry, then as much as 25 percent of these enterprise funds might be used for military purposes. On the other hand, a good argument can be made that because of the strong, centralized administration and support for military R&D, the practice of generating funds for military R&D at the enterprise level is more limited. What evidence we have indicates that deductions for military industries are, in fact, less than for civilian.

16. As for the rest of the *other funds* category, we have little specific Soviet data on sources or applications. The Soviet Ministry of Defense has a complex organizational structure to support, coordinate, and monitor military R&D programs. All the military services have institutes which conduct research to define new or improved weapons system concepts and to establish system requirements. The services operate test facilities to conduct suitability tests at the end of development programs as part of the process of accepting new systems for series production and deployment. Military representatives hold important positions on industrial commissions formed to evaluate design proposals. They are permanently assigned to the administrative apparatus of industrial ministries and to research and design institutes involved in the development of weapon systems. The personnel of the Ministry of Defense working on these and other R&D matters within or outside the Ministry are probably financed from the Defense Budget rather than from *science budget funds.* It seems likely that these costs are then included in *total funds,* where they would show up in *other funds.* It is also possible that certain operational military space programs such as satellite reconnaissance, which carry scientific designators—e.g., "Cosmos"—could be funded from the Defense Budget rather than from *science budget funds* and their costs included in the *other funds* portion of *total funds.*

17. As a maximum, one could reason that 25 percent of the *other funds* coming from enterprise funds and all, or virtually all, of the rest of *other funds* support activity related to military R&D or space. If this were correct, about 60 percent of the total of *other funds* should be counted as expenditures for military R&D and space. On the other hand, it is also reasonable to argue that the portion of enterprise funds applied to military R&D or space is small—less than 10 percent—and that no more than 25 percent of the balance of *other funds* should be similarly assigned. On this basis about 15 percent of the total of *other funds* would be for military R&D plus space. The data do not support a more precise or confident distribution of the total of *other funds.* We have chosen the approximate midpoint of this range and included about a third of *other funds* in our estimate for military R&D plus space. Admittedly, this is an arbitrary distribution, but even if the proper share were as high as 60 percent or as low as 15 percent, the total military R&D estimate for any particular year until 1969 would vary only by about 10 percent in either direction.

In 1969 and 1970, however, the pattern of science funding changes, and judgments about the application of *other funds* have more effect on the trend and magnitude of the military R&D plus space estimates.

Funding Changes in 1969-1970

18. Soviet spending for R&D and space had reached high levels by the late 1960s, and most Western analysts expected that both the growth rate and absolute increases in spending for R&D would decline substantially. Contrary to these expectations, however, the Soviets announced increases in *total funds* of 0.8 billion rubles (10 percent) in 1968, 1.0 billion (11 percent) in 1969, and 1.7 billion rubles (17 percent) in 1970.

19. At the same time the pattern of funding changed significantly. *Science budget funds*, which had accounted for some 60 percent of total spending, increased at a fairly moderate rate of 10 percent per year during 1969-1970. Actual expenditures on *capital investment*—which had represented only about 15 percent of *total funds*—are not available, but plan figures and statements by the Soviets indicate that no unusual increases were planned for this component. *Other funds*, in contrast, grew dramatically by 27 percent in 1969 and 36 percent in 1970. In another significant departure from the stable pattern of earlier years, employment in R&D and wage costs failed to keep pace with the growth of *total funds*. Estimated total employment in all R&D increased by only about 8 percent in 1969 and 5 percent in 1970. Wage costs, which normally account for about half of *total funds*, took less than 25 percent of the 1970 increases.

20. Several alternative explanations, not all mutually exclusive, have been offered to account for the puzzling growth in *other funds* in 1969 and 1970: (a) the increase is due to a broader definition of R&D involving the movement to the "science" account of certain expenditures which previously had been carried in some other category; (b) existing science accounts may have been inadequately covered or incompletely reported by the Soviets in the past, and the new figures reflect a correction of the deficiency; and (c) certain aspects of Soviet R&D—for example, civilian industrial R&D—may be increasing very rapidly.

21. None of these explanations can be either confirmed or completely eliminated. Published Soviet data often show some remarkable and unexplained changes. In this instance, however, it seems unlikely that only a relocation of existing accounts took place. In the past there have been redefinitions of the science categories, but these were accompanied by changes in the historical data as well. For example, in 1965, when costs for museums, libraries, and science exhibits were transferred from the science account to an education account, this adjustment was reflected in figures for earlier years. Also, in 1959 and 1967, when new sources of funds were added to total funds, figures for prior years were adjusted.

22. It is possible that the Soviet Central Statistical Administration is measuring more accurately and completely areas of R&D activity that it has slighted in the past. For example, Soviet literature indicates that most of the R&D performed by industrial enterprises was not previously included in the science figures. Therefore, in early 1969 the Central Statistical Administration undertook an investigation to quantify the cost of development being carried out by industrial plants and financed from production funds, rather than science budget funds. The addition of these previously unreported costs could account for some of the increase in 1969 and

1970. Because the activity was performed by industrial production personnel, we would not expect a comparable increase in the growth of scientific manpower and wage costs, and this did not occur.

23. It is difficult to explain the large increases in *other funds* as representing only the rapid growth of certain current programs or the initiation of major new programs. The increase could represent an expansion of military R&D or of space programs, but we would expect the development of major new systems to be centrally funded by the State Budget and included in *science budget funds*. The growth of *science budget funds*, in fact, does seem to allow for ample funding of all large-scale development programs which have been observed or can be reasonably postulated. Moreover, we would expect a real increase in the Soviet R&D effort to be accompanied by a comparable growth in employment and wage costs. Military R&D which we think may be financed by *other funds*—expenses of the Ministry of Defense for administrative and liaison personnel, military institutes, etc.—almost certainly could not have been expanded so rapidly. If this reasoning is correct, there remains the difficult task of identifying the civilian R&D programs which are receiving such generous financial support.

24. One possibility occurs to us—the sharp growth in *other funds* may reflect Soviet efforts to stimulate the introduction of new products, and new manufacturing technology. That is, one can hypothesize that Soviet priorities are shifting and that relatively more emphasis is being placed on this area. The need to improve and speed up the introduction of new technology is a constant theme in the Soviet press. The Soviet literature speaks about funds to implement new technology and for the development of production. These funds appear to be intended in particular to offset the costs associated with the introduction of new products and to subsidize the additional costs incurred by enterprises during the early stages of new production. Descriptions of the uses of these funds all center on the conceptually gray area between prototype development and series production. In the Western view, expenditures of this nature would be stretching the conceptual limits of R&D. The Soviets, however, may well consider money spent on these problems as properly counted in support of their R&D effort.

25. This explanation would also account for the failure of scientific employment and wages to grow as rapidly as expenditures. To the extent that wages or bonuses are covered by these funds, most of the payments would be to workers in industry rather than to employees of R&D organizations.

26. Soviet efforts to improve industrial technology on a broad scale could benefit both defense and civilian objectives. Because civilian industry is so much more extensive and has greater problems in introducing new technology, the rapid increase in *other funds*, if accounted for by this explanation, is probably largely for civilian production.

27. These explanations are only reasoned guesses, and none is fully persuasive. Consequently, for 1969 and 1970 we have assigned a range to the estimates of the portion of *other funds* going to military R&D plus space. On the low side the military R&D plus space share of *other funds* is assumed to continue to grow at a rate of 10 percent. For the higher estimate we assume that the military R&D plus space share continues to account for a third of *other funds*. This range introduces an uncertainty of about 0.4 billion rubles in the figures for 1970.

Results of the Analysis of Soviet Financial Data

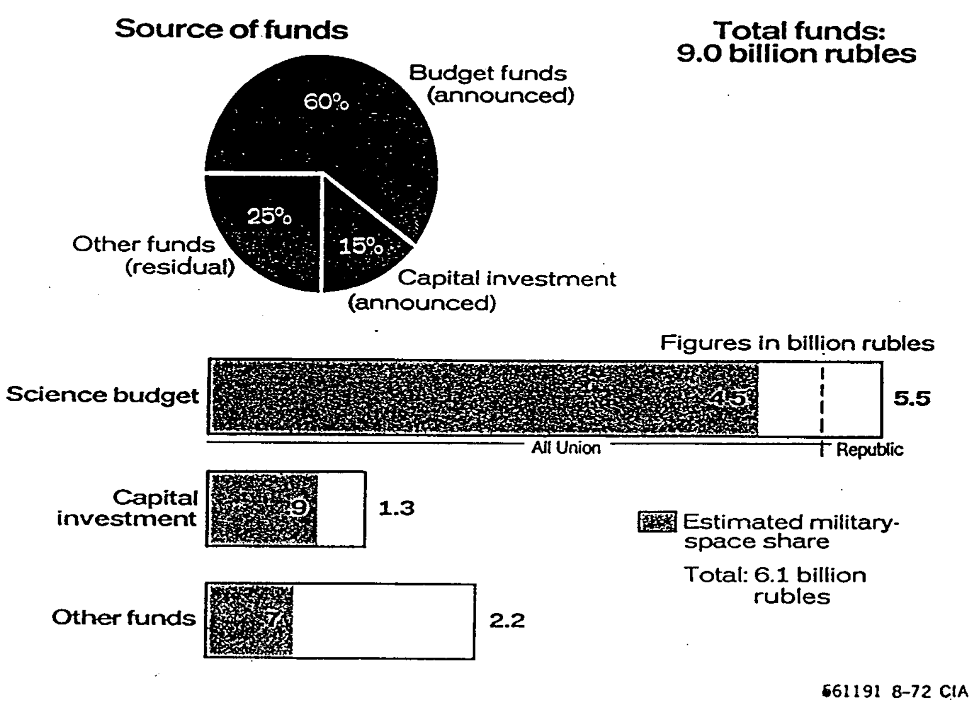
28. Under the assumptions described so far, the calculations show that the military R&D plus space portions of *science budget funds, capital investment,* and *other funds* together account for about 65-70 percent of *total funds.* Analysts in other research organizations have estimated the military R&D plus space share of R&D funds to be as low as 45 percent or as high as 75 percent. This divergence of estimates points up the inherent uncertainties and reveals that widely different conclusions have been deduced from the same body of data.

29. Figure 1 shows how the methodology, described up to this point, is applied in a sample year, 1968.

30. *Adjustment for Price Changes.* In the Soviet Union, just as in the US, some of the growth in science expenditures is due to price changes. A general revision of the prices of commodities was initiated in the Soviet Union in 1967, and throughout the 1960s the Soviet Government implemented a series of upward wage adjustments. Soviet data on manpower, average wages, and prices for materials and construction have been used to calculate the R&D price index. This index has been applied

Figure 1

Science and Military Research and Development Plus Space Expenditures in 1968



to the current ruble estimate in order to obtain a constant ruble estimate that better represents the growth of the Soviet R&D effort in constant prices.

31. Table B-I, page 32, presents estimates of total Soviet military R&D plus space expenditures for the period 1960-1970 in constant 1968 rubles. It also shows expenditures by category in current rubles.

Advantages and Disadvantages of This Approach

32. Deriving estimates of Soviet expenditures for military R&D plus space programs from Soviet financial data enables us to start from a documentary base; one can have some confidence that the figures for *total funds* represent expenditures for all R&D and space in the Soviet Union. The method permits comparison with other Soviet data, such as total budget appropriations, and information on education and employment of scientists and engineers. The share of these science expenditures that is allocated to military R&D plus space, however, must be derived on the basis of a large number of inferences subsidiary estimates, and subjective judgments. The uncertainty about the meaning of the recent increases in published statistics on expenditures for "science" only points up the degree to which, with little evidence to go on, our estimates are a direct function of our judgments. Another disadvantage of financial data analysis is that the results, expressed in rubles, cannot be compared directly with dollar figures for military R&D plus space in the US; such a comparison requires the development of a ruble/dollar exchange rate (see paragraphs 54-63). Finally, the methodology does not supply the detail necessary to make further breakdowns of the aggregated data and, in particular, to derive a figure for military R&D alone.

33. Despite the problems connected with the method based on Soviet financial data, however, it does furnish a basis for a systematic derivation of the cost of the Soviet R&D and space effort as reflected in Soviet statistics. Although the resulting figures are open to adjustment in the future as we learn more about Soviet accounting methods, they do provide a useful picture of the aggregate Soviet R&D effort and that portion related to various defense and space programs, especially when viewed in conjunction with estimates based on direct costing.

III. THE DIRECT COSTING APPROACH

34. Another method of estimating the cost of Soviet military R&D and Soviet space activities is to estimate what Soviet programs would cost in dollars if they were carried out in the US. A number of studies which attempt to cost particular aspects of the Soviet R&D effort directly in dollars have been done within the Intelligence Community, but no single research study has presented comprehensive estimates of what it would cost *in the US* to undertake all Soviet military R&D plus space programs. For purposes of this Estimate, the work done in the Intelligence Community was collected and combined in order to develop for the first time this alternative approach for estimating the magnitude of the Soviet military R&D plus space effort. We call this method the direct-costing method.

35. This section describes the techniques used to derive costs of Soviet military R&D plus space programs in 1970 dollars. The results are presented in Table B-II, page 38. Because different kinds and amounts of data are available on different aspects of Soviet military R&D plus space activity, the methodology is not uniform. For the major Soviet military programs—such as ballistic missiles, defensive missiles, and military aircraft—we derive the costs of system development, testing, and

TABLE B-II

ESTIMATED SOVIET EXPENDITURES FOR MILITARY RESEARCH AND DEVELOPMENT PLUS SPACE BASED ON THE DIRECT-COSTING METHOD [a]

(Billion 1970 Dollars)[b]

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Weapon Systems [c]	4.5	4.6	4.6	4.8	5.0	4.8	4.9	4.9	5.1	5.1	4.9
DOD-Type Space R&D [d]	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.6
Other DOD-Type R&D [e]	1.4	1.4	1.4	1.5	1.6	1.5	1.5	1.5	1.6	1.6	1.6
AEC-Type R&D [f]	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.4	0.4	0.4
DOD-Type Space Operations [g]	0.0	0.0	0.0	0.2	0.3	0.5	0.6	0.7	0.9	1.0	1.0
NASA-Type Space [h]	0.6	0.8	1.1	1.6	2.7	3.6	4.6	5.4	5.6	6.0	5.1
Total [i]	6.9	7.2	7.7	8.5	10.0	10.9	12.1	13.1	13.8	14.5	13.6

[a] The figures in this Table are presented as single values rounded to one decimal place for reasons of ease of presentation, not because we have the confidence in them implied by such values. Because of the many sources of possible error in these figures, we have no good basis for stating a range. The reader's attention is directed to the pertinent paragraphs of this Annex describing the methodologies and assumptions on which these figures are based.

[b] Cost estimates have been either calculated directly in 1970 dollars or converted to 1970 dollars by applying the US gross national product (GNP) deflator for federal government purchases of goods and services.

[c] Includes expenditures for research, development, design, fabrication of flight test vehicles, testing, and evaluation for the weapon systems involved. Does not include costs of development of nuclear weapons, nor general electronics research. Includes military aircraft only; excludes civil transports, such as the SST.

[d] Includes expenditures for R,D,T,&E on military space systems—expenditures analogous to those funded as "astronautics" under R&D in the DOD in the US.

[e] Includes DOD-type expenditures for military science research, R&D on other equipment not included in the two lines above, and program-wide management and support. Calculated at 30 percent of the total of the lines above.

[f] Includes expenditures for military R&D activities such as are funded by the AEC in the US.

[g] Expenditures for space programs such as those funded under general support in the DOD in the US.

[h] Expenditures for programs such as those funded by National Aeronautical and Space Administration (NASA) in the US.

[i] Totals may not equal the sum of the parts because of independent rounding.

evaluation from US cost models which we call CERs.[16] Since many space programs can also be costed in this fashion, CERs (or cost models) are the basis for some 40 percent of the costs derived by the direct-costing method. Simple US analogy is the basis for another 20 percent of the costs; US analogy is used for other space programs, AEC-type programs, and R&D on ordnance, naval ships, and submarines. Study of overhead photography of Soviet facilities and a combination of various other methods are the basis for another 10 percent each. Finally, some 20 percent of the costs are derived simply by adding a factor, based on US analogy, to the sum of the above

[16] CERs (cost estimating relationships) describe the relationships between several key characteristics of a weapon or space system (such as take off weight, speed, and thrust in the case of aircraft) and the cost of developing the system. In some cases a CER is developed for each functional cost element (engineering, development, prototype production, flight test); in other cases a CER is developed to embrace all costs in a single equation. In either case the CER (i.e., a single equation relating characteristics to cost) is used for each broad category of weapon or space system, e.g., aircraft, unmanned spacecraft, space boosters, ballistic missiles, etc.; CERs are not developed for each type or model.

costs. More specific explanations of the above methods are set forth in the following paragraphs, with examples.

36. *Application of Cost Estimating Relationships.* We illustrate the use of CERs by a description of their employment in costing R&D for Soviet aircraft. Of the elements research, development, testing, and evaluation (R,D,T,&E), the CERs for aircraft are the basis for estimating the costs of "D, T, & E;" the estimate of the cost of research (the "R") together with capital investment in R, D, T, & E, is based on an analysis [redacted]

37. The CERs for aircraft were derived by a US Air Force contractor on the basis of a study of the costs of developing, testing, and evaluating US aircraft in relation to such parameters as the weight and speed of the aircraft. Separate CERs were developed for various cost elements: initial design engineering and preproduction tooling for the airframe, development of the engine, production of the test aircraft, flight tests, and development support.[17]

38. The CERs were utilized to calculate the cost of each model of aircraft developed by the Soviets in the past (whether it reached test and deployment or not), those currently under test, and those projected in the future.[18] The inputs into the CERs for this calculation were estimates of the weight and speed of the Soviet aircraft; the power, type, and number of engines; the complexity and quality of the aircraft; and the number of test vehicles. The results of the calculations were separate costs for each of the cost elements. The costs were expressed initially in 1965 dollar prices, which were then adjusted to 1968 dollar prices using factors developed by the US Air Force. The costs for each aircraft model were summed and phased over time, using certain observed bench marks (date of first test, initial operational capability, etc.) as well as US experience to judge the rapidity of system development. Since the costs of "D,T,&E" were estimated by aircraft model, there was an easy basis for distinguishing between the costs of military aircraft and the costs of civilian aircraft.

39. Two problems remained. The first was to estimate the cost of research (the "R" portion of RDT&E) and of capital investment in RDT&E. [redacted] The second was to apportion the costs of research and of capital investment between civilian and military aircraft. This was done by assuming that the *aggregate cost* of RDT&E on aircraft should be divided between military and civilian purposes in each year in the same proportion as the costs of "D,T,&E" *alone*. When the total cost for R,D,T,&E on military aircraft for each year had been calculated in this fashion in 1968 dollars, the annual figures were adjusted to 1970 dollars by multiplying them by the price index for federal government purchases of goods and services, a component of the GNP.

40. CERs were used in similar ways to cost R&D on some space programs and on ballistic and defensive missiles. The inputs to the CERs for space launch vehicles, for instance, included estimates of the pounds of thrust for each stage, the number of developmental tests, and the type of instrumentation, among other

---

[17] The cost estimates did not include the cost of tooling for series production or the cost of series produced aircraft. The development cost of the avionics package in the aircraft was not included, but the manufacturing costs of the avionics package in test aircraft was.

[18] Projections of future systems were based generally on the "high-middle" projections in the Soviet military NIEs. Projections of space systems were based on NIE 11-1-71, "The Soviet Space Program," dated 1 July 1971, SECRET.

things. In developing inputs to CERs for missiles, certain questions arose with regard to coverage. These were resolved as follows: for ballistic missiles, [redacted] used as inputs to the estimate of R&D costs. [redacted] For defensive missiles, the costs were defined to include the costs of the development of associated radars and their construction and programming at test ranges, but not the cost of construction of an operational radar, even if it were the first (e.g., the Dog House).

41. [redacted] US Air Force studies of the cost of constructing and equipping similar facilities in the US in 1968 furnished appropriate factors of costs [redacted] To such costs was added a factor of 10 percent, based on US analogy, for the costs of roads, utilities, etc. The costs of the facilities going into operation each year was summed and used as the estimate of the total investment in each year.

42. The annual operating costs of research institutes supporting the development of aircraft and missiles were developed [redacted] Factors developed from US Air Force studies of the costs of operating similar facilities in the US in 1968 were applied [redacted] in order to arrive at an estimate of the costs of operating these institutes. It was judged that the cost of design bureaus would be covered by costs derived from the cost models but not the costs of research bureaus, which carry on more general research.

43. *Simple US Analogy.* Costs of Soviet programs similar to those funded by the US AEC are used as an example of the utilization of simple US analogues. General R&D on nuclear weapons in the USSR was assumed to cost one-third as much as that of the US, on the grounds that the Soviet test rate is about one-third that of the US. The cost of weapon tests was derived by multiplying the number of Soviet tests each year by an average cost for a US test. An amount for development of military reactors, again based on US analogy, was added to these costs to obtain the total costs.

44. *Various Other Methods.* The costing of the Salyut program furnishes an example of the use of a combination of other costing methods. The program uses two major types of hardware—the Soyuz ferry spacecraft and the Salyut station itself, on the one hand, and the space launch vehicles to place them in orbit on the other. Soyuz costs were scaled up from the cost of the Vostok/Voskhod spacecraft (which had been estimated by a US contractor) on the basis of estimates of increased size and complexity. The Salyut station was costed as an analog of a proposed US space station. The SL-4 space launch vehicle for the Soyuz spacecraft is a composite of the SS-6 booster and the Venik upper stage. The purchase and launch costs of this launch vehicle, and of the SL-12 launch vehicle for the Salyut station, were derived from a cost curve showing the cost in the US of placing payloads of various weights in orbit.

45. An estimate was made of the number of Salyut stations that would be launched, by the time the program is complete. An appropriate number of Soyuz ferry vehicles was also estimated. The numbers of launches were multiplied by the cost of each booster/spacecraft combination and the products were added to get the hardware cost of the total program. Non-hardware costs based on US analogy, were added to the hardware costs to get total costs. The total costs were then phased over time, based on US experience, and keyed to the first flight. These costs were then adjusted to 1970 dollars by application of the price deflator for federal government purchases of goods and services.

46. *Adjustments to Cover Additional Costs.* In any large R&D effort there are always additional costs that cannot be estimated on the basis of any of the above methodologies. In some cases, the activity cannot be isolated for study; in others the activity is so small or so widely scattered that the effort to isolate it is not justified. To get at these costs, adjustments, based on US experience, were made to the total of the programs already estimated by the approaches described above. These adjustments were used for activities comparable to those funded under R&D in the US DOD on the one hand, and for space programs funded by NASA on the other.

47. In the US DOD there are three aggregative R&D accounts called military science, other equipment, and program-wide management and support. Military science covers general research in physics, chemistry, and other disciplines, such as would be carried on in the USSR by the Academy of Sciences. Other equipment is catchall for R&D on general electronics, command and control, DOD expenditures on nuclear weapons R&D, and a host of other programs. Program-wide management and support includes the housekeeping costs of military R&D facilities and test ranges, and the costs of general management and support.

48. In the US, the costs of this nature incurred in the R&D portion of the Defense Budget have equaled about 30 percent of the DOD R&D expenditures for weapon systems and space programs. In estimating Soviet expenditures under these headings, a similar percentage is used.

49. In the case of space, the methods described so far do not cover the costs of activities such as advanced research, and management and support. Adjustments to cover such additional costs were made, based largely on US analogy. These adjustments amounted to about 30 percent of the total of costs estimated by other methods.

50. Because direct costing produces costs for many discrete programs or groups of similar programs, these costs can be aggregated in a large variety of ways. For purposes of comparison with US expenditures, it is useful for us to aggregate them in a manner similar to that followed in the US, even though the Soviets do not do so. The results of the direct-costing method are presented in Table B-II, page 38 in such a manner.

51. As can be seen in Table B-II, the major growth in expenditures for military R&D plus space programs during the 1960s was in space programs, military and civilian, and the decline in 1970 was largely attributable to the estimated drop in expenditures for civilian (NASA-type) space programs.

Advantages and Disadvantages of the Direct-Costing Method

52. The direct-costing method allows us to specify precisely what is being costed and therefore to get some appreciation of the resource implications of particular Soviet R&D

programs. It also permits direct comparison of Soviet programs with US programs. But considerable uncertainty is also associated with this methodology. CERs may call for more information than intelligence can supply; in these cases either engineering judgments have to furnish some of the inputs to the equations or simpler CERs have to be found. The manner of phasing the costs over the development cycle is also a matter of judgment, as much of the development has to take place before we have any evidence of the program. Moreover, we do not know for sure how much R&D activity that never progresses to test is being undertaken. Fortunately, costs for such early work are usually relatively small. A similar problem is that annual cost estimates for recent years are particularly dependent upon projections of future programs. For example, Soviet costs for 1970 and thereafter can vary by hundreds of millions of dollars, depending upon what judgments are made about the pace and success of the J-vehicle development and the programs associated with it—manned lunar landing, very large space station, planetary probes, etc. Analysis of facilities can lead to overestimating costs when programs are cut back and budgets reduced.

53. Despite the many problems connected with the direct-costing method, enough different aspects of the Soviet military R&D and space effort have been examined to provide a basis for a systematic quantification of the Soviet effort based on direct observation of R&D programs. Although the resulting figures must, of course, be considered as preliminary at this time, they do provide a useful picture of the Soviet programs, especially when viewed in conjunction with the estimates based on Soviet financial data which we translate to dollars by means of a ruble/dollar ratio.

IV. RUBLE/DOLLAR RATIOS [19]

54. The conversion of ruble expenditure estimates to dollar equivalent or dollar costs to rubles, requires the use of an appropriate exchange rate, i.e., a ruble/dollar ratio, which reflects the comparative purchasing power of the ruble and the dollar in the area of R&D. Conceptually, a ruble/dollar ratio for R&D should quantify precisely the financial outlays needed in the US and in the USSR to achieve a given R&D product or output. Unfortunately, a satisfactory method for measuring R&D output as a whole has never been devised.

55. When *output* cannot be measured the standard approach is to measure *inputs* instead. Thus a dollar valuation of the Soviet R&D output would be achieved by calculating the dollar cost of all the manpower, materials, equipment, and facilities used. A ruble/dollar ratio based on inputs would be appropriate as a representation of that for output if both countries used a similar mix of capital and labor in their R&D activity; if the relative prices of manpower, materials, equipment, and facilities were approximately the same in both countries; and if the productivity of the inputs were roughly comparable.

56. For several reasons, however, including distortions introduced by the administered price structure of the USSR, and the technological and bureaucratic differences that exist, the structure of Soviet inputs and their prices differs grossly from that of the US. In the

[19] The "official" ruble/dollar rate of exchange (one ruble equals $1.22) is not a realistic indicator of the purchasing power of the ruble in relation to the dollar. The ruble is not a freely convertible currency in international markets; its use is limited to internal transactions and accounting in the USSR and in intra-CEMA trade. Even there its value is established unilaterally by government decree, not by the market mechanism.

US, for example, scientific instruments and computers are of higher quality and are used more intensively than in the USSR. US manpower costs are much higher relative to other costs than is the case in the Soviet Union. Accordingly, the US uses relatively less manpower and more capital equipment in its R&D programs than does the Soviet Union. In these circumstances an attempt to measure one country's activity using the input and price structure of the other is not very meaningful.

57. To improve the frame of reference for establishing an R&D exchange ratio, therefore, we have considered Soviet and US prices for the most complex products which are reasonably comparable in the two countries. There are, of course, still problems of limited data in this approach. We have little recent information on Soviet prices for a wide range of high technology equipment. In the key area of electronics, however, substantial research has been done. This work forms a basis for making reasonably informed judgments about comparative ruble/dollar prices for product categories which include communication equipment, scientific instruments, testing and measuring equipment, radars, avionics, and computers. Overall, the estimated ruble/dollar ratio for electronics equipment is about .6 (i.e., 1 ruble is equal to $1.65, with rubles adjusted to 1968 prices, and dollars adjusted to 1970 prices). In the military procurement categories the ratio for electronic equipment is .51 (1 ruble=$1.96); and for instruments, testing, and measuring equipment it is .59 (1 ruble=$1.70). For all military procurement, the estimated weighted ruble/dollar ratio is .42 (1 ruble=$2.38) and the unweighted ratio is .49 (1 ruble=$2.04).

58. This procedure permits us to approach our objective of finding a conversion ratio that represents the dollar cost of the Soviet R&D effort as if it were being conducted in the US with US resources and supporting technology. It is likely that an R&D conversion ratio based on ruble/dollar ratios for electronics and other advanced machinery and equipment more accurately reflects relative efficiency of inputs in R&D than one based directly on the prices of inputs. The limited sample on electronics and other complex equipment which has military applications suggests that a rounded ratio of about .5 (i.e., 1 ruble=$2.00) is a reasonable approximation for converting Soviet ruble expenditures for R&D to US dollars.

59. There is still another way to derive a ruble/dollar ratio. The method of calculating Soviet expenditures for military R&D plus space based on Soviet financial data described earlier in this paper gives us a *ruble* estimate of these costs. The direct-costing method discussed subsequently provides *dollar* estimates of costs for what are—conceptually at least—the same activities. Thus, if each of the two series accurately measured what it purports to measure, one would secure weighted ruble/dollar ratios for each of the years covered by simply dividing the ruble estimate by the dollar estimate.

60. In practice, matters are not so simple. For reasons already given, it is not possible to be confident that the two series cover the same things, or that they accurately measure whatever they do in fact cover. Nonetheless, a comparison of the two series is revealing and helpful (see Table B-III, page 44). For one thing, it appears to rule out overall ruble/dollar ratios as low as that derived by applying US prices to Soviet inputs, or as high as the official exchange rate of one ruble equals $1.22. For another, it suggests that a ruble/dollar ratio close to .5 (1 ruble=$2.00) is about right. This is the approximate ratio yielded by a comparison of Soviet and US prices for advanced machinery and equipment.

TABLE B-III

RUBLE/DOLLAR RATIOS FOR SOVIET MILITARY RESEARCH AND DEVELOPMENT PLUS SPACE PROGRAMS [a]

	Billion 1968 Rubles Soviet Data [b]	Billion 1970 Dollars Direct Cost [c]	1968 Ruble-1970 Dollar Ratio
1960.....	2.7	6.9	39/100
1961.....	3.2	7.2	44/100
1962.....	3.7	7.7	48/100
1963.....	4.2	8.5	50/100
1964.....	4.8	10.0	48/100
1965.....	5.1	10.9	46/100
1966.....	5.5	12.1	45/100
1967.....	5.8	13.1	44/100
1968.....	6.1	13.8	44/100
1969.....	6.4–6.5	14.5	44/100–45/100
1970.....	6.9–7.3	13.6	51/100–54/100

[a] The figures in this Table are presented as single values rounded to one decimal place for reasons of ease of presentation, not because we have the confidence in them implied by such values. Because of the many sources of possible error in these figures, we have no good basis for stating a range. The reader's attention is directed to the pertinent paragraphs of this Annex describing the methodologies and assumptions on which these figures are based.

[b] From Table B-I, page 32.

[c] From Table B-II, page 38.

61. Aside from its rough agreement with the ratios derived from a comparison of these two independent estimates, there are *a priori* reasons for placing some confidence in the ratio of one ruble equals $2.00. This ratio is based on the cost of outputs, rather than of inputs, and therefore incorporates an adjustment for relative efficiency. Moreover, in comparing the cost of advanced machinery and equipment, one is dealing with a combination of inputs, processes, and products which can be assumed to represent the purchasing power parity between the ruble and the dollar in advanced areas of technology such as R&D and space. Thus, this paper uses .5 (1 ruble=$2.00) as the ratio to convert estimates of the ruble costs of Soviet R&D into dollars.

62. We recognize that a separate ruble/dollar ratio for each year, rather than a single ratio for the entire period, would better reflect changes in the mix of military R&D and space activities. But we have no good basis for such adjustments and, in any case, the potentials for error already in the data are much greater in magnitude than likely year-by-year changes in the ratio. Consequently, we have used a single ratio throughout the period.

63. Table B-IV provides the dollar values for Soviet expenditures on military R&D plus

TABLE B.IV

ESTIMATED SOVIET EXPENDITURES FOR MILITARY RESEARCH AND DEVELOPMENT PLUS SPACE PROGRAMS, 1960–1970 [a]
(BASED ON SOVIET FINANCIAL DATA)

Year	Billion 1968 Rubles	Billion 1970 Dollars [b]
1960.........	2.7	5.4
1961.........	3.2	6.4
1962.........	3.7	7.4
1963.........	4.2	8.5
1964.........	4.8	9.7
1965.........	5.1	10.2
1966.........	5.5	11.0
1967.........	5.8	11.7
1968.........	6.1	12.2
1969.........	6.4–6.5	12.7–13.0
1970.........	6.9–7.3	13.8–14.6

[a] The figures in this Table are presented as single values rounded to one decimal place for reasons of ease of presentation, not because we have the confidence in them implied by such values. Because of the many sources of possible error in these figures, we have no good basis for stating a range. The reader's attention is directed to the pertinent paragraphs of this Annex describing the methodologies and assumptions on which these figures are based.

[b] Using a conversion ratio of $2 to the ruble.

space that result from the application of this ratio to the estimate based on Soviet financial data.

V. EXPENDITURES FOR MILITARY RESEARCH AND DEVELOPMENT PLUS SPACE

64. Table B-V shows the estimates for Soviet expenditures on military R&D plus space derived from analysis of Soviet financial data and the application of a ruble/dollar ratio of .5, with those developed by combining direct-cost estimates of individual programs.

TABLE B-V

COMPARISON OF ESTIMATED DOLLAR EQUIVALENTS OF SOVIET EXPENDITURES FOR MILITARY RESEARCH AND DEVELOPMENT PLUS SPACE PROGRAMS [a]

Billion 1970 Dollars

	Soviet Financial Data [b]	Direct Costing [c]
1960	5.4	6.9
1961	6.4	7.2
1962	7.4	7.7
1963	8.5	8.5
1964	9.7	10.0
1965	10.2	10.9
1966	11.0	12.1
1967	11.7	13.1
1968	12.2	13.8
1969	12.7–13.0	14.5
1970	13.8–14.6	13.6

[a] The figures in this Table are presented as single values rounded to one decimal place for reasons of ease of presentation, not because we have the confidence in them implied by such values. Because of the many sources of possible error in these figures, we have no good basis for stating a range. The reader's attention is directed to the pertinent paragraphs of this Annex describing the methodologies and assumptions on which these figures are based.

[b] From Table B-IV, page 44.

[c] From Table B-II, page 38.

65. The estimates derived from Soviet financial data are roughly of a similar magnitude and grow at about the same rate as those based on the direct-costing methodology, except for recent years. There is no basis for considering one more accurate than the other, nor do the two series represent a likely range. The validity of the dollar estimates derived from Soviet financial data depends upon three factors: (a) the extent to which the coverage of science expenditures conforms to Western definitions of R&D; (b) the precision of the distribution of the Soviet expenditures between military and civilian programs; and (c) the accuracy of the ratio used to convert the rubles to dollars. The rate of growth of the ruble series is affected by the deflators used to convert currency units into constant units, and therefore by any inaccuracies in the deflators. Considerable uncertainty exists for each aspect of these calculations and it must be recognized that the estimate could overstate or understate the Soviet effort by a substantial margin. The validity of the direct dollar costs depends upon the precision with which the Soviet programs have been identified, defined, and projected both for past and future years, and upon the accuracy and relevance of the direct-costing relationships which have been applied. Again much uncertainty is present, and this approach could also overstate, or understate, by a substantial margin the true magnitude of the Soviet programs. Nevertheless, the two series are reasonably consistent despite the uncertainties of the task and the completely different approaches on which they are based. This consistency en-

courages the presumption that the general magnitudes which result are in accord with reality.[20]

66. The only year in which results are at considerable variance is 1970. Here the problem probably results from the sharp and puzzling upturn in reported Soviet expenditures when considered in relation to the difficulties in identifying and costing Soviet military R&D plus space programs in the most recent years. Much current Soviet R&D activity has not yet produced an identifiable prototype or test vehicle, and this tends to introduce a downward bias for the most recent years in the estimates based on direct costing. This phenomenon may account for the rapid drop in estimated space expenditures for 1970. Time is likely to provide new data to support analysis with both methodologies and as the estimates for recent years are refined and revised, they may move more closely together, particularly those for 1970.

VI. EXPENDITURES FOR MILITARY RESEARCH AND DEVELOPMENT ALONE

67. The two series of figures presented so far cover expenditures for *both* military R&D plus space. The next step is to remove from them the estimated cost of *civilian* space programs (e.g., unmanned lunar exploration and planetary probes) and the estimates cost of operational space programs on which R&D has been completed (e.g., satellite reconnaissance and communications) in order to get figures for Soviet *R&D* directed at purely *military* goals. In the case of the estimates of military R&D plus space derived from direct costing, the procedure is simple and straightforward—to drop for each year the costs calculated for the aforementioned space activities. This cannot be done, however, within the series based on Soviet financial data, because the necessary detail is not available. Consequently, it is necessary to subtract from the series derived from Soviet financial data the cost of civilian and operational space programs derived from the direct-costing method. As a result each series is reduced by the same amount in each year, and the absolute difference between the two series—now representing military R&D *alone*—remains the same as that for the two series when they represented military R&D *plus* space (see Table B-VI, page 47).

68. Of necessity, both series again appear roughly consistent, except in more recent years. The data imply that after the early 1960s, Soviet military R&D expenditures increased very little if at all, and that most of

[20] Vice Adm. Vincent P. de Poix, USN, the Director, Defense Intelligence Agency; Maj. Gen. Phillip B. Davidson, the Assistant Chief of Staff for Intelligence, Department of the Army; Rear Adm. Earl F. Rectanus, the Director of Naval Intelligence, Department of the Navy; and Maj. Gen. George J. Keegan, Jr., the Assistant Chief of Staff, Intelligence, USAF, do not believe that the general consistency of results obtained from the two methodologies should encourage the presumption stated above. They believe that neither methodology produces very credible results, but they have considerably more confidence in the direct costing approach. They believe that the lack of recent detailed data (as indicated in paragraph 11 of this Annex) makes the results obtained through the financial data method highly questionable. They believe that the estimates for more recent years derived through the financial data method depend too heavily on extrapolation of the 1950-1957 data. Further, they note that in the results of the analysis of Soviet financial data there is an apparent absolute decline in expenditures for military R&D from 1965 through 1968 which they find inconsistent with the direct costing results and with their appreciation of the general magnitude of the Soviet effort. While believing that the direct costing approach provides an aggregated total estimate that is almost certainly low, they have more, though not high, confidence in that method. In view of their doubts concerning the validity of the financial data methodology, they would discourage the presumption that the roughly parallel results can be taken as supportive of either costing methodology.

TABLE B-VI

COMPARISON OF ESTIMATED DOLLAR EQUIVALENTS OF SOVIET EXPENDITURES FOR SOVIET MILITARY RESEARCH AND DEVELOPMENT [a]

	Billion 1970 Dollars	
	Soviet Financial Data [b]	Direct Costing [c]
1960	4.8	6.2
1961	5.6	6.4
1962	6.3	6.6
1963	6.7	6.6
1964	6.7	7.0
1965	6.1	6.8
1966	5.8	6.9
1967	5.6	7.0
1968	5.7	7.4
1969	5.7–6.0	7.5
1970	7.7–8.5	7.5

[a] The figures in this Table are presented as single values rounded to one decimal place for reasons of ease of presentation, not because we have the confidence in them implied by such values. Because of the many sources of possible error in these figures, we have no good basis for stating a range. The reader's attention is directed to the pertinent paragraphs of this Annex describing the methodologies and assumptions on which these figures are based.

[b] Expenditures for military R&D and space from Table B-IV, page 44, less DOD-type space operations and NASA-type space expenditures from Table B-II, page 38.

[c] Total of expenditures for weapon systems R&D, DOD-type space R&D, other DOD-type R&D and AEC-type military R&D from Table B-II, page 38.

the growth in Soviet R&D came from the space programs. This conclusion is best understood in light of the fact that Soviet expenditures for military R&D were already high at the beginning of the 1960s. The relatively slow rate of growth during the 1960s—averaging only 2 percent a year—thus reflects consistently high levels of activity throughout the 1960s. At the beginning of the 1960s more ballistic missiles, aerodynamic missiles, and military aircraft were under development than at the end. Although aircraft are now more advanced and more costly to develop, most of the missiles now in test are modifications of existing ones, rather than new systems, and are consequently less costly to develop.

69. In contrast, Soviet space programs, at the beginning of the 1960s, were in their infancy. During the decade (1960-1970), the numbers of space launches and estimated expenditures for space programs grew about nine-fold. We estimate that Soviet space programs of all types in 1970 cost the Soviets almost as much as military R&D programs.

70. We believe the resulting estimate that the predominant growth element in Soviet R&D has been the space effort is a true reflection of actual developments in the USSR, and not the result of attributing high costs to space programs and low costs to military ones. In both the US and the USSR the same plants and test facilities support missile and space development. Analogous, if not identical, methods have been used to estimate costs of the space and missile programs. They both, in turn, use methodologies similar to those developed to cost aircraft airframes. Thus, we discern no reason for systematic upward bias in the estimates of the costs of Soviet space programs when compared to military R&D programs.

71. Concerning 1970, estimates for both military R&D and for space based on direct costing may well be low because of the tendency noted earlier for direct costing to understate the results for the most recent years. To the degree that this is so, the military R&D estimate based on Soviet data would be high, because it is derived by subtracting the estimate for space based on direct costing.

VII. EXPENDITURES FOR MILITARY RESEARCH AND DEVELOPMENT, 1971-1975

72. The Ninth Five-Year Plan (1971-1975) calls for expenditures for science (i.e., R&D plus space) of 80 billion rubles, or an increase of 60 percent over the previous five-year period. This represents an average annual increase for the period of about 10 percent in current rubles. It is not unusual for actual expenditures to deviate from the planning figures, and it may well be that reported expenditures for the 1971-1975 period will fall below the planned levels. In any event, further inflation will probably make real growth less than 10 percent. If past rates of inflation continue, the projected rate of 10 percent in current rubles would equate to about 7 percent a year in constant rubles.

73. Military R&D alone may also increase by about 7 percent a year. There are, however, various considerations that could lead us to estimate slower or faster rates of growth. Supporting an estimate of a slower rate of growth is the apparent predominance of civilian R&D in recent growth and the fact that the expansion of facilities that carry out Soviet military R&D has slowed. Studies show that during the early and middle 1960s facilities to support space programs and R&D on aircraft and missiles grew at roughly the same rate as expenditures for these programs. It may be significant, therefore, that the expansion of facilities declined to about 3 percent a year at the end of the 1960s. On the other hand, in the SALT context, Soviet leaders may wish to push military R&D programs more rapidly than in the past. An appropriate upper limit may be established by the following set of assumptions: if, (a) civilian R&D will grow at the same rate as the overall planned rate; (b) civilian space expenditures will not grow; and (c) the remaining growth will be for military R&D, then an arithmetic calculation indicates that military R&D; could grow at 11 percent a year. These rates of growth—a low of 3 percent a year, and a high of 11 percent—can be viewed as a reasonable assumed range for future possibilities. Under these assumptions, Soviet expenditures for military R&D may grow to the amounts indicated below:

	(Billion 1970 dollars)		
Method	1970	1972	1975
Soviet Financial Data	8–9	8–11	9–14
Direct Costing	8	8–9	9–13

ANNEX C

ORGANIZATION FOR SOVIET RESEARCH AND DEVELOPMENT

ORGANIZATION FOR SOVIET RESEARCH AND DEVELOPMENT

Note: This Annex provides a descriptive framework of the overall arrangement of the principal institutions and organizations involved in Soviet research and development (R&D). Military aspects are emphasized. The discussion is general, and therefore only the key institutions are covered in any detail.

1. *Top Party-Government Level.* R&D is controlled at the apex of state power by the Politburo of the Communist Party and by the Council of Ministers. All basic decisions on the scale, direction, and organization of R&D are made, or subject to approval, at that level of authority as if by directors of a giant corporation. Since there is no private sector in the Soviet economy, all institutions having an R&D function are operated directly by one or another agency of the government.

2. Identification of key personnel and organizations and their roles in the Soviet military R&D sector is derived almost exclusively from classified materials. [ ] While the available data permit us to make a broad assessment of the management of Soviet military R&D, major gaps remain in our understanding of how decisions actually are made at all levels from the Politburo down to the design bureau. Specifically, little is known about the impact of interest groups and key figures on decisions at the various levels. In addition, there is only fragmentary information on the Defense Council, the Military-Industrial Commission, the role of the Central Committee Secretariat, and the Ministries for General Machine Building and Medium-Machine Building in military R&D policy making and management [ ] has provided a base for the development of assumptions and hypotheses about management and policy making in this sector.

3. The 15-man Politburo establishes broad policy on R&D. It is served in this function by various staff organizations controlled through its Secretariat. Within the governmental structure, the Council of Ministers, and its subordinate committees, implement the national policies established by the Party. It is in the key governmental committees, the State Planning Committee (commonly referred to by its acronym "Gosplan") and the State Committee for Science and Technology (GKNT), that many important decisions are made and coordination of R&D at the national level takes place. The USSR Academy of Sciences provides advice to these bodies, including counsel on the exploitation of resources and the various aspects of economic planning.

4. The State Planning Committee conducts planning of long-range R&D (up to 20 years into the future) and makes provisions for the input of the materials needed for R&D. Its principal science planning is encompassed in

the Five Year Plan.[21] The plan sets forth the main scientific and technological problems and the requirements for their solution.

5. The State Committee for Science and Technology has the overall responsibility for coordinating non-military scientific and technical planning and planning for basic and applied research. Its function is to ensure the effective utilization of the results of this R&D. The GKNT establishes basic and applied research priorities on the basis of an annual list of some 250 "key problems of national importance" compiled from the recommendations of country-wide councils on scientific problems. It also allocates science funds for these projects.

6. The Academy of Sciences advises the government on matters relating to science and technology, including the exploitation of resources and the various aspects of economic planning. It is the most prestigious Soviet scientific institution, and has primary responsibility for basic and theoretical research; it also conducts some applied research. It manages some 200 research institutes employing the best known Soviet scientists, and many of these institutes do work in support of military needs.

7. The Party Politburo receives advice on policy planning involving *military R&D* primarily from the staffs of the Central Committee, the Council of Ministers, and the Defense Council. One of the Defense Council members, also a candidate member of the Politburo, is D. F. Ustinov who has spent more than three decades managing various weapon programs. He probably is the key top-ranking figure in matters concerning management of military R&D.

8. The Military-Industrial Commission (VPK) of the Council of Ministers controls military R&D programs and plans, and the activities of the various ministries involved in defense work. It is headed by L. V. Smirnov, operates under the control and guidance of Ustinov, and is made up of representatives of the eight ministries engaged in military production.[22] Its primary function is to coordinate military R&D, the production of military items, and plans involving the work of more than one ministry of the defense-related industries. This function includes designation of the research institutes, design bureaus, and plants to carry out R&D and ultimately, the production, on a particular program. It also organizes financial, materiel, and manpower resources to support specific programs.

9. The development and production of a submarine-launched ballistic missile illustrates how the VPK discharges its coordination function. At least five of the defense-related ministries probably would be involved in this program. The Ministry for General Machine

---

[21] Two of the four basic tasks of the current plan (1971-1975) concern science and technology. One of these emphasizes the speeding up of scientific progress and the carrying out of a unified technological policy. Industry is to be mechanized and automated more extensively with modern electronic and computer technology, quality is to be raised and standardization broadened, and scientific and technical information is to be made more readily available. The other of these basic tasks is the "comprehensive development of fundamental and applied scientific research" and application of its results in the national economy more rapidly. Also envisioned are various incentive schemes that would make it advantageous for organizations and individuals to try to bring about the efficient and prompt use of R&D results by industry and the military.

[22] The principal branches of the Soviet economy are administered by ministries. Eight ministries comprise the so-called "defense industrial sector": Defense Industry (conventional armaments), General Machine Building (strategic missiles and space vehicles), Machine Building (munitions and solid propellants), Medium Machine Building (nuclear weapons and energy), Aviation Industry, Electronics Industry, Radio Industry, and Shipbuilding Industry.

Building would be responsible for developing the missile itself. Insuring the compatibility of the missile with the submarine would be the job of the Ministry of Shipbuilding Industry. Electronic subsystems would be developed by the Ministry of Radio Industry which would get the necessary components from the Ministry of Electronics Industry. The warhead of the missile would come from the Ministry of Medium Machine Building. The VPK would supervise the coordination of the many components of these ministries from inception of the project to completion of development.

10. *Ministerial Level.* The headquarters of the Ministry of Defense (MOD), the defense-related production ministries, and headquarters at various levels of each of the five armed forces components have military-technical committees that provide R&D advice and guidance to the VPK. These committees develop and coordinate various research plans and examine new projects. They also advise their respective commanders in chief on weapons development and procurement. At the MOD level, support for this activity is drawn from pertinent sectors of the scientific community such as academies of science and higher educational institutions.

11. *Institute and Bureau Level.* Most development work on military products is performed by scientific research institutes or design bureaus which are part of the ministries they serve—mostly the defense-related ministries. These organizations are headed by a chief designer and usually have both experimental and production facilities. The design bureaus generally depend on the basic research done by others, but many of the larger ones conduct their own. "Central design bureaus" coordinate and supervise the work of the many design bureaus that work on the same type of product, such as fighter aircraft.

12. Early in the development of a particular piece of military hardware, the Soviets commonly will form a special commission within one of the defense-related ministries to make recommendations on each phase of development including preliminary design, construction of a mockup, detailed design, construction of a prototype and, finally, testing. The commission normally will include representatives from other industrial ministries, scientific research institutes, the military users, and the chief design bureaus, thereby assuring communication and coordination between research, production, and user. Final tests are conducted by the special commission to ensure that performance meets the military's requirements. Operational tests are then conducted by a military test organization to determine if series production of the hardware ought to follow.[23]

---

[23] The principal Soviet military test ranges for the various kinds of armaments are: *Tyuratam*—the largest of the Soviet test ranges—most intercontinental ballistic missiles (ICBMs) and all large space boosters are flight tested here. [redacted] *Plesetsk* has been used in recent years [redacted] Military support, and other satellites are launched from this facility. The *Nenoksa* range is solely devoted to naval missiles and is currently involved with the development of the newest and largest of these. *Kapustin Yar* is the oldest missile test facility, and is the primary test center for surface-to-surface ballistic missiles of less than intercontinental range. It also has been used for the testing of certain strategic surface-to-air missiles (SAMs). *Ramenskoye* is the main base of the Flight Test Institute responsible for conducting acceptance tests on all aircraft. The *Vladimirovka* testing facility is used for both surface-to-surface and air-to-surface aerodynamic vehicles used against land and sea targets. The *Emba* test center is the site of the development of tactical SAM systems. *Sary Shagan*—the most heavily instrumented R&D range—is used for testing antiballistic and advanced strategic SAM systems. *Novaya Zemlya* and *Semipalatinsk* are the major nuclear weapons test facilities.

ANNEX D

SOVIET PERFORMANCE IN KEY TECHNOLOGICAL AREAS

SOVIET PERFORMANCE IN KEY TECHNOLOGICAL AREAS

1. The ultimate measure of the performance of Soviet military research and development (R&D) is its ability to solve the complex technical problems posed by advanced weaponry. In this Annex we evaluate the *general* quality of Soviet R&D in major technological areas, primarily in the military context. No attempt is made to review specific products and systems—for this purpose, the reader is referred to the Estimates on the various components of the Soviet military forces.

A. Materials

2. *Metals.* Soviet metallurgical technology is sufficiently well developed to meet foreseeable military requirements. R&D in this field has supported adequately the development and manufacture of such weapon systems as missiles, high performance aircraft, and submarines. The Soviets effectively use conventional materials and proven techniques to give military products the desired service life, and to decrease the time needed to develop them. In materials for airframes, they appear to be taking advantage of high strength alloys to reduce weight. Soviet titanium technology is well developed. Higher strength steels probably are being developed, particularly for submarine hulls. Materials technology for aircraft engines is weak in such areas as high temperature protective coatings, but R&D in metallurgical vacuum techniques and high temperature processes are believed to be equivalent to that in the West.

3. As in the past, progress by the Soviets in the important areas of metallurgy will continue to benefit from their knowledge of developments in foreign technology. The Soviets have repeatedly demonstrated an ability to combine effectively their own R&D effort with knowledge of foreign accomplishments to solve materials engineering problems.

4. *Polymers.* Soviet R&D on polymers, such as plastics, fibers, and rubbers, has improved markedly in both quality and quantity over the past 10 years. The Soviets are doing work on a level comparable with that in the US on the development of stronger, fiber-reinforced, polymers some of which are stable at high temperatures. Nevertheless, there has been a notable deficiency in the application of polymer processes discovered in the laboratory. In the area of synthetic rubber, for example, Soviet capabilities lag many Western countries. There is a gap between competence in research and industrial technology—fundamental research on synthetic rubber is of high quality, but in developing the facilities for producing this material in quantity, the Soviets are seriously deficient.

B. Electronics and Sensor Subsystems

5. *Materials, Components, and Devices.* The quality of Soviet fundamental research in electronic materials is approximately equal to that of the US. In areas directly in support of military needs there appears to be a good coupling between basic and applied research. The Soviets have available all conventional types of electronic materials and they have developed some with special performance such as

solar cells and radiation detectors with high temperature resistance—characteristics of particular value for some military and space uses.

6. The quality of research on electronic components and devices is generally comparable with that of the Free World; actual practical developments in these areas, however, lag those of the Free World. Work in discrete devices such as microwave transistors and diodes is adequate to provide near term improvements in Soviet electronic warfare, avionics, and phased-array radar equipment. Studies continue in opto-electronics using lasers, and logic applications have been devised which may greatly increase the capacity of future information systems. Considerable research is devoted to components used in computers.

7. The major shortcoming in this area of technology is poorly developed manufacturing techniques. The quality and reliability of finished Soviet components therefore is generally rather low by Western standards. Quality in this area depends upon cleanliness, the use of high precision instruments operated by competent technicians, the establishment of adequate testing and quality-control methods, and the use of high purity gases and other materials. Soviet industry has met these requirements only marginally.

8. *Computers.* Soviet R&D on computer theory and design is on a par with that of the West. But in the manufacture of computers and related equipment, the USSR is presently developing prototypes comparable to US models first produced in 1965. The translation of basic research into high quality end items has lagged the West due largely to inadequate manufacturing procedures and an inadequate supply of parts. The Soviets are also far behind the West in the development of storage memories and input-output devices. These shortcomings have retarded the development and use of advanced computer programming techniques.

9. In spite of these problems, the Soviets probably are able to satisfy their requirement for computers in high priority military applications. For the present, they probably will continue to follow their general practice of employing computer designs and mathematical techniques that are just able to meet the minimum required performance of computers in military projects. (In a few instances the Soviets appear to have deliberately avoided using computers by adopting design concepts which do not require them.) The advent of the newer Soviet computers will inevitably provide the additional experience needed to advance the development of programming techniques and to expand time sharing systems.

10. *Ballistic Missile Guidance.*

[ ]

11. While there are many uncertainties in assessing the precision of Soviet ballistic missile guidance systems, we are confident that the Soviets are not yet approaching the limits of accuracy attainable by improving components—with no change in the basic guidance system design. The quality of guidance system components—most importantly gyroscopes and accelerometers [25]—is the controlling factor in achieving very high accuracies. The sum of the evidence points to a lag in the USSR's capability to produce very precise gyroscopes and accelerometers. This is due in part to a preoccupation with theoretical, rather than practical, investigations. Engineering problems have also hindered the development of high quality inertial components. For example, the USSR's continued dependence on ball bearings (rather than gas bearings or other suspension techniques) and the use of aluminum (rather than beryllium) in these critical assemblies have been primarily responsible both for shortened operational lifetimes and for significant reductions in quality.

12. The Soviets have a high priority research effort on a range of new approaches to improving conventional gyroscopes and accelerometers. They probably are also working toward developing unconventional inertial sensors, such as the laser and cryogenic gyroscope. In developing new gyroscopes and accelerometers, the USSR probably will concentrate on the complex engineering and manufacturing problems, since much of the theoretical groundwork in these areas already has been laid.

13. If the Soviets elect to develop still more precise guidance, we would expect them to turn to more sophisticated techniques, such as stellar-inertial, or terminal, guidance. [ ] stellar-inertial guidance [ ] is particularly attractive for missiles launched from mobile platforms, such as submarines, in order to reduce errors resulting from uncertainty in the precise position of the launch platform. In any case, the quality of gyroscopes and accelerometers will continue to be important factors in determining guidance system accuracy.

14. *Radar.* Soviet radar R&D has generally followed traditional radar design principles, but major advances have been made in the development of radars incorporating phased-array technology. Present research appears to be concentrated on improving existing radar designs and using proven concepts. The Soviets probably now lead the West in the development of large radar antennas. They still lag, however, in such areas as signal processing and solid-state radar developments.

15. Because of the different design philosophies used by the US and USSR radars for their strategic defense, direct and specific comparison is difficult. Although the level of sophistication of Soviet radar technology appears to be somewhat less than that of US designs, the Soviets have deployed some equipment superior to similar operational US equipment. This difference in capabilities is more a matter of kind than degree; there are a number of examples of US radars with performance capabilities which the Soviets have not demonstrated and probably cannot match. Still, the Soviets have demonstrated a degree

---

[25] Despite the difference in design, both the US and the USSR use inertial guidance for their ballistic missiles. This technique insures that the missiles are immune to jamming because the guidance system is contained in the missile. No radio link with the ground is required. The prime components are accelerometers (which measure acceleration in a given direction) and gyroscopes (which measure deviation from a reference direction).

of independence, especially in their large phased-array radar development which indicates a high level of confidence in their own engineering decision-making and R&D capability.

16. The further development of radar systems for ballistic missile defense, over-the-horizon detection, space surveillance, and low-altitude air defense is being given high priority. Concentrated and competent research is underway in such areas as signal processing, data processing, and electronic steering applicable to such systems, which probably will lead to significant advances within the next five years.

17. *Communications.* The Soviets, over the years, have supported a large scale, high quality R&D program in all areas of communications. While this program has resulted in a high level of technology in some of these areas, their overall research efforts have culminated in systems inferior to those developed in the Western world. Strong points of Soviet efforts include the theoretical aspects of communications, among which are information, modulation, and coding theories. They have excelled in propagation and hardware R&D aspects associated with high frequency (HF) long distance radio communications.

18. With few exceptions, among them laser communication R&D, the Soviets have come up short when compared to the West in almost all aspects of high capacity multichannel system R&D. This is especially true concerning high frequencies (VHF and UHF) which are used to take advantage of the greater bandwidths. Illustrative of the Soviet lag in communication system R&D is their tropospheric scatter systems which have failed to attain the level of technology of the West, particularly in terms of the development of high capacity systems.

19. Future Soviet efforts probably will be concentrated in systems development as opposed to phenomenological or theoretical R&D. Such areas as filtering technology and HF wideband components and devices will probably be stressed. The overall prospects for future progress in these areas appear good. One possible limiting factor during the next several years, however, may be the inability of the Soviets to provide high-quality, HF, electronic components on a large scale.

20. *Lasers.* The Soviet Union occupies an advanced position in laser R&D, with its overall program second only to that of the US. The Soviets have demonstrated competence in all areas of laser research which are of importance to military applications. They are actively engaged in the development of a multi-kilowatt gas dynamic laser, and although they have admitted to achieving powers of only a few watts, the techniques they are employing are the same as those used by the US to surpass the 500 kilowatt power level. Similarly, the Soviets are pushing the development of electrically-excited and chemical lasers, other devices with the potential for large power outputs. All of these lasers are being studied in the US as possible weapons.

21. Another area of Soviet expertise is the high-power pulsed laser field, especially neodymium-glass lasers capable of producing short pulses of light at extremely high-power levels. The Soviets have used these huge, multistage devices in studies related to plasma generation and controlled thermonuclear reactions (CTR) and probably have extended their interests in laser/plasma interactions to include those aspects related to nuclear weapons research.

22. The general direction of Soviet laser research is expected to remain the same with emphasis on high-power lasers (pulsed and

continuous), laser/CTR studies and, very likely, the application of lasers to weapon systems. They are faced with the same difficulties as face the US, however, in perfecting lasers for weapons purposes. These include both the production of the required high energies and the transmission of these energies through the atmosphere to the target, as well as the problems associated with pointing and tracking. It is highly unlikely that in the next five years the Soviets can overcome the existing obstacles and succeed in developing laser kill weapons. Other military laser devices such as target illuminators, range finders, and similar devices requiring low power also may be under development.

C. Propulsion

23. *Missile and Space Propulsion.* At the end of World War II, the Soviets had available the German V-2 missile with its throttleable rocket engine. They incorporated this engine in their early missiles and refined the thrust throttling feature to a point well ahead of comparable US technology. This technique obviates the need for onboard digital computers by varying the missile's thrust so that it can fly a preprogrammed trajectory to its target. It also obviates the need for vernier (control) engines in some Soviet missile designs and permits other simplifications as well. The Soviets also led the US in developing the materials and techniques needed for very high chamber pressures to increase the efficiency of rocket engine combustion.

24. Nonetheless, the USSR has lagged the US in many important areas of missile and space propulsion technology. Notable examples are the development of liquid-hydrogen engines (an essential ingredient in the US Apollo program) and the development of large solid-propellant rocket motors (long used by the US for both missile and space applications).

25. *Liquid Propellants.* Soviet work on liquid-propellant systems has resulted in the production of reliable rocket engines for a wide variety of missile and space launch systems. Both the US and the USSR progressed from non-storable liquid propellants to liquids that could be stored in a missile to improve reaction times and to simplify handling. While the US then turned to solid propellants for its ballistic missiles, the USSR continued with liquid-propellant systems, which still serve as the backbone of the Soviet ballistic missile force.

26. The USSR's more recent ballistic missiles use nitrogen-base oxidizers with hydrazine fuel, which provide the highest energy of all conventional storable propellants. If the Soviets elected to improve the performance of their intercontinental ballistic missile (ICBM) propellants, we would expect them to use additives with their present propellant combinations, rather than turning to propellants such as fluorine—which would be more efficient, but would greatly increase toxicity and handling problems. Fluorine or other high-energy propellants, however, probably will be used eventually in the space program.

27. *Solid Propellants.* Despite a large capacity for manufacturing solid propellants, the Soviets have flight tested only two solid-propellant ballistic missiles—the SS-13 ICBM and the SS-14 medium-range ballistic missile (which is made up of the upper two stages of the SS-13). Only the SS-13 is known to be operationally deployed, and thus far only in limited numbers. Solid propellant ICBMs have some unique advantages, such as ease of handling and simplicity of construction. But they require stringent environmental controls and do not lend themselves to the guidance concept long used by the USSR.

28. The Soviet production capacity appears to be more than adequate to meet the USSR's present solid-propellant requirement—for the SS-13, the SS-14, and an array of defensive missiles and tactical rockets. Additional solid-propellant facilities are under construction. We believe, therefore, that the Soviets will press forward with solid-propellant R&D. There are indications that they are developing large prototype solid-propellant rocket motors for ballistic missiles and probably for space boosters, and that effort appears to be moving at a steady pace.

29. *High-Energy Propellants.* We believe that the USSR has been working on the development of high-energy propellants for the space program since the mid-1960s, but they have not yet been used in any flight tests.

30. The construction of R&D and static test facilities suggests that the Soviets have been conducting research aimed at exploiting liquid hydrogen and liquid fluorine as high-energy propellants. It is difficult to predict the current status of these programs, but the Soviets probably are about ready to flight test a liquid-hydrogen engine. A space system using a liquid-fluorine engine could reach flight testing stage within two years.

31. *Marine and Naval Propulsion.* The steam propulsion plants of the latest Soviet naval ships and submarines are of higher power per unit of weight and volume than comparable US systems. The major Soviet naval combatant ships pack more horsepower, and are capable of higher sustained speeds than US ships. The Soviets were the first to develop and operate ships utilizing all-gas turbine propulsion plants of a power rating not yet achieved by the West. Certain Soviet submarines are the fastest in the world. Soviet literature indicates that there will be continued development and expansion of the uses of steam plants incorporating higher steam temperatures and pressures, and superheating.

32. There is no specific information available on current developments in Soviet naval and marine nuclear propulsion. We can, however, make some generalizations based on the past performance of units using nuclear propulsion systems. The Soviets have chosen compact propulsion plants of high power to get maximum speeds for their nuclear submarines, while paying the price of noiser operation and more difficult maintenance. Nuclear fuel cores must be replaced more frequently than is the case with US reactors. The Soviets are aware of current Western research developments in this field such as the concept of the consolidated nuclear steam generator, which permits a more efficient and compact reactor system, and on the natural circulation reactor, which requires no pumps and therefore is quieter, and they may now be performing R&D in these areas.

33. *Aircraft Propulsion.* Turbine engines for their aircraft are well designed, but the Soviets have had problems because of the practice they follow in producing them—the use of low quality materials have resulted in engines that need frequent overhaul and which have relatively short lifetimes. This approach also produces larger and heavier engines that are less efficient than Western engines because of their lower operating temperatures. Fuel consumption rates for most of the known Soviet turbine engines are higher than for those of the West, especially when the afterburner is in use. The increasing use of advanced metal alloys has produced modest improvements in the performance of Soviet engines, most notably in operating temperatures and fuel consumption, but the Soviets are still far behind Western standards for the time that elapses between engine overhauls.

D. Systems Design

34. *General.* It is particularly difficult to evaluate the effectiveness of Soviet design of entire weapon systems, as such evaluation presupposes our knowledge of the design goals and performance standards. We do not have this information. In the absence of such criteria, we often tend to evaluate Soviet systems designs on the basis of their effectiveness relative to similar US systems. If Soviet strategic military objectives (and hence weapons development objectives) were the same as those of the US, this would be a valid exercise. But Soviet objectives, design approaches, and production and performance standards are different from those of the US. Consequently, weapon systems that may appear less effective than comparable US systems, often lag US developments for reasons of less pressing force requirements, not for reasons of inferior R&D effectiveness. Alternatively, other systems that appear to lead the US often do so merely because a requirement was identified earlier in the USSR and they have little relation to technical capabilities.

35. There are, however, common denominators in all Soviet weapon systems design that are indicative of the effectiveness of their general approach. Their weapon systems appear uniformly to be relatively simple in concept, rugged in construction, and reliable in operation. They seem to use conservative approaches, preferring many small technical advances, tested at each step, rather than greater steps. When they have departed from these principles, they have been less successful.

36. The effectiveness of their R&D as expressed in systems design thus consists not so much in a few large bold steps, as it does in persistently pushing ahead with a continually growing effort on many fronts. This is not to say the Soviet approaches lack imagination, rather that they limit risk taking, and rely upon a considerable momentum of effort to carry them forward.

37. *Ballistic Missiles.* The Soviets have tended to be conservative in designing their ICBMs and other surface-to-surface missiles. They have chosen relatively simple and rugged systems, which, after flight testing, have proven to be reliable[ ]The Soviets tend to stick with proven design concepts for their ICBMs and no persistent technological weakness has been evident. For the most part, present designs evolved gradually as a result of improvements in earlier missiles. During the flight testing of specific missiles, which usually involves about 20 firings and lasts about two years, the Soviets occasionally experience serious difficulties but these have been overcome in most instances. Some missile programs, however, never reached the flight test stage. We know of at least a dozen[26] that were abandoned, some after construction of facilities for their launch indicating selectivity and competition in the R&D work in this area.

38. Modifications to Soviet ICBMs over the past decade have included alteration of the size and shape of re-entry vehicles (RVs), redesign of tankage to permit greater ranges and payload, the use of multiple RV systems, and the introduction of penetration aids. The time required to flight test these modifications has varied considerably. On the average, however, about two years has been required for each one, and the number of flight tests has ranged from about 12 to 24.

39. *Space Launch Vehicles.* Six distinct space boosters, with a wide range of capabilities, have been developed by the Soviets. Through the mid-1960s these boosters were reliable adaptations of proven ballistic missile designs, usually with additional upper stages, thereby simplifying development. The Soviets have had dismal results with their R&D on boosters developed solely for use in space.

40. The first booster developed exclusively for the Soviet space program—the SL-12—has been plagued with problems since its introduction about four years ago. Its most recent tests have been successful, but there were 13 failures out of the first 19 attempts at launch. The only other booster specifically designed for space missions is the huge J-vehicle which failed catastrophically both times test flights were attempted. We do not know the reason for this poor record. Inadequate testing of design concepts, poor quality control during manufacture, and less than vigorous prelaunch checkout procedures, may all be contributing factors.

41. *Aircraft.* The Soviets have a very strong capability in both theoretical and applied aircraft design that has grown steadily in facilities, personnel, and capabilities. They have demonstrated their capabilities in these fields by effectively designing all types of aerodynamic vehicles. Since the mid-1950s the Soviets have developed at least 21 distinct fighter types, of which 8 are not in operation and 2 currently are in test. Eight bomber prototypes have appeared in the same period, of which two were deployed and one is in flight test. A large number of helicopters, transports, and utility aircraft prototypes have appeared, of which 43 were produced and deployed. In addition, the Soviets have developed, tested, and deployed several variants of each basic design subsequent to its initial appearance.

42. Soviet theoretical work in aerodynamics is among the best in the world. Whereas the earliest research was concentrated on high speed phenomena, current programs are examining ways to improve aerodynamic efficiency at all speeds in association with specific vehicles. The strength of the Soviets in this general area grows out of a long-term and continuous effort which evaluates and applies research results only after extensive experimental work. The Soviets also have shown a willingness to invest in environmental test facilities well in advance of actual needs. Research is characterized for the most part by low cost, simple solutions to specific design requirements. Thus, for example, large weights are used to eliminate flutter in aircraft wings rather than lighter designs requiring complex and expensive construction; protruding devices (flow fences) which affect the flow of air over the wings are employed on swept wings.

43. Basic theoretical and experimental research has been broadened in recent years. Presently, emphasis is being placed on the technology of vertical, short takeoff and landing aircraft. Another aspect of R&D which could see application in the near future is the study of supercritical airfoils which reduce the drag on aircraft.

44. The Soviets have mounted what they term "an all-out national effort" on laminar flow techniques which increase the range of high performance aircraft. Western nations abandoned this technique after initial tests concluding that weight and power consumption penalties would offset any gains. The persistent effort by the Soviets indicates that they see a reasonable prospect for successful development.

45. The most significant Soviet advances have been made in the area of applied aerodynamics. The Soviets tend to concentrate on single purpose designs which facilitate construction and maintenance while accepting some performance penalties. As a result, aircraft designs in the past were often crude, with protruding structural components. They have made great strides in overcoming these and other undesirable aspects of aircraft design as demonstrated by the Foxbat aircraft.

46. *Naval Systems*. The effectiveness of the Soviet approach to designing naval systems is difficult to evaluate, primarily because development is based on Soviet, not Western needs and strategy. And since we have not penetrated the Soviet decision-making process, we can only make informed guesses as to how they perceive these needs. Even a cursory examination of Soviet naval development technology reveals that the quality of the systems it has produced has been very uneven compared to Western efforts. Some programs appear to be comparable, other surpass comparable technology, and still others seem to lag Western developments by a substantial amount.

47. In some cases, the Soviets have vigorously pursued lines of development which the West has abandoned or dismissed as unworkable. In others they have given up or not attempted programs which the US regards as essential. It is tempting to conclude from all of this that Soviet naval R&D is erratic and poorly organized and that it is incapable of solving basic problems in such areas as afloat logistics or sonobuoy manufacturing. But a more realistic judgment is that Soviet naval R&D—which are merely systematic means of producing the hardware to carry out Soviet naval strategy—are shaped by the Soviets' perception of their needs and the threat facing them.

48. The effort which produced a variety of antiship cruise missiles is perhaps the best illustration of this thesis. Although the West abandoned its early efforts in the submarine-launched cruise missile field, the Soviets have developed, adapted, and refined the antiship missile concept to the point where cruise missile-equipped subsurface, surface, and air units are now the backbone of the Soviet general purpose fleet. The magnitude of this program was a direct result of Soviet realization that the major seaborne threat facing them in the 1950s was Western carrier-based aviation, and that, as dramatically illustrated by the Cuban missile crisis, a counterstrategy is still required today and in the foreseeable future to limit Western options for intervention in distant areas. Thus the cruise missile effort is eminently justifiable in strategic terms. It is also more economical than a large fleet of aircraft carriers, which did not fit with the traditionally defensive strategy of the Soviet Navy.

49. If cruise missiles represent an example of naval development patterned on peculiarly Soviet needs, there are other programs which were either abandoned, or never undertaken because there was no perceived need to support them. The Soviets have, as yet, no attack carriers or nuclear-powered surface warships, at least partly because there has been no doctrinal need for them. Traditionally a con-

tinental power, largely self-sufficient in strategic materials, with no overseas allies or long sea lines to safeguard, the Soviets could concentrate on building an "anti-navy navy." They therefore steered clear of expensive power projection forces with great endurance, emphasizing submarines and high-speed, and heavily armed surface warships.

50. But not all of the differences can be explained away in strategic terms. There are many requirements which are common to both East and West. Some of these have been adequately covered by Soviet development programs. Examples are the excellent naval guns and underwater ordnance which the Soviets have produced. Nevertheless, there is one key area in which the apparent lack of progress remains puzzling—antisubmarine warfare (ASW) detection. Despite frequent discussion of the magnitude of the submarine-launched ballistic missile threat to the USSR and praise of Soviet antisubmarine forces, their hardware development, particularly in the areas of sonobuoys and moored acoustic detection systems, seems poor by Western standards. There are a number of possible explanations for this apparent lack of progress—all of which probably contribute to their poor showing. It is possible that the Soviets have not yet decided on the final course of their ASW strategy

Or the answer may simply be poor management, inefficiency, or a lack of skilled technical manpower. Whatever the reason, it is clear that Soviet naval R&D is not always immediately responsive to stated Soviet needs, even those of the greatest strategic importance.

51. Another apparent anomaly is the continued appearance of bulky, unsophisticated components in some of their newer systems. Whether deliberate or dictated by reason of economy, maintainability, or simply by poor management techniques which left large stockpiles of older components to be consumed, certain Soviet electronic and cruise-missile systems in particular have relatively simple components adequate to do the job, but without undue sophistication. Rather than indicating a poor quality of effort, this might very well indicate the ability to plan and construct systems designed to fulfill a mission with minimum cost, while avoiding problems of maintainability, cost, and reliability attendant upon more sophisticated systems.

52. *Defensive Missile Systems.* Soviet technology has produced some impressive accomplishments in defensive missile systems. Because of the priority given by the Soviets to problems of territorial defense, this has been an area in which the Soviets have been particularly active and willing to allocate large portions of available resources. In general, the Soviets have attached great importance to the creation of a defensive missile force able to cope with an immediate air or missile threat, rather than to the development of highly sophisticated systems able to cope with such threats anticipated for the future. The result has been the continued existence of defenses which appear anachronistic. Examples are the SA-1 air defense system deployed around Moscow in the early 1950s for defense against the "thousand plane raids" that were typical of World War II, and the present Moscow antiballistic missile (ABM) defenses which cannot cope with the penetration aids now carried by US ICBMs. The Soviets therefore have had to devote considerable effort to the continual modification and improvement of older systems so as to main-

tain their viability in the face of more sophisticated threats. In large measure this is the result of a peculiarly Soviet set of imperatives rather than the result of any limitations in Soviet technology.

53. When there has been a need for high technology, the Soviets have generally met the requirement without reliance upon advanced technology from the West. Indeed, the approach taken by the Soviets in the design of air defense systems is an original one which spurned even the contributions made by German scientists taken to the Soviet Union after the war. Most important in this regard was the early Soviet development of track-while-scan systems able to cope with many targets simultaneously.

54. The Soviets have tended to take simpler, less complex approaches to solving many of their defensive missile problems. Rather than build into a single set of equipment the ability to cope with many types of threats, they have proliferated the number of deployed sets of equipment and have filled identified gaps in coverage through the addition of new systems which become integrated into a complete air defense network. Nonetheless, a high level of technological sophistication has been shown in certain cases. For example, the propulsion most likely employed by the SA-6 air defense missile appears to involve a hybrid ramjet solid-propellant system investigated but not yet built by the US. And in their ABM system. the operational flexibility of the Galosh missile, which is achieved by a rather elaborate fuel management scheme, has provided the Soviets with a long-range interceptor not matched by anything yet flown in the US.

55. There are, to be sure, notable gaps in high technology in Soviet defensive missile systems. These include the lack of a high acceleration ABM interceptor, and testing of look-down airborne intercept radars. These appear to be highly desirable developments which the Soviets should logically pursue in order to meet requirements they must feel. Their absence though may be the result of design choices not entirely apparent to us.

CENTRAL INTELLIGENCE AGENCY

DISSEMINATION NOTICE

1. This document was disseminated by the Central Intelligence Agency. This copy is for the information and use of the recipient and of persons under his jurisdiction on a need to know basis. Additional essential dissemination may be authorized by the following officials within their respective departments:

a. Director of Intelligence and Research, for the Department of State
b. Director, Defense Intelligence Agency, for the Office of the Secretary of Defense and the organization of the Joint Chiefs of Staff
c. Assistant Chief of Staff for Intelligence, Department of the Army, for the Department of the Army
d. Assistant Chief of Naval Operations (Intelligence), for the Department of the Navy
e. Assistant Chief of Staff, Intelligence, USAF, for the Department of the Air Force
f. Director of Intelligence, AEC, for the Atomic Energy Commission
g. Assistant Director, FBI, for the Federal Bureau of Investigation
h. Director of NSA, for the National Security Agency
i. Director of Central Reference, CIA, for any other Department or Agency

2. This document may be retained, or destroyed by burning in accordance with applicable security regulations, or returned to the Central Intelligence Agency by arrangement with the Office of Central Reference, CIA.

3. When this document is disseminated overseas, the overseas recipients may retain it for a period not in excess of one year. At the end of this period, the document should either be destroyed, returned to the forwarding agency, or permission should be requested of the forwarding agency to retain it in accordance with IAC–D–69/2, 22 June 1953.

4. The title of this document when used separately from the text should be classified: FOR OFFICIAL USE ONLY

DISTRIBUTION:
White House
National Security Council
Department of State
Department of Defense
Atomic Energy Commission
Federal Bureau of Investigation

TOP SECRET
Controlled [redacted]
Limi[redacted]ribution

TOP SECRET