~~Secret~~

19573

19573

DIRECTORATE OF
INTELLIGENCE

Intelligence Report

The Technological Gap:
The USSR vs the US and Western Europe

~~Secret~~

ER IR 69-13
June 1969

Copy No.

CONTENTS

CENTRAL INTELLIGENCE AGENCY
Directorate of Intelligence
June 1969

INTELLIGENCE REPORT

The Technological Gap: The USSR vs the US and Western Europe

Summary

The technological gap between the Soviet Union and the developed West is large and is probably widening. The gap apparently narrowed somewhat during the 1950's but evidently has been widening during the 1960's. Thus, except in the military field, the Soviet Union has not shared in the post-World War II technological revolution to the same extent as have the United States and Western Europe. The Soviet lag will probably become even greater, as long as the USSR continues to preserve all of the essentials of the present system of planning and economic administration that have retarded innovation in the past.

The Soviet technological lag is reflected in the large productivity gap that exists between the USSR and the West. The productivity (output per unit of capital and labor) of the Soviet economy is only about one-third that of the United States and a little over three-fifths that of Western Europe. Because full allowance cannot be made for differences in product quality, this measure tends to overstate the relative capabilities of the USSR. Although the measure of productivity differences reflects a number of factors -- notably differences in the quality of the labor force, in the allocation of resources, in management, and in natural endowments -- the level of technology actually employed

Note: This report was produced solely by CIA. It was prepared by the Office of Economic Research and was coordinated with the Office of Scientific Intelligence. The judgments on the technology in use in military industries have been coordinated with the Office of Strategic Research.

is an important ingredient, but one that cannot be quantified.

During the 1950's, productivity rose somewhat more rapidly in the USSR than in the United States, but considerably less rapidly than in Western Europe. In the 1960's, productivity has slowed markedly in the USSR, speeded up considerably in the United States and continued at about the same high rate in Western Europe. These data suggest, but do not prove, that the technological gap is widening; they indicate unmistakably, however, that the Soviet Union is falling farther behind the West in the efficiency with which it manages its economic resources, including technology.

In the postwar period the USSR has borrowed technology extensively from the West, particularly from Western Europe. Total imports of machinery and equipment from the developed West increased from a mere $100 million in 1950 to nearly $800 million in 1968. In the 1960's the USSR imported plant and equipment for the chemical industry amounting to more than $1 billion and plant and equipment for the consumer goods industries totaling about $500 million. Contracts totaling more than $1 billion have been let or are under negotiation with Western firms in a massive Soviet effort to modernize and expand the small and obsolescent motor vehicle industry.

In the market economies of the West new technologies are spread rapidly, and the pace evidently has quickened in recent years. Private business firms, spurred by competition and profit incentives, have been the innovators in this process and governments have provided tax incentives and financial support. In addition, the multinational firms, which have burgeoned in the West in the postwar period, have greatly facilitated the international transfer of technology.

In the USSR the development and diffusion of new technology tends to be much more balky than in the West. The USSR's centrally administered economy has no automatic mechanism for bringing about technological change; the incentives that are intended to do so are ineffective. Instead, new production methods and products are "introduced" by administrative bodies through plans for new technology and new products. The required materials and equipment are also planned and distributed centrally. As a concomitant, most research and development is carried out in government institutes rather than by enterprises. This bureaucratization of the innovative process is a severe drag on technological change.

An even greater obstacle is the built-in reluctance of plant managers to change technology, because such changes threaten plan fulfillment, may result in loss of bonuses, and bring on more demanding plan assignments. Because of taut planning, there are few reserve supplies and plant capacities to handle bottlenecks and provide flexibility. Finally, because of the peculiarities of Soviet prices, there is no accurate means for determining the payoff on new technology. Even when new plants and equipment are imported, licenses acquired, or foreign technologies merely copied, the *modus operandi* of the Soviet system delays their introduction and reduces their effectiveness in comparison with results that would be obtained in the West.

The ability of the USSR to manage technological change (investment programs) evidently has deteriorated in the past decade. Both the rate of productivity growth and the return on invested capital have fallen sharply during the 1960's in contrast to a stability or rise in the United States and Western Europe. The current Soviet leadership is relying on a series of economic reforms to achieve a breakthrough in coping with the chronic obstacles to technological change. These reforms represent merely one more attempt -- and an exceedingly cumbersome one -- to make the system work better without changing its essential features. The prospects for their speeding up the innovative process in the Soviet economy are not promising.

In the industrial sector the level of Soviet technology relative to the West differs greatly among the various branches, a direct reflection of Soviet priorities over the years. These priorities have favored the military sector above all. This favored status, coupled with rigid secrecy policies, has, in effect, resulted in a dual economic system -- military and civilian -- with the former having been protected from the frustrations in resource supply that plague the latter. Consequently, the USSR has achieved near-parity with the United States in technology for producing many types of weapons and space equipment, and even superiority in a few areas.

Second priority has been accorded to the basic industries whose output directly supports both military production and the investment programs essential to rapid growth -- steel, fuels, electric power, producers' equipment, and more recently, chemicals. Although these basic industries have equaled or even occasionally surpassed the West in some technologies in a few plants, the bulk of their output is produced with technology obsolescent by a number of years relative to that predominantly in use in the West.

Last in the scale of priorities have been the industries catering to the population -- textile and clothing, food processing, consumer durables, and household products. Their low status has resulted in an average level of production technology that is woefully backward by Western standards -- by several decades in many cases. These industries, by and large, also turn out products of a quality and assortment far inferior to those produced anywhere in the industrial West.

In no major branch of industry is the average level of Soviet technology in use on a par with that in the United States or Western Europe, and the Soviet position does not appear to be improving relative to the West:

The Soviet aircraft industry produces high-performance fighters and interceptors comparable with those in the West, but civil transport aircraft now entering production are inferior to similar Western aircraft in range, payload, fuel consumption, and engine life.

Soviet technology for producing computers, peripheral equipment, and solid-state electronic components is behind that of the West by at least five years, and the gap is widening; Soviet comsat technology lags three to five years behind the West and is likely to remain so for the foreseeable future.

The Soviet stock of machine tools is considerably younger than in the United States, but its technological composition is inferior, because of its poor quality and the preponderance of standardized, general-purpose tools.

Both the production technology and the product mix in the Soviet automotive and tractor industry are obsolescent compared with the West; many products are merely copies of old US designs.

In almost all aspects of petroleum technology the USSR lags well behind the United States, by as much as 10 years in seismic exploration and offshore drilling.

Soviet blast furnace technology is approximately on a par with the West, but only 12 percent of Soviet steel is made by the modern oxygen converter process, compared with over one-fourth in Western Europe and over one-third in the United States, and Soviet rolling and finishing facilities are grossly inadequate and technologically inferior to those in the West.

Although the USSR leads the world in construction of hydroelectric powerplants and in high-voltage long-distance transmission, Soviet thermal power engineering lags at least five years behind the United States both in size of units and in other technology.

In coal mining, Soviet longwall technology is behind that of the United Kingdom and West Germany, where natural conditions are comparable, and the USSR lags behind both the United States and Western Europe by a decade or more in mechanical loading, mechanization of surface work, and coal preparation techniques.

The Soviet chemical industry is at least five years behind the West in the technology used to produce most important chemicals, and its product mix with its relatively small production of synthetics is obsolescent; no Soviet plant yet produces ammonia using the new technology that is revolutionizing fertilizer production in the West.

By and large, the technological level of the Soviet food processing and textile industries is a generation behind the West; Soviet appliances and housewares, often produced as sidelines in heavy machinery and aircraft plants, are mainly copies of obsolete Western models.

I. Introduction

1. This report is intended as a preliminary analysis of the current extent of the technological gap between the United States and the USSR, and of recent trends in the relative positions of the two countries. Wherever possible, comparisons are also made with Western Europe. The review is made on two levels: (1) overall, by quantitative measurements in the size and trends in the gap to the extent that it is reflected in total output per unit of total inputs (factor productivity) in the two economies and in other aggregate indicators, and (2) in industry, by a series of brief summaries of the differences in technological levels and trends in the two countries in individual industries. The relative commitments of resources to technological development are also discussed. Finally, a summary and comparative description is given of the innovative processes -- invention, diffusion, and adaptation of new technologies in the two radically different economic systems, followed by an assessment of the USSR's near-term prospects for significantly narrowing the gap.

2. Following more or less along the lines of a recent, somewhat similar study of the gap between the United States and Western Europe,* this report defines technology simply as the methods of converting raw materials into semifabricants and final products and the design of final products. Technological advance (innovation) means the introduction of new methods and designs that, compared with existing ones, either reduce costs or improve the quality and services of existing products or yield new products and services. Technological advance in the narrower sense thus takes the form of new products, such as video-tape recorders, and new processes, such as the oxygen converter process for steelmaking. In a broader sense, technological progress also involves the application of advanced management techniques -- for example, statistical quality control -- and the use of efficient forms of economic organization -- for example, the assembly lines.

3. In comparing one country's technological level with another's, it is important to distinguish

* *US Department of Commerce,* The Nature and Causes of the Technological Gap Between the United States and Western Europe, *FOR OFFICIAL USE ONLY. (To be published.)*

between technological *knowledge* and technology *in use*. At any given time, even in the same country, a much greater store of technological knowledge exists than is actually being employed to produce goods and services. This storehouse of knowledge about potentially economical designs and processes is an amalgam of ideas in various stages of fruition. Some may have been tested and await only the necessary incentives for exploitation; others are reasonably well worked out and close to operational; still others are merely embryonic. Technology progresses as these ideas become operational and are put to use. These considerations apply to a country's domestically developing technology. In addition, through trade and patent-licensing possibilities, countries can borrow technology from one another. This report considers only that Soviet and Western technology actually in use. No attempt is made to measure the gap in technological knowledge. In the modern world, new technological knowledge spreads very rapidly. Hence, the disparities in the level of technological knowledge among countries are likely to be much smaller than the disparities in the levels of technology in use.

4. Judgments about relative levels and trends in technology in use (hereafter referred to simply as technology) necessarily must be largely qualitative, because of the many qualifications that must be attached to the various quantitative measures bearing on overall technological levels and trends. With respect to specific industries, large elements of subjectivity are involved in estimates of how many years one country is behind or ahead of another country in a particular area. Speculations about the future are especially hazardous when they concern such a complex matter as technological change. The conclusions presented in this report are tentative and provisional.

II. The Current Size of the Gap

A. Development of Soviet Technology

5. From the outset of its industrialization drive the USSR has used every device available to keep abreast of worldwide developments in technology, while simultaneously maintaining a policy of cultural and political isolation. In the early 1930's the USSR borrowed technology from abroad on

a massive scale via imports of machinery and equipment to further its goal of industrializing at breakneck speed. After a period of retrenchment that lasted from the late 1930's until the mid-1950's the USSR again went into the borrowing business on a broad front. It did so primarily by sharply increasing its imports of machinery and equipment from the industrial West.

6. Soviet technology has been further boosted by the purchase of foreign patents and licenses, by the conclusion of scientific and technical agreements with Western firms, and by the exploitation of foreign scientific and technical literature. A special institute under the Academy of Sciences conducts a large-scale program of abstracting and disseminating such literature; in 1967 some 16,350 foreign periodicals and 6,500 books were abstracted. Over the past decade the USSR also has actively participated in a program of scientific and technical exchanges with the United States, from which it must have benefited in terms of technological advance in civilian fields.

7. Finally, the USSR, particularly since 1955, has built up a large domestic capability to develop technology through a massive research and development establishment, which has worked out its own innovations and adapted foreign technologies to Soviet use. As a result, Soviet technology may be ahead of the West in a few military-related areas, such as large helicopters. Nevertheless, although the USSR now sells patents and licenses on its own technologies to the West, the innovations emanating from its research and development establishment have been few.

B. Measurement of the Technological Gap

8. The average level of technology throughout the Soviet economy can be compared with that in the United States and Western Europe by using several different quantitative measures that reflect the general levels and trends in technological development. The measurements and their limitations are discussed in the following section.

1. Overall Levels

9. No precise measure of international differences in levels of technology has yet been devised,

even assuming that the term itself could be defined precisely enough to permit such measurement. An assortment of aggregative measures can be used, however, to give some quantitative content to the impression obtained by all Western observers that the USSR is not on a par with the West in overall technology. The measures are: gross national product (GNP) per unit of labor and capital (factor productivity), GNP per worker (labor productivity), and value of capital stock per worker. The measures are summarized in Table 1. The data for Western Europe relate to 1964, and those for the USSR are for 1967; the estimate of factor productivity is based on an estimate for 1960 made by Abram Bergson* and extrapolated to 1967 by means of estimates of growth of inputs and output.

Table 1

Approximations of Relative Levels of Technological Advancement of the United States, Western Europe, and the USSR in the Mid-1960's a/

	GNP per Unit of Capital and Labor	GNP per Worker	Capital Stock per Worker
United States	100	100	100
Northwest Europe	55	48	45
Italy	35	33	31
USSR	34	33	31

a. All percentage comparisons of levels of GNP, productivity, and expenditures for various purposes given in this report are the geometric means of two comparisons -- one carried out in US prices and one carried out in the domestic prices of the countries being compared.

10. Each of these measures has serious limitations as an indicator of relative levels of

* *Bergson,* Planning and Productivity Under Soviet Socialism, *Columbia University Press, 1968, p. 22.*

technological development among countries. The measure "capital stock per worker" implies that all technology actually available for use is embodied in the capital stock, an assumption that would serve to define technology in an essentially physical and quite narrow way. Moreover, the technological composition (proportion of the old compared with new) of the stock varies among countries, and in any event international comparisons of values of capital stock, to say nothing of domestic valuations of the stock, are especially tenuous. The other two measures -- GNP per worker and GNP per unit of capital and labor -- pertain to relative productivity levels among countries. Obviously, productivity differences are attributable to many factors other than technology in the fairly narrow way defined in this report -- for example, differences in natural resource endowments, levels of education, and managerial methods in the broad sense. Indeed, allowance for the effect of differences in the quality of the labor force (level of education and extent of female employment) reduces the "productivity gap" significantly, but the pattern is essentially the same. The USSR and Italy are at about two-fifths and Northwestern Europe is at about three-fifths of the US level.

11. With all appropriate reservations, differences in the technology actually being employed unquestionably constitute a major element in these international differences in productivity. They indicate clearly that the average level of technology in the Soviet economy is far below that of the United States and also well below that of Western Europe. Moreover, these measures make inadequate allowance for the quality of what the technology produces. Were full allowance to be made for product quality, the average level of Soviet technology would be, comparatively, even lower than the level indicated above.

2. In Industry

12. Although no attempt to quantify has been made because of lack of data, the average level of technology in use in the industrial sector alone is probably somewhat higher in the USSR relative to the West than is that for the economy as a whole. There are, however, enormous variations among the branches of industry, and within individual branches, in the level of technology vis-a-vis the West. Moreover,

in all countries there are wide differences among individual plants in the age of the technology used, but the variation is much greater in the USSR than in the West. Within a given branch of industry some Soviet plants may use technologies equal to or even superior to the average for that industry in the United States or Western Europe. Within each branch, also, the Soviet average level relative to the West will differ widely among product groups. In no major branch, however, is the average technological level on a par with the average level in use in the United States or Western Europe. Roughly speaking, Soviet technology probably comes closest to Western levels in machinery (including electronics and military equipment) and in metallurgy, and it lags farthest behind in coal mining, forest products, textiles and clothing, and food processing. Chemicals, petroleum, electric power generation, and construction materials seem to occupy a middle position. The following sections are capsule assessments of Soviet technology relative to the West in important branches of industry.

Aircraft

13. The Soviet aircraft industry produces high-performance fighters and interceptors, comparable with those in the West, but Soviet civil transports now entering production are inferior to similar Western transports in range, payload, fuel consumption, and engine life. Moreover, the development of Soviet transport aircraft typically has required an extremely long period between initial flight and series production. The USSR leads the world in development of rotor systems for very large helicopters and has also been first in many other features of helicopter design. The United States, however, has had a substantial lead in design and production of high-speed tactical helicopters and associated weapons systems.

Electronics

14. Soviet production technology is behind that of the West in computers by at least five years and in solid-state electronic components by at least three years. Soviet computers now in production are second generation machines using transistors and capable of performing, at best, 1 million operations per second. Some current model US and

West European computers are third generation machines using integrated circuits. The fastest US computer is capable of performing 6 million operations per second. Moreover, the United States now is moving into fourth generation computers employing large-scale integration that makes possible more complex computers having greater speed and reliability. In the production of auxiliary input/output equipment and software, the Soviet Union lags even farther behind the United States than it does in making the computers themselves. Soviet communications satellite technology lags three to five years behind that of the United States.

Machine Tools

15. Even though the Soviet inventory of machine tools is considerably younger than in the United States, its technological composition is inferior. In the USSR a much larger percentage of the machine tools produced are of the general purpose type than in the United States, where the production of specially designed tools tailored directly to customer requirements is the usual practice. For priority customers, however, the USSR produces machine tools equal in quality and accuracy to those produced in the United States. The Soviet industry leads in some nonconventional machining processes such as electrodischarge machining, ultrasonic machining, and in hot rolling of gears and shafts, but is far behind in the use of numerically controlled machine tools. The proportion of metalforming machine tools relative to metalcutting tools is low in the USSR compared with the United States, with a consequently larger waste of metal.

Automotive and Tractor Industries

16. The production technology used in the Soviet automotive and tractor industries is, on the whole, obsolete by Western standards. The same is true of the product mix. In accord with Soviet priorities the automotive industry emphasizes the production of trucks, especially medium-size trucks with cargo carrying capacities of 2 to 5 tons, rather than passenger cars and light delivery and service vehicles as does the West. Trucks now in production in the USSR are still basically copies of old US designs. New Soviet truck engines incorporate modern features and have good performance characteristics, although

they deliver less horsepower per cubic inch of displacement than do US engines, because the low octane ratings of Soviet gasolines dictate low compression ratios. Soviet trucks have lower cargo ratings than US trucks of similar weight and tire size, because lower strength steels are used in frames and axles and because Soviet trucks are subjected to severe punishment by poor road conditions. Soviet tractors are inferior by Western standards in weight-to-horsepower ratio, service life, fuel consumption, reliability, and ease of operation. Although features such as four-wheel drive and power steering for wheeled tractors and automatic transmissions for wheeled and tracked tractors are now being copied from Free World designs, few such tractors are being produced as yet.

Petroleum

17. Petroleum industry technology in the USSR is behind that of the United States by perhaps as much as 10 years in seismic exploration methods and in offshore operations. The USSR also lags seriously in deep drilling, in the design and engineering of oil and gas producing equipment, and in secondary refining including the use of catalytic cracking. The Soviet industry appears to lead the world only in water flooding to maintain the pressure of oil reservoirs and in use of large-diameter pipelines for both oil and gas. Future increases in production of oil and gas will have to come largely from deposits located at depths that will require the use of improved drilling techniques and equipment. A growing demand for higher octane gasoline and for a wider assortment of high-quality low-sulfur petroleum products also will require more and better secondary refining facilities.

Metallurgy

18. In metallurgy, Soviet mining enterprises, relative to the West, use inferior mining, crushing, and grinding equipment, slower and less durable quarry trucks, and poor-quality chemical reagents. Soviet blast furnace technology is more or less on a par with the West. The USSR has built some of the largest blast furnaces and open-hearth furnaces in the world but has been slow in expanding the use of new techniques, such as pelletizing of fine ore concentrates. In steelmaking, however, Soviet technology lags considerably; for example, only about

12 percent of its steel is now made by the oxygen converter process, compared with a third in the United States, one-fourth in Western Europe, and three-fourths in Japan. The USSR lags grossly in the availability and modernity of rolling and finishing facilities. Although the Soviet steel industry has been a world leader in development of continuous casting, the West has diffused the process much more rapidly. With the exception of a few large new plants, Soviet nonferrous metals facilities are inefficient and obsolete by Western standards. Soviet technology for production of titanium alloys and products, however, appears to be on a par with that of the United States and the United Kingdom.

Electric Power

19. The USSR leads the world in construction of hydroelectric powerplants and in high-voltage transmission of large amounts of power over long distances. Soviet thermal power engineering, however, lags at least five years behind the United States, both in size of units and in other technology. Supercritical thermal power units are not operating at design level or realizing anticipated economies in fuel consumption. Boiler and turbine units have not been able to stand the high temperatures and pressures because of shortcomings in metallurgy and welding.

Coal Mining

20. Soviet longwall coal mining equipment is not as dependable as that employed in the United Kingdom and West Germany. The Soviet Union lags behind the United States and Western Europe by 15-20 years in mechanical loading of coal underground and by 10-15 years in mechanization of surface work at underground mines. Soviet power shovels and draglines used in strip mining of coal are not as large as those in use in the United States, and disposal of overburden is more costly in the USSR because of the techniques employed. Soviet coal preparation techniques are believed to be about 10 years behind those used in the United States and Western Europe.

Chemical Industry

21. The Soviet chemical industry is the second largest in the world, but the technology it employs

to produce many chemicals is at least five years behind that of the West. In the field of petro-chemicals, for example, the USSR does not yet produce synthetic glycerine on a commercial scale, despite 10 years of research and development whereas plants producing synthetic glycerine account for 60 percent of US capacity to produce glycerine. Problems in developing suitable domestic technology and also in assimilating technology purchased abroad account in part for the small Soviet production of synthetic rubber, plastics, and manmade fibers, relative to the United States. The Soviet lag is particularly great in almost all aspects of fertilizer production. The USSR as yet has no plants producing ammonia (the principal ingredient of nitrogen fertilizer) with a new technology that reduces costs by as much as 50 percent. The United States built its first such plant in 1965, and by the end of 1968, approximately half of its total capacity to produce ammonia consisted of plants using the new technologies.

Consumer Goods

22. The technology of production in Soviet consumer goods industries varies widely -- from highly modern bread factories to archaic textile mills. In other than bread products, the food industry of the USSR lags 20-25 years behind the United States. Soviet textile mill equipment is 25-30 years behind that of the United States. Although efforts are being made to modernize the mills with domestically produced machinery, most of it differs little from that produced 50 years ago. Technology in the USSR for production of consumer durables lags far behind that of the United States. Appliances and other housewares are frequently produced as a sideline by heavy machinery and aircraft plants, which have little incentive to update their technology for producing consumer goods. Household appliances are smaller, less attractive, and less durable than their US counterparts, and in most cases are merely copies of obsolete Western models.

III. Trends in Technological Advance, 1950-68

23. Within the conceptual and other limitations already specified, the aggregative measures of productivity can also be used to provide some notion of relative rates of technological progress. Thus

they can reveal something about whether the technological gap between the USSR and the industrial West is widening or narrowing. Table 2 presents comparisons of average annual rates of growth of GNP per unit of capital and labor combined (factor productivity) for the USSR, the United States, and Western Europe for various periods.

Table 2

Comparison of Average Annual Rates of Growth of Factor Productivity of the United States, Western Europe, and the USSR

	1951-60	1961-67
United States	1.7	2.7
USSR	2.2	1.4

	1950-64	1960-64
United States	2.0	3.0
Northwest Europe	3.2	3.0
Italy	4.4	4.5
USSR	1.9	1.0

24. These data show that the rate of productivity growth in the USSR exceeded that of the United States during the 1950's, but was well below that for the 1960's. The Soviet rates were far below those of Western Europe, and especially below those for Italy and Western Germany, throughout the period. Indeed, the Soviet rate of growth in productivity is well below that for all major countries of Western Europe except the United Kingdom for the period 1950-64 as a whole. During 1960-64 the Soviet rate was less than half the rates achieved in all countries of Western Europe, including the United Kingdom.

25. Thus, assuming that trends in productivity reflect trends in technological development, the gap between the Soviet and US levels narrowed during the 1950's but has been widening during the 1960's. Compared with Western Europe, the relative position of the USSR has been worsening steadily since 1950.

The relative deterioration of the Soviet position was greatest of all with respect to Italy, the country nearest to it in level of productivity in the mid-1960's. In summary, the USSR apparently has not shared in the technological revolution of the postwar period nearly to the extent that Western Europe has. The performance of Western Europe illustrates the catching up that could be expected of industrial countries which were temporarily behind in technology because of the war. The USSR, even further behind, has not caught up much, if any, military and space-related technology excepted.

26. The relative technological levels and trends among industrialized countries, at least in the manufacturing sector, are also reflected in the nature and extent of their trade with one another in machinery and equipment. The machinery industries are probably the most "technologically intensive" of the manufacturing industries. The industrialized countries of the West and Japan carry on a large trade in machinery with one another; each country is both a substantial importer and a substantial exporter in this trade. Also, as industrialization proceeds, the large surplus of machinery imports over exports, characteristic of a developing country, tends to decrease as the country develops its own capability to produce and sell machinery and equipment abroad. The pattern of trade for the USSR shows no such characteristics. In Soviet trade with the Developed West there is a large gap between the share of machinery in total imports and its share in total exports; machinery makes up one-third or more of total imports from the Developed West and a mere 2-3 percent of total exports to these countries. This large imbalance has remained essentially unchanged for the past decade. Its persistence suggests no significant improvement in the level of Soviet manufacturing technology relative to that of the West, including the ability to diversify and specialize production, as well as to provide service for the machinery. This imbalance also persists, although to a lesser extent, in Soviet trade in machinery with the industrialized countries of Eastern Europe -- East Germany, Poland, and Czechoslovakia.

27. In industry and among its various branches the relative trends in productivity and technological advance undoubtedly varied widely among

countries during this period. The comparative data required to measure these trends are not available, but some evidence bearing on them can be culled from the descriptions of technology in the various branches of industry included in the Appendix.

28. Since the mid-1950's the USSR has been making great efforts to upgrade its industrial technology both by substantially boosting expenditures on domestic research and development and by importing machinery and equipment from abroad. The former was directed very largely toward the military-space sector (see IV, A). During 1955-67 the USSR imported nearly $4 billion in production machinery and equipment (excluding ships and marine equipment) from the West (see Table 3). Nearly 15 percent represented imports of plant and equipment for the consumer goods industries, and 30 percent represented imports of chemical equipment. The USSR, however, experienced considerable delay and difficulty in getting the imported plant and equipment installed and operating at capacity. The machinery and metalworking industry experienced a much more rapid growth in productivity than did industry as a whole during 1951-67. The rate of growth of capital stock in that sector was more than twice the average for industry. Hence, the average age of capital stock was declining rapidly, and presumably the average technology embodied in it was becoming more modern. The same above-average growth of capital stock in the petroleum and chemical industries, however, was not reflected in above-average growth in productivity.

29. In summary, the evidence above, together with the descriptive evidence presented in the Appendix, suggests that the USSR may have improved its technological position relative to the West during the 1950's, but may not have done so during the 1960's. The productivity trends show such a pattern. As pointed out earlier, however, technology is only one factor accounting for the international differences in productivity trends, as measured in this report.

30. The worsening of the Soviet position during the 1960's relative to the West could reflect a relatively greater lagging behind in technology. It could, however, also indicate the following:

(1) *Divergent trends in the quality of the labor force.* Although the educational attainment of the labor force and extent of female employment have increased somewhat faster in the Soviet Union than in the United States and Western Europe, available evidence indicates that the trends proceeded evenly throughout the period.

(2) *Disparate trends in management of economic resources in the broad sense.** The Soviet Union has been considerably less successful than the United States and Western Europe in shifting labor from agriculture to nonagricultural sectors, but the timing of the shift did not differ greatly among the countries.

(3) *Economies of scale.* All of the countries compared evidently benefited from this factor, the USSR perhaps less so than Western Europe; but again there is no evidence that this factor was much more important in the 1950's than in the 1960's.

31. In short, a hodgepodge of variables with divergent trends and effects are mixed up in the measure of productivity trends.* Management and

* *During 1950-62, both Italy and the USSR reduced the share of agriculture in total employment by 14 percentage points (from 43 to 29 for Italy and from 54 to 40 for the USSR). Edward F. Dennison attributes about 1 percentage point in the growth of Italy's GNP over this period to this "improved" allocation of resources. If a similar gain can be inferred for the USSR from the reallocation of labor, very little of the productivity residual remains to be explained by other factors. Indeed, it is possible that, if accurate allowance could be made for quality changes in the labor force, economies of scale, and misallocation of resources in the USSR, their total would significantly exceed the productivity residual. If so, this would imply, not the absence of technological progress, but a gross mismanagement of the technical progress (investment programs) and probably a worsening of the degree of mismanagement.*

Table 3

USSR: Imports of Machinery and Equipment from the Developed West

Million US $

	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
Total	*181.4*	*229.1*	*217.2*	*194.1*	*293.9*	*464.8*	*409.8*	*601.8*	*588.5*	*621.0*	*510.0*	*560.2*	*669.6*
Machine tools	4.2	4.7	8.0	7.4	7.8	17.5	13.4	19.7	27.1	34.1	22.1	18.8	34.4
Equipment for the food industry	3.9	7.7	15.4	8.7	7.4	63.5	29.1	69.9	28.8	4.1	7.7	10.9	34.5
Equipment for light industry	17.3	6.8	8.1	6.2	8.1	25.8	24.5	20.7	16.2	19.8	22.9	33.4	63.3
Chemical equipment	--	0.3	7.4	19.5	77.8	135.4	131.9	87.8	124.1	113.2	110.5	147.4	176.7
Wood processing equipment	8.8	16.9	24.0	19.7	28.6	41.5	32.5	139.1	117.7	73.5	36.9	34.7	60.9
Instruments, bearings, and tools	3.3	5.2	13.2	9.6	11.6	16.2	15.1	14.2	15.0	12.4	18.3	20.3	22.1
Ships and marine equipment	96.8	137.7	86.5	72.0	77.8	57.0	101.5	144.1	159.1	253.5	194.4	190.0	127.4
Other	47.1	49.8	54.6	51.0	74.8	107.9	121.8	106.3	100.5	110.4	97.2	104.7	150.3

technology are important ones, however, and the ones that seem most likely to explain the worsening of the Soviet position vis-a-vis the West during the 1960's. In particular, the Soviet ability to manage investment programs seems to have deteriorated; there is evidence that the translation of investment rubles into plants in operation has been relatively more costly and has taken longer in the USSR since 1960, whereas such evidently was not the case in the United States and Western Europe. The two factors -- management and technology -- are closely intertwined, and their respective effects cannot be separated.

IV. Some Factors Bearing on the Gap

A. Allocation of Relevant Resources

1. Education

32. Some part of the disparities in technological development reflects differences in educational attainment of the labor force, particularly differences in the supply of college-trained manpower. Comparisons as of the mid-1960's are given in Table 4.

Table 4

Comparison of Levels of Education of the Labor Force of the United States, Western Europe, and the USSR in the Mid-1960's

	Median Years of Education	Percent of Labor Force with College Education
United States	11.2	11.6
Northwest Europe	9.0	3.2
Italy	5.3	2.6
USSR	6.8	3.8

33. The USSR has made great efforts to narrow the educational gap since 1950. Total Soviet expenditures on education relative to the United States have risen rapidly, so that the USSR, with a GNP half that of the United States, now spends about three-fourths as much on education as does the United States. The average educational attainment of the labor force rose from about five years in 1950 to about seven years in 1968 and will probably be about eight years in 1975. The average educational attainment of the US labor force was 10.7 years in 1950 and 12.3 years in 1967. The proportion of college graduates in the Soviet labor force rose from 1.7 percent in 1950 to 4.6 percent in 1968; comparable figures for the United States are 6.4 and 11.4. During this period, the educational attainment of the labor force in Western Europe has risen less rapidly than in the United States and the USSR.

34. In the postwar period the USSR, unlike the West, has oriented its educational effort at the college level toward scientific and technical fields. This pool of technically trained manpower fills a large part of the administrative-managerial jobs, as well as purely scientific and engineering jobs throughout the economy. Since 1955 the annual number of college graduates in the USSR has doubled, reaching about 525,000 in 1968. Close to half of these graduates received degrees in scientific and technical fields. The United States graduated some 675,000 in 1968, one-fourth with majors in scientific and technical fields. Although such an orientation might seem favorable to technological progress in the Soviet Union, much of the training is narrowly specialized and makes for inflexibilities in the pool of college-trained manpower.

2. Research and Development

35. Relative expenditures on research and development differ considerably among the countries. Although the data are not strictly comparable, the United States devoted about 3 percent of its GNP to research and development in the mid-1960's, compared with an average of a little under 2 percent for Western Europe and about 2.5 percent in the USSR. Also, the proportion of the total devoted to applied research, compared with basic research, would have some connection sooner or later with disparities in technology.

36. Both the United States and the USSR have devoted a rising share of total output to research and development during the past decade, but the proportion of the total allocated to the military-space sector has risen much faster in the USSR than in the United States. The USSR devotes about three-fourths of total research and development (R&D) expenditures to military and space, compared with about three-fifths in the United States. Since Soviet GNP has been growing more rapidly than GNP in the United States, Soviet expenditures on R&D, in absolute terms, have been rising relative to those of the United States and are now about two-thirds of the US level. The United States has devoted a considerably larger share of its total R&D outlays to development work, in comparison with basic research, than either Western Europe or the USSR; this emphasis on development would facilitate a rapid translation of research findings into new products and improved production processes.

37. The size of R&D activities in various countries is approximately indicated by the allocations of scientific and engineering manpower to that purpose. In the mid-1960's the United States had more than twice as many scientists and engineers employed in R&D as did all of Western Europe, and perhaps about the same number as did the USSR. According to estimates of the Organization for Economic Cooperation and Development (OECD), between 454,000 and 631,000 scientists and engineers were engaged in R&D activities in the USSR in 1966, a four-sixfold increase over 1950 and double the number in 1960. According to National Science Foundation estimates, 520,000 scientists and engineers were engaged in R&D in the United States in 1966, three times the number in 1950 and over a third more than in 1960.

B. Process of Diffusion of New Technology

38. In market economies new technologies are developed and diffused throughout the economy through a fast-acting, seemingly almost biological process. Private enterprises, spurred by profit incentives and by competition to the degree that it exists, are the innovators in this process. Profits provide a powerful stimulus for cost-saving innovations, and competition encourages the speedy diffusion of such innovations. These same stimuli

also facilitate their speedy adaptation for use in other industries. Likewise, profits and competition provide the incentives for the introduction of new products and for the quick development of imitations or competing products. This almost invisible process also ensures that obsolescent technologies disappear from use expeditiously in most cases and that old, less useful products go off the market. Governments encourage and help to finance this process but, for the most part, are not the prime movers. Even in the military field, where governments are the only customers, competition among profit-seeking potential contractors serves to induce technological advance in the military sector. Aided by the deliberate policy of governments (at least in the United States), this factor also ensures that there will be spin-offs of military-space technology to the civilian sector whenever this is technically possible and, moreover, that such spin-offs will come sooner rather than later. Finally, multinational firms, which have burgeoned in the West in the postwar period, greatly facilitate the diffusion of technology and managerial know-how through their investments in foreign subsidiaries. This is not to say that there are no obstacles to innovation and its spread in the West. There are difficulties in obtaining the required capital, and there are monopolistic practices, patents, and corporate secrecy, to name a few. As deterrents to technological progress, however, their adverse effects tend to be short-lived.

39. In the USSR's centrally administered economy there is no such automatic mechanism for fostering technological progress; the incentives that are supposed to help to perform this function are ineffective. New production technologies and new products, therefore, have to be "introduced" by deliberate actions of administrative bodies; likewise, obsolete technology and old products must be taken out of use or production in the same way.

40. This complex process is carried out, enterprise by enterprise, through annual and long-range plans for the introduction of new technology and for the output of new products. In turn, the materials and equipment required to carry out these two key parts of enterprise plans must be provided for, and this, in turn, must be done by incorporating specific requirements into the production plans of other enterprises. Moreover, the innovations that are

incorporated in enterprise plans are developed, by and large, not by the enterprises but in research and design institutes attached to government ministries and other organs. Then the whole process has to be coordinated -- at the top by the State Committee for Science and Technology and the State Planning Commission, and at intermediate levels among the numerous industrial ministries. Finally, assorted other administrative bodies also get into the act. In a word, the development and dissemination of innovation in the USSR is an administered process carried out by a cumbersome bureaucracy in a centralized manner. As a result, innovations come much less frequently and are spread much more slowly than in the West. This generalization does not apply to the military sector of the economy, which has been protected from the obstacles to innovation that plague the civilian sector.

41. The bureaucratization of the innovative process is only one reason for the balkiness of innovation in the USSR's civilian economy. An even greater obstacle to rapid technological advance is the fact that the key actors -- the producing enterprises -- tend to resist the new and cling to the old, because of the incentives that are set for them. Indeed, they are tacitly aided and abetted in this footdragging by their bosses -- the ministries, whose incentives are similar.

42. Until the recent reform the main success criterion for enterprises was their performance with respect to fulfillment of production plans, and bonuses for managerial personnel were keyed to this criterion. In practice, if not on paper, all other performance criteria (including the "mandatory" fulfillment of plans for new technology) played a subordinate role. Hence, managers were reluctant to innovate, because of the likelihood of interruptions to production and the consequent threat to plan fulfillment and bonuses. Moreover, plan assignments were increased after an innovation had been adopted. Plant managers tended not only to resist putting such measures in their plans but also to delay putting the new measures into effect after they became a part of the plan. They could always lay the blame on failure or delays in receiving the needed materials and equipment. The supervisory agencies tended to condone this attitude because fulfillment of the production plan in the aggregate was the primary determinant of their own success.

43. The regime itself has long recognized that the basic system of incentives was not conducive to technical change. In typical Soviet fashion the remedy has been sought in the issuance of government decrees setting forth measures to speed up the introduction of new technology, most of them amounting merely to exhortations. In addition, special bonus funds and arrangements were set up from time to time to reward managers who adopted innovations. At one time, fulfillment of the plan for new technology was made a mandatory condition for payment of regular bonuses to managers; this restriction evidently was generally ignored, and later was rescinded. During the past 15 years there have been at least a dozen such decrees dealing directly with one or another aspect of the problem, including special bonuses for improving product quality and for fostering exports. Evidently, their net effect has been small, if not nil.

44. Other powerful drags on the rate of technological progress have been woven in the very warp and woof of the Soviet system. By and large, innovations are planned and developed by a hefty and burgeoning research establishment quite separate from industrial enterprises. All important supplies and equipment are planned and distributed centrally. Taut planning has prevailed, so that there have been no reserves (supplies or plant capacities) to handle bottlenecks.

45. These features coupled with the inhibiting system of incentives account for the deficiencies perennially cited in the Soviet press. For example, new plants usually take five to seven years to build compared with one to three years in the West. Completed plants usually take several more years than planned to attain capacity output. Some new products take so long to develop that either they are obsolete when finally produced or there is no demand for them. Often the technology developed in scientific institutes is not wanted by the intended user. An innovation generated at the enterprise level frequently takes so long to receive higher level sanction that it becomes obsolete before it can be implemented. New designs or products often turn out to have serious technical flaws. Even when new plants and equipment are imported from abroad or licenses are acquired or foreign technologies merely are copied, the *modus operandi* of the Soviet system delays their introduction and reduces their effectiveness in

comparison with the results that would be obtained in the West. On this point the Soviet press provides ample evidence.

46. Finally, technical progress has been inhibited at all levels by the lack of a satisfactory means for determining the payoff to innovation. Soviet prices, being centrally fixed, inflexible, and based on industrywide average costs, provide no accurate guides to choice. Throughout the years, various formulas have been used by the planners to calculate the effectiveness of new investment, and academic debates have been waged over those formulas for more than a decade. Currently a debate is in progress on how to measure the effectiveness of scientific research. An eminent Soviet scholar recently asserted that the yield on investment in "science" (R&D) is 3.5 times that of investment in industrial plant and equipment. This assertion was primarily political in intent, since there is no known way of separating the yield of R&D from plant and equipment. Moreover, Soviet ideology, besides eschewing marginal calculations, has long regarded the concept of obsolescence as peculiar to capitalism. Hence, retirement policies have resulted in plants being kept in operation far longer than in the West and also in extraordinarily long production runs for given products. Until very recently, capital costs were largely ignored and amortization charges have been purely arbitrary.

C. The Effects of Different Priorities

47. The wide disparities among branches of industry in average level of technology vis-a-vis the West directly reflect the longstanding priorities of the Soviet regime. These priorities above all have favored the military sector. This favored status, coupled with rigid secrecy policies with regard to military programs, has in effect produced a dual economic system -- the military sector and the civilian sector. The two sectors are administered by separate bureaucracies that seemingly have as little to do with each other as possible. The military sector has had first claim on the best resources -- the brightest scientists and engineers, the most skilled workers, the best quality materials and equipment, and the best construction talent. Its overriding priority has enabled it to break bottlenecks quickly and to escape most of the frustrations in supply that plague the civilian sector. The scientists and engineers engaged in military and

space R&D and production apparently have been largely immune from Communist Party interference in day-to-day affairs. They also have had the advantage of a clear-cut, single minded goal -- achievement and maintenance of at least parity with the United States in defense and space. With this priority and protected status, the military sector has flourished and has achieved near-technological parity with the United States in many types of weapons and space equipment and even superiority in a few areas.

48. Second priority over the years has been accorded the basic industries whose output directly supports both military production and the investment programs essential to rapid growth -- steel, fuels, electric power, producers' equipment, and, more recently, chemicals. Research and development resources have been allocated to these industries, and some world technical innovations have resulted. A few Soviet innovations, such as continuous casting of steel, have been quickly picked up and further developed in the West but have spread at a snail's pace in the USSR itself. Although these basic industries have equaled or even occasionally surpassed the West in some aspects of technology in a few plants, the bulk of their output is produced in plants having technology obsolescent by a number of years relative to that predominantly in use in the United States and Western Europe.

49. Lowest of all in the scale of priorities have been the industries catering to the population -- textile and clothing, food processing, consumer durables, and household products of all kinds. Their low status over the years has resulted in an average level of production technology that is woefully backward by Western standards -- by several decades in many cases. By and large, these industries also turn out products of a quality and assortment far inferior to those produced anywhere in the industrial West. The low level of production technology is only one factor in explaining this disparity. Most of the blame belongs to the low priority that the consumer has had in the Soviet scheme of things, the disregard for customers' wishes, and the planners' penchant for concentrating resource allocations on a narrow range of standardized mass-produced products.

V. The Likely Effects of Current Reforms

50. Soviet leaders are fully aware of the USSR's great technological lag behind the West. Clearly, they must also be distressed about the small return that the USSR has been getting in recent years from the use of its traditional method of problem-solving -- the injection of massive resource inputs. In the 1960's the USSR has nearly tripled its outlays on "science," and total employment in scientific research and design organization has nearly doubled. Gold reserves have been depleted to import plant and equipment from the West. Investment has continued to rise considerably faster than GNP, hence increasing its share in total output. Yet the return on new investment has declined sharply during the 1960's, in contrast to stability or a rise in the United States and Western Europe. Although stepping up the rate of technological advance in the economy has been recognized as the key need, how to achieve this has been far from clear. The voluminous press reporting of the 1960's on the problems in developing and introducing new technologies echoes the voluminous reporting of the 1950's on the same theme.

51. The current Soviet leadership is hoping to achieve a breakthrough in solving this chronic problem in a series of major economic reforms, some of which have been introduced piecemeal during the past three years and others of which are still in the process of implementation. One explicit objective of these reforms is to raise efficiency, primarily by speeding up the introduction of new technologies. One of them -- the restoration of the industrial ministries -- was effected in 1965, with the declared intent of restoring unity and direction to policy on new technology; the diffusion of responsibilities in this field was alleged to have been the major shortcoming of the system of regional economic councils (*sovnarkhozy*) introduced by Khrushchev in 1957. According to Soviet testimony, the benefits of the reorganization in this area have yet to be realized. Other reforms concern (1) revision of planning and incentives, (2) reform of the industrial price system, and (3) changes in organization and the system of incentives in the research and development complex. Infinitely complicated in detail, these three reforms are fairly simple in intent and concept, and tentative conclusions can be drawn about their likely impact on the rate of technical advance in

the Soviet economy. The conclusions about the probable effects of the first two are based in part on an assessment of the experience thus far; the third one is still mainly on the drawing board.

A. Reforms of Planning and Incentives in Industry

52. The reform of planning and incentives, launched by Kosygin in late 1965, has now been extended to most of the industrial sector. In brief, the reforms broaden the authority of enterprise managers with regard to plan formulation, establish sales or profits and return on invested capital as the main success criteria for enterprises and the determinants of bonuses, and levy an interest charge on invested capital. Among other things, the new profit criteria and the interest charge are intended to lead enterprises to reduce costs by adopting new technologies and scrapping obsolescent equipment. The emphasis on sales and profits, in place of gross output, is supposed to spur the output of new and improved products. By all accounts, the new measures have had no such effect thus far, nor are they likely to have in the future. The reason is that the reform retains all of the features long characteristic of the Soviet system that have inhibited innovation in the past: centrally fixed plans for output, investment, and new technology; central physical allocation of key materials and machinery; and establishment of success criteria for enterprises that are based on fulfillment of plans. Moreover, great emphasis continues to be put on "tight" plans, and enterprise plan assignments are boosted after technological improvements are adopted. Finally, the greater independence of action granted to enterprise managers on paper is already being curtailed by the ministries, both through direct interference and through issuance of a host of detailed rules and regulations on how the new freedom is to be exercised.

53. With bonuses linked to plan fulfillment and with supply uncertainties undiminished, enterprise managers are unlikely to be any more eager to adopt new methods than before. Because of the perversities of Soviet prices, the charge on capital may lead them even to avoid the purchase of new machinery, whose payoff remains as hard to determine as before. Indeed, decisionmaking at the enterprise level is made much more difficult under the reform, because

the new success criteria are inconsistent and extremely complicated and because many of the old arrangements were retained -- special bonuses for introducing new technology, for adding new products, and for upgrading the quality of old ones. In short, the new so-called "economic levers" will not automatically foster innovation; it will continue to require "introduction" by the planners.

B. Reform of Industrial Prices

54. Along with these general reforms in planning and incentives, the USSR has adopted a new set of industrial prices and a new price system. The new, higher prices include an allowance for interest on capital for the first time. The new price system consists of the establishment of an enlarged and unified bureaucracy with broad price-fixing powers and the declared intent to use prices to influence enterprise behavior. The new Price Committees are explicitly charged with "raising the role of prices in promoting technological progress in all its many-sided aspects."

55. Press discussion thus far indicates unmistakably that the committees have every intent of carrying out this mandate literally. They are attempting to set prices in great detail. Prices fixed for individual machines and equipment are to be those that will encourage enterprises to buy new machines and get rid of old ones. Similarly, prices on consumer goods and industrial materials are to be juggled to accomplish the same objective. The prices on new products are to be set high enough to encourage their production, but not so high as to discourage their purchase.

56. All this is to be done product by product by the new government price fixers, and changes are to be made as frequently as necessary. Already it has been announced that "to stimulate technical progress" enterprises will be informed that successive price reductions on their products will be made on specified dates. To set prices that will really accomplish these intended objectives means, in effect, to set market prices without markets. The magnitude of the task defies description, but an army of government clerks seems determined to take it on. The result will be further complication of the decisionmaking process and further bureaucratization of the system.

C. Revamping of Organization and Incentives in the Research and Development Establishment

57. The guidelines for far-reaching changes in organization and incentives in the research and development establishment are set forth in a government decree issued in October 1968. The State Committee for Science and Technology is to coordinate the drafting of detailed instructions for implementing these policies, and experimental changes are to begin in 1969. The program, in effect, extends the principles of the economic reform in industry to the R&D sector. Wages and bonuses for individual scientists and the profits of research institutes are to be based in part on calculations of the economic effectiveness of their work. Organizational changes will be made throughout the establishment, as required, to reduce the cost of the program and to link its work more closely with the needs of producing enterprises.

58. Although it is too early to evaluate the full significance of the new program, its possible favorable long-term results may be limited by bureaucratic inertia and resistance to some of the proposed new techniques. Delays, temporary confusion, and much dissatisfaction are likely to result from the numerous reorganizations and other changes to be brought about by the implementation of the resolution. It subjects academy and university research institutes to periodic review using the same criteria of effectiveness applied to industrial research establishments. The research programs in these institutions therefore can be expected to give more emphasis to applied research.

59. The high status traditionally enjoyed by scientists and engineers in the USSR and the absence of economic success indicators and accountability have led to a degree of independence of action for the Soviet R&D community. The new program will tend to decrease this independence, which may or may not be beneficial.

D. Conclusions

60. In summary, the ongoing reforms represent still another attempt -- and a very cumbersome one -- to tinker with the highly centralized system of economic management to make it work better. The reform adopts market-type concepts and criteria for

efficiency -- prices, sales, profits, return on capital -- but eschews the use of markets and instead manipulates the economic variables by the traditional means -- planning and administration. Thus, the USSR has vastly enlarged its administrative objectives, along with the size of the bureaucracy.

61. How scientific and technological progress can flower under these conditions is hard to see. Technological change is a highly dynamic process, requiring entrepreneurship and flexibility. There are no entrepreneurs in the USSR except the state, and bureaucracies are notoriously slow-moving and resistant to change. Furthermore, Soviet higher education continues to emphasize narrowly specialized engineering and scientific fields -- training ill-suited to producing graduates with entrepreneurial ability, even should the environment be conducive to exercising it.

62. In the technological race, countries whose economic institutions permit fast action and rapid adaptation to new things are likely to come off best. In periods of particularly rapid technological change like the present, therefore, the USSR seems likely to be at an increasing disadvantage relative to the West in the average level of technology in use. This may be so even in the field of advanced weapons and space.

APPENDIX

Comparison of Major Branches of Soviet and US Industry

Introduction

63. This appendix provides a brief description of the present level of technology in the major branches of industry in the USSR relative to the United States. Wherever possible, comparisons are also made with Western Europe. The descriptions are necessarily impressionistic, incomplete, and summary in nature. Comparisons of technological levels among countries in a given industry are extremely difficult to make, and to do so in detail is beyond the scope of this report. By way of background, the industry summaries include information about the general size of the industry relative to that of the United States.

64. In these brief descriptions the attempt has been made to restrict them as much as possible to technological aspects per se. Nevertheless, more than technologies are involved in the comparisons, and precise distinctions cannot easily be made. Thus, the low quality of Soviet products in general relative to the West reflects not only technological lags, but also unfavorable incentives, relative priorities, and the results of pervasive shortages and centralized control of supplies. Some of the differences in production methods -- for example, in the degree of mechanization of materials handling -- primarily reflect differences in relative costs of labor and capital. In the USSR, labor costs have been low compared with capital costs over the years, whereas the opposite has been the case in the United States; Western Europe resembles the USSR in this regard. Therefore, production processes tend to be much more labor-intensive in the USSR than in the United States, but they are also more so than in Western Europe.

Electric Power

65. The electric power industry of the USSR is the second largest in the world, but has an installed capacity and annual production less than half the level of that in the United States. The difference largely reflects the much greater use of power in the United States for nonindustrial purposes. Despite the fact that the largest powerplants in the world, both hydro and thermal, have been built in the Soviet Union, Soviet conventional thermal power engineering lags at least five years behind the United States, both in size of units and in advanced technology. The lag is even greater in use of automation and computer control systems, both for power generation and for transmission. Control and data logging systems in use in major Soviet powerplants, both conventional and nuclear, are of a quality and type that has not been installed in the United States for at least 10 years. No powerplant in the USSR is under direct automatic control from a computer system, whereas in the United States a number of plants built since 1963 are controlled by computers.

66. In the United States, thermal generating units with a capacity of 500 megawatts (MW), operating at supercritical parameters of temperature and steam pressure,* have been in operation since 1960, and units of up to 1,000 MW are now going into operation. In the USSR, units of only 300 MW are the basis for the development of thermal powerplants during 1966-70. In 1968, five years after the first such units were installed, they were not operating at design level, achieving sustained operation, or realizing anticipated economies in fuel consumption. Poor performance is due primarily to failures of boiler units caused by metallurgical shortcomings in boiler drums and tubes and by improper welding procedures. Frequent turbine failures stem from poor casting, heat treatment, and welding. Defects

* *Pressure above 3,206 pounds per square inch and temperature above 705°F., the point at which water flashes into dry steam without boiling.*

in valves, pumps, and fittings have also caused shutdowns. Although the 300-MW units are far from perfected, during 1968 Soviet engineers conducted operational tests of supercritical units having capacities of 500 MW and 800 MW.

67. In the field of nuclear electric power, the USSR has kept abreast of the most advanced technological developments, doing research on or actually experimenting with almost all of the same reactor concepts that are of interest in the West. It has, however, limited construction of demonstration or commercial-size nuclear powerplants to a small number, while waiting for technological advance to reduce the capital and operating costs of nuclear plants to a level competitive with those of conventional thermal powerplants. In the United States, on the other hand, competition of private industry led to construction of a larger number of demonstration and commercial-size nuclear powerplants, even though such plants were not yet economically competitive. At the end of 1968 the USSR had a total of more than 1,600 MW of electric generating capacity installed in nuclear powerplants, compared with 4,200 MW in the United Kingdom and 2,700 MW in the United States. The costs of the more recently constructed Soviet nuclear powerplants have been coming down, and their operating record compares very favorably with the record of the best and most modern nuclear powerplants operating in the United States in 1968. Soviet plants are now being built according to a standard design consisting of two blocks of 440 MWe (megawatts electric), each block comprised of one pressurized water reactor and two 220-MWe turbogenerators. In contrast, the reactors in most nuclear powerplants now under construction in the United States will serve single turbogenerators with capacities of 800-1,300 MWe.

68. The USSR is moving ahead of the United States in construction of more advanced fast-breeder reactors that are expected to produce more fissionable material than they consume as fuel. The United States pioneered in this field with the world's first breeder, the small EBR-1 that began operation in 1951, and also built the largest breeder to go

into operation thus far -- Detroit Edison's 200-MWt (megawatts thermal) Enrico Fermi-1 that operated during 1963-66. The only breeder operating in the United States at present is the EBR-2 that has a design capacity of 17.4 MWe or 62.5 MWt but that operates well below this level. This reactor, which began operation in 1962, has approximately the same designed capacity as the Soviet-built BOR-60, an experimental 60-MWt fast-breeder that went into operation at Melekess on 30 December 1968. However, since mid-1964, Soviet technicians have been constructing at Shevchenko the BN-350 which is to have a capacity of 350 MWe or 1,000 MWt. When completed in 1970 or 1971, this will be the world's largest fast-breeder and will be the main component of the world's first large-scale nuclear power and desalination plant. The plant will have the capacity to generate 150 MW of electric power and to supply 32 million gallons of fresh water per day. The USSR also plans to construct at Beloyarsk an even larger breeder, the BN-600 that is to have a capacity of 600 MWe or 1,430 MWt. The only fast reactor now planned for construction in the near future in the United States is the 400-MWt Fast Flux Test Facility to be built during 1970-73.

69. The USSR leads the world in construction of hydroelectric powerplants. The Bratsk hydroelectric powerplant, on the Angara River in East Siberia, has a capacity of 4,100 MW, more than twice the capacity of Grand Coulee, the largest hydroelectric powerplant in the United States. The Krasnoyarsk hydroelectric powerplant, under construction in Siberia, will have a capacity of 6,000 MW when completed. The generating units, five of which were in operation by the end of 1968, have a capacity of 500 MW each and are the largest hydrogenerators in the world.

70. The USSR also leads the world in high-voltage transmission of electric power, 330 kilovolts (kv) and higher. Rapid advance in this field has been stressed because of the need to transmit large amounts of power over long distances. The Soviet Union put the first 500-kv line in the world into operation in 1959, and by the end of 1967 had in use 10,000 kilometers (km) of 500-kv and 9,000 km

of 330-kv transmission line. An additional 5,000 km of 500-kv and 3,000 km of 300-kv line are under construction. In the United States, use of high-voltage transmission only began in the early 1960's, and the first 500-kv line went into operation in 1965. By the end of 1967, about 6,300 km of 500-kv transmission line and 8,000 km of 345-kv line were in use. In 1962 the USSR commissioned a 475-km experimental direct current (DC) transmission line from Volgograd to the Donbas. This line, which operates at 800 kv and has a capacity of 750 MW, is being used to gain experience for a planned 1,500-kv DC line that is to stretch 2,500 km from North Kazakhstan to the central European region of the USSR. The planned line, which is the world's most ambitious DC transmission project thus far, is to have a capacity of 5,250 MW and is to be commissioned in 1975. In the United States an 800-kv 1,330-km DC line is under construction in the Pacific Northwest. This line, which is to have a capacity of 1,440 MW, will be completed in 1969.

Coal Mining

71. The USSR leads the world in production of coal, with an output of almost 600 million tons in 1968. The coal mining industries of the Soviet Union and the United States are not comparable in most of their major aspects because of the different physical and geological characteristics of the coal deposits exploited. Where Soviet mining technology and equipment can be appropriately compared with that of the United States or of West European countries, the USSR lags considerably. The thin, faulted, and pitching seams frequently encountered in Soviet underground coal mines inhibit use of the highly mechanized room-and-pillar method of mining prevalent in the United States. Instead, about 85 percent of the coal mined underground in the USSR is obtained by the longwall method. The level of mechanization of longwall operations in the USSR is relatively high, but the equipment is not as advanced or as dependable as that employed in longwall mining in the United Kingdom or in West Germany. Heading or tunneling machines, used in longwall mining to bore entries or haulageways, have only recently been serially produced in the USSR and are probably inferior to their US

counterparts, the "continuous miners" used in room-and-pillar mining. The ultimate objective in major coal producing countries using the longwall method is to develop a fully automated self-advancing longwall-complex unit that mines the coal and conveys it to the mine transport system. The United Kingdom leads the world in development of such equipment. The USSR lags behind but is actively working toward the same goal.

72. The largest gap between Soviet and US technology in underground mining occurs in ancillary surface work. The fact that the more than 20 percent of the Soviet labor force employed in underground mining is engaged primarily in hand labor above ground indicates that the USSR may be 10-15 years behind the United States in the mechanization and efficiency of surface work. Only about 70 percent of the coal mined underground in the USSR is loaded mechanically, a level equal to that in the United States about 1950; at present more than 90 percent of all such US coal is loaded mechanically. In Western Europe the mechanization of surface work is close to the US level, even though labor is cheap relative to capital there, as it is in the USSR.

73. The USSR lags behind the United States, and also East Germany, by perhaps 5-10 years in development and application of modern equipment and technology for strip mining. The largest element of cost in strip mining is the removal of overburden. The cheapest method of overburden removal, used in nearly all US strip mines, is the "direct dumping" method whereby an excavator -- usually a power shovel or dragline -- removes and dumps a load of overburden in one continuous cycle. In the USSR, only about 30 percent of the overburden is stripped by the direct dumping method, primarily because of the extreme thickness of the overburden at many coal deposits. This method requires giant-size power shovels and draglines. The largest US power shovels and draglines have bucket capacities of up to 200 cubic yards, whereas the largest Soviet dragline, still in the design stage, has a bucket capacity of only 105 cubic yards. The USSR also is 5-10 years behind the United States in the manufacture and use of giant-size trucks for hauling

coal from strip pits. As yet there is no known Soviet equivalent of the US specialized high-capacity unit trains used exclusively for transporting coal from the mines.

74. In general, Soviet coal preparation techniques are about 10 years behind those of the United States as well as Western Europe. In 1967, only about 42 percent of total Soviet coal output was cleaned mechanically, compared with approximately 64 percent in the United States. The Soviet level of 42 percent mechanical cleaning is about the same as was achieved in the United States in 1950-51. Moreover, a substantial part of the Soviet coal preparation equipment would be considered obsolete in the major coal-producing countries of the Free World. Another area of great lag is in the application of computers to management and engineering problems. In this field the Soviet coal industry is probably 5-10 years behind its US and West European counterparts.

Petroleum

75. The petroleum industry of the USSR is surpassed only by that of the United States in production of crude oil and natural gas and in refining capacity. Exploitation of the relatively accessible and highly productive reserves that have been the Soviet Union's major sources of petroleum since World War II has not required the advanced technology and equipment employed by Western oil companies. Moreover, the requirement of the Soviet economy for high-octane gasolines and other high-quality petroleum products has not been sufficient to command extensive investment in secondary refining facilities. Consequently, the USSR has generally lagged behind the United States in seismology, in deep drilling and offshore operations, and in the design and engineering of oil and gas producing equipment and of secondary refining installations. Only in two aspects does the Soviet petroleum industry appear to lead the world: in the use of water flooding for maintaining the pressure of reservoirs, and in transmission of oil and natural gas through pipelines of very large diameter.

76. The Soviet Union is about 10 years behind the United States in exploration methods, especially in applied seismograph techniques and ability to map deep drilling prospects. Gravity and magnetic readings are used to delineate areas for seismograph prospecting, but the accuracy of Soviet gravity meters is less than that of US instruments because Soviet engineers have been unable to make reliable quartz elements. The low quality of Soviet geophones and seismic cable prevents reception and transmission of low-frequency signals reflected from deep-lying structures, and lack of computer hardware and software precludes automatic processing of seismic records, display of variable density cross sections, and "stacking" or integration of seismograms. The application of computers to seismograph procedures in the United States since 1963 has revolutionized deep exploration for petroleum.

77. About 85 percent of all the oil and gas wells in the USSR are now drilled by the turbodrill method, which is exceptionally well suited for drilling in shallow hard rock formations such as those encountered in development of the Urals-Volga region. The turbodrill is inefficient, however, in the deep soft rock formations found elsewhere in the country, from which most future increases in production must come. In the United States, rotary drilling is used about 99 percent of the time because it is much more efficient than turbodrilling at depths of more than 2,000 meters and in soft rock formations. Soviet use of rotary drilling below 2,000-meter depths has been limited by shortages of related oilfield equipment. In recent years the USSR has been a net importer of rotary tools, tricone and diamond drill bits, high-pressure mud pumps, blowout preventers, high-quality drill pipe, and cementing equipment.

78. Production methods in the USSR are similar to those used in the West except that Soviet technicians begin water flooding inside new fields to maintain reservoir pressures from the outset of primary production. In the United States, water flooding is regarded as a secondary recovery technique and is restricted to the outer edges of old fields where the primary reservoir drive has been exhausted. The Soviet practice increases the share

of reserves ultimately recovered from high-yield flowing wells and results in the drilling of a smaller number of wells. However, it also has led to early encroachment of water into some producing wells.

79. Offshore technology in the USSR is quite primitive and more than 10 years behind that developed in the United States and in use throughout most of the Free World. Petroleum deposits located offshore in the Caspian Sea in water depths exceeding 40 meters have been inaccessible, except by directional drilling from onshore locations or by drilling from manmade islands connected to the mainland by trestle-supported roadways. At least a half-dozen mobile offshore platforms will be required to explore these offshore deposits which Soviet geologists believe are extensive. Thus far, the USSR has built one such platform, has another under construction, and has imported one from the Netherlands. The Soviet-built platform is capable of drilling wells 2,000 meters deep in 20 meters of water, only about one-third of the depths for which the Netherlands platform was designed. The United States has several hundred offshore platforms, some of which are capable of drilling wells to depths of more than 6,000 feet in 300 meters of water.

80. The USSR uses the largest pipe in the world for transporting crude oil and natural gas, but automation of pipeline systems is less advanced than in the United States. Oil and gas pipelines 48 inches in diameter currently are being laid in the Soviet Union, whereas the largest line pipe in use in the United States is about 42 inches in diameter. Soviet plans call for use of line pipe with diameters of 56, 80, and 100 inches. Some equipment installed on sections of Soviet pipeline systems, however, is not adequate for the size of the line pipe employed. For example, undersize valves used on the 40-inch central Asia-Urals gas pipeline reduced its capacity by 10 percent. In general, Soviet natural gas pipelines operate at lower pressures and throughput capacities than US pipelines of the same diameter, because of weaker pipe and the lower number and capacities of Soviet compressor stations.

81. No new oil refinery has been started in the USSR since 1961. Although most of the refining processes employed in the West are in use somewhere in the USSR, Soviet operational experience with some of them is quite limited. Secondary refining capacity (catalytic cracking, catalytic reforming, hydrocracking, hydrogen treating, and alkylation) in the USSR is equal to only about 20 percent of primary crude oil charge capacity, whereas in the automobile-oriented economy of the United States, with its greater demand for high-octane gasoline, secondary capacity exceeds primary capacity. Secondary facilities are necessary to improve product quality and product mix.

82. In recent years the USSR has begun to install a catalytic reforming process using platinum catalysts. This process has been in use in the United States and other Western countries since the mid-1950's. Soviet production of silica-alumina catalysts for fluid catalytic cracking units is believed to be adequate to satisfy domestic needs and to permit exports to Eastern Europe. Moreover, the USSR is conducting research on zeolite-type catalysts, now in widespread use in the United States for increasing yields of gasoline. Whether these catalysts are in actual use is not known.

Chemical Industry

83. The Soviet chemical industry is the second largest in the world, but the technology it employs for production of many chemicals is five or more years behind that in the United States or in Western Europe. The lag in Soviet technology is reflected in continued use of inferior and outmoded processes, in the low quality of products, in the small production of many newer chemicals, and in the low level of mechanization and automation. This situation reflects the inadequate attention given to development of chemical technology during the 1950's and early 1960's and the failure to make effective use of available domestic and foreign technology.

84. The USSR is far behind the United States in almost all phases of fertilizer technology, including basic process engineering, design and fabrication of equipment, and final treatment of fertilizer to impart desirable properties. The lag is particularly evident in development of concentrated and complex

(multinutrient) fertilizer and in processes for production of ammonia, the major intermediate in manufacturing nitrogen fertilizer. The average nutrient content of Soviet fertilizer was planned to reach 28 percent in 1968, whereas in the United States it was 38.5 percent in the year ending in mid-1968. The United States has a lead of four to five years in construction and operation of large integrated ammonia plants that make possible substantial savings in costs. These plants use more efficient purification processes for the raw material, better catalysts, and superior centrifugal compressors. By the end of 1968, approximately one-half of US capacity to produce ammonia was provided by plants of this type, whereas in the USSR the first few plants employing similar technology were still under construction. The United States also has better techniques for granulation to make fertilizer less susceptible to loss of nutrient during transport and storage and easier to apply with seed.

85. In the field of petrochemicals, the United States has a substantial lead over the USSR. In 1966, despite 10 years of development work, synthetic glycerine was not yet produced in the USSR on a commercial scale, whereas, in the United States, plants producing synthetic glycerine accounted for 60 percent of all glycerine capacity. In 1967, almost 90 percent of the total output of benzol in the United States came from petrochemical sources, compared with less than 15 percent in the USSR. In 1968 the largest known units for production of ethylene in the USSR had annual capacities of 60,000 tons, and at least some of these units had been purchased from Free World firms. In the United States, many ethylene units have annual capacities of more than 200,000 tons. Soviet efforts to develop petrochemical processes comparable in efficiency to those used in the United States for producing acetylene, acrylonitrile, ammonia, butadiene, ethylene, synthetic glycerine, propylene, and many other chemicals have been hampered by the lack of effective catalysts for unit operations such as dehydrogenation, and by inability to produce, in the required quantity and assortment, some types of highly productive pumps, compressors, and other equipment.

86. Differences in levels of production of major synthetic materials in the USSR and United States

reflect in part the Soviet failure to develop effective production technology. In 1967, output of plastics in the USSR was only 18 percent, manmade fibers only 30 percent, and synthetic rubber little more than one-third the level of production of these products in the United States. Soviet technological lag has been apparent with respect to processes for production of polyester and acrylic fibers, butadiene-styrene and polybutadiene rubber, and plastics such as polyethylene and polyvinyl chloride. The USSR has also been slower than the United States in development of products such as fluorocarbon plastics and thin polyester film that have important strategic uses in the nuclear, aerospace, and electronics industries.

87. Continued use of outmoded technology is responsible for the substandard quality of some Soviet synthetic materials. The fact that the service life of many Soviet rubber goods is only one-half that of similar products made in the United States probably reflects not only poor Soviet process technology for synthetic rubber but also inferior fabrication equipment and a lack of high-quality additives and stabilizers.

88. During 1958-67, deficiencies in Soviet technology led to imports of plant and technical data from the Free World valued at about $1.1 billion. Most of the imported equipment was for the manufacture of synthetic materials and agricultural chemicals and associated intermediates. Many of the imported installations were more highly instrumented than models developed in the USSR. Frequently, however, the purchased technology failed to provide the anticipated benefits, because of Soviet inefficiency in building and operating the imported installations.

Metallurgy

89. In the mining of metal ores, the level of Soviet technology lags well behind the West, although advanced specialized techniques such as mining underwater and in coastal placers have been developed to meet particular Soviet conditions. The Soviet mining industry uses inefficient and obsolete trucks of 12-25 ton capacity, while in the West, trucks of 70-100 ton capacity are in use. The technical level of Soviet ore crushing and processing equipment

is very backward relative to the West; the USSR recovers only 70-85 percent of the copper in the ore, compared with 90 percent or more in the United States, and the USSR recovers only 35-40 percent of byproduct gold, compared with 65-70 percent in the United States.

90. Although the USSR has made notable advances in production technology in some sectors of the metals industry, metallurgy technology in general lags considerably behind the West. The USSR has become a world leader in blast furnace technology by constructing some of the largest furnaces in the world and by extensive use of advanced operating practices, notably efficient preparation of the blast furnace charge by sintering iron ore concentrates. However, the USSR lags far behind in the use of the newer and more effective technique, already employed extensively in the West, for pelletizing fine iron ore concentrates. In 1968, Soviet production of pellets amounted to about 3 million tons, compared with 50 million tons in the United States.

91. In the steelmaking sector, the USSR has constructed the largest open-hearth furnaces in the world but has been slow in adopting the capital-saving oxygen converter process which is coming rapidly into use in the West. In 1968, Soviet production of oxygen converter steel amounted to only 12 percent of total steel production, compared with 74 percent in Japan, about 25 percent in Western Europe, and 37 percent in the United States. Although the USSR has been a world leader in development of continuous casting, less than 3 percent of the steel is processed with this technology. Recent indications are that the United States will soon move rapidly ahead of the USSR in industrial use of the new process.

92. The greatest technological lags in the Soviet steel industry are in rolling and finishing. Not only is much of the equipment inefficient and obsolete by Western standards, but also the USSR has inexplicably failed to balance its steel production capacity with suitable rolling and finishing facilities. Particularly lacking are adequate and modern cold rolling mills, heat treatment facilities, and continuous electrolytic tinning and galvanizing lines. These deficiencies result in poor assortment and quality of steel products, causing large waste

throughout the economy. For example, the failure to produce adequate quantities of grain-oriented electrical sheet forces the electric power industry to use hot rolled silicon sheet, which is less efficient, and raises the cost of power transmission. Most Soviet tinplate is produced by the obsolete hot-dip process, whereas in the West the much cheaper electrolytic process is almost universal.

93. In expanding its aluminum industry, now second in size only to that of the United States, the USSR has constructed modern smelters that compare favorably in size and operating characteristics with any in the Free World. Electrolytic cells in new Soviet plants operate at 150,000 amperes, while cells in the newer US plants operate at only 120,000 amperes. Soviet aluminum fabricating technology for strategic and some industrial applications is well advanced, but the overall level of technology in plants producing consumer products, such as aluminum foil and kitchen wares, lags far behind that in the Free World, reflecting the continued Soviet use of old and inefficient rolling and fabricating equipment.

94. In the other major nonferrous industries -- copper, lead, and zinc -- the USSR in recent years has constructed a few large plants with technical standards equal to those in the Free World. In general, however, the technological level of these industries is well behind the Free World because Soviet plants are older, less efficient, and frequently obsolete. For example, the USSR is only now introducing byproduct recovery of sulfuric acid at nonferrous metals plants, a practice in use for many years in the United States. The USSR lags considerably behind the United States in developing techniques for the leaching with acid of material in copper waste dumps and the flotation processing of copper oxide ores, both of which account for significant shares of US production.

95. The USSR is a world leader in the development and production of titanium. Soviet technology for the production of titanium alloys and products is about on a par with that of the United States and the United Kingdom. The USSR has produced some of the world's largest titanium forgings for aircraft.

96. The USSR has made notable progress in research in metallurgy and has attained world leadership in the

determination of equilibrium phase diagrams for metallic systems. Practical difficulties have been encountered, however, in translating research results into suitable production technologies. In the use of vacuum metallurgical techniques, for example, the USSR has less competence and experience than the United States. The USSR is improving in this field, however, benefiting from the importation of electron beam furnaces from East Germany as well as from its own developmental programs in vacuum metallurgy. The USSR also has become a world leader in the development and use of the electroslag remelting technique, which it employs as a substitute for traditional vacuum processes in some applications. However, in advanced rolling techniques, involving the use of such specialized equipment as Sendzimir mills, the USSR lags behind the United States.

97. Notwithstanding its general inferiority compared with the United States in advanced metallurgical capabilities, the USSR has been able to produce the special metals and alloys required for military and strategic uses. For these priority customers it produces a wide range of high-strength steels and stainless steels, including precipitation hardening types. Soviet work on mar-aging* steels is largely experimental and not as advanced as that in the United States, although the USSR has announced that tonnage quantities of mar-aging steels have been produced.

98. In production technology for superalloys the USSR is about on a par with the United States. The USSR also has devoted considerable attention to the development of high-temperature corrosion-resistant metals, such as tantalum, niobium, tungsten, molybdenum, rhenium, and zirconium, but has not attained results fully comparable to those in the United States with respect to the assortment or quality of products.

99. The USSR is ahead of all other countries in development of the thermomechanical treatment of metals -- a technique for simultaneous deformation and thermal processing which can improve mechanical properties of metals quite radically. As yet,

* *Mar-aging steel is a nickel steel of ultrahigh strength obtained by special heat-treating and aging processes.*

however, little industrial use has been made in the USSR or elsewhere of this technique.

Automotive and Tractor Industry

100. The automotive industry of the USSR was established in the early 1930's with the technical assistance of US automotive firms, and even now its products are copied from old US designs. In 1968 the Soviet automotive industry produced about 500,000 trucks and 280,000 passenger cars, compared with about 2 million trucks and 9 million passenger cars in the United States. Moreover, compared with the United States, the USSR has a very small assortment of special body styles for trucks, restricted primarily to ordinary dump bodies, fire apparatus, tank wagons, cranes, and standard vans. Such specialized truck bodies as those for mechanical refrigeration, transit cement mixing, trash removal, powerline maintenance, furniture moving, and the like are produced in negligible amounts or not at all.

101. From the end of World War II until 1963, most of the investment in motor vehicle production facilities in the USSR was devoted to the production of 4- and 4½-ton trucks at the ZIL plant in Moscow and 2- and 2½-ton trucks at the GAZ plant in Gor'kiy, essentially copies of US trucks built during World War II. Today, the ZIL trucks of 1946 have finally been replaced by modernized vehicles, and new models have been introduced at GAZ. At GAZ, however, the 1946 model of the GAZ 2½-ton truck is also still being produced.

102. Soviet trucks now in production incorporate a number of modern features such as pneumatic or vacuum boosted brakes, power steering, oil coolers, and radiator shutters for better engine temperature control. Engine designs are copied from US engines and incorporate modern features such as chromium plating of upper compression rings, sodium filling of exhaust valves, and replaceable cylinder liners. The new Soviet truck engines are V-8's with good performance characteristics. They typically deliver less horsepower per cubic inch of displacement than do US engines because the low octane rating of Soviet gasoline dictates low compression ratios. Octane ratings of fuel for motor vehicles are on the average about 20 percent below US ratings. Compression

ratios for Soviet truck engines are between 6.0:1 and 6.5:1, compared with between 7.5:1 and 8.5:1 in the United States.

103. Soviet trucks have lower cargo ratings than US trucks of similar weight and tire size. The fairly modern ZIL 130 carries 4-5 tons, depending on road conditions, whereas a US truck of about the same gross vehicle weight (truck plus cargo) carries more than 7 tons. This limitation on the loading of Soviet trucks is necessary because lower strength steels are used in frame members and axles and because severe punishment is imposed on Soviet trucks by poor road conditions. Some progress is being made in lowering the weight-cargo ratio in new types of heavy dump trucks (25 tons and higher), but for most heavy trucks this ratio lags behind comparable US models.

104. Until very recently, passenger automobile production was treated as a regrettable necessity and has been the most backward area of the Soviet automotive industry. Now, however, an expansion program is under way that is supposed to raise annual passenger car production from about 250,000 in 1967 to over 1 million in 1973. Soviet passenger car production has consisted principally of the microsize four-passenger Zaporozhets (analogous to the FIAT-600), the small four-passenger Moskvich (analogous to the Opel Kadet), and the compact-size Volga (analogous to the Chevy II or the Rambler American). A few limousines of the GAZ "Chaika" and the ZIL-111 types are made, practically by hand. Except for the Chaika and the ZIL-111, no Soviet passenger car engine has more than four cyclinders, and all these engines have less horsepower than engines used in analogous Free World cars.

105. Soviet passenger cars are designed to accommodate the severe winter climate and the rough roads in the USSR. Because of stiff springing, they have a hard ride. Engine noise levels and vibration are high by modern standards. Typical complaints of Soviet owners refer to the poor grades of rubber used for sealing doors and windows, short life of upholstery materials and paint, and inadequate heat and sound insulation. The poor quality of Soviet cold rolled steel sheet results in auto bodies that are excessively heavy and have a poor surface finish.

106. The level of production technology used in the Soviet automotive industry is on the whole as outmoded relative to the West as is the product mix. Much of the machinery, although well maintained, is old. A Western observer has described the Soviet auto industry as "incredibly obsolete and inefficient" by Western standards. The USSR is relying on imported plant and equipment to narrow this enormous technological gap. A gigantic automobile plant at Tol'yatti is being erected under contract with FIAT of Italy, and Renault of France is supplying equipment and technical help to refurbish and double the capacity of the Moskvich car plant in Moscow. Negotiations are now under way to buy processes and equipment in the United States to increase the production of ZIL trucks and to buy from France a complete plant to produce 180,000 trucks a year.

107. The USSR has held first place in the world in volume of tractor production since 1960. It produced about 405,000 units in 1967, compared with about 262,000 units in the United States. However, despite great improvements in the last 10 years, Soviet tractors are inferior to US tractors in weight-horsepower ratio, transmission efficiency, reliability, service life, and ease of operation. The excessive weight of Soviet tractors results in part from a need to compensate for low-strength metals and from neglect of quality control in foundry practice. The poor reliability and short service life results in part from the low quality of even such ordinary items as bolts and other fasteners, paint, and rubber parts. Short life, by US standards, is common for the track and suspension parts of Soviet tracked tractors because their design does not provide for adequate lubrication, the sealing of bearing surfaces against abrasive dirt, and the proper hardening of wearing surfaces.

108. The transmissions of Soviet farm tractors are much less efficient than those of US tractors. Drawbar horsepower of the typical Soviet wheeled tractor is 60-65 percent of the engine horsepower, compared with 90 percent for US tractors. Consequently, the fuel consumption of Soviet tractors is high by Western standards. Although modern features copied from Free World designs -- such as four-wheel drive and power steering for wheeled tractors and automatic transmission for wheeled and tracked

tractors -- are now included in some models, they do not embody the latest advances nor is their reliability and performance equal to Free World equipment.

109. The Soviet tractor industry does not produce tractors with the horsepower and productivity of the D-9G Caterpillar, which is highly effective in mining and construction, nor has it yet developed the necessary engines and powershift transmissions. The USSR has imported a number of Caterpillar D-9 tractors which, because they can rip deeply frozen earth at a high rate, are extending the gold mining season in Magadan by several weeks. In 1968, one of the world's most prominent civil engineering firms attempted to use five DET-250 tractors, the largest made in the USSR, in bulldozing work on a canal site on the US-Canadian border. The tractors proved to be unwieldy, oversized, and underpowered, with high fuel consumption. Moreover, rubber parts and track links wore out rapidly, and the oil had to be changed very frequently.

Machine Tools

110. Although the USSR is the world's largest producer of machine tools, its product mix is heavily weighted with general purpose machines, and in almost all categories -- both general and special purpose -- its tools are equaled or exceeded in efficiency, durability, and accuracy by those of the United States. Because of its large output, the average age of the USSR's machine tool inventory is considerably younger than that of the United States, but because of the emphasis on standard models, the technological composition of the stock is much less advanced than that of the United States.

111. The USSR is far behind the United States in the use of numerically controlled machine tools. While the United States produces numerically controlled machines with continuous path control on five axes and with automatic tool changing devices, the USSR has achieved only point-to-point control on two and three axes without automatic tool changing. The production of numerically controlled machine tools accounts for no more than 1 percent of the value of output of Soviet machine tools,

whereas, in the United States, this share amounts to about 20 percent. The use of numerically controlled machine tools is still confined generally to the aerospace industries in the USSR but is now widely distributed throughout the US machine building industries. A unique numerically controlled machine tool of US manufacture is an automatic transfer machine which can completely machine tractor engine blocks of both in-line and vee configurations according to a numerical program. This installation combines a high degree of automation with the versatility to handle a wide assortment of product. The Soviets are years away from achieving this degree of automation and control of the machining process. The USSR has produced automatic transfer machines for industries with high volume production -- for example, the automotive and tractor industries -- but this production capacity is very small, delivery leadtimes are very long, and the Soviet Union therefore is dependent on imports from the Free World for tooling for substantial investment programs like the new passenger car plant at Tol'yatti.

112. An outstanding example of the technological lag that the USSR is building into new plants because of the long leadtime they require is the procurement for the Tol'yatti Motor Vehicle Plant of $8 million worth of gear-cutting equipment for rear axle gears for the Soviet FIAT. The equipment was supplied by the Gleason Works of the United States before the end of 1968, will not be installed until 1970, and will not be in full production until 1972. Meanwhile, Gleason is now selling machinery for cutting bevel drive gears that includes a machine costing $400,000, which replaces five roughing cutters and ten finishing cutters sold to the USSR at a price of $825,000. The new machine raises labor productivity in this operation by more than seven times and requires less than half the floorspace of the older machines.

113. The USSR is the world leader in electrodischarge machining (EDM) and ultrasonic machining and produces 40-50 percent of world output of these machines. The United States has put little effort into the development of these machines but appears to lead the USSR in the development of electrochemical machining (ECM) and electron beam machining and welding, both techniques of considerable value in the aerospace industries.

114. The USSR produces and uses far fewer metalforming machines than the United States, and as a result wastes a much larger percentage of its steel and nonferrous mill products in the form of chips. In isolated instances the USSR appears to lead the United States in metalforming technology. One example is the unique Soviet process for rolling gears and shafts from heated steel billets at a much higher rate than cutting tools can achieve. Moreover, the USSR currently possesses two 75,000-ton forging presses, the world's largest, which give the USSR significantly increased capabilities for forging large parts for large high-performance and supersonic aircraft, compared with the United States. The largest press available to the US aerospace industry has a capability of only 54,000 tons.

Aircraft

115. Although the Soviet aircraft industry is the world's second largest, it produces only about one-fifth as many planes as the United States but about three-fifths as many military aircraft. Because the USSR long has stressed research on supersonic and hypersonic flight, the industry can produce fighters and intercepters equal in performance to any in the world. Because of engine deficiencies, however, the performance of Soviet transport aircraft lags somewhat behind that of the West. The new Soviet civil transports now entering production are considerably better than their predecessors, but because of these deficiencies they are still inferior to similar Western aircraft in range, payload, fuel consumption, and engine life. Passenger accommodations on the largest transports are also inferior to those on comparable Western aircraft.

116. At any point in time, Western transports in service lead those produced by the USSR. For example, the IL-62, the only Soviet jet transport comparable in load and range to the 707, the DC-8, and the British VC-10, first flew in 1963, but because of delays attributable to a number of deficiencies in design did not enter regular service until mid-1967. Similarly, the TU-134, a Soviet transport similar to the DC-9, made its first flight in mid-1963, but because of control problems and structural deficiencies was not placed in series

production until late 1967. In comparison with the slow pace of the TU-134 program, 40 DC-9's were delivered within 18 months of its first flight.

117. Soviet aircraft technology closely approaches Western technology in its applications to supersonic flight. In some cases the US has achieved a production capability sooner than the Soviets. The new Soviet interceptor, Foxbat, probably now nearing series production and constructed primarily of titanium, is capable of sustained speeds near Mach 3, while carrying a large payload on long-range missions. Its capabilities exceed those of any operational aircraft other than the SR-71, a US strategic reconnaissance aircraft. The Soviet Flagon, a twin-jet Mach 2.5 intercepter now in production and service, has better performance capabilities than any US intercepter now in service. Although the USSR is testing aircraft with variable geometry wings (VGW) like the US fighter/bomber F-111, the best of these, the Flogger, requires two or three more years of testing before it can become operational. It is much lighter than the F-111 and not likely to serve in so many different roles.

118. Experience with the Mach 3 XB-70 has given the United States a broader technological base than the USSR for the development of advanced strategic bombers. There is no evidence that such large fast aircraft are under development in the USSR, although test data from the slower (Mach 2.2) TU-144 supersonic transport (SST), which recently made its first flight, will add to Soviet capabilities in this area. Based on experience with the XB-70 and the SR-71, US industry is able to undertake the design of SST's with speeds in the Mach 2.7-3.0 range.

119. The USSR leads the world in the development of rotor systems for very large helicopters. The USSR also was first in such features of helicopter design as rear ramp loading, electrical bonding on external controls, ice detector systems, rotor blade deicing system, autopilot, stubwing, oxygen system, and blade tip lights. On the other hand, the United States has had a substantial lead in the design and production of high-speed tactical helicopters and associated weapons systems, as well as in rigid rotor and compound helicopters.

Electronics

120. The Soviet electronics industry, officially classified as a defense industry, shares with the missile, nuclear weapons, and other strategic industries a priority claim to Soviet economic resources, and most of its output is defense-related. From a relatively small base in 1955, it has become the world's second largest electronics industry, and its level of production of military electronics closely approximates that of the United States.

121. The level of technology embodied in Soviet electronic equipment, however, is generally below that of the United States. For at least 10 years electronic equipment manufactured in the United States has been transistorized -- that is, designed around the use of transistors and semiconductor diodes. In the USSR, the wide-scale application of transistors to electronic equipment, even in the area of military electronics, has become noticeable only during the past two or three years.

122. There are significant disparities in the technology embodied in the basic semiconductor components themselves: the United States manufactures mainly silicon devices using epitaxial planar manufacturing techniques, and the USSR produces mainly germanium transistors and apparently has only recently achieved a capability for the mass production of silicon planar devices. Thus US electronic equipment, thanks to the inherently superior indices of silicon planar devices, tends to exceed its Soviet counterpart in all important operational parameters.

123. Moreover, in the area of military electronics, the USSR continues to use equipment containing hybrid packages -- that is, both transistors and obsolescent electron tubes. Thus, even in the few high-priority military areas -- for example, missile/space guidance and control systems and strategic early-warning radar systems -- where the USSR has achieved a rough parity with the United States in terms of equipment performance, Soviet equipment tends to be larger, heavier, less transportable, more difficult to maintain, and less reliable than similar US equipment.

124. The gap in component technology is widening. In the United States the transistor is giving way

increasingly to integrated circuits which are still largely experimental in the USSR. The USSR lags at least four years behind the United States in microelectronic technology. In some areas the relative inferiority of Soviet electronic technology has prevented the USSR from achieving even a rough parity with the United States in equipment capabilities -- for example, computers, electronic instrumentation, telephone equipment, and color television.

125. US computers are substantially superior to Soviet computers in reliability and in all major operational parameters such as speed, memory size, and multiple access capability. Moreover, the associated software and the electromechanical peripheral equipment supplied by US industry are substantially superior to their Soviet counterparts. Soviet computers in current production are based on transistor technology; many computers now made in the United States incorporate integrated circuits, which improve performance, reduce the size of equipment, and lower manufacturing costs.

126. The gap in computer technology is widening; the United States is now moving into fourth generation machines based on large-scale integration characterized by greater speed and reliability. The highest speed yet attained by a Soviet computer -- the BESM-6 -- is 1 million operations per second, compared to about 6 million operations per second for currently produced IBM models. Although introduced as far back as 1965, only a handful of BESM-6 machines have been produced. The USSR is making great efforts to reach US state-of-the-art in computer technology, but the prospects of doing so are remote without direct access to US technology.

127. In the technology of industrial and scientific instrumentation, the USSR lags well behind the United States. Soviet oscilloscopes, representative of the Soviet state-of-the-art in electronic instrumentation, typically are inferior to those of the United States. For example, measured by bandwidth (the most significant single index of complexity, flexibility, and overall capability), oscilloscopes capable of sensing radio frequencies above 30 million cycles per second

are in very short supply in the USSR, whereas oscilloscopes with capabilities of 150 million cycles per second are quite ordinary in the United States. For exacting scientific research, the USSR has to import such instruments as electron microscopes and nuclear magnet resonance spectrometers from the Free World. US instruments of this kind are among the best in the world.

128. In the technology of commercial telephone communications, the USSR lags several years behind the United States. The USSR has only recently developed, for example, crossbar telephone exchanges of 1,000-line capacity, whereas crossbar exchanges of several thousand lines have been commercially available in the United States for many years. Moreover, the United States is now moving rapidly into electronic switching systems. In the technology of carrier (multiplexing) systems for cable and radio relay communications, the capacity of commercially available systems in the United States is at least 10 times greater than those produced in the USSR.

129. Finally, color television provides a conspicuous example of deficiencies in Soviet production technology in the consumer area. Although the USSR successfully developed a color picture tube in the laboratory as early as 1959, it failed to evolve a technology for series production in the factory. As a result, Soviet plans to introduce color television on a commercial scale have been delayed for several years. Recently, the USSR purchased the crucial color tube manufacturing know-how from the United States to ensure volume production of color television receivers by 1970.

130. The USSR currently lags perhaps three to five years behind the United States in communications satellite technology. The US Army's Score satellite first transmitted prerecorded messages in 1958, and in the early 1960's the United States followed up this early success with the Courier, Telstar, Relay, and Syncom satellites which paved the way for the successful US launching in April 1965 of Early Bird, the world's first satellite to be deployed operationally and used regularly for commercial communications. During that same month, the USSR conducted its first successful tests of a satellite specifically designed for communications relay. The USSR

called this comsat "Molniya" and did not remove its "experimental" label until the sixth launching was completed in 1967.

131. The USSR has yet to orbit a satellite with a satisfactory active lifetime. The short useful lifetime of the Molniya satellites is due in part to the USSR's choice of a highly elliptical orbit. This type of orbit provides excellent coverage of the Soviet Union, but is hard on satellite components owing to the repeated passage of the spacecraft through the Van Allen radiation belts and requires correcting the lateral drift inherent in an elliptical orbit. Since 1965 the USSR has successfully orbited at least 11 Molniya satellites, but only three of these are fully operational. In contrast, the Early Bird satellite was still operating satisfactorily when "retired" from active service in early 1969. Likewise, three Intelsat II satellites successfully injected into stationary orbit by the United States in 1967 are still fully operational.

132. On-board transmitter power of the Molniya satellites is much higher than that of any US-developed satellite, but the traffic-handling capacity of all Molniyas has been confined to only 60 two-way telephone channels. In contrast, Early Bird and the Intelsat II series were designed for 240 channels, and the two Intelsat III satellites recently orbited by the United States have an operating capacity of 1,200 channels. Thus, while the channel capacity of Soviet comsats has remained static since 1965, US technological advance has produced a 500-percent increase in comsat channel capacity in the same period.

133. The USSR has progressed rapidly in developing the ground segment of its comsat program during the last two years. Until late 1967, the ground segment used to handle Molniya transmissions consisted of only two common carrier ground stations, one at Moscow and the other at Vladivostok. However, in November 1967 the USSR put into operation a network of more than 20 so-called "Orbita" ground stations capable of receiving one channel of television relayed from Moscow via Molniya. Unlike the terminals at Moscow and Vladivostok, none of the Orbita stations is currently able to receive telephone and telegraph traffic or has a ground-to-satellite transmission

capability. The United States has now put into operation six Intelsat ground stations on its own territory, and US technology is directly or indirectly responsible for most of the 16 Intelsat ground stations now operating in other Free World countries. All Intelsat ground stations have full-range capabilities -- that is, they are able to transmit and receive all types of communications.

134. Measured against present accomplishments, Soviet comsat technology can be expected to reflect much greater sophistication during the next several years. There are indications, for example, that the USSR intends to put a comsat into equatorial synchronous orbit, possibly some time late in 1969. In addition, the USSR almost certainly will attempt to provide its future comsats with increased channel capacity and a capability for simultaneous relay of both television and multichannel voice communications (this latter capability is already a feature of the Intelsat III satellites). If achieved within the next year or two, these advances could narrow the comsat technology gap between the USSR and the United States in the short run. However, US technology is also moving rapidly ahead. The fourth generation of Intelsat satellites, for which the United States is prime contractor, is already under development. This new satellite is being designed for 5,000-6,000 two-way voice channels, for simultaneous access by a large number of ground stations, and for a useful lifetime of seven years. If the Intelsat IV series is deployed as scheduled, beginning in 1971, a US lead of at least three years over the USSR in comsat technology is likely to be maintained for the foreseeable future.

Consumer Goods

135. The technology of production in Soviet consumer goods industries varies widely -- from highly modern bread factories to archaic textile mills. The typical Soviet bread factory employs a continuous flow process that starts with the mixing of ingredients in large vats on the top floor of the multistory building. As the product descends, floor by floor, the dough is processed into a variety of bread products, baked, and delivered unwrapped to special trucks at the ground level which transport it to the distributing bakeries. The process is distinguished by the small number of employees

required and the precision of the quality control maintained. Such mass-production processes are far less common in the West.

136. In products other than bread, the technological level of the food industry in the USSR lags 20-25 years behind the United States. Some of the best equipment in current production is copied from US equipment of the 1930's and does not apply the advanced methods developed in the United States and Western Europe or even in East Germany. Freezer storage is not yet widely available in Soviet households, and the USSR processes very little fresh frozen produce and meats. Considerable effort is being directed toward developing processes for the preservation of food by freeze-drying and irradiation, but the principal process for preserving foods is canning in glass jars. The USSR is particularly deficient in equipment for automatic packaging of liquid dairy products in paper containers and for automatically wrapping and packaging butter and cheese.

137. Soviet textile mill equipment is 25-30 years behind that of the United States. Efforts are being made to modernize the mills with domestically produced machinery, but most of it differs very little from that produced 50 years ago. For the production of textiles from synthetic fiber, the USSR is dependent on imported machinery. Soviet textile plants lack modern finishing equipment, and the quality of fabrics is therefore very poor by Western standards. Preshrinking machines are few. Steaming of expensive woolen fabric at some dressmaking factories is now being introduced, but equipment to make wrinkle-free, no-iron, and permanent-crease materials is not yet being produced. Because bleaching machinery is lacking, most Soviet cotton fabrics are dyed without first being bleached, thus giving them a drab appearance.

138. In the footwear industry, less than 65 percent of the operations are mechanized and 30 percent of the equipment is obsolete, according to Soviet statements. In leather processing, 65 percent of the machinery in use is considered obsolete, and new domestically produced machinery is below world standards. Technology in the Soviet clothing industry is geared to mass production of a small range of simple styles, and evidently is as backward relative to the West as are the textile and footwear industries.

139. With respect to consumer durables, household appliances produced in the USSR are undersized, old fashioned, and inefficient, compared with those in the United States. Most of them resemble models produced in the West before World War II. Appliances and other housewares are often produced as a sideline by plants that produce heavy machinery or aircraft. The production technology undoubtedly is as obsolescent relative to the West as is the design of the product. Radios and television sets are produced by the electronics industry, using production techniques that lag considerably behind those of the West.