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NIE 11-2-71

SOVIET NUCLEAR PROGRAMS

CONTENTS

SOVIET NUCLEAR PROGRAMS

THE PROBLEM

To review recent developments in Soviet nuclear programs and to estimate their course over the next five years or so.

SUMMARY CONCLUSIONS

A. The nuclear energy program of the USSR has evolved over the years from an intensive effort devoted exclusively to the development of nuclear weapons to a diversified endeavor embracing a variety of peaceful applications as well. In the development of nuclear weapons, the Soviets have attained an advanced level of technology enabling them to produce weapons of diverse types, weights, and yields, to meet their requirements for present and future delivery systems. They have produced exceptionally powerful nuclear propulsion systems for their submarines. In non-weapon applications, they have the largest program of research on controlled thermonuclear reactions in the world, and have carried out a more versatile program than others in the peaceful use of nuclear explosions.

B. The USSR has extensive facilities for the production of nuclear materials and nuclear weapons, and ample stockpiles of natural uranium. Although we cannot make a meaningful independent estimate of Soviet military requirements for nuclear weapons, we have no reason to believe that the availability of nuclear materials has imposed restraints on the military program that the Soviets have chosen to carry out. Indeed, the Soviets have offered to provide uranium enrichment services to others and to export nuclear power stations. We have no reason to believe that for the foreseeable future they will lack the capacity to meet their domestic needs, both military and civil, and to continue their international activities.

Testing

C. The Soviets have continued to test nuclear devices underground during the past two years, at about the pace characteristic of the previous six years. They have apparently been willing to take greater risks than the US of venting debris to the atmosphere which might be detected beyond their borders. In 1969 and 1970, the percentage of tests producing debris that carried beyond the borders of the USSR increased over any previous two year period. This could suggest that the Soviets have recently given a higher priority to test objectives than to concerns over possible venting.

D. There is no reason to believe that the Soviets intend to resume nuclear testing in the atmosphere. We believe that the Soviets plan to test underground for at least the next two years. Should the Soviets decide to resume atmospheric testing, intelligence sources would provide little, if any, advance warning.

Weapons

E. [

]We have a fair degree of confidence in our estimates of the general characteristics and performance of the nuclear weapons developed during this period, but almost no information on the actual size and composition of the Soviet stockpile of such weapons.[

]

F. [

]

[ ]The limited number of underground tests of high-yield devices, and the spectrum of the yields, suggest that the technology incorporated in *thermonuclear warheads* of three megatons and above has not changed substantially since 1962.[ ]

G. We know little about the hardness of Soviet re-entry vehicles (RVs), i.e., their ability to withstand the effects of nuclear radiation. It is reasonable to assume that hardness has been considered by the Soviets in designing at least their more recent RVs, particularly in the light of their increasing concern for survivability and penetrability.

Production of Nuclear Materials

H. Soviet procurement of uranium has exceeded, by a considerable margin, current and past needs for the production of fissionable materials. We estimate the cumulative Soviet production of *plutonium-equivalent* as of mid-1971 at between 48 and 62 tons, with a best estimate of about 55 tons, and production for the year ending 1 July 1971 at 5 to 6 tons. The methodology used is reasonably direct and we have confidence in the results. More indirect methods must be used to estimate the production of weapons grade *U-235* and the results are subject to greater uncertainty. Cumulative production through mid-1971 was probably not less than 240 tons nor more than 550 tons. We believe that actual Soviet production would probably be near, or in a region somewhere above a mid-range figure of 360 tons, rather than at, or near, either extreme.

I. During the past several years the Soviets have apparently become less concerned with increasing the output of U-235 and more concerned with reducing costs, and probably have taken older gaseous diffusion buildings out of operation. We have seen no evidence of a shutdown of reactors for the production of plutonium.

Power and Propulsion

J. Nuclear power plants represent only a small portion of the total electrical generating capacity of the Soviet Union. Present capacity is 2,250 megawatts of electricity (MWe), and the total planned for 1977 is about 10,000 MWe. On a basis of past performance, the Soviets are unlikely to achieve this goal before the early 1980s.

K. The reactors on the newer Y, C, and V classes of nuclear submarines have exhibited excellent operational characteristics, and the Soviets appear to have a high degree of confidence in them. The C- and V-classes probably have a reactor generating about 150 megawatts, and the Y-class a total reactor power of about 270 megawatts. Work has not yet begun on the two *Arktika*-class nuclear icebreakers which the Soviets plan to construct.

L. The USSR is making an active effort to exploit nuclear energy for use in space, but it has not yet launched a nuclear reactor for use there. The Soviets recently developed the world's first prototype thermionic reactor. In the last half of this decade, they could have a 10 kilowatt thermionic reactor as a power source in space.

M. The Soviets are continuing their efforts to find a practical way of producing electricity from controlled thermonuclear reactions. They are investigating many approaches, but their main effort is directed at toroidal (doughnut-shaped) plasma and laser-plasma devices. We expect that one of their Tokamak-type toroidal devices will succeed in demonstrating the technical feasibility of the controlled release of fusion energy late in the decade.

Peaceful Uses and International Cooperation

N. The Soviets have a vigorous program for the peaceful use of nuclear explosions (PNE). Since it began in 1965, 15 nuclear detonations specifically for peaceful purposes have been detected, mostly in support of the Soviet oil and gas industry or for excavation projects. The Soviets clearly intend to carry out an extensive program in the future; they have mentioned projects intended to stimulate the production of oil and gas, to store oil and gas, to strip ores, to crush rock, and to create dams and canals.

O. The USSR has provided limited nuclear assistance to its allies and to certain non-Communist countries since the mid-1950s. At first, its aid was primarily in the form of training and the supply of reactors and equipment for research, but more recently it has included the construction of nuclear power stations. The USSR is constructing nuclear power stations in Eastern Europe and recently contracted to supply two power reactors to Finland, the first non-Communist country to buy them from the USSR.

P. The USSR has been an active member of the International Atomic Energy Agency (IAEA) since its inception in the mid-1950s. At the IAEA meeting in 1970, the Soviets stated that they were prepared to negotiate contracts to enrich uranium for non-nuclear countries that are parties to the Non-Proliferation Treaty (NPT). The USSR recently concluded an agreement to enrich uranium for France and return it for use in power reactors. This marks a major step in what is probably a Soviet effort to become actively competitive in the world market for reactor fuel.

DISCUSSION

I. THE NUCLEAR WEAPONS PROGRAM

A. The Nuclear Test Program

1. The Soviets have continued underground testing during the past 2 years, with 18 tests detected in 1969 and 13 in 1970. These magnitudes are about the same as those for the previous 6 years. By the end of May 1971, an overall total of 290 nuclear tests had been detected, 186 before the Limited Test Ban Treaty (LTBT) went into effect in 1963, and 104 thereafter. At least 15 of the underground tests were part of the Soviet program for peaceful uses.[1] [

]

2. Underground weapons-related tests have averaged about 1 per month since 1963. These tests have ranged in yield from less than 1 kiloton (kt) to up to 3 to 6 megatons (MT). Most if not all of the 18 tests with yields above 100 kt were probably for the development of thermonuclear weapons. Of the remaining tests, some were probably for fission weapon development, and some were tests of weapons effects. [

]

3. Most Soviet underground tests occur in either the Semipalatinsk area of Kazakhstan or in the Novaya Zemlya area of the western Arctic. Since 1963, we know of a total of 15 underground detonations which have taken place in other areas. In October 1970, the Soviets conducted their largest underground test at Novaya Zemlya, which yielded an esti-

[1] See Annex A for a listing of Soviet underground tests since the LTBT went into effect. See Section V for a discussion of the tests for peaceful uses.

[

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mated 3 to 6 megatons. An area off the west coast of Novaya Zemlya was closed to shipping at the time of the test, indicating that the Soviets were less sure of the containment of debris from the test than for previous underground tests in the area.

4. The Soviets are apparently willing to take greater risks than the US of venting debris to the atmosphere which might be detected beyond their borders. Of the underground tests conducted since the LTBT went into effect, possibly 52 vented into the atmosphere beyond the borders of the USSR. We are certain that 11 did—5 since October 1970. [redacted] In 1969 and 1970, the percentage of tests that probably or possibly vented beyond the borders of the USSR increased over any previous two year period. This could suggest that the Soviets have recently given a higher priority to test objectives than to concern over possible venting.

5. We have no reason to believe that the Soviets intend to resume nuclear testing in the atmosphere. We believe that the Soviets plan to test underground for at least the next two years. Should the Soviets decide to resume atmospheric or exoatmospheric testing, intelligence sources would provide little, if any, advance warning. [redacted]

B. Weapons Developed During the Period of Atmospheric Testing

6. Our estimates of the Soviet nuclear devices tested prior to 1963, when the LTBT went into effect, are made with a fair degree of confidence. On the basis of these tests, we have postulated models of Soviet weapons representative of those believed to be in the stockpile. These postulated weapons reproduce the yield observed in specific atmospheric tests. [redacted]

7. [redacted]

Thermonuclear Weapons

8. [redacted]

C. Weapons Developed Since the Beginning of Underground Testing

13.

The information available for analysis consists of only the estimated yields of the tested devices based on their seismic magnitude, and the evidence on underground nuclear test sites. We rely wholly on our understanding of what US weapons development has demonstrated to be technically feasible, and of what Soviet requirements might be for their new delivery systems.

14. Despite the limitations of the data, we can at least place limits on the kinds of new developments that the Soviets may have achieved through underground testing. We believe the Soviets would have a military requirement to test new warheads for important weapon systems at, or near, the full yield. This becomes difficult and very expensive, however, in underground testing at high yields. In any event, by the end of 1962, the Soviets had developed thermonuclear weapons which afforded very good yield-to-weight ratios in the yield range appropriate to most of the strategic delivery systems operational at that time. This, and the limited number of underground tests of high-yield devices, suggest that the technology incorporated in *thermonuclear* warheads with yields above about 3 MT has not changed substantially since 1962.

15. We do not know specifically what requirements the Soviets might have for thermonuclear warheads of lower weight and yield. They might want small, compact warheads such as would be required for multiple reentry vehicles (MRVs) on the SS-11 intercontinental ballistic missile, or on submarine-launched ballistic missiles.

16. [redacted]

D. Other Weapon Developments

17. In their high-altitude tests of 1961 and 1962, the Soviets showed concern about the possible blackout of antiballistic missile (ABM) radars by nuclear bursts. [redacted]

18. The Soviets may have a requirement for an improved Galosh warhead. If so, they would have to undertake modifications of past weapon designs, or develop an entirely new type of thermonuclear weapon. We think that the Soviets would want to test the resulting weapon; it could account for some of the underground tests which have been detected. If so, the number, magnitude, and chronology of these tests suggests that an operational warhead could be available in a year or two. [redacted]

19. Little is known concerning the ability of Soviet re-entry vehicles (RVs) to withstand the effects of the radiation produced by nuclear blasts. It is reasonable to assume that the vulnerability of RVs has been considered by the Soviets in designing at least their more recent RVs. We are aware of the increasing Soviet concern for survivability and penetrability, as evidenced by the development of MRVs, higher ballistic coefficients, and the use of penetration aids, and we would expect a balanced program to include some degree of RV hardening.

20. The need to insure survivability of their strategic weapons systems, and the cost of full-scale testing underground, have almost certainly caused the Soviets to implement a program to simulate weapon effects. We believe the Soviets have made efforts to simulate the various forms of energy released from a nuclear burst (blast, thermal, and nuclear and electromagnetic pulse radiation) and the effects of this energy on materials, facilities, and weapons systems.

21. We know that the Soviets have an extensive research program to study the effects of high pressure on materials; their experimental and theoretical efforts in this area are probably sufficient to enable them to simulate the effects of blasts. The simulation of thermal effects poses no particular difficulty and is also within their capability. The Soviets are certainly aware of the electromagnetic pulse (EMP) produced by a weapon, and we believe they are capable of simulating the EMP field to some extent.

22. The high-altitude nuclear tests conducted in 1961-1962 were basically for other purposes and probably gave the Soviets limited or no information on the vulnerability of nuclear components to the effects of radia-

tion. They are probably expanding their knowledge in this area both through underground tests and the use of various simulation techniques. The Soviets are probably following the same techniques used by the US for simulating nuclear radiation. They have made significant progress through using plasma focus and laser-produced plasmas. They have numerous steady state and pulsed reactors suitable for simulating the neutron energy released by fission weapons, and we believe they have used them for this purpose. The Soviets probably have used various techniques to simulate the effects of low temperature x-rays and some high temperature x-rays. They also have high voltage flash x-ray machines and reactors which provide them with a limited capability to simulate the effects of gamma radiation.

E. Storage and Control of Nuclear Weapons

23. The Soviets store their nuclear weapons in national reserve stockpiles, at regional storage facilities, at what we call "sensitive operations complexes", and at operational storage sites at military bases. Because they exist in large number and are of considerable size, the operational sites probably account for the bulk of the weapons inventory.

24. The highly-secured national reserve stockpile sites are spread throughout the country. The regional sites are far smaller than the national reserve sites, and apparently are used to serve remote areas. The storage of nuclear weapons is probably only one of the functions of the 12 so-called "sensitive operations complexes". They differ from the national reserve stockpile sites in several respects. We are not able to determine what other functions these complexes may have.

25. The numerous operational storage and handling sites are physically separated from the other facilities at the bases where they are located. They are found at airfields serving naval, tactical, and strategic air forces; at strategic missile launch sites; at tactical surface-to-surface missile (SSM) support facilities; near Moscow, for the ABM system there; and at naval bases. In general, the newer installations are less complex than the older ones, probably reflecting the development, over the years, of weapons that require less handling. The chronology of construction shows that the strategic forces have received priority in the allocation of nuclear weapons.

26. The Soviets maintain a few nuclear storage facilities at Soviet tactical airfields in Eastern Europe. These sites were constructed in the mid-1950s in East Germany, Poland, and Hungary. It is possible that they provide some service to the ground forces as well as to the tactical air forces. It is not known whether nuclear weapons are actually stored there.

27. We have very little information on Soviet procedures for preventing the accidental or unauthorized use of nuclear weapons. The information we do have is fragmentary and deals only with limited aspects of the overall problem. At the Strategic Arms Limitation Talks, the Soviets have showed great concern about preventing the accidental or unauthorized use of nuclear weapons, but have addressed their comments to US procedures rather than to their own.

28. We have no evidence as to how the unauthorized use of operational nuclear weapons—e.g., bombs on board aircraft or warheads on ready missiles—is prevented. We assume that the Soviets employ some procedure or system which they regard as effective for this purpose, but we do not know whether they utilize authentication systems and/or permissive links.

II. PRODUCTION OF NUCLEAR MATERIALS

29. Uranium is basic to any nuclear energy program. It is found in nature as an ore; the uranium in the ore consists mostly of U-238 (99.28 percent), which is not readily fissionable, and only in small part of U-235 (0.72 percent), which is. By itself, natural uranium will not produce the chain reaction of fission which is required to achieve a nuclear explosion. There are two ways to use uranium to produce materials that will. The first involves the creation of plutonium-239 from uranium-238 within a nuclear reactor. The second is an enrichment process which increases the ratio of U-235 to U-238 in the uranium, and thereby enhances its explosive potential. This section looks at Soviet production in each of these areas, and at the amount of natural uranium available to the Soviets.

A. Production of Plutonium-Equivalent

30. Plutonium, one of the fissionable materials used in nuclear weapons, is produced by bombarding U-238 with neutrons in nuclear reactors (the irradiation process). The uranium that served as fuel for the reactor contains both U-238 and U-235; the two isotopes may appear in the same ratio as in nature, or the fuel may be enriched in U-235. The latter supplies the neutrons which bombard the U-238. After the fuel has been irradiated, it contains a mixture of uranium, plutonium, and many fission products. The plutonium is separated from the irradiated fuel by a chemical process in "chemical separation plants". Reactors can also be used to produce other nuclear materials, such as tritium and U-233. We use the term "plutonium-equivalent" to describe the output of nuclear reactors. It encompasses all the products of the process of irradiation (principally plutonium, uranium-233, and tritium) expressed in terms of equivalent amounts of plutonium; we have no means of determining the actual amounts of each.

31. The Soviets have reactors, for the production of weapons grade plutonium (or other reactor products) and chemical separation plants at Kyshtym in the Urals, and at Tomsk in western Siberia.

32. Plutonium is also produced by reactors at nuclear power plants and by the propulsion reactors used on nuclear submarines. The Soviets have stated that the plutonium produced in power reactors has not been separated and is still contained in the irradiated fuel; we believe that this is true for the plutonium produced in the propulsion reactors as well. They have further stated that the plutonium produced in power reactors would be used in their power reactor program. We do not know when the Soviets will actually start processing this irradiated fuel, but we estimate that it will be in 1972.

33. We estimate the cumulative Soviet production of plutonium-equivalent as of mid-1970 to be about 50 metric tons with a range between 43 to 56 metric tons. Comparing this amount with the amount estimated for a year earlier, we derive a Soviet production of about 5,500 kilograms of plutonium-equivalent for the year ending 1 July 1970 (see Table III).

34. In estimating the future production of weapons grade plutonium through 1976, we assume, on the low side, continuing production at present levels from the production reactors now in operation, and, on the high side, additional production at new production reactors of about 750 kilograms a year beginning in early 1972. We of course have considerably less confidence in our projections of plutonium-equivalent production than in our estimates of past production. On the one hand,

TABLE III

ESTIMATED
CUMULATIVE PRODUCTION AND AVAILABILITY OF SOVIET
PLUTONIUM-EQUIVALENT
(*Metric Tons At Mid-Year*)[a]

Year	CUMULATIVE PRODUCTION				AVAILABLE FOR WEAPONS IN STOCKPILE [d]		
	Power and Propulsion Reactors [b]	Production Reactors [c]					
		Minimum	Best Estimate	Maximum	Minimum	Best Estimate	Maximum
1966	0–1	24	29	34	22	26	30
1967	0–1	28	33	38	25	29	34
1968	0–1	33	39	44	29	34	39
1969	0–1	38	44	50	33	39	44
1970	0–1	43	49	56	38	44	49
1971	1–2	48	55	62	42	48	55
1972	1–2	53	61	69	46	53	60
1973	1–3	58	67	75	51	58	66
1974	2–4	63	73	82	55	64	72
1975	3–5	68	79	89	60	69	78
1976	5–7	74	85	96	64	74	84

[a] Cumulative production figures have been rounded.

[b] We believe that the plutonium produced in power and propulsion reactors to date is still contained in the irradiated fuel. The Soviets have stated that the plutonium produced in power reactors has not been processed. The Soviets have also stated that plutonium produced in power reactors is to be used in the power reactor program. We believe that the same will be true of plutonium produced in propulsion reactors. Therefore neither has been included as available for weapon use, although a portion could be diverted for this purpose.

[c] This plutonium has been processed through chemical separation plants.

[d] This column takes into account the loss of plutonium-equivalent due to radioactive decay of the tritium. The production of tritium is believed to constitute 10 percent of the total plutonium-equivalent production. An additional 10 percent has been deducted for the material contained in a production and reworking pipeline.

the Soviets could be building additional reactors. They could, conceivably, increase output at existing production reactors, or they could also optimize the operation of some of their power reactors to produce weapons grade plutonium. On the other hand, the production of weapons grade plutonium could slow down as military requirements are met. Moreover, plutonium will become increasingly available from power and propulsion reactors. We estimate that this output will increase to two metric tons a year by 1976, on a basis that all the power reactors in Table V, page 20, are completed as estimated there, and that the Soviets build nuclear-powered submarines at the rate we now project.

35. The estimate of plutonium-equivalent available for weapons in stockpile is derived from the estimate of the cumulative output of production reactors. In estimating the amount available, we have assumed that about 10 percent of cumulative production is in a production and reworking pipeline, or undergoing quality control check. We also substract the small quantities of plutonium estimated to be used in weapon tests. Finally, we make allowance for the production and decay of trit-

ium. Ten percent of the plutonium-equivalent produced in, or after, 1955 was assumed to be tritium. This is about the maximum amount that can be obtained from the graphite-moderated type of reactors that account for most of the Soviet production, when they are fueled with natural uranium. The cumulative tritium stockpile so derived was reduced each year by the amount of tritium decay.

B. U-235 Production

36. Natural uranium contains only some 0.72 percent U-235, the isotope which is essential for nuclear weapons utilizing uranium as the source of an explosive chain reaction. The USSR, like the US, uses the gaseous diffusion process to enrich natural uranium, i.e., to increase the U-235 content to some 90 percent of the total uranium content, a ratio necessary for weapon grade material.

37.

38. Gaseous diffusion plants are found at four places in the USSR—Verkh-Neyvinsk in the Urals, Tomsk in western Siberia, and Angarsk and Zaozerniy in central Siberia. Some of the older gaseous diffusion buildings probably have been shut down either permanently or for the purpose of effecting improvements.

39.

49. *Future Production.* Annual Soviet U-235 production could change significantly in the next few years. There is even a question as to the processes that may be used: available evidence can be construed as being consistent with substitution of gas centrifuge equipment in the older gaseous diffusion buildings. Because of the massive quantities of U-235 ac-

TABLE IV

ESTIMATED
SOVIET U-235 PRODUCTION
(*Metric Tons*)[a]

Year	CUMULATIVE PRODUCTION [b]			AVAILABLE FOR WEAPONS USE [b c]		
	Minimum	Mid-Range	Maximum	Minimum	Mid-Range	Maximum
1966	140	210	300	120	185	265
1967	160	240	350	130	200	300
1968	180	270	400	145	225	345
1969	200	300	450	160	250	385
1970	220	330	500	165	265	420
1971	240	360	550	170	280	450
1972	260	390	600	175	290	480
1973	280	420	650	180	305	515
1974	300	450	700	185	320	545
1975	340	480	750	190	335	575
1976	340	510	800	195	350	610

[a] In terms of uranium enriched to 93 percent of U-235 content.

[b] The actual Soviet U-235 production is more probably near, or in a region somewhere above, the mid-range values than at or near either extreme.

[c] Cumulative production less 10 percent for a production and reworking pipeline, and for the amount required for weapons tests and reactor programs.

cumulated over the past 22 years and the prolonged outages required for major modernization or equipment replacement, it is unlikely that resulting changes in annual production rates could affect cumulative production significantly during the next 5 years. For this reason, and because we lack a basis for estimating the effects of changes that may now be underway, we have projected future production estimates on the basis of the[

]We have reasonable confidence, through mid-1976, in the resulting range of *cumulative* production estimates; but extrapolation thereafter based on the implied annual production may become increasingly erroneous in either direction after 1976.

C. Uranium Procurement

50. We estimate that the Soviet procurement of natural uranium has exceeded, by a considerable margin, current and past needs for the production of fissionable materials. The Soviets are believed to maintain large stockpiles of uranium concentrate (uranium oxide). The stockpiles are probably explained by the ability of the Soviets to procure large amounts of concentrate from East European sources at relatively low cost, and by their desire to conserve their own uranium deposits.

51. Our information on Soviet domestic uranium resources is scanty, but we believe that reserves are ample for probable future Soviet needs. We know that several areas of the Soviet Union have been designated for future uranium exploitation, but the Soviets appear in no hurry to go ahead with the work.

52. Each year, the Soviet Union produces or processes uranium concentrate containing an estimated 17,000 metric tons of uranium. The total, representing domestic and East European sources combined, has changed little over the past decade. Since 1946, concentrate with an estimated total of 295,000 metric tons of uranium metal has been processed or produced.[4]

53. Our estimate of the cumulative production of fissionable materials could be satisfied with a cumulative uranium supply somewhere within a range of 100,000 to 140,000 metric tons. The annual uranium requirement needed to meet the current estimated fissionable material production rate falls within a range of 9,000 to 13,000 metric tons.

III. NUCLEAR POWER AND PROPULSION PROGRAMS

A. Nuclear Power Stations

54. Nuclear power plants represent only a small portion of the total electrical generating capacity of the Soviet Union. Because of the abundance of relatively cheap fossile fuels and hydroelectric power, it will probably be well into the 1980s before the Soviets feel the need to rely upon nuclear power sources to a greater

[4] A potential error in our estimate of procurement from East European sources arises from the uncertainty of defectors about whether they are referring to contained uranium metal or uranium oxide in their reports of East European production. If, in all cases, the defectors were referring to uranium oxide this would have the effect of reducing the East European portion of our estimate on the order of 20 percent. Uranium oxide contains 85 percent uranium and 15 percent oxygen. In addition we assume that the Soviets lose 5 percent of this uranium during processing.

degree. When they begin to do so, we believe that they will concentrate on breeder-type power reactors;[5] the Soviets have stated, in the past, that this is their intention.

55. The Soviet nuclear power program announced in 1956 called for the generation of 2,000 megawatts of electricity (MWe) by 1960, but this goal was not achieved until last year. The total Soviet nuclear power generation capacity at the present time is 2,250 MWe. Construction presently planned will result in an overall capacity of about 10,000 MWe by 1977. Because of their history of poor performance in meeting reactor construction schedules, we believe that the Soviets are unlikely to achieve this goal before the early 1980s.

56. The Soviets have indicated that they intend to standardize on two types of power reactors during the next 10 years. These are 440 and 1,000 MWe pressurized water reactors (PWR), and a 1,000 MWe water-cooled, graphite-moderated, pressure tube reactor (GMPTR). In addition, two experimental liquid metal fast-breeder reactors (LMFBR) are under construction, which are scheduled to contribute a total of 750 MWe of power by 1975, or 10 percent of the total nuclear power capacity at that time. These reactors are to provide the basis for designing the large fast-breeder reactors to be installed in the 1980s. (See Table V for a list of Soviet nuclear power stations and their characteristics.)

57. It is difficult to compare the technology of Soviet and Free World reactors because of basic differences in design and in safety philosophy. A Soviet nuclear power station would not be acceptable in the Free World because in designing for the containment of radioactive materials released during a nuclear accident, the Soviets do not meet Western standards. The Soviets believe that there can be no accidents involving an uncontrolled chain reaction or total loss of coolant. Their design is concerned mainly with coping with what they regard as the most serious accident that can happen, i.e., the loss of site power.

[5] Breeder reactors produce more fissionable material than they consume. This is accomplished by placing fertile materials, such as U-238, in the reactor to absorb neutrons which are in excess of those needed for maintaining the fissioning process. The absorption of neutrons converts fertile material into fissionable material which can serve as fuel for reactors. This process is called "breeding".

TABLE V

SOVIET NUCLEAR POWER STATIONS[a]

Location and Units	Moderator/Coolant	Power Level MWe/MWt[b]	Estimated Year in Operation (At Full Power)
Tomsk[c]			
1	Graphite/Water	625/8,700 (units 1 and 2)	At 100 MWe in 1958; modified in 1963
2	Graphite/Water		1961; modified in 1964
3	Graphite/Water	350/1,900	1966
4	Graphite/Water	350/1,900	1968
Beloyarsk			
1	Graphite/Water	100/286	1964
2	Graphite/Water	200/530	1967
3	Sodium Fast Breeder Reactor	600/1,430	By 1975
Novovoronezh			
1	Water/Water	240/760	1965
2	Water/Water	365/1,400	1969
3	Water/Water	440/1,370	1971
4	Water/Water	440/1,370	By 1973
5	Water/Water	1,000/2,550	1975
Shevchenko			
1	Sodium Fast Breeder Reactor	150/1,000[d]	1972
Bilibino			
4 Units	Packaged Power Reactor[e]	12/60 each	1972
Kola			
1	Water/Water	440/1,370	1974
2	Water/Water	440/1,370	1975
Yerevan			
1	Water/Water	440/1,370	1975
2	Water/Water	440/1,370	1977
Leningrad			
1	Graphite/Water	1,000/3,200	1973
2	Graphite/Water	1,000/3,200	1974
Kursk			
1	Graphite/Water	1,000/3,200	1976
2	Graphite/Water	1,000/3,200	1977

[a] The Soviets recently announced that two new power stations will be constructed, one in the Ukraine at Chernobyl', and the other at Smolensk. We do not know what type of reactor is to be built, nor do we know what the power level will be for these stations, and therefore have not included them in this table.

[b] *MWe:* capacity of the electric power generating equipment in megawatts of electric power. *MWt:* capacity of the reactor in megawatts of thermal power.

[c] These are dual purpose reactors which also produce weapons grade plutonium.

[d] This reactor could generate about 350 MWe, but most of the thermal power is for a desalination plant.

[e] The sections of this type of reactor are transported to the reactor site for assembly.

B. Marine and Naval Nuclear Propulsion

58. The Soviets first designed nuclear submarines and icebreakers in the early 1950s. After a decade of development, three classes of nuclear submarines and one icebreaker were operational. These first-generation submarines all utilized the same power plant. In the late 1960s, new classes of submarines appeared, five of which are nuclear powered, and the Soviets have announced that they will build two new nuclear icebreakers.

Submarines

59. The first nuclear submarines were the H-class, a ballistic missile submarine; the E-class, armed with cruise missiles; and the N-class, an attack submarine. We believe that the nuclear power plant used in these boats is capable of generating about 30,000 shaft horsepower from a reactor whose power is on the order of 150 megawatts. The reactor core originally had an average lifetime of about 3 years. Current overhauling schedules indicate that the average lifetime is now 4 to 5 years.

60. In about 1965, the Soviets began constructing a second generation of nuclear submarines, represented by the Y, C, and V classes.[6] These submarines have exhibited excellent operational characteristics during the few years that they have been in service. The Soviets have employed them on extensive long-range patrols and thus appear to have a high degree of confidence in their reliability.

61. We estimate that a reactor generating about 150 megawatts is required to attain the speeds (30 to 32 knots) of the C- and V-class attack submarines. We estimate that the propulsion system of the Y-class ballistic missile submarine, and the boat's maximum observed speed of 30 knots, require a total reactor power of about 270 megawatts.

[6] More recently, we have detected two additional classes, the P and the A, which are nuclear powered, but we know little about their propulsion systems.

Icebreakers

62. The first Soviet icebreaker, the *Lenin*, was commissioned in 1958. It experienced early operational problems and was out of service for lengthy periods, one lasting 4 years. A Soviet official has stated that the 3 original reactors of the *Lenin* were removed and replaced by a system containing 2 reactors. It is likely that the new reactors generate about 150 megawatts of power each and have an increased lifetime of about 10,000 full power hours. The *Lenin* resumed operation during the Arctic navigation season which began in the spring of 1970.

63. There is no evidence that work has begun on the two *Arktika*-class nuclear icebreakers which the Soviets plan to construct. The Soviets have stated that the reactors of these ships will have an effective lifetime 2.5 times that of the original *Lenin* reactors, and that they will be similar to those of the "reconstructed *Lenin*".

IV. ADVANCED NUCLEAR RESEARCH AND DEVELOPMENT

64. The Soviet program of advanced nuclear research and development (R&D) includes an active effort to exploit nuclear energy for use in space. It also includes the world's most extensive effort to demonstrate the feasibility of producing and controlling energy through nuclear fusion.

A. Aerospace Applications of Nuclear Energy

65. The Soviets have relied on solar cells and batteries almost exclusively for electric power on their spacecraft. They have used

radioisotopes as a power source on a few Cosmos satellites and as a heat source on the Lunakhod-1 vehicle. The USSR could make extensive use of nuclear sources for electric power if it chose to do so, since it has the necessary technology in thermoelectrics. The Soviets are doing extensive research on various other energy conversion processes including thermionics, magnetohydrodynamics (MHD), and various heat engine cycles employing turbogenerator machinery.

66. Technical literature indicates that the Soviets have established the materials technology for solid-core, nuclear rocket engines (i.e., engines utilizing solid fuel in their reactors). Rockets of this kind would enable the Soviets to transport very large payloads over interplanetary distances. There is no direct evidence, however, that a program is under way. A Soviet scientist working at a scientific institute in Moscow stated recently that he was involved in a project to study the feasibility of a rocket using a gas-core nuclear engine, i.e., one using gaseous fuel. Although the development problems are much more difficult, the temperature of the gaseous fuel can be made considerably higher than that of solid fuel. The gas-core rocket, therefore, can have a higher specific impulse. We believe that a solid-core rocket engine could be developed in the next decade, but considerably more time would be required to develop a gas-core rocket engine, or to make either system operational.

67. The Soviets have not yet launched a nuclear reactor into space, and they are unlikely to do so until the late 1970s. They operated a developmental reactor (called "Romashka") for about 15,000 hours a few years ago to test thermoelectric conversion, but it was then dismantled. Because of inherent power limitations and excessive weight, this reactor was not well suited for use in space.

68. The Soviets must overcome major technical problems to achieve success in their R&D work on the use of a large MHD[7] power source. These problems mostly involve the coupling of the nuclear reactor to the MHD generator. There is no evidence that the Soviets plan to use heat cycles employing turbogenerators in space.

69. The Soviets have been conducting an aggressive research program for the development of thermionic reactors.[8] Recently, they successfully operated the world's first prototype thermionic reactor. We estimate that the Soviets could have a 10 kilowatt thermionic reactor as a power source in space in the last half of this decade.

70. The Soviets are continuing research on new materials suitable for use in nuclear engines for aircraft. There is no evidence, however, that they are engaged in the development of nuclear-powered aircraft.

B. Controlled Thermonuclear Reactions

71. The Soviets are endeavoring to demonstrate the technical feasibility of a reactor which can produce and control the energy released by nuclear fusion.[9] Their program is the largest in the world. They are investigating many approaches to the control of fusion re-

[7] Electricity produced by MHD conversion involves the passing of an ionized fluid at extremely high temperature through a magnetic field. The reactor is the source which heats the fluid.

[8] A reactor that converts atomic energy into electric power directly. Heat from the reactor fuel causes electrons to move from the emitter to the collector of a diode thereby generating an electric current.

[9] In fusion reactions, light atoms, such as those of hydrogen, are combined to form heavier ones. As in fission—where heavy atoms, such as uranium, are split—a small amount of matter is converted to enormous quantities of energy. Since fusion uses forms of hydrogen, which can be derived from sea water, as fuel, it could provide a virtually unlimited source of energy.

actions, but their main effort is directed at toroidal (doughnut-shaped) plasma and laser-plasma devices.[10] The most promising results to date have been achieved with Tokamak T-3, their large toroidal device. A larger Tokamak machine is now being designed. We believe that in the late 1970s, this machine will demonstrate the technical feasibility of the controlled release of energy produced from fusion. If the approach used in the Tokamak device does not prove successful, the Soviet program will have suffered a considerable setback, because of the heavy emphasis on this particular method.

V. PEACEFUL USES OF NUCLEAR EXPLOSIONS

72. The Soviets have a vigorous program for the peaceful use of nuclear explosions (PNE). Since the program began in January 1965, 15 nuclear detonations specifically for peaceful purposes have been detected, mostly in support of the Soviet oil and gas industry, or for excavation projects. Soviet officials have provided considerable information on these shots, including the dimensions of craters and yields of the devices used, but have consistently withheld information on the time and place of the explosions.[11]

73. The first Soviet PNE experiment was a cratering test conducted in January 1965, that involved the formation of two reservoirs through the damming of the Shagan River. The device used for this experiment yielded 250 kt. Four other cratering tests have been conducted for experimental purposes, one a row charge and another designed to investigate the contamination and the radioactive fallout produced by cratering shots. Other PNE shots have been used successfully to plug runaway gas wells, to stimulate the production of oil and gas, and to produce underground storage cavities.

74. The most recent PNE experiment, in mid-March 1971 (with a total yield of about 140 kt), was associated with a plan to create a canal, in the North Urals, connecting the Pechora and Kama Rivers. The canal project is intended to draw water from the Pechora, which flows north, into the Kama, which flows south, and thus ultimately increase the amount of water moving down the Volga to the Caspian Sea. The water would be used for irrigation and the production of hydroelectric power, and would help restore the falling level of the Caspian Sea. The Soviets plan eventually to detonate a series of 250 devices totaling 36 megatons in yield. The initial test vented particulate debris which carried beyond the borders of the Soviet Union. Subsequent explosions almost certainly will also.

75. Statements about future projects show that the Soviets intend to remain active in a large way in the PNE field. They have discussed projects intended to stimulate the production of oil and gas, to store oil and gas, to strip ores, to crush rock, and to create dams and canals.

VI. INTERNATIONAL COOPERATION

76. The USSR has provided limited nuclear assistance to its allies and to certain non-Communist countries since the mid-1950s. At first, its aid was primarily in the form of train-

[10] The problem in achieving fusion is to push the atomic nuclei close enough together to fuse, despite the strong positive electric charges by which they repel one another. This can be done in a very hot gas, or plasma, in which the atomic nuclei have been stripped of their electrons.

[11] In discussing some of their PNE tests, the Soviets have mentioned yields at variance with what we estimate them to be[

]

ing and the supply of reactors and equipment for research. More recently, it has included the construction of nuclear power stations. One station is in operation in East Germany, and other large power stations are under construction in East Germany, Czechoslovakia, and Bulgaria. The Soviets have agreed to provide nuclear power stations to Hungary and Romania, and plan additional stations in Czechoslovakia. Finland, the first non-Communist country to do so, has purchased two power reactors from the USSR. Preparation for the construction of one of these reactors is already under way. Various kinds of safeguards have been imposed by the Soviets in their agreements on nuclear assistance. The spent fuel of the power reactors provided to Czechoslovakia and East Germany is to be returned to the USSR.

77. The Soviets have in general done a good job of meeting their commitments to the countries of Eastern Europe. The construction of nuclear power reactors in East Germany and Czechoslovakia has run into difficulties and delays, however, largely because of the inability of these two countries to meet their commitment in cooperative projects, and the inability or unwillingness of the Soviets to take up the slack. The Soviets should be able to meet their commitments for future nuclear power reactors in Eastern Europe because they involve the construction of the standardized pressurized-water type.

78. The Joint Institute of Nuclear Research (JINR) at Dubna, USSR, is the primary Soviet vehicle for conducting multilateral cooperation with other Communist countries in nuclear research. Most Communist countries are members of JINR and contribute to its support (Communist China and Albania have withdrawn). Dubna provides advanced research and training for the member countries in such fields as high energy physics, which it would normally not be feasible for the smaller countries to conduct individually. JINR also cooperates with CERN, the European Organization for Nuclear Research.

79. The USSR has been an active member of the International Atomic Energy Agency (IAEA) since its inception in the mid-1950s, but it has allowed the IAEA no access to its facilities for producing weapons grade nuclear materials, and only limited access to power reactors and research facilities. At the IAEA meeting in 1970, the Soviets stated that they were prepared to negotiate contracts to enrich uranium for non-nuclear countries that are parties to the Non-Proliferation Treaty. The Soviets stipulated that the countries taking advantage of this service must furnish their own uranium.

80. The USSR recently agreed to enrich uranium for France in Soviet gaseous diffusion plants and to return it to France for use in power reactors. This is a major step in what is probably a Soviet effort to become actively competitive in the world market for reactor fuel.

GLOSSARY OF NUCLEAR ENERGY TERMS

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GLOSSARY OF NUCLEAR ENERGY TERMS

The terms in this glossary are provided primarily for those who do not deal routinely with the subjects covered and who may therefore desire simplified definitions. No attempt is made to provide a truly rigorous definition of the terms; the objective is to give their meaning as succinctly as possible.

Cratering Test—A nuclear test which is conducted to displace great quantities of earth.

Enriched Uranium—Uranium containing more of the U-235 isotope than the uranium found in nature.

Fertile Material—A material that can be transformed into a fissionable material. The two principal fertile materials are Uranium-238 and Thorium-232, which respectively form Plutonium-239 and Uranium-233.

Fissionable Material—A material which will sustain a chain reaction in a nuclear weapon or reactor. The three primary fissionable materials are Uranium-235, Plutonium-239, and Uranium-233. Uranium-238 will fission, but it will not by itself sustain a chain reaction.

Fusion—The process by which nuclei of light-weight elements combine to form heavier and more tightly bound nuclei accompanied by the release of a great amount of energy.

Gaseous Diffusion—A process of isotope separation used for the production of enriched uranium. A *gaseous diffusion cascade* is an arrangement of thousands of diffusers whose purpose is to increase the enrichment of U-235 in quantity.

Irradiation—Exposure to radiation (the propagation of energy through space or matter), whether in the form of electromagnetic rays, charged particles, or neutrons.

Isotope—A form of an element belonging to the same chemical species, e.g., U-235 and U-238 are both isotopes of uranium. *Isotope separation* is designed to change the proportions in which the isotope of a given chemical element appear and hence to produce a form of the element enriched in one or another isotope.

Nuclear Rocket—A rocket employing a nuclear reactor to provide heat to the propellant. A *gas-core* rocket is one in which the fuel in the nuclear reactor is in a gaseous form. A *solid-core* rocket uses a reactor whose fuel is in a solid state.

Oralloy (*Oak Ridge Alloy*)—Uranium highly enriched in the isotope U-235.

Plutonium—Commonly refers to Plutonium-239, a heavy element which undergoes fission under the impact of neutrons. Plutonium does not occur in nature, but must be produced in a reactor.

Power Utilization Index (PUI)—The ratio of separative work to the input of power to a gaseous diffusion cascade.

Reactor—An assembly of nuclear fuel and other components capable of sustaining a controlled chain reaction based on nuclear fission.

A *production reactor* is used to produce fissionable materials by the irradiation of fertile materials with neutrons.

A *power reactor* is used as the energy source for the generation of electric power, and a *propulsion reactor* as a source of energy for propulsion.

In *pressurized water reactors,* natural water is used both to cool the reactor and to moderate (slow down) the neutrons. The term "pressurized" indicates that the pressure of the water is kept high enough to prevent its boiling. In *graphite-moderated, pressure-tube reactors,* graphite is used to moderate the neutrons, and water is used to cool the reactor. The *liquid metal fast-breeder reactor* uses liquid metal (e.g., sodium) as a coolant because it requires a high-temperature coolant with good heat transfer properties. No moderator is used in this type of reactor and the velocity of the neutrons therefore remains high. The term "fast" refers to this fact.

Separative Work Unit—A measure of the effort expended in an isotope separation plant to separate a quantity of uranium into a portion enriched in U-235, and a portion depleted in U-235. The number of separative work units required to produce a given quantity of enriched uranium depends upon the concentration of U-235 required, the concentration of the feed material, and the concentration of the waste (tails).

Toll Enrichment—The enrichment of uranium on a commercial basis. The customer supplies uranium for feed and gets back as product a lesser amount of uranium containing a greater concentration of U-235, and optionally, the rest of the uranium (tails) containing a lesser concentration of U-235. For this service, a "toll" is levied on the customer expressed in terms of the price per unit of separative work performed.

Uranium—A heavy, slightly radioactive metallic element. *U-235*—One of the two principal isotopes of natural uranium. It is the only readily fissionable material which occurs in appreciable quantities in nature—hence its importance as a nuclear fuel. Only one part in 140 (.72 percent) of natural uranium is U-235. The other principal isotope of natural uranium is U-238, a fertile material; it makes up 99.27 percent of natural uranium.

Yield—The energy released by a nuclear weapon expressed in terms of the quantity of TNT that would be needed to generate the same energy release. The usual units are kilotons (thousands of tons) or megatons (millions of tons) of TNT equivalence abbreviated as kt and MT, respectively.

ANNEX A

SOVIET UNDERGROUND NUCLEAR TESTS
MARCH 1964-MAY 1971

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ANNEX A

SOVIET UNDERGROUND NUCLEAR TESTS
MARCH 1964-MAY 1971

Number	Date	Location	Estimated Yield (kt)[a]
187	15 March 1964	Degelen Mountain Test Area (DMTA)	50
188	16 May 1964	DMTA	50
189	6 June 1964	DMTA	2
190	19 July 1964	DMTA	30
191	18 September 1964	Novaya Zemlya Test Area (NZTA)	2
192	25 October 1964	NZTA	9
193	16 November 1964	DMTA	50
194 [b c]	15 January 1965	Shagan River Test Area (SRTA)	250
195	4 February 1965	DMTA	75
196	3 March 1965	DMTA	40
197	11 May 1965	DMTA	6
198 [b]	10 June 1965	Ufa	2
199	17 June 1965	DMTA	20
200	29 July 1965	DMTA	3
201	17 September 1965	DMTA	15
202	8 October 1965	DMTA	30
203 [b d]	14 October 1965	Konystan Test Area (KTA)	2
204	21 November 1965	DMTA	60
205	24 December 1965	DMTA	8
206 [d]	13 February 1966	DMTA	450
207	20 March 1966	DMTA	200
208	21 April 1966	DMTA	30
209 [b]	22 April 1966	Azgir	7.5
210	7 May 1966	DMTA	4
211	7 May 1966	DMTA	3
212	29 June 1966	DMTA	40
213	21 July 1966	DMTA	35
214	5 August 1966	DMTA	33
215	19 August 1966	DMTA	4
216	7 September 1966	DMTA	5
217 [b]	30 September 1966	Karshi	16
218 [d]	19 October 1966	DMTA	85
219 [c]	27 October 1966	NZTA	1,200
220	3 December 1966	DMTA	4
221 [c]	18 December 1966	KTA	140
222	30 January 1967	DMTA	5

Footnotes at end of table.

ANNEX A (Continued)

Number	Date	Location	Estimated Yield (kt)[a]
223	26 February 1967	DMTA	220
224	25 March 1967	DMTA	24
225	20 April 1967	DMTA	60
226 [c]	28 May 1967	DMTA	33
227	29 June 1967	DMTA	20
228	15 July 1967	DMTA	30
229	4 August 1967	DMTA	25
230	2 September 1967	DMTA	1
231	16 September 1967	KTA	18
232	22 September 1967	KTA	15
233 [b]	6 October 1967	Tyumen	8
234	17 October 1967	DMTA	62
235	21 October 1967	NZTA	170
236	30 October 1967	DMTA	32
237	22 November 1967	KTA	2
238	8 December 1967	DMTA	20
239 [c]	7 January 1968	DMTA	9
240	24 April 1968	DMTA	8
241 [b]	21 May 1968	Karshi	40
242	11 June 1968	DMTA	16
243	19 June 1968	SRTA	45
244 [b]	1 July 1968	Azgir	65
245	12 July 1968	DMTA	18
246	20 August 1968	DMTA	6
247	5 September 1968	DMTA	33
248	29 September 1968	DMTA	125
249 [b c]	21 October 1968	Taylan Test Area (TTA)	1
250	29 October 1968	DMTA	3
251 [d]	7 November 1968	NZTA	260
252	9 November 1968	DMTA	4
253 [b d]	12 November 1968	TTA	2
254	18 December 1968	DMTA	13
255 [d]	7 March 1969	DMTA	65
256	4 April 1969	DMTA	0.3
257	13 April 1969	DMTA	2
258	16 May 1969	DMTA	20
259	31 May 1969	KTA	16
260	4 July 1969	DMTA	23
261	23 July 1969	DMTA	35
262 [b]	2 September 1969	Osa	9
263 [b]	8 September 1969	Osa	9
264	11 September 1969	DMTA	8
265 [b]	25 September 1969	Stavropol	100
266	1 October 1969	DMTA	20
267 [d]	14 October 1969	NZTA	450

ANNEX A (Continued)

Number	Date	Location	Estimated Yield (kt)[a]
268	27 November 1969	DMTA	1
269	30 November 1969	SRTA	270
270	6 December 1969	Kushata	160
271 [d]	28 December 1969	KTA	120
272	29 December 1969	DMTA	2
273 [d]	29 January 1970	DMTA	55
274	27 March 1970	DMTA	9
275	27 May 1970	DMTA	1
276 [b]	25 June 1970	Sovkhoz	10
277	28 June 1970	DMTA	120
278	21 July 1970	KTA	21
279	24 July 1970	DMTA	23
280 [d]	6 September 1970	DMTA	50
281 [c]	14 October 1970	NZTA	
282 [c]	4 November 1970	KTA	50
283	12 December 1970	Kushata	350
284 [c]	17 December 1970	DMTA	40
285	23 December 1970	Kushata	450
286	29 January 1971	DMTA	1.5
287 [c]	22 March 1971	DMTA	90
288 [b] [c]	23 March 1971	North Urals	140
289	25 April 1971	DMTA	200
290	25 May 1971	DMTA	10–15

[a] Except for test number 281 (see footnote f), estimated yields are based on full tamping in hard rock. The margins of error are −50 percent and +100 percent, thus the actual yield may be twice as large as that estimated, or half as much. (See Annex B.)

[b] These tests are believed to have been for peaceful purposes. (See Section V, "Peaceful Uses of Nuclear Explosions.")

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ANNEX B

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ANNEX B

CENTRAL INTELLIGENCE AGENCY

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