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CONTENTS

SOVIET ATOMIC ENERGY PROGRAMS

THE PROBLEM

To review significant recent developments in Soviet atomic energy programs and to estimate the probable course of those programs over the next 5 to 10 years.

CONCLUSIONS

A. The USSR has a large stockpile of nuclear weapons, in sufficient numbers and variety to fulfill the basic requirements of the Soviet military forces. We believe that the Soviets have now, or will be able to develop under the Limited Test Ban Treaty, improved nuclear weapons for new delivery systems which we estimate will become operational over the next decade.

B. The Soviets are probably well aware of the potential of various forms of radiation as kill mechanisms for antiballistic missile (ABM) application, and they can further investigate these phenomena by means of underground testing and the use of simulation techniques. We believe that Soviet design practices reduce the vulnerability of their warheads to certain types of X-ray damage, and consider the chances about even that the Soviets have already developed a medium energy X-ray warhead suitable for exoatmospheric use by the Moscow ABM system. If they have not already done so, they could develop such a weapon on the basis of existing technology without violation of the Limited Test Ban Treaty.

C. The Soviets appear to be approaching their planned capacity for production of fissionable materials. We estimate that annual rates of production will level off in the near future, and that these rates of production will be sufficient to support foreseen Soviet weapons requirements.

D. The Soviets probably will continue to test nuclear devices underground in a manner that, in some cases, exceeds the US interpretation of the limits of the Limited Test Ban Treaty. We do not believe that military requirements will cause them to resume atmospheric testing in the near future. Should they elect to resume atmospheric testing, however, intelligence sources would have only very limited capability to provide advance notice.

E. We believe that the engineering problems formerly apparent in Soviet marine propulsion reactors have been overcome, and that new classes of nuclear submarines now under construction will probably have increased reliability. We do not anticipate that the Soviets will achieve within the next decade a nuclear rocket, a nuclear space propulsion system, or a militarily useful nuclear-powered aircraft. We believe that they will not be able to develop an operational nuclear auxiliary power supply of sufficient power to support space exploration before the mid-1970's.

F. The Soviets are moving forward with a program for peaceful uses of nuclear explosives, and probably lead the world in some applications. We do not expect nuclear electric power to occupy a very important place in Soviet plans for power production over the next decade.

DISCUSSION

I. PRODUCTION AND UTILIZATION OF FISSIONABLE MATERIALS

Production

1. We believe that the Soviets are approaching their planned capacity for production of fissionable materials and that annual rates of production will level off in the future. Facilities under construction when our last estimate was published are now coming into operation. Current construction appears to be directed only toward completion of facilities started several years ago; during the past two years we have detected no new construction starts on major production facilities.

2. *U-235.* The USSR has four large gaseous diffusion complexes for the production of uranium enriched in U-235: at Verkh-Neyvinsk in the Urals, at Tomsk in western Siberia, and at Angarsk and Zaozerniy in central Siberia. We believe that all but the last of these are complete, and that Zaozerniy will soon be completed. We have no evidence that the Soviets are planning or constructing any additions to their capacity to produce U-235. We estimate that, with completion of Zaozerniy, annual Soviet production of U-235 will level off at some 40-50 metric tons (mt) a year.

3. The use of new evidence and methodology has this year led us to revise our past estimates of both annual and cumulative production of U-235 in the USSR. In the past, we have based our estimates of the production at Soviet gaseous diffusion plants primarily upon estimates of electric power usage and of plant efficiencies. We have considered the estimates of electric power inputs to be reasonably accurate, but considerable uncertainty has been attached to the estimates of plant efficiencies. Our judgments on the latter have, in large measure, been extrapolated from information provided by German returnees in the early 1950's. We have postulated improvement since that time, but our margins of error (minus 40 percent, plus 30 percent) have allowed for the possibility that little improvement has taken place, or, conversely, that the improvement has been considerably greater than we have estimated.

4. Recent information has, however, permitted another approach to the estimate of U-235 production, which has helped to establish a lower limit. This information suggests that Soviet production of U-235 may be substantially below our previous estimates based on power and efficiency calculations. On the other hand, it is unlikely to support an estimate of production significantly above our past estimates of the most probable cumulative production.

5. We have expressed these judgments in TABLE I by giving a range for cumulative production of U-235 which uses, as the high end of the range, our

past estimates of the most probable production based on power and efficiency and, as the low end of the range, two-thirds of this figure. We think it unlikely that production is substantially outside this range.

6. We think it unlikely that efficiencies would be any less in the future than is implied by the low side of the estimate for 1967; on the other hand efficiencies may improve somewhat—say, 10 percent—above those implied by the high side of the estimate. Within the efficiency ranges implied, our estimates of future

TABLE I

ESTIMATED CUMULATIVE PRODUCTION AND AVAILABILITY OF SOVIET [redacted] FISSIONABLE MATERIALS

(Metric Tons)

Year	U-235 [a]				Plutonium Equivalent [b]			
	Cumulativ Production	[redacted]	In Weapons In Stockpile	[redacted]	umulative roduction	[redacted]	In Weapons n Stockpile [f]	[redacted]
1965	130-200		110-170		20-26		17-23	
1966	160-250		140-210		23-31		20-27	
1967	200-300		170-250		26-37		23-33	
1968	230-350		200-300		29-44		26-38	
1969	270-410		230-350		33-51		29-43	
1970	310-470		260-400		37-59		32-50	
1971	340-530		290-450		41-67		35-57	
1972	380-590		320-510		45-75		38-64	
1973	420-650		360-570		49-84		41-71	
1974	460-720		390-630		53-93		44-78	
1975	500-790		420-690		57-101		47-85	
1976	530-870		450-750		61-110		50-92	
1977	570-950		480-810		65-119		53-99	

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

[b] Includes both plutonium and tritium. One kilogram of plutonium is equivalent to 12 grams of tritium.

[c] The upper end of the range represents production utilizing efficiencies as estimated in past years, with a slight allowance for increases in efficiencies by the mid-1970's. The lower end of the range represents production utilizing lower efficiencies than have been estimated in past years, which is consistent with interpretations of new data. (See paragraphs 4-6.) The range thus reflects different methodologies and assumptions. We have no good basis for selecting a most probable single figure within the range.

[d] Cumulative production, less a production and reworking pipeline estimated to be 10 percent of cumulative production, and less U-235 used in the test program and in power, propulsion, and research reactors.

[e] These ranges represent limits within which we think the true value lies. A figure midway between the top and the bottom of the range is the most probable.

[f] Cumulative production, less a production and reworking pipeline estimated to be 10 percent of cumulative production, and less plutonium equivalent used in weapons tests and lost through tritium decay.

production of U-235 are based on assumed full power operation of all existing production facilities, but no construction of additional facilities.

7. *Plutonium Equivalent Production.*[1] The USSR has large reactor complexes at Kyshtym in the Urals and at Tomsk in western Siberia. There is also a large multipurpose nuclear complex at Dodonovo, north of Krasnoyarsk in central Siberia, which, we believe, has one or more reactors installed underground. We believe another reactor at Tomsk is nearing completion and will probably be in operation next year; we have no evidence of construction of new reactors designed for production of plutonium. We believe that any additional increases in plutonium production capacity will therefore come from power reactors.

8. We continue to believe that the best estimate for cumulative Soviet production of plutonium equivalent through mid-1966 is that [redacted] given in TABLE I [redacted] Our mid-1967 estimate of cumulative production [redacted] projected one year, and represents a range of 20 percent above and below a central figure.

9. Estimates of future production assume the completion of the reactor at Tomsk and of those nuclear power and propulsion reactors that we estimate will be completed over the next decade.[2] We have no evidence of the construction of additional production reactors. Our estimates assume no such construction, but they do assume continued operation of existing production reactors.

Utilization

10. Not all cumulative production of fissionable materials is in weapons, however. The principal nonweapons use of U-235 is for use in propulsion systems in nuclear submarines, and in other power, propulsion, and research reactors that require uranium enriched in U-235. [redacted] In addition, the Soviet test program has used, and will continue to use, both U-235 and plutonium. We believe that these nonweapons uses and losses do not now amount to more than about five percent of the total cumula-

[redacted]

[2] See paragraphs 45-49 for discussion of such reactors.

tive production of Soviet fissionable materials, but they have to be considered in estimates of the amounts of fissionable materials available in weapons.

11. Other quantities of fissionable materials which are in pipeline, or which are in weapons withdrawn from stockpile for quality control or reworking, are also not available for weapons use. We have no information on Soviet practice in these areas, but US experience indicates that the amounts involved can be significant. In estimating the fissionable materials available for weapons, we have assumed that (in addition to nonweapons uses and tritium decay) about 10 percent of total cumulative production will be involved in pipeline, reworking, and quality control checks at any given time, and therefore will not be available in weapons in stockpile.

12. The estimates of the amount of enriched U-235 and plutonium equivalent in weapons in stockpile shown in TABLE I take the foregoing considerations into account.

Relative Abundance of U-235 and Plutonium Equivalent

13. [redacted] Such ratios are not unusual but there are apparent inconsistencies when they are considered in terms of [redacted] The inconsistencies appear to be in the direction, particularly in future years, of a larger relative quantity of U-235 available than appears necessary for foreseeable requirements.

14. These inconsistencies suggest (a) that our estimates of availability of fissionable materials may be incorrect; (b) that our assumptions regarding the allocation of fissionable materials to stockpile weapons may be incorrect; (c) that Soviet production capacities, planned years ago, may no longer be consistent with changing requirements; or (d) that some combination of errors in the many estimates and assumptions involved has led to the appearance of an imbalance that does not actually exist. The answer may be a combination of these possibilities. On the other hand the Soviets may have foreseen a requirement which we have not recognized.

II. SOVIET NUCLEAR TEST PROGRAMS

Test Activity

15. The Soviets have been slowly but steadily increasing the pace and scope of their underground nuclear test program since the Limited Test Ban Treaty went into effect in 1963. [redacted]

[redacted] 7 underground tests in 1964, 12 in 1965, and 16 in 1966. [redacted] 5 tests so far in 1967. The maximum yields of the devices tested have also been increasing, from 50 kilotons (kt) in 1964, to 250 kt in 1965, and 1,200 kt in 1966. In addition to the 40 tests detected since 1963, the Soviets had previously conducted 2 underground tests in late 1961 and early 1962. [redacted]

16. Since the Memorandum to Holders of NIE 11-2-65, "The Soviet Atomic Energy Program," dated 23 June 1966, we have judged that a seismic event equating to about 8 kt, which occurred on 22 April 1966 near Azgir north of the Caspian, was of nuclear origin. In addition, we now estimate that the previously reported single test at Semipalatinsk on 7 May 1966 was in fact 2 nuclear events, [redacted] separated in time by about 3 seconds and in distance by about 4 kilometers. These tests, plus 15 [redacted] since then, are listed in TABLE II. Underground testing will probably continue.

TABLE II

SOVIET UNDERGROUND NUCLEAR TESTS
APRIL 1966 – MAY 1967

JOE No.	Date	Location	Estimated Most Probable Yield (kt)
209	22 Apr 1966	Azgir [a]	8
210	7 May 1966	Semipalatinsk	[redacted]
211	7 May 1966	Semipalatinsk [b]	
212	29 Jun 1966	Semipalatinsk	40
213	21 Jul 1966	Semipalatinsk	35
214	5 Aug 1966	Semipalatinsk	33
215	19 Aug 1966	Semipalatinsk	[redacted]
216	7 Sep 1966	Semipalatinsk	5
217	30 Sep 1966	Karshi [a]	16
218	19 Oct 1966	Semipalatinsk	85
219	27 Oct 1966	Novaya Zemlya	1,200
220	3 Dec 1966	Semipalatinsk	[redacted]
221	18 Dec 1966	Semipalatinsk [c]	140
222	30 Jan 1967	Semipalatinsk	5
223	26 Feb 1967	Semipalatinsk	220
224	25 Mar 1967	Semipalatinsk	25
225	20 Apr 1967	Semipalatinsk	60
226	28 May 1967	Semipalatinsk	35

[a] These tests are believed to have been for peaceful purposes.

[b] Located about 4 km from the preceding test and detonated about 3 seconds later.

[c] This test was probably, at least in part, for peaceful purposes.

Testing and the Limited Test Ban Treaty

17. Debris from the shots at Novaya Zemlya on 27 October 1966, and at Semipalatinsk on 18 December 1966 was collected outside the territorial limits of the USSR; debris possibly from the test of 19 October 1966 has also been collected. In addition to these instances, at least two earlier tests conducted by the Soviets since the Limited Test Ban Treaty was signed have also released debris identifiable beyond the borders of the USSR. This record leads us to believe that the Soviets have run considerable risks of putting debris in the atmosphere which could be detected outside the USSR, and that the number of such occasions has increased in the past year.

18. Although Soviet military leaders are probably pressing for a more vigorous testing program, we do not believe that military requirements will become so urgent as to cause the Soviets to withdraw from the Treaty or to resume atmospheric testing in the near future.[3] We believe, rather, that they will continue deliberately to test in a manner that, in some cases, exceeds the US interpretation of the limits of the Treaty. However, should they elect to break the Treaty by resuming atmospheric testing, intelligence sources would have only very limited capability to provide advance notice. [redacted]

Peaceful Uses of Nuclear Explosives

19. Soviet scientists in 1964 showed interest in the US Plowshare program, discussed it with US scientists, and indicated that they were considering peaceful uses of nuclear explosives in the USSR. Starting in January 1965, the Soviets have conducted 4 nuclear tests primarily for peaceful purposes and 2 others that may belong, at least in part, in the peaceful uses category. Three were in 1965, and 3 in 1966. In addition, we believe they have derived valuable data from the use of kiloton amounts of conventional explosives for construction and mining projects, and from nuclear weapon tests at the Semipalatinsk underground test site.

20. Three of the six tests mentioned above may have been connected with a program to explore the capabilities of nuclear explosives for construction. These tests probably also provided information on shock and earth movement applicable to missile silo vulnerability and to peaceful nuclear explosives projects in which damage to nearby structures could be a problem.

[3] See paragraphs 33-37 for discussion of military requirements.

21. Three of the peaceful uses tests appear to have involved application of underground nuclear explosives to problems associated with the petroleum industry. Tests at Ufa in June, 1965, and Azgir in April, 1966, were probably attempts to stimulate production of oil or gas in a depleted field and a new field, respectively. The Soviets used a 16 kt underground detonation near Karshi in September, 1966, to snuff out a large gas well fire that had been burning for about three years.

22. These tests indicate that the Soviets are quite sophisticated in their program for peaceful uses of nuclear explosives and that this is an area in which the Soviets lead the world in some applications. They have not chosen to disclose their tests or their results publicly, but they probably can estimate reasonably well the extent of our knowledge of their program. We believe the USSR has much to gain from peaceful uses of nuclear explosives and that the program will continue. We cannot judge when or under what conditions the Soviets may see fit to publicize their program.

III. DEVELOPMENT OF SOVIET NUCLEAR WEAPONS

Weapons Now in Stockpile

23. *Thermonuclear Weapons.* Until the signing of the Limited Test Ban Treaty in 1963, the Soviets had, in a nuclear test program of almost 14 years duration, developed nuclear weapons in a variety of designs and sizes, which could have yields ranging from fractions of a kiloton up to 100 megatons. The Soviets have emphasized the development of multimegaton thermonuclear (TN) weapons, rather than relatively small, light weight weapons of lower yield, and have achieved high thermonuclear performance in the multimegaton range. Weapons based on the 1961 and 1962 test series probably began to enter stockpile for the Soviet strategic attack systems in 1964-1965 and have probably been produced in sufficient quantities since then to meet most of the present needs of these forces.

[redacted]

25. *Fission Weapons.* The Soviet fission weapons program has been directed toward development of reliable, efficient, and economic devices. [redacted]

As a result of the 1961-1962 tests, the Soviets were able to develop fission weapons in the low kiloton and possibly subkiloton range, to reduce nuclear system weights [redacted] and diameters [redacted] Most of the newer fission weapons entering the stockpile for Soviet general purpose and air defense forces over the past few years have probably been these improved low-yield weapons.

[redacted]

Development to Date Under the Limited Test Ban Treaty

27. It is now more than four years since the Soviets last tested in the atmosphere. [redacted] The number of underground tests and their associated yields suggest that the Soviets could have made advances in weapons ranging in yields from a few kt up to a few MT. However, we cannot determine specifi-

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cally what has been accomplished and what impact these tests might have upon future weapons capabilities.

28. *Thermonuclear Weapons.* Since the Limited Test Ban Treaty, the Soviets have conducted four tests in the 200 to 1,200 kt range which we believe were related to tests of TN weapons. Another test in this yield range was probably associated with a peaceful nuclear explosive experiment, but some weapons development data could have been obtained from it. The yields of a large number of the remaining Soviet underground tests fall between 30 and 85 kt. Many of these were probably TN development tests since it does not appear to us that the Soviets have a requirement for extensive development of such high-yield fission systems at this time.

[redacted]

30. We believe that the chances are about even that the Soviets have developed a [redacted] warhead suitable for exoatmospheric use by the Moscow ABM system. They are probably well aware of the potential of various forms of radiation as kill mechanisms for ABM application. [redacted] They could have further investigated this subject in their underground testing.

[redacted]

[1] A low energy X-ray output is one of about 1-2 Kev. An X-ray energy of 5 Kev is considered medium energy, and 8-9 Kev is high energy.

31. We have no direct evidence of specific Soviet efforts to harden their nuclear warheads against nuclear effects, but we believe that Soviet warhead design practices reduce the vulnerability of their warheads to certain types of X-ray damage. In their past test programs, they have gained considerable experience with blast and thermal effects. In their high altitude tests in 1961-1962, conducted at the Sary Shagan test center, they also gained considerable information on radar blackout phenomena and possibly some limited information relating to the effects of radiation on antimissile guidance systems and nuclear weapons components.

32. *Fission Weapons.* Improvement in fission weapons, [redacted] could have occurred since 1963. A number of Soviet tests since the signing of the Limited Test Ban Treaty have been in the 2-30 kt range; [redacted] Some of these tests probably represented improvements in fission weapons technology, particularly in reducing diameters and developing special effects warheads. [redacted] They might also be developing small fission weapons for atomic demolitions.

Future Weapons Development and Requirements

33. *Under Current Treaty Conditions.* The Soviets could probably test up to a few megatons under the current Limited Test Ban Treaty, and thus could probably meet any present or future weapon development requirements except for full-scale systems tests and tests above a few megatons. We believe that they could make significant advances in the submegaton and low megaton range of TN weapons. This is a yield range in which they appear to have a major requirement for improved warheads for new strategic missile delivery systems and possibly for multiple warhead application.

34. [redacted] They could also test the response of various materials to X-rays at various energy levels in a simulated exoatmospheric environment, and conduct development tests of new hardened warheads. [redacted]

35. Tests of fission devices will probably be directed toward further reductions in size and weight. If there is a Soviet requirement for small diameter weapons, e.g., for use in tube artillery, the Soviets could probably develop [redacted]

[redacted] by 1970. [redacted]

36. *Under Unrestricted Testing.* If the Soviets were to resume unrestricted testing, they might be able to achieve over the next decade yield/weight ratios [redacted] Completely new designs might lead to weapons [redacted] usable for exoatmospheric intercept.

37. Probably one of the strongest Soviet weapons development requirements is in the area of high altitude effects of nuclear weapons and the response of materials to those effects. We believe that earlier Soviet high altitude tests, while highly sophisticated in their missile involvement and probably well instrumented, lacked the characteristics of tests designed to give detailed information on warhead kill mechanisms. The Soviets probably also need more information about the effects of ground shock and electromagnetic pulse from high yield, near surface bursts. They would probably like to conduct an ABM vs. ICBM system test to refine the blackout data gathered in 1961-1962 and to improve the effectiveness of an exoatmospheric intercept system.

IV. STORAGE AND CONTROL OF SOVIET NUCLEAR WEAPONS

Storage

38. Soviet nuclear weapons storage includes two general classes of storage sites: national reserve stockpile facilities, and operational storage sites at military bases in direct support of military operations. National reserve stockpile sites are characterized by isolation, extreme security, hardened bunkers, and self-sufficiency in housing and service support. The operational military storage sites associated with military bases are usually located apart from other base facilities and are characterized by stringent physical security measures. Their design has been different in each stage of the stockpile program; most of the earlier sites have been modified by the addition of a bunker of more recent design. In the event of war, the initial needs of Soviet forces for nuclear weapons would be met by the operational storage sites. The national reserve stockpile installations are intended to provide strategic reserve and direct support to the operational sites. Some national sites are located near the borders and could provide direct support to Soviet forces in the area. In addition to the weapons stored at these locations, we believe that sizable numbers of nuclear weapons are deployed with certain operational forces, including the Strategic Rocket Forces, missile-equipped surface ships, and missile submarines.

39. *Sensitive Operations Complexes.* There are 10 large, self-contained, highly secured, military installations located throughout the European USSR which we call Sensitive Operations Complexes (SOCs). Each complex has extensive railroad and motor transport facilities and extensive operations and support

areas. They have been under construction since the late 1950's; the first probably became operational in the mid-1960's. The rail and rail-to-road transfer facilities and high degree of security at the SOCs lead us to believe that one function of the SOCs may be nuclear weapons storage. On the other hand, the extensive operations and support areas at the SOCs indicates that they perform operations in addition to nuclear weapons storage, and that these additional activities may, in fact, be an important purpose of the SOCs; some of these activities may be missile associated.

40. The functions of these complexes remain unclear. We believe that one explanation of the purpose of the SOCs is that they are rear area storage and maintenance bases for the support of operational forces. In this role they could support a number of Soviet nuclear missile delivery systems, providing storage, checkout, retrofit, and repair of nuclear weapons and other critical items. Their location and spacing is such that they could give support to Soviet fronts defending the main approaches to the European USSR from the West.

Control

41. We believe that decisions on the deployment and use of nuclear weapons are made by the Politbureau of the CPSU, and implemented through the Supreme High Command and the Ministry of Defense. A high level authority within the Ministry of Defense serves as executive agent for the Minister in the operation and control of the nuclear weapons logistics system. We have no evidence concerning how operational nuclear warheads on ready missiles on land or at sea are controlled, but some form of authentication system or use of permissive links in weapons is probably used to maintain a high degree of control.

42. Although the non-Soviet forces of the Warsaw Pact have nuclear capable delivery systems, we believe that the USSR has not furnished nuclear weapons to these countries, and that any nuclear weapons which may be located in Warsaw Pact countries are under strict Soviet control.

V. NUCLEAR POWER AND PROPULSION PROGRAMS

43. Soviet research on nuclear power and propulsion reactors has explored a fairly wide spectrum of reactor types, but development has concentrated on pressurized-water, pressure-tube superheat, and fast-breeder types. Industrial and military applications of these reactors have, however, suffered from inadequate chemical and metallurgical engineering. Moreover, limited development testing of components under operational conditions, dictated by attempts to achieve scheduled goals, has often tended to degrade operational reliability. In an attempt to overcome these problems, Soviet reactor research now tends to utilize existing reactors in extensive materials testing programs, rather than to explore new reactor concepts.

Nuclear Electric Power

44. The Soviet nuclear power program announced in 1956 called for electric generating capacity of 2,000-2,500 megawatts (mw) in nuclear power stations by 1960. Progress toward this goal has, however, been extremely slow, and the program has been extensively modified. Two power plants in the original plan—at Beloyarsk and Novovoronezh—with a total capacity at present of some 340 mw went into operation at full power in 1965. (See TABLE VI.) In addition, some 600 mw of generating equipment has been installed to utilize heat from the Tomsk plutonium production reactors. With other plants, the Soviets now have over 1,000 mw of nuclear generating capacity. Additional reactors under construction for several years at Tomsk, Beloyarsk, and Novovoronezh will probably be completed in 1968-1969, and add another 1,300 mw of generating capacity. The Soviets expect to complete a new 150 mw fast breeder reactor running a dual purpose power generation and desalination facility at Shevchenko on the eastern shore of the Caspian Sea in 1969-1970, but we believe that the state of Soviet fast reactor and desalination technology is such that they probably will not be able to meet this deadline, and that Soviet nuclear generating capacity therefore probably will not reach 2,500 mw until the early 1970's.

45. The Soviets have a program to develop and deploy packaged (transportable) nuclear power stations. One such station went into operation at Melekess in 1964, and a station is being constructed at Bilibino on the Chukotskiy Peninsula which will probably become operational in the 1970-1972 period. We have no evidence of further development of a "mobile" 1.5 MWe pressurized-water prototype nuclear power plant, which went into operation at Obninsk in 1959.

46. The long stretch-out of the Soviet nuclear electric power program as originally announced has been due both to technological problems encountered and the economic costs involved. Construction costs of nuclear power stations are 2-3 times the cost of comparable thermal power stations. The Soviets have apparently decided to call a temporary halt in the construction of new nuclear power stations, and to await operational data from the Shevchenko reactor and the second units of the power stations at Beloyarsk and Novovoronezh before planning new construction. The Soviets are also giving some thought to the design of a large 1,000 mw pressure-tube type reactor similar to the one constructed at Beloyarsk and to a large new fast reactor, but we do not expect these proposals to be realized before the mid-1970's. It seems likely, therefore, that it will be the mid-1970's before the Soviets move much beyond the 2,500 mw now foreseen, and that nuclear electric power stations will continue to account for less than one percent of Soviet electric power generating capacity. This slow pace leads us to believe that the Soviet nuclear electric power program does not now occupy a very important place in Soviet plans for power production over the next decade. Several European programs are somewhat larger, and planned US nuclear generating capacity far exceeds this level.

TABLE VI

SOVIET NUCLEAR POWER STATIONS

Location and Type — Reactors	Moderator/Coolant	Power Level MWe/MWt [a]	Year In Operation
Dual Purpose Reactors			
Tomsk			
1	Graphite/Water	625/3,700 (reactors 1 and 2)	At 100 MWe in 1958; modified to 200 MWe in 1963
2	Graphite/Water		1961
3	Graphite/Water	350/1,900	1967
4	Graphite/Water	350/1,900	1969
Power Reactors			
Beloyarsk			
1	Graphite/Water Pressure tube, with nuclear superheat	100/286	Full power operation in 1965
2	Similar to 1	200/560	Full power in 1969
Novovoronezh			
1	Water/Water Pressure vessel	240/760	Full power in 1965
2	Similar to 1	365/1,400	1969
Shevchenko			
1	—/Sodium Fast reactor	150/1,000 [b]	Estimated 1970-1971
Bilibino			
4	Packaged power reactor	12 MWe each	Estimated 1970-1972
Experimental Power Centers			
Obninsk			
1	Graphite/Water	5/30	1954
1	Water/Water Packaged power reactor	1.5/10	1959
Melekess			
1	Graphite/Boiling Water	50/300	Full power in 1965
1	—/Sodium Fast test reactor (BOR)	60 est/?	1970
1	Organic/Organic Packaged power reactor	0.75/5	Full power in 1964

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

[b] Part of the thermal power is for a desalination plant.

47. Notwithstanding these problems, the Soviets during the latter half of 1966 signed agreements with Hungary and Bulgaria to construct 800 mw pressurized-water nuclear power stations, each containing two reactor units of the type being built at Novovoronezh. In addition, a bid to construct the same type of nuclear power station was submitted to Finland. During the past year, the Soviets did place in operation at Rheinsberg in East Germany a 70 mw pressurized-water nuclear power station, that had been under construction since 1958. A 150 mw station at Bohunice in Czechoslovakia, started at the same time, will probably not be operating until 1970. Considering past Soviet performance, we believe that a Soviet bid to enter the world power market, if one is in fact made, is not likely to meet with great immediate success.

48. *Safeguards.* The Soviets probably have imposed safeguards on the countries to which they gave nuclear assistance. The bilateral agreement under which they provided a reactor to Yugoslavia contained provisions for a safeguards protocol, but this has not been seen by the West. In the contracts for sale of small research reactors provided to such countries as the UAR and Indonesia, the nuclear fuel was sold outright. However, the contracts do restrict those countries from passing the fuels, documentation, or any technical information to a third country. In the case of the large power reactors provided to Czechoslovakia and East Germany, it was stipulated that the fuel was to be returned to the USSR.

Marine Propulsion

49. The early nuclear propulsion systems in the icebreaker Lenin and in nuclear submarines encountered major problems and proved unreliable. The Lenin was laid up during the 1966 navigation season but the main problems apparently were related to hull structure. It may not yet be operational. Our evidence indicates that the difficulties in many of the nuclear submarines have been overcome through extensive overhauls. Thus Soviet nuclear submarines are now sufficiently reliable to conduct regular long-duration patrols without surface ship support, and we expect to see increasing numbers of them on station.

50. No new classes of nuclear submarines have appeared in the Soviet fleet since 1960, and only one of the three original classes is still being built—the E-II cruise missile submarine. We estimate that at least one new class of nuclear submarine is now under construction; we believe a new ballistic missile submarine will probably enter the fleet in 1968. We estimate that the Soviets are also building a new attack class which could become operational at about the same time. We have no information regarding the nuclear reactor to be used in the new classes of submarines, but we expect that it will be a single pressurized-water reactor of the same general type as that employed in earlier submarines. It will probably have a longer service life, and provide the new submarines with increased reliability and performance.

Air and Space Applications

51. *Aircraft Propulsion.* We do not believe that the Soviets are actively engaged in development of a propulsion system suitable for nuclear-powered aircraft. There is however continuing Soviet materials research which could be applicable to such a program. Even if the Soviets now have a program under way, we believe that a militarily useful nuclear powered aircraft could not be operational during at least the next five years, and probably not during the term of this estimate.

52. *Rocket Propulsion.* The Soviets have investigated the basic materials problems connected with a nuclear rocket and probably have developed satisfactory materials. They have followed the progress of the US Rover nuclear rocket program, and may be undertaking developmental work in this field. We do not anticipate that the Soviets will develop an operational nuclear rocket within the next decade.

53. *Space Propulsion.* The Soviets have also shown considerable interest in electric propulsion systems for space applications. However, such systems using a nuclear power source are still in an early stage of development, and are probably at least a decade away from becoming operational.

54. *Nuclear Auxiliary Power Supply.* The Soviets are actively engaged in the development of nuclear auxiliary power supplies for use in spacecraft. They are exploring all the major energy conversion systems, including thermoelectric,[6] thermionic,[7] magnetohydrodynamic,[8] and turboelectric generators. We believe, however, that they will not be able to develop an operational nuclear auxiliary power supply of sufficient power to support space exploration before the mid-1970's.

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[6] Thermoelectric conversion is used to produce directly small amounts of electricity from the heat of radioisotopes, using two materials in the thermocouple in which application of heat induces a flow of electricity.

[7] Thermionic conversion produces electricity directly from heat by thermal emission of electrons, which in streaming from a cathode to an anode in a vacuum produce an electric current.

[8] Magnetohydrodynamic conversion produced electricity by passing an ionized gas, at extremely high temperature, through a magnetic field.