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NATIONAL INTELLIGENCE ESTIMATE

NUMBER 11-2A-63

The Soviet Atomic Energy Program

LIMITED DISTRIBUTION

Submitted by the

DIRECTOR OF CENTRAL INTELLIGENCE

Concurred in by the

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This estimate was prepared and agreed upon by the Joint Atomic Energy Intelligence Committee which is composed of representatives of the Central Intelligence Agency and the intelligence organizations of the Departments of State, Defense, the Army, the Navy, the Air Force, AEC, NSA, and FBI.

Concurring:

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Director, Defense Intelligence Agency
Assistant Chief of Staff for Intelligence, Department of the Army
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NATIONAL INTELLIGENCE ESTIMATE

THE SOVIET ATOMIC ENERGY PROGRAM

NUMBER 11–2A–63

2 JULY 1963

This estimate supersedes NIE 11–2A–62, 16 May 1962.

This estimate was prepared and agreed upon by the Joint Atomic Energy Intelligence Committee, which is composed of representatives of the Departments of State, Army, Navy, Air Force, the Atomic Energy Commission, the Defense Intelligence Agency, the National Security Agency and the Central Intelligence Agency. The representative of the Federal Bureau of Investigation abstained, the subject being outside his jurisdiction.

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THE PROBLEM

To estimate the current status and probable future course of the Soviet atomic energy program to mid-1968.

PRINCIPAL CONCLUSIONS

Nuclear Testing and Technology

1. The Soviets have a highly developed nuclear weapon technology which differs in design philosophy and emphasis from that of the West. They have tested thermonuclear devices in very high yields (up to 63 megatons) well above any in Western experience, and in this range have achieved an outstanding yield-to-weight performance. They have also shown an excellent performance in thermonuclear devices of lower yields, down to about two megatons. In the submegaton thermonuclear class, their yield-to-weight performance has improved considerably but has not equaled that of the West.

2. The Soviets have conducted many tests below 50 kilotons.

Weapon Stockpiles

3. A small number of individually produced weapons for interim use could be fabricated within a few months after device testing.

Thus, a few weapons with very high yields of up to 100 MT could now be available. However, we believe that the Soviet time lag between nuclear tests of a device and initial stockpile entry of a serially produced weaponized version is about two years at a minimum. On this basis, some of the new devices tested in 1961 could be entering stockpile during the latter part of 1963 if a priority development is assumed. It is estimated, however, that this could be done only on a limited scale, and that, in general, the devices tested in 1961–1962 would be stockpiled in 1964 and 1965. We believe that weapons currently stockpiled are derived primarily from devices tested in 1958 or earlier; these weapons range in yield from a few kilotons up to 6 megatons.

Requirements for Further Testing

4. Soviet nuclear weapon technology appears to be highly sophisticated and adequate for present delivery systems, but significant advancements can still be made through further development and testing. Probably one of the strongest requirements is in the area of high-altitude effects of nuclear weapons. The Soviets conducted several such tests in 1961–1962, but probably need additional tests to obtain weapon effects data pertinent to antimissile development and countermeasures. They also lack direct information on effects of high-yield weapons on hardened ground targets and on the effects of lower-yield weapons on deep underwater targets. The Soviets probably also have requirements to conduct further tests to improve yield-to-weight ratios particularly in the lower weight range and to develop new weapon capabilities such as light-weight thermonuclear warheads for smaller missile systems, and very small weapons for tactical employment.

5. We believe that the Soviets are continuing a vigorous weapons research and development program, and that they are maintaining a posture to resume nuclear testing promptly if a decision is made.

Fissionable Materials Production

6. We estimate the mid-1963 cumulative Soviet production of fissionable materials at about 15,000 kilograms of plutonium

equivalent and 130,000 kilograms of U–235.[1] These quantities are somewhat lower than previously estimated for mid-1963, as the result of further analysis and additional evidence. The Soviets are continuing to expand their fissionable material production capability at a significant rate. We estimate that by mid-1968 cumulative production will amount to about 35,000 kilograms of plutonium equivalent and 380,000 kilograms of U–235.

Reactor Development

7. Soviet research reactor development continues to be competent in most areas and is unique in a few. However, the original, unrealistic Soviet nuclear electric program has been abandoned and they are now proceeding with one which is more commensurate with their economic requirements and the state of their reactor technology. Moreover, the Soviets have encountered numerous difficulties with the nuclear propulsion of the icebreaker LENIN, and there is considerable evidence of similar difficulties with Soviet nuclear powered submarines. Soviet work on ion propulsion and nuclear auxiliary power supplied for space applications is continuing, and we believe that they have a program to develop materials suitable for nuclear rocket motors. The Soviet aircraft nuclear propulsion program appears to have been delayed and may have been cut back or even canceled.

[1] See page 13 for the views of the Assistant Chief of Naval Operations (Intelligence).

SUMMARY

I. SOVIET NUCLEAR WEAPON PROGRAM

1961–1962 Soviet Nuclear Tests

8. Between 1 September 1961 and 25 December 1962 [redacted] 112 nuclear tests which brings the total number of detected Soviet tests to 186. (See Figure 1 and Annex A.) A tabulation of tests to date is as follows:

YEAR	LOCATIONS Semipalatinsk	Novaya Zemlya	Sary Shagan-Kapustin Yar	Totskoye
1949–1958	42	27	4	1
1961	16	25	4	0
1962	28	36	3	0
Total	86	88	11	1

9. Only low-yield tests have occurred at Semipalatinsk since 1957. Test operations at Semipalatinsk have included ground bursts, air drops, and tower shots; some of these tests were designed to determine the effects of nuclear detonations on arrays of military equipment. Only two underground tests have been detected, both near Semipalatinsk—one in 1961 and one in February 1962.

10. Except for several missile-associated tests in the Kapustin Yar and Sary Shagan areas, all high-yield tests since 1957 have been held at Novaya Zemlya. In addition, there have been some lower-yield air-bursts at the Novaya Zemlya test areas near the center of the island, and several low-yield detonations on or under the sea off the southern coast. We believe that the majority of airburst tests in the Novaya Zemlya area were delivered by medium and heavy bombers. In addition, Soviet statements and various intelligence sources indicate that a number of the 1961 and 1962 Novaya Zemlya tests probably involved operational missile systems.

11. Several tests in the 1961 and 1962 series were conducted at high altitudes. In September 1961, a 25 KT shot was conducted near the Kapustin Yar rangehead; it probably involved a surface-to-air missile warhead. Another, in October 1961, at Kapustin Yar involved detonation of a 200 KT warhead; it probably was designed to provide data on effects at high altitudes. In addition, five very high altitude tests were conducted on the Kapustin Yar-Sary Shagan missile test ranges, two in 1961 and three in 1962. The 1961 tests yielded about 1 KT each, whereas two of the 1962 tests yielded about 200 KT, and the third about 2 MT. The test devices were delivered by medium range (1020 n.m.) missiles fired from the Kapustin Yar rangehead. We believe that these tests provided basic high altitude effects data and other data applicable to the antimissile problem.

Weapon Development Program

12. *Fission Weapon Developments.* From 1949 through 1958, the Soviets conducted about 40 tests of low-yield devices (1–200 KT) [redacted] By 1958, the Soviets had developed implosion warheads ranging in yield from about 1 to 200 KT.

13. [redacted] 27 fission tests in 1961 and 35 in 1962. [redacted] The 1962 test series, where the majority of fission tests were 10 KT or under, [redacted]

14. [redacted]

15. *Thermonuclear Weapon Developments.* Between 1955 and 1958, tests of full-scale thermonuclear devices were held by the Soviets at a variety of yields from about 200 KT to 7.6 MT. Over two-thirds of the tests were between 1 and 5 MT.

16. Of the 112 tests of the 1961–62 series, 50 were thermonuclear devices with yields ranging from about 150 kilotons to 63 megatons. [redacted] We estimate that yield-to-weight ratios of some of their nuclear devices have been substantially improved over 1958. In addition, new weight classes appeared with yields ranging from 25–63 megatons, which permit the development of weapons with yields up to 100 megatons.

17. The two largest Soviet detonations (30 MT and 63 MT) were both clean thermonuclear devices. As a normal (dirty) weapon, the 63 megaton device could yield 100 megatons. The Soviets also tested a new thermonuclear design at yields from 3 to 25 megatons.

18. [redacted]

Weapon and Systems

19. A small number of individually produced weapons for interim use could be fabricated within a few months after device testing. Thus, a few weapons with very high yields of up to 100 MT could now be available. However, we believe that the Soviet time lag between nuclear tests of a device and initial stockpile entry of a serially produced weaponized version is about two years at a minimum. On this basis, some of the new devices tested in 1961 could be entering stockpile during the latter part of 1963 if a priority development is assumed. It is estimated, however, that this could be done only on a limited scale, and that, in general, the devices tested in 1961–1962 would be stockpiled in 1964 and 1965.

Future Weapon Development and Testing

20. The status of Soviet nuclear weapon technology, while highly sophisticated and in most respects apparently adequate for their present delivery systems, is such that significant advancements can still be made through further development and testing. Such advances can be made in at least four areas: (a) adaptation of present designs to meet the needs of future delivery systems; (b) development of very small weapons for tactical employment; and (c) improvement in yield-to-weight ratios.

21. Probably one of the strongest requirements for further Soviet nuclear testing is in the area of high-altitude effects of nuclear weapons. The Soviets have not detonated a warhead in the vicinity of a re-entering missile nosecone, nor do we have firm evidence that the Soviets have placed instrument pods near their high altitude bursts. We also have no

knowledge of Soviet activities in providing information on effects upon hardened missile launch sites. Other areas where the Soviets require additional effects information may exist; in particular, the Soviets lack experience with very deep underwater bursts.

22. We believe the Soviets are currently maintaining a vigorous weapon research and development program and are in a posture to resume nuclear testing promptly if a decision is made.

Organization and Facilities

23. The Soviet atomic energy program is directed by two organizations recently placed under the supervision of the newly created Supreme Council of the National Economy. One of these, the State Production Committee for Medium Machine Building, USSR, is responsible for the overall direction of the atomic energy program including the production of fissionable materials and nuclear weapons. The Ministry of Defense participates with this Committee in the development, testing, and stockpiling of nuclear weapons. The other organization, the State Committee for the Utilization of Atomic Energy, is responsible for nonmilitary applications of the program and all official contacts with the atomic energy programs of foreign countries.

24. The USSR maintains a substantial degree of control over the atomic energy activities of the Soviet Bloc nations through interlocking associations of top Soviet personnel and by means of bilateral agreements and the Standing Committee for Peaceful Uses of Atomic Energy of the Council for Mutual Economic Aid (CEMA). This relationship is such that the Soviets have precluded the development of an independent nuclear military capability by the other participating nations. Communist China, an observer rather than a member of CEMA, has proceeded independently with its own nuclear program since the withdrawal of Soviet technical aid in mid-1960.[2]

25. The oldest Soviet center specifically concerned with nuclear weapon research, design, and development is located at Sarova about 200 miles east of Moscow. A second nuclear weapon research and development center, near Kasli in the Urals, probably became operational late in 1959. Although the installation, which is quite similar to Sarova, is considerably smaller than that center, we believe it represents a major addition to the Soviet nuclear weapon development potential. There is evidence that there is a research and development establishment, probably concerned with nuclear weapon systems development at the Kerch/Bagerovo airfield in the Crimea. The Soviet nuclear weapon program has also been supported by research conducted at a number of other institutes in the USSR probably including the Institute of Atomic Energy, Moscow; the Physics Institute, Obninsk; Physical-Technical Institute, Sukhumi; and especially the Institute of Chemical Physics, Moscow.

Weapon Fabrication Sites

26. Nuclear weapon fabrication complexes have been identified in the Urals at Nizhnyaya Tura and at Yuryuzan. A possible third complex is located in Central Siberia near Krasnoyarsk. National reserve stockpile sites are co-located with these complexes.

Weapon Stockpile Sites

27. The Soviet nuclear weapon logistic system includes (a) National Reserve Stockpile facilities at interior locations; (b) National Assembly Stockpile sites located near major order-of-battle concentrations; and (c) Regional and Operational storage sites at military bases for the direct support of military operations.

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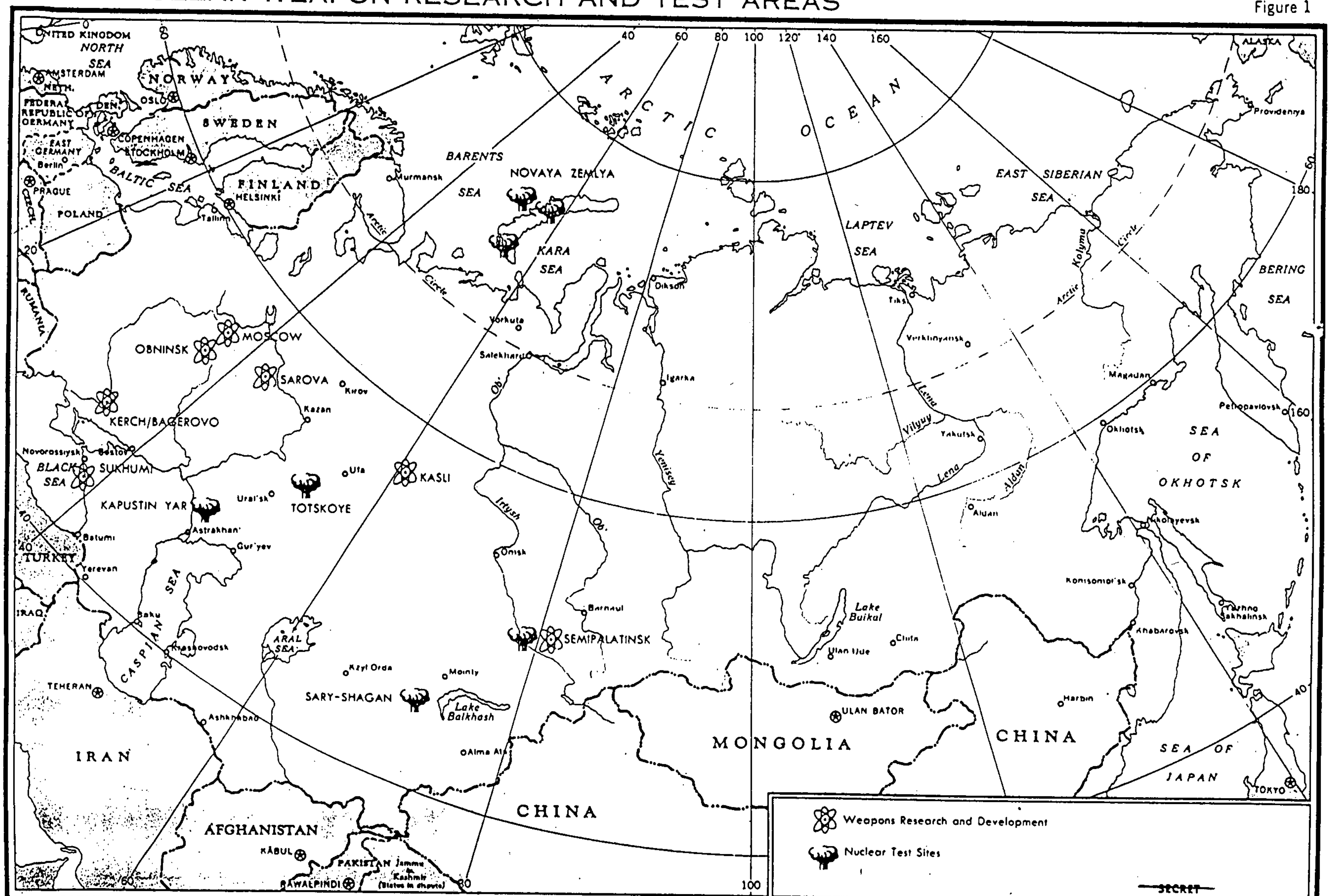
USSR: NUCLEAR WEAPON RESEARCH AND TEST AREAS

Figure 1



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28. Between 1951 and 1955, the USSR activated a total of about 6 stockpile sites of all classes. Over the next three years at least 17 additional stockpile sites of all classes were activated, bringing the total to about 23 at the end of 1958. This expansion supported primarily the growing nuclear capability of the Soviet strategic bomber force which was then rapidly converting to jet aircraft, and a limited development of nuclear capability in Naval and Tactical Aviation and probably ground and naval forces as well. Since 1958, a third stage of rapidly accelerated stockpile site construction has coincided with the deployment of strategic and tactical missiles with a nuclear capability, and with a wider distribution of nuclear weapons among Soviet military forces. In this period, the USSR has substantially increased the capacity of about two-thirds of the previously existing stockpile sites, and has more than doubled the total number of stockpile sites. [redacted]

29. The National Reserve Stockpiles and the National Assembly Stockpile facilities are characterized by isolation, extreme security, hardened bunkers (either earth-mounded or underground) and self-sufficiency in housing and other services required by the permanent cadres.

30. Operational and regional military storage sites now positively identified include three generations of airfield sites, sites at two staging bases in the Arctic, regional military depots resembling in design the third generation airfield sites, and a naval site used primarily to support missile-carrying submarines. These sites are typically situated apart from other facilities at their associated base, and are characterized by stringent physical security and by hardened storage bunkers.

31. We believe that nuclear warheads are available to all operational ICBM, IRBM, and MRBM complexes either on-site or at nearby storage facilities. Soviet ground forces may have field storage facilities in addition to the regional depots which probably serve them. Some nuclear storage probably is required by

[redacted]

Naval Aviation for its BADGER-delivered air-to-surface missile. We have no evidence of nuclear storage facilities at surface-to-air missile sites. No nuclear warhead storage facilities have been identified in European satellites nor is there definitive information that nuclear weapons have been deployed to any of the Soviet forces stationed there.

Command and Control

32. In the USSR, the Presidium of the Party Central Committee exercises ultimate control over nuclear weapons, and its authorizations govern their use, storage, movement and issuance. In a war situation, control would be exercised by the Presidium Chairman in his capacity as Supreme High Commander who, through the Ministry of Defense, would authorize the principal commanders of the forces directly concerned to use nuclear weapons.

33. We believe that the national stockpile storage sites are administered by the State Production Committee for Medium Machine Building, and operational storage sites by the Ministry of Defense. The Committee for State Security (KGB) is responsible for the security of nuclear stockpile facilities, provides their guard force and is responsible for escorting movements of nuclear weapons to and from national stockpile facilities and military depots. There is some evidence that responsibility for the management of logistical functions, such as storing, maintaining and delivery of nuclear weapons in support of military operations has been assigned to organizations operating in direct support of the major force components of the Ministry of Defense.

34. The flow of orders from the Supreme High Command is arranged so as to achieve maximum control and minimum delay in action. In the Strategic Rocket Forces, for instance, orders pass through the Commander and his main Staff directly to regiments responsible for nuclear fire. In the case of Theatre Forces, once employment of nuclear weapons has been authorized, responsibility for alerting forces and ordering execution of nuclear fire is delegated to major joint service commanders at the Military District, Group of Forces, or Front Level. The Commander at this level may allow his subordinate commanders down to Army level some discretion in authorizing the use of nuclear weapons, but it is evidently rare for commanders below that level to have any such discretion. In the case of special nuclear attack groups of tactical missiles and artillery, the Joint Service Commander evidently issues the order to prepare and execute nuclear fire directly to the units concerned, and their immediate superiors merely supervise execution of the order. Presumably Long Range Aviation, the Naval Forces and the Air Defense Forces operate in similar fashion.

35. There is abundant evidence that the USSR was seriously preoccupied with the problem of improving its command and control procedures for nuclear weapons from 1959 through at least 1961. The introduction of strategic missiles had complicated the problem of central control and had made more rapid response an urgent necessity. In addition, [redacted] Soviet Theatre forces [redacted] under field conditions many of the logistical practices and procedures governing the issue and servicing of nuclear weapons were cumbersome and operationally impractical. Some streamlining of the control system has probably occured by now, although precise details are not yet known.

36. We have no evidence to indicate whether or not the Soviets have either considered or installed mechanical or electronic

safeguards in their nuclear weapon control procedures (such as permissive links).

II. FISSIONABLE MATERIALS PRODUCTION (See Figure 2)

Uranium Ore Procurement

37. Soviet Bloc uranium reserves are estimated at several hundred thousand tons in medium grade ores and an even greater quantity in low grade deposits. A number of well-designed ore concentration plants of 500 to 1000 metric tons capacity are currently in operation, and active prospecting for additional orebodies continues.

38. We estimate that the annual procurement of uranium ore by the Soviet Union is currently 20,000 metric tons of recoverable metal equivalent and will gradually increase to 25,000 metric tons per year over the next five years. The cumulative recoverable metal through mid-1963 is estimated at 190,000 metric tons and through mid-1968 at 300,000 metric tons. These amounts of ore, which could be higher or lower by as much as 50%, are believed to be sufficient for the fissionable material production estimated herein and for a substantial stockpile in addition.

Uranium Feed Materials

39. Uranium metal and other feed materials are produced at Elektrostal, near Moscow; at Glazov, just west of the Urals; and at Novosibirsk in Central Siberia. The large size of these facilities and the process improvement detailed in the Soviet published literature suggest that the USSR has adequate feed materials plant capacity for the program estimated herein.

Plutonium-Equivalent

40. Three major plutonium-equivalent production sites have been identified in the USSR. The earliest and largest is located near Kyshtym in the Urals, the second is collocated with the U-235 production complex at the atomic energy site north of Tomsk in Central Siberia, and the third is located within the large atomic energy site northeast of Krasnoyarsk in Central Siberia. Review of all available information led to the conclusion that there are no other major production reactor sites in operation in the USSR.

41. We estimate that mid-1963 Soviet cumulative plutonium-equivalent production is about 15,000 kilograms. Interpretation of available data would permit a mid-1963 cumulative production estimate as large as 23,000 kilograms; however, it is almost certain that actual mid-1963 cumulative production is not less than 12,000 kilograms.

42. It is estimated that annual plutonium-equivalent production will increase at a rate consistent with performance during the period 1958–1962, resulting in a cumulative plutonium-equivalent production of about 35,000 kilograms by mid-1968. (See Table II.) Even with an extremely high priority effort, the cumulative plutonium-equivalent stockpile would not exceed 45,000 kilograms by mid-1968. Alternatively, the minimum likely cumulative production by that date will not be less than 25,000 kilograms.

43. Highly irradiated plutonium will be produced as a byproduct of the nuclear power and propulsion programs of the USSR in amounts gradually increasing to about 600 kilograms per year in 1968, and has been included in Table II. This production could be used in weapons by mixing with plutonium produced at considerably lower irradiation levels and would have other uses.

U–235 Production

44. Three large gaseous diffusion isotope separation complexes capable of concentrating U–235 up to weapon-grade production are in operation in the USSR; one at Verkh-

Neyvinsk in the Urals, one north of Tomsk in Central Siberia, and the third at Angarsk in the Lake Baykal region. A fourth large gaseous diffusion complex is under construction north of Zaozerniy near Krasnoyarsk. We believe that no undetected large gaseous diffusion plant is currently in operation. Continued construction of large gaseous diffusion plants in the USSR suggests that significant U-235 production by other means such as the ultracentrifuge is unlikely.

Table II

ESTIMATED SOVIET FISSIONABLE MATERIALS PRODUCTION[a]

(Cumulative Production in Kilograms Rounded)

Mid-Year	U-235 (93%)[b,e] Total	U-235 Available for Weapon Use	Plutonium Equivalent[d]
1950	25	25	100
1951	160	160	330
1952	600	600	550
1953	1,550	1,550	1,000
1954	3,350	3,350	1,600
1955	6,300	6,300	2,200
1956	10,500	10,500	2,900
1957	16,500	16,000	3,800
1958	24,500	24,000	4,500
1959	36,500	35,500	6,000
1960	53,000	51,000	8,000
1961	72,000	70,000	9,700
1962	100,000	96,000	12,000
1963	130,000	125,000	15,000
1964	170,000	165,000	18,000
1965	210,000	200,000	22,000
1966	260,000	250,000	26,000
1967	320,000	310,000	30,000
1968	380,000	370,000	35,000

[b] Production of less highly enriched uranium is included as equivalent quantities of 93% material.

[d] Non-weapon uses of plutonium are expected to be negligible during the period of this estimate.

[e] See Page 13 for view of the Assistant Chief of Naval Operations (Intelligence), Department of the Navy.

[a] Our current and future estimates of cumulative production of fissionable materials represents some decrease from those estimated in NIE 11-2A-62. These changes are the result of further analyses and the acquisition of additional information. However, it should be noted that the margin of error involved in any one year's value of cumulative production is larger than the magnitude of these changes.

45. Early Soviet gaseous diffusion plant operating efficiencies are derived from information supplied by German scientists who worked on the program through 1952. Later plant operating efficiencies have been extrapolated from this base primarily on advances in Soviet compressor technology and changes in process building design. Changes in process building design indicate the use of an improved barrier starting in 1958. The efficiency of this barrier can only be estimated, since there are no data on its operating characteristics.

46. Our estimate of U-235 production is based upon estimated electric power consumption, available site data, and on estimated plant operating efficiencies. Estimates of the growth of electric power supplies taken in conjunction with available site data indicate that the Soviet U-235 program is still undergoing significant expansion. It is believed that the current program of expansion will not be completed before 1968.

47. Our estimate of total Soviet cumulative U-235 production is presented in Table II in terms of cumulative production of uranium enriched to 93 percent U-235 content. It includes the 93 percent equivalent of material produced at lesser enrichment. Estimated expenditures for weapon tests and non-weapon uses have been subtracted from the value of cumulative U-235 production to give our estimate of equivalent 93 percent U-235 available for weapon use.

48. It is estimated that the Soviet cumulative U-235 production for mid-1963 is 130,000

kilograms.[7] It is unlikely that actual Soviet cumulative production in mid-1963 could be less than 80,000 kilograms or more than 180,000 kilograms. We estimate that the mid-1968 cumulative production will be 380,000 kilograms and that the actual U–235 production would not be less than 190,000 kilograms or more than 570,000 kilograms.

Other Nuclear Materials

49. *Thorium and U–233.* A moderate interest in the procurement of thorium ores was noted during the 1946 and 1952 period. [The only certain evidence of the production of U–233 from thorium is the single appearance of U–233 on 22 November 1955 in the thermonuclear weapon test JOE 19.]

50. *Lithium.* Lithium ores have been obtained primarily from three areas in the USSR. Soviet nuclear weapons have probably been using lithium enriched in the lithium-6 isotope since late 1955. The locations of Soviet lithium-6 isotope separation plants have not been positively identified, but could be located in certain facilities at the Nizhnaya Tura and Novosibirsk atomic energy sites.

51. *Tritium.* [

] We are unable to determine which of the Soviet reactor sites is used to produce tritium or the amount of tritium produced.

52. *Zirconium.* Zirconium-niobium alloys are used to clad fuel elements for the nuclear reactors of the icebreaker LENIN and by implication the nuclear submarine cores. Adequate zirconium-niobium production capacity is believed available for the needs of the Soviet atomic energy program.

53. *Beryllium.* The USSR processes large reserves of beryllium ore at Izumrud in the Urals, and established, in the pre-war period, a combine there to manufacture beryllium-copper and other alloys. Returned German scientists have reported interest in beryllium metal shapes at the Elektrostal feed materials plant as early as 1946. Sufficient quantities of beryllium ore and metal producing facilities are believed available to support both nuclear weapons and reactor programs of the USSR.

54. *Polonium.* Reactor-produced polonium has been available for use in nuclear weapons initiators since at least as early as 1950.

55. *Heavy water.* Since 1945 the USSR has operated heavy water (D_2O) production plants at some 8 locations, using at least 4 different processes. All the plants are relatively small, but it is believed that cumulative production has been adequate for Soviet needs. We estimate that the current annual production of heavy water is about 90 metric tons per year and the cumulative production through mid-1963 about 1,100 metric tons. The actual production could be up to 50% more than that estimated if hydrogen distillation processes were adopted at all plants, or if an unknown large additional facility exists.

III. NUCLEAR REACTOR PROGRAM

Research and Testing

56. The Soviets have constructed, and are currently operating, 23 research reactors of 13 different types within the USSR, and have supplied 12 foreign countries with research reactors. (See Table III.) While in recent years the Soviets have adopted the light-water moderated and cooled IRT swimming-pool type as their general purpose research reactor, they have also built a few research reactors of unique design which have proved to be

[7] The Assistant Chief of Naval Operations (Intelligence), Department of the Navy, believes that the lower limit of the estimated value for the cumulative production of U–235 is the more nearly correct. He believes that the evidential base is insufficient to support the production efficiency which a higher cumulative total would require.

Table III

SOVIET RESEARCH REACTORS AND REACTOR EXPERIMENTS

Reactor Designation	Location	Power Thermal (KW)	Max. Thermal Neutron Flux (neutrons/ cm^2 sec)	Fuel	Moderator	Coolant	Date Critical	Remarks
				Operating Research Reactors				
1. Fursov Pile	Moscow Inst. of A.E.	500 (max)	..	45 tons of natural U	Graphite	Air	1946	Similar to US CP-1, served as prototype for 1st Soviet production reactor.
2. TR (rebuilt)	Moscow, Inst. of Theoretical & Exp. Physics	2,500	2.5×10^{13}	270 kg of 2% enriched U	Heavy Water 4.5 tons	Heavy Water	June 1957	Originally a 500 kw prototype for Soviet heavy water production reactors. Critical in April 1949. Rebuilt version has 9 vertical & 52 horizontal experimental channels.
3. RPT-III	Moscow Inst. of A.E.	20,000	2×10^{14} 6×10^{14} (flux trap)	90% enriched U	Beryllium & Water	Water (20 atms.)	Under const.	Old RPT loop facilities to be retained; 200 atm. coolant loop; 60 atm. helium loop; 2.5 MW power loop.
4. BR-1 Fast Reactor	Obninsk	0.10	..	12 Kg Pu	none	none	Early 1955	Uranium & copper reflectors.
5. BR-3 combined fast thermal reactor	Obninsk	0.05	..	Pu	none	none	Mid-1957	Uranium & water reflector.
6. VVR-2 (rebuilt)	Moscow Inst. of A.E.	3,000	4×10^{13}	45 kg of 10% enriched U	Water	Water	1955	Original version critical in 1952. Tank-type reactor designed for testing of shielding materials & configuration. Now has 5 horizontal channels with choppers, 3 vertical channels, & a "neutron multiplier" (spent fuel elements in a tank adjacent to reactor).

7. VVR-S	Moscow, Moscow State Univ.	2,000	$2.5x10^{13}$	60 kg of 10% enriched U	Water	Water	1955	Tank-type; 10 vertical channels, 9 horizontal channels. Supplied to Rumania, Hungary, Czechoslovakia, E. Ger., Poland & Egypt.
8. VVR-S	Tashkent, Inst. of Nuclear Physics	2,000	$2.5x10^{13}$	60 kg of 10% enriched U	Water	Water	Late 1959	Tank-type; 10 vertical channels; 9 horizontal channels.
9. IRT	Moscow Inst. of A.E.	2,000	$3.2x10^{13}$	40 kg of 10% enriched U	Water	Water	Nov. 1957	Swimming-pool type for use in universities & institutes. Reactor to be modified to 4000 KW using 36% U-235.
10. IRT	Tbilisi	2,000	$3.2x10^{13}$	40 kg of 10% enriched U	Water	Water	Nov. 1959	Swimming-pool type for use in universities & institutes.
11. IRT	Moscow Inst. of Physical Engineering	2,000	$3.2x10^{13}$	40 kg of 10% enriched U	Water	Water	1962	Same as above.
12. IRT	Riga	2,000	$3.2x10^{13}$	40 kg of 10% enriched U	Water	Water	1962	Same as above.
13. IRT	Minsk	1,000	$1.6x10^{13}$	40 kg of 10% enriched U	Water	Water	1962	Same as above.
14. IRT	Tomsk	1,000	$1.6x10^{13}$	40 kg of 10% enriched U	Water	Water	1962	Same as above.
15. IRT	Sverdlovsk	1,000	$1.6x10^{13}$	40 kg of 10% enriched U	Water	Water	1962	Same as above.
16. VVR-M	Leningrad Physical-Technical Institute	10,000	$1x10^{14}$	20 kg of 20% enriched U	Water	Water	Dec. 1959	Beryllium reflected, used for neutron diffraction studies, probably in connection with solid-state work in Leningrad.
17. VVR-M	Kiev Physical Technical Inst.	10,000	$1x10^{14}$	20 kg of 20% enriched U	Water	Water	Feb. 1960	Beryllium reflected, used for isotope production, prod. of trans U elements.
18. Intermediate Flus Trap (SM-2)	Melekess, Ul'yanovsk Oblast	50,000	$2.2x10^{15}$	13 kg of 90% enriched UO_2 in a Ni matrix	Water	Water	Oct. 1961; Full Power Nov. 1962	BeO reflected, central water cavity where max. thermal neutron flux is obtained.
19. IBR (Merry-go-round)	Dubna Joint Inst. of Nuclear Research	1 Ave. 100,000 Max.	10^{17} during burst	UO_2 impregnated in graphite PuO_2 in stator	Graphite	Water	June 1960	Used with a 1 km time of flight spectrometer.

Table III (*Continued*)

Reactor Designation	Location	Power Thermal (KW)	Max. Thermal Neutron Flux (neutrons/ cm^2 sec)	Fuel	Moderator	Coolant	Date Critical	Remarks
Operating Research Reactors								
20. Isotope Reactor (IR)	Unknown-Possibly Kyshtym	50,000	3–4.5x10^{13}	3 tons of 2% enriched U	Graphite	Water	1952	Experimental facility for production of isotopes.
21. BR–5 Fast Reactor	Obninsk	5,000	10^{15} (fast)	50 kg Pu Oxide	None	Sodium	June 1958; full power July 1959	Uranium & nickel reflector.
22. VVR–Ts	Alma Ata	10,000	1x10^{14}	25 kg of 20% enriched U	Water	Water	1963	Specialized radio-chemical research reactor.
23. OR	Moscow Inst. of A.E.	20,000	. . .	U-unknown concentration	Organic Fluid-possibly isopropyl-diphenyl	Same as moderator	Prob. 1962	The first organic cooled & moderated reactor in the Soviet Union.
Low Power Reactor Experiments Now in Operation								
1. Fast Zero Power Critical Assembly (BFS)	Obninsk	. .	. .	U discs	. .	. .	1962	Used to study large diluted reactors.
No Longer in Operation								
1. Beryllium Physical Reactor (BFR)	Obninsk	0.05	. .	U_3O_8 with 20% enriched U	Beryllium metal	none	Aug. 1954	Zero-power critical assembly, bare & reflected.
2. BR–2 Fast Reactor	Obninsk	100 10^{14} (fast)	. .	Pu-U	none	Mercury	Early 1956	Uranium reflector. (Dismantled to make BR–5).
3. UF_6 Gas-fueled reactor	Moscow Inst. of A.E.	1.5	2.7x10^{10}	UF_6 with 90% enriched U	Beryllium metal	none	Aug. 1957	Probably dismantled.

valuable experimental facilities. These include a pulsed reactor which provides a burst of neutrons over a period of 40 microseconds; a plutonium fueled, sodium cooled, fast reactor; and a 50 megawatt, intermediate fluxtrap reactor.

57. The Soviet series of fast reactors are being used in the development of breeder-type reactors for the production of electric power and, it is believed, in connection with the development of compact propulsion reactor systems and/or as an auxiliary power source.

Nuclear Electric Power

58. Following the successful operation of a 5 electrical megawatt (MWe) nuclear electric power station at Obninsk in June 1954, the USSR announced plans in February 1956 for the installation of 2000–2500 MWe of nuclear generating capacity by the end of 1960. This ambitious program was cut back considerably in 1958 and has consistently been slipping behind subsequently revised schedules. Soviet officials have stated that their nuclear power program was reduced for economic reasons, since their nuclear reactors are not yet competitive with conventional power sources except in special locations. However, it is also certain that Soviets underestimated the engineering difficulties in a major nuclear power program. (See Table IV and Figure 3.)

59. We estimate that, including the dual-purpose reactors in Siberia, the USSR will have about 500 MWe of nuclear generating capacity installed by the end of 1963 and about 1500 MWe by the end of 1968.

60. Soviet research on controlled thermonuclear reactions (CTR) began about the same time as the US. Both programs have been proceeding at about the same pace. It is estimated that the USSR will not achieve a useful controlled reaction within at least the next 3–5 years; and consequently will not attain useful power from nuclear fusion within the next decade.

Marine Nuclear Propulsion Systems

61. Three different classes of nuclear powered submarines are known to have been constructed in the USSR and identified in operational status. We estimate that a fourth class will be completed and undergo trials within a year or two and will probably have an improved propulsion system.

62. It is estimated that the Soviet Navy has about 26 nuclear submarines. The Northern Fleet has under its command about 20 nuclear submarines in operational or near operational status composed of ballistic missiles-carrying submarine of the "H" class and attack type ("N" class) submarines, while the Pacific Fleet is currently operating six cruise missile type submarines ("E" class). We believe that the Soviets can fabricate at least the number of reactors needed to support the estimated construction program of 8 to 10 nuclear submarines per year. (See Table V.)

63. The reactor systems used on the nuclear icebreaker, LENIN, and the nuclear submarines are of the pressurized-water type. It is believed that many of the design characteristics and the performance of the LENIN Power Plant are reflected in the submarine propulsion system, particularly for the early submarines. In general, the design and integration of propulsion system components is poor compared to US standards and limits the reliability of their nuclear submarines. On at least five occasions in the past four years, propulsion plant failures have necessitated towing nuclear-propelled submarines back to base. We continue to estimate that Soviet technical and operational experience with pressurized-water reactor propulsion systems is limited in comparison to US experience.

USSR: NUCLEAR MATERIALS PRODUCTION SITES

Figure 2

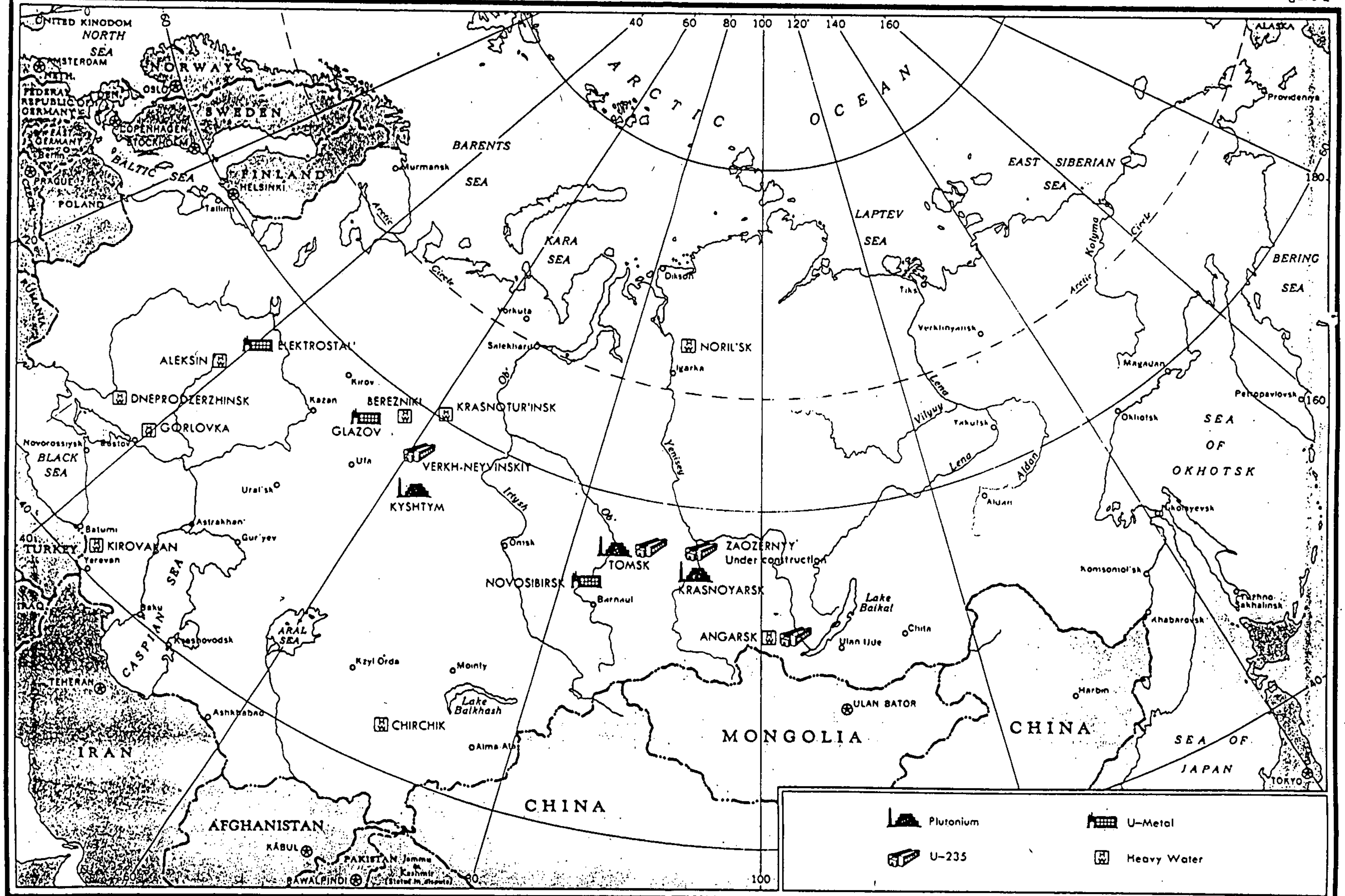

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Table IV

SOVIET NUCLEAR POWER STATIONS AND EXPERIMENTAL CENTERS

Station Location	No. of Reactors and Type	Elec. Power Per Reactor (MW)	Thermal Power Per Reactor (MW)	Fuel Loading Per Reactor	Conversion Ratio	Annual Consumption ETP U-235 Per Reactor (Kg)	Annual Production Pu Per Reactor (Kg)	Fuel Lifetime	Estimated date of Full Power Operation	Remarks
Tomsk	3 reactors in various stages of construction	200 (est.)	1400 (est. peak power)	200 metric tons of natural U	0.8	..	400	..	1st reactor critical 1958; in mid-1960 at 100 MWe.	Construction to be completed by end of 1968.
Beloyarsk	1 Graphite-moderated water cooled, pressure tube configuration	100	286	90 metric tons of 1.3% U metal	0.65 at beginning of cycle, 0.55 at end	74	66	2 yrs	1963	Employs nuclear superheat. Est. schedule: 1st. reactor, 1963. 4 originally planned.
	Unit 2	200	..	..	..	..	..	..	1966	..
Novo Voronezh	1 water-moderated water-cooled pressure vessel configuration	210	760	23 metric tons of 1.5% UO_2 % 17 metric tons of natural UO_2 (820 kg U-235 metal equivalent)	0.75 to 0.80	108	117	1.5	1963	Zr-Nb alloy clad fuel elements. 2 originally planned.
	Unit 2	360	..	..	..	..	..	..	1966	..
Obninsk	1 Graphite-moderated, water cooled, pressure tube configuration	5	30	550 kg of 5% U metal	0.32	..	3	100 days	1954	First Soviet nuclear power station. Prototype of Beloyarsk reactors. Used extensively for experiment as well as power production.
Obninsk	1 package power water-moderated water-cooled, pressure vessel	2	10	..	0.5 assumed	..	1	..	1959	Assembled for testing at Obninsk.

Melekess, Ul'yanovsk Oblast	1 boiling water reactor	50	250	..	0.60 assumed	..	43	..	1965	Same type fuel element as large PWR's. Plant factor assumed 0.6.
	1 organic reactor (ARBUS)	0.75	5	22.5 Kg 10–15% U-235	..	..	..	..	1963	Package power reactor.
Bohunice (Czechoslovakia)	1 gas-cooled heavy water reactor	150	590	25,400 kg natural U	..	..	..	..	1965	Possible trouble with pressure vessel in 1962.
Rheinsberg (East Germany)	1 pressurized water reactor similar to Novo-Voronezh	70	265	19,600 kg UO_2 1.5%	0.75–0.80	36	40	1.5 yr.	1965	Progress very slow.

Aerospace Nuclear Applications

64. No installations concerned with an aircraft nuclear propulsion (ANP) program have been identified in the USSR, and there is no evidence that the Soviets have conducted a flying test bed experiment. The ANP program appears to have been delayed and may have been cut back or even canceled. In any event, we do not believe that a militarily useful nuclear powered aircraft could appear prior to 1968.

65. There is no specific evidence that the Soviets have a nuclear ramjet missile or a nuclear rocket under development. Nevertheless, the Soviet scientific literature indicates that an extensive research program exists which is capable of developing the materials and establishing the technology required. We estimate that the Soviets will not conduct a static test of either a nuclear rocket or a nuclear ramjet engine before 1966, at the earliest.

66. An extensive effort appears to be underway in the Soviet Union to develop a nuclear electric propulsion system for space vehicles. The contact ion engine program is the most advanced of the various electrical propulsion systems in a practical sense. If no major difficulties are encountered in developing a suitable nuclear power source, it is estimated that the Soviets could flight test a full-scale ion propulsion system operating at a power of about 75 KWe as early as 1964 or more probably 1965–1966.

67. There is substantial evidence that the Soviets are conducting research fundamental on the development of nuclear space power supplies capable of producing on the order of several hundred watts. We believe, that they could have a suitable thermoelectric device capable of generating about a kilowatt of electric power in 1964. For higher power systems, we believe that the Soviets will probably use a turboconversion type nuclear power supply of about 100 KWe and that a system of this size could be flight tested as early as 1965. The Soviets have conducted extensive research on thermionic phenomena and the development of suitable high-temperature materials. Such a system would permit the direct conversion of heat to electricity. We estimate that a thermionic nuclear power supply will become available towards the end of this decade.

Table V

ESTIMATED CHARACTERISTICS OF SOVIET NUCLEAR SUBMARINES

Class	Type	Length Over-all (ft)	Beam (ft)	Displacement in tons	Maximum Surface Speed (knots)	Maximum Submerged Speed (knots)	Estimated Maximum Depth (ft)	Estimated Reactors Horsepower
N	A torpedo attack submarine	330	32	surfaced 3,800 submerged 4,300	about 20	about 20	750	15,000 hp. probably pressurized water reactor.
H	Ballistic Missile Firing	315	32	surfaced 3,500 submerged 4,000	about 20	about 20	750	15,000 hp. probably pressurized water reactor.
E	Cruise Missile Firing	385	33	surfaced 5,600 submerged 6,700	about 20	18	750	15,000 hp. probably pressurized water reactor.

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USSR: NUCLEAR MATERIALS PRODUCTION SITES

Figure 2

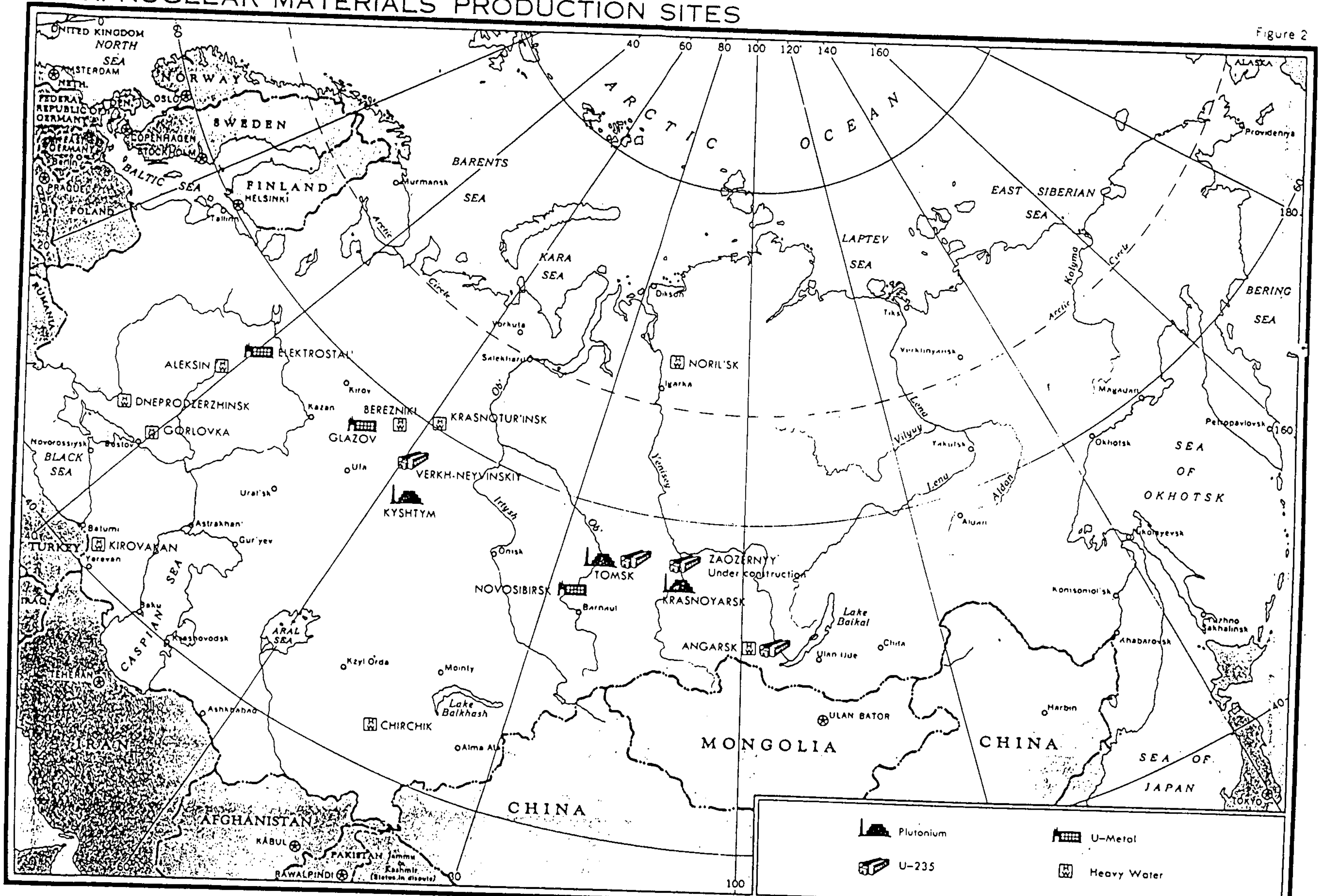

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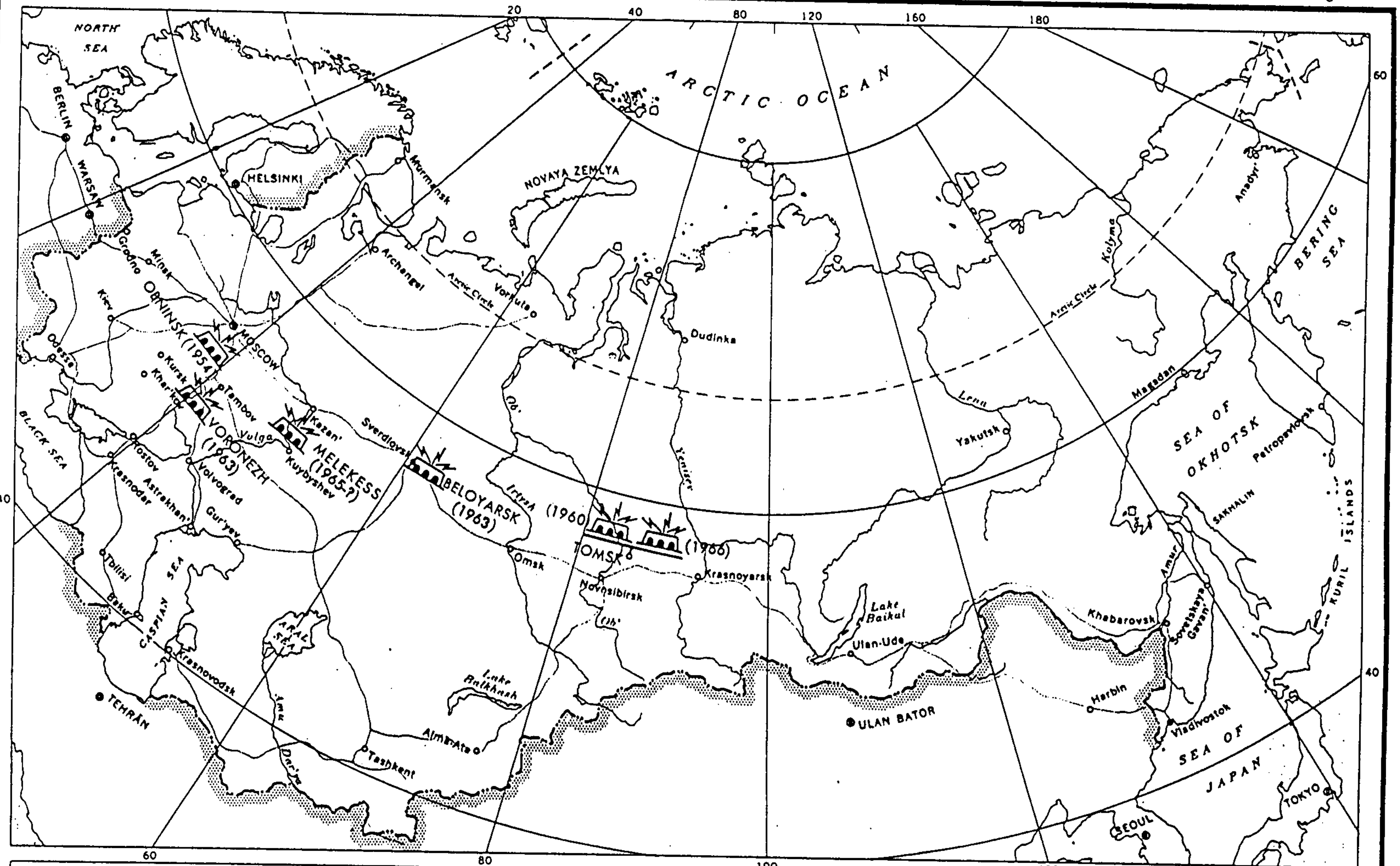
Figure 3



In Operation (date of full power)

Under Construction (expected date of full power)

USSR NUCLEAR-ELECTRIC POWER REACTOR SITES

Statute Miles: 0 250 500 1000 1500 2000

Kilometers: 0 250 500 1000 1500 2000

Railroad (selected)

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GROUP 1 Excluded from automatic downgrading and declassification

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DISCUSSION

I. ORGANIZATION OF THE SOVIET ATOMIC ENERGY PROGRAM

68. The Soviet atomic energy program is directed by two organizations recently placed under the supervision of the newly created Supreme Council of the National Economy: the State Production Committee for Medium Machine Building, USSR, and the State Committee for the Utilization of Atomic Energy. The State Production Committee for Medium Machine Building, USSR, was, prior to 15 March 1963, the Ministry of Medium Machine Building. The Chairman of the Committee, Ye. P. Slavskiy, has retained his rank of Minister, USSR. The Committee is responsible for the over-all direction of the atomic energy program including the production of fissionable materials and nuclear weapons. The State Committee for the Utilization of Atomic Energy, still headed by Andronik M. Petrosyants, is responsible for non-military applications of the program and official contacts with the atomic energy program of foreign countries.

69. We believe the Ministry of Defense participates with the State Production Committee of Medium Machine Building, USSR, in the development, testing, and stockpiling of nuclear weapons. The weapon research and development centers are probably under the administrative control of the State Production Committee, but there is undoubtedly direct military participation at these centers. The nuclear weapon proving grounds are probably under military operational control with technical direction provided by the State Production Committee. The Ministry of Defense is believed to control operational nuclear weapon storage facilities located at military bases.

70. We believe that the State Production Committee will remain organized along the customary ministerial lines, with its over-all activities subject to technical review by a Collegium composed of outstanding production and scientific leaders both from within and without the Committee. In addition to its mining and production enterprises, the Committee has several factories which make specialized equipment. The Committee has its own supply elements and its own design and construction directorate. A design bureau of the State Committee is located in Leningrad. Construction directorates of the Chief Directorate for Capital Construction and elements of the Chief Installation Directorate are responsible for the construction of all installations. Finally, the State Production Committee also has laboratories under its direct control probably including the nuclear weapon development centers at Sarova and Kasli.

71. The State Production Committee and its installations are operated under a system of rigid security. Installations as well as classified shipments are guarded by uniformed troops or members of the Counter Intelligence Directorate of the Committee of State Security (KGB). Extensive physical security around atomic energy installations is prevalent and includes the compartmentation of installations into a number of fenced and guarded internal areas. Almost all information concerning the atomic energy program is considered a state secret and is subject to various security classifications and access on a need-to-know basis.

72. The State Committee for the Utilization of Atomic Energy is concerned with nonmilitary applications of atomic energy within

the USSR and also cooperation between the USSR and other countries in the non-military uses of atomic energy. It is involved with the introduction of atomic energy into industry and the coordination of research in nuclear technology for peaceful uses. In the non-military field it has concerned itself with the production and supply of radioactive isotopes, the transportation of radioactive materials, and with problems of radioactive waste disposal. There is very close coordination between the State Production Committee and the State Committee for the Utilization of Atomic Energy. The State Production Committee appears to exercise a certain amount of control over the installations and activities of the State Utilization Committee.

73. The USSR maintains a substantial degree of control over the atomic energy activities of the Soviet Bloc Nations through interlocking associations of top Soviet personnel and by means of bilateral agreements. Uranium mining in these countries is probably directed by the State Production Committee. The other atomic energy activities are coordinated through the Standing Committee for Peaceful Uses of Atomic Energy of the Council for Mutual Economic Aid (CEMA) under the Chairmanship of V. S. Emelyanov. Emelyanov is also a Deputy Chairman of the State Committee for the Utilization of Atomic Energy and a member of the Board of Governors of the International Atomic Energy Agency. The long-range plan of the CEMA Committee is to provide a single integrated atomic energy program by dividing tasks in atomic energy among the Satellite nations. This type of inter-country collaboration is probably intended by the Soviets to preclude the development of an independent nuclear military capability by the other participating nations.

II. NUCLEAR REACTOR PROGRAM

Research and Testing Reactors

74. The Soviets have constructed and are currently operating 23 known research reactors of 13 different types within the USSR. (See Table III.) The US has in operation nearly 100 research, testing and teaching reactors of about a dozen different types. The Soviets have supplied 12 foreign countries with research reactors of the tank of swimming pool type (VVR–S, IRT and TVR–S). The TVR–S reactors are 7–10 MW heavy-water moderated reactors designed specifically for China and Yugoslavia. We have no knowledge of the construction of reactors of this design in the USSR. Most Soviet research reactor facilities are used for a variety of purposes. For instance, they are used for nuclear training of personnel as well as for extensive studies of neutron physics, materials testing and development, radiochemistry, isotope production, and new reactor concepts.

75. The variety of research reactors constructed indicates an excellent capability in this field. While in recent years the Soviets have adopted the IRT swimming pool type as their general-purpose research reactor, they have also designed and built a few research reactors of exceptional originality. For instance, the IBR, merry-go-round type of pulsed reactor at Dubna provides a burst of 10^{18} to 10^{19} neutrons over a period of 40 microseconds. However, this pulse degenerates in the one kilometer time-of-flight spectrometer to 10 neutrons/cm²-sec so that the actual usable beam strength is quite small.

76. At Obninsk, the BR series of fast reactors is used not only for the development of breeder-type reactors, but also for the development of compact reactor systems for future propulsion systems. For irradiating materials under high fluxes, a 50 megawatt, intermediate flux trap type reactor (SM) with unperturbed thermal flux in the central trap of 2.2 x 10^{15} neutrons/cm²-sec has been built at Melekess. Its major aim is the production of small quantities of Californium-252, probably for research purposes. A 5 MW organic moderated and cooled transportable reactor is also located at Melekess. The VVR–M reactor located at Kiev is also being used to produce materials for transuranium research.

77. The Soviets have a need for high flux reactors suitable for testing large engineering systems under irradiation. Construction has begun at Melekess on a 75 thermal megawatt materials test reactor with beryllium and water moderation. It is similar to the RPT reactor now being rebuilt at the Institute of Atomic Energy in Moscow. The Melekess reactor is expected to be completed in 1965.

Nuclear Electric Power Program

78. Following the successful operation of a 5 electrical megawatt (MWe) nuclear electric power station at Obninsk in June 1954, the USSR announced plans in February 1956 for the installation of 2000–2500 MWe of nuclear generating capacity by the end of 1960. This ambitious program was cut back considerably in 1958 and has consistently been slipping behind subsequently revised schedules. Soviet officials have stated that their nuclear power program was reduced for economic reasons, since their nuclear reactors are not yet competitive with conventional power sources except in special locations. However, it is also certain that Soviets underestimated the engineering difficulties in a major nuclear power program. (See Table IV and Figure 3.)

79. The US Atomic Energy Commission delegation to the USSR in 1963 noted that the

program at the experimental reactor site near Melekess in the Ul'yanovsk Oblast is proceeding at the reduced rate suggested by Soviet unofficial statements. The 50 MWe experimental boiling water reactor station at this site was under construction and is expected to be completed in 1964.

80. The 2 MWe portable nuclear power station which was nearing completion at Obninsk in 1958 probably began operation in 1959. It is mounted on four heavy trailers.

81. Two large nuclear electrical power stations are now under construction in the USSR, one at Novo-Voronezh which will develop 210 MWe from a 760 thermal megawatts (MWT) pressurized water reactor, and another at Beloyarsk where 100 MWe will be produced from a 285 MWT graphite-moderated pressure-tube reactor. Both are expected to be completed late in 1963.

82. Expansion of the Novo-Voronezh station with a second unit of 360 MWe, and the Beloyarsk station with a second unit of 200 MWe is underway with a planned completion date of about 1965–1967.

83. The USSR is assisting the governments of Czechoslovakia and East Germany in the design and construction of nuclear power plants. The station at Bohunice in Czechoslovakia, designed to develop 150 MWe from a gas cooled heavy-water-moderated reactor, is scheduled for completion in 1965. The station at Neu-Globsow in East Germany is essentially a one-third capacity copy of the Novo-Voronezh station and is reportedly to produce 70 MWe from a pressurized water reactor system. We believe that it is unlikely that this station will be completed before 1964.

84. A recent study of the Tomsk site indicates that the two dual-purpose reactors previously identified there can be modified to operate at a thermal power of about 1400 MW.

85. Longer range plans currently favor construction of pressurized water and fast neutron reactors. The Soviets seem to be concentrating on very large units where over-all efficiency is more favorable than with smaller ones. Calculations have been made on the design of a pressurized water reactor which generates supercritical steam and is theoretically capable of developing 1000 MWe. In the fast neutron reactor field, a power station with a capacity of 800–1000 MWe is being studied but will not be constructed until 1970. Nevertheless, smaller mobile stations are not being completely neglected. An organic moderated and cooled reactor is under construction at Melekess. In December 1962 it was announced in "Pravda" that a 750 KWe was to be built for use in the permafrost region.

86. In summary, we estimate that, including the dual-purpose reactors at Tomsk, the USSR will have about 500 MWe of nuclear generating capacity installed by the end of 1963 and not more than 1500 MWe by the end of 1968.

Marine Nuclear Propulsion Systems

87. *Nuclear Icebreaker LENIN.* Extensive modifications of the icebreaker LENIN's nuclear propulsion system were required at the end of her first operational season in June–November 1960. These modifications were completed in August 1961 after which the LENIN completed the 1961 season with a moderately successful voyage into the Far North.

88. *Nuclear-Powered Submarines.* Three different classes of nuclear-powered submarines are known to have been constructed in the USSR and identified in an operational status. The estimated characteristics of these nuclear submarines are given in Table V. Recent information indicates that a fourth class is under construction. We estimate that

submarines of this class will be completed and undergo trials within a year or two, and will probably have an improved propulsion system.

89. It is believed that the Soviet Navy has about 26 nuclear submarines in operational or near operational status. The Northern Fleet has about 20 nuclear submarines under its command, including ballistic missile carrying submarines of the "H" class and attack type ("N" class), submarines. The Pacific Fleet is currently operating 6 cruise missile type nuclear submarines ("E" class). We believe that the Soviets can fabricate at least the number of reactors needed to support the estimated construction program of 8 to 10 nuclear submarines per year.

90. *Marine Reactor Technology.* Indicative of both the urgency and the scope of the Soviet nuclear submarine program is the fact that during the period mid-1954 to mid-1958 the designs of at least 3 different classes of nuclear submarines and a nuclear icebreaker were undertaken (all probably using the same type reactor) before any operational experience was obtained. The reactor system used on the nuclear icebreaker LENIN is a pressurized-water type. We believe that the same system is used on nuclear submarine, probably in a somewhat modified form in order to meet the spacelimited conditions. Both systems were probably designed by the same group in about the same time period. Thus, it is believed that many of the design characteristics and the performance of the LENIN power plant are reflected in the submarine propulsion system, particularly for the early submarines.

91. The LENIN reactor was designed to operate at a pressure of 200 atmospheres [ ] Information obtained at scientific conferences and during visits indicates that the Soviets have experienced sticky valves and excessive leakage in the primary system of the LENIN.

92. The over-all propulsion plant layout of the LENIN is poor and provides inadequate accessibility to equipment and piping to permit easy repair. The shielding concept of the LENIN was to place the entire primary system (including all three reactors) within a single shield compartment. Such an arrangement has the advantage of minimizing the shield weight but it prevents maintenance of primary equipment during operation. Although a minimal shield was also placed around each of the reactors, enough neutrons pass through the reactor shield to induce secondary radiation within the compartment. Repairs in this area, therefore, have to be delayed until this secondary radiation has decreased to a reasonable level. If this shielding concept is reflected in the submarines, their ability to operate under conditions when repairs are required in the primary circuit is indeed limited. On at least five occasions in the past four years, propulsion plant failures have necessitated towing nuclear-propelled submarines back to base. We continue to estimate that Soviet technology and operational experience with pressurized water reactor propulsion systems is indeed limited in comparison with US experience.

Aerospace Applications

93. *Aircraft Nuclear Propulsion.* The key problem in any aircraft nuclear propulsion (ANP) program is the development of suitable materials for structural components for the reactor system which operates in an oxidizing atmosphere at a temperature of about 2000° F. Soviet literature indicates that the development of high-temperature reactor fuels

and cladding (including impregnated beryllium oxide), and the use of liquid metals, monatomic gases, and fused salts as coolants, were underway in 1957. By late 1958, the Soviets believed they were in a position to conduct the initial experiments leading to the development of an atomic aircraft engine and made an announcement to this effect. However, in the fall of 1959, during exchange visits between the US and USSR in the atomic energy field, the US group was told that the Soviets had abandoned the beryllium oxide development and were directing their efforts toward highly-purified, temperature-resistant metals or their alloys and that no flight was contemplated until 1966. [redacted] indicates that, as of October 1960, the Soviet Navy was considering the possible advantages of a nuclear-powered aircraft for low-level reconnaissance and attack missions. To date, there has been no evidence that the Soviets have constructed a flying test bed experiment. The ANP program appears to have been delayed and may have been cut back or even cancelled. In any event, we do not believe that a militarily useful nuclear powered aircraft will appear prior to 1968.

94. *Nuclear Ramjets.* There is no specific evidence that the Soviets have a nuclear ramjet missile under development. The Soviet scientific literature contains several articles on optimum parameters of a nuclear ramjet engine which are probably sections of a feasibility study. If the Soviets have a nuclear ramjet program, it is not expected that they will test a nuclear ramjet engine before 1966 at the earliest.

95. *Nuclear Rocket.* A Soviet nuclear rocket program has not been identified to date. From the scientific literature it is apparent that an extensive research program exists in the USSR which is capable of developing the materials and establishing the technologies required by an advanced nuclear reactor system such as a nuclear rocket engine. In particular, research has been noted involving the development of refractory metal carbides which are suitable as erosion resistant coatings on graphite in a high temperature, non-oxidizing atmosphere, as found in nuclear rocket engines using hydrogen as the propellant. A recent study of Soviet progress in cryogenics indicates that their cryogenic tanks do not appear to be suitable for long-term liquid hydrogen storage. There is no evidence of development of large-scale liquid hydrogen production. However, a very competent research program in cryogenics exists in the USSR. On balance, we estimate that the Soviets will not conduct a static test of a nuclear rocket engine before 1966, at the earliest.

96. *Nuclear Electric Propulsion Systems for Space Applications.* Electric propulsion using nuclear energy sources offers a possibility for producing a low-thrust, high specific impulse system suitable for outer space and inter-orbital applications but would be useless for take-off. The most promising types of electrical propulsion engines appear to be: a contact cesium ion engine, a plasma engine, and a thermal arc jet engine.

97. The contact ion engine program is the most advanced of the various electric propulsion systems in a practical sense. The research program which began in 1958 appears to be centered at the Physics-Energetic Institute located near Obninsk. The applied research program conducted here receives extensive support from various basic research groups throughout the USSR. These groups are providing the fundamental data and understanding of the phenomena.

98. The development of the in-flight instrumentation for an ion propulsion system to operate in a power range of 75 to 500 KW was to be completed at the State University imeni Shevchenko located in Kiev by early 1962. This may indicate that the contact cesium ion

engine was expected to be available by that time.

99. Research which is applicable to the development of a plasma engine has been observed in the USSR. The effort seems to be confined to one or two research groups at the Georgian Physics Institute at Sukhumi and the Ukranian Physical Technical Institute at Kharkov. Their major innovation has been to develop techniques of forming and shaping plasma boundaries so that high currents can be extracted and focused from large plasma surfaces. The resultant Soviet duoplasmatron ion source performance is considerably beyond that attained by US ion propulsion researchers.

100. Significant developmental research on the thermal arc jet engine has not been noted in the USSR. Recently, however, the Soviets have indicated that a research team has been formed in this electrical propulsion area.

101. It is not feasible to reproduce the actual conditions of operation for a space electrical propulsion system in the laboratory. Thus, there remain problem areas such as beam neutralization, zero-g operation and possible communications interference which can be studied only in a true space environment. From the contact cesium engine instrumentation time schedule, it is estimated that the Soviets could have conducted such flight tests as early as 1962. Various Soviet space experiments, such as the COSMOS series, give no indication of ion propulsion experimentation. If no major difficulties are encountered in developing a suitable nuclear power source, it is estimated that the Soviets could flight test a prototype ion propulsion system operating at a power of about 75 KW possibly as early as 1964 or more probably 1965-1966.

102. *Nuclear Auxiliary (Non-Propulsion) Power Supplies.* There is substantial evidence that the Soviets are conducting research fundamental to the development of space nuclear auxiliary power supply systems.[8] However, the exact status of their efforts can only be estimated, since their program continues to be classified to a major extent.

103. Soviet scientific literature describes the design of radioisotope batteries, but we have no evidence that a radioisotope type power supply has been used in the Soviet space program. Nevertheless, we estimate that the Soviets can certainly develop a power source of this type capable of producing several hundred watts.

104. Either a hydrogen moderated thermal or epithermal reactor or a fast non-moderated reactor can be made small enough to be considered for space use. The Soviets have prepared metallic hydrides such as zirconium hydride, capable of operating in the range of 1300° to 1400° F with a moderation capability comparable to water. However, most of the desirable systems require temperatures

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[8] A nuclear power supply for space vehicle application is composed of 3 major subsystems: a nuclear heat source (radioisotope or reactor), a power conversion system, and a heat rejection system. The power supply must be compact and absolutely reliable over a long period of time. The relatively high temperatures required by the radiative heat rejection system requires that the heat source operate at high temperature. The radioisotope type power source can reliably supply power up to several hundred watts. The reactor-type power source can supply quite substantial amounts of power depending largely on the type of power conversion system used. The highly reliable thermoelectric conversion system with no moving parts operates effectively over a power range of 0.02 to 10 KWe; the turboelectric conversion system is best over a 2 to 500 KWe range; and it is anticipated that the thermionic method, wherein the reactor and the conversion system are a single unit, will operate well in the 100 to 200 KWe range.

in excess of this range. It is believed, therefore, that the initial reactor developed for space use will probably be of a fast neutron type. This permits selection of fuels which have extremely high temperature capabilities resulting in a reactor with a high specific power. The Physics-Energetics Institute at Obninsk, the center of the fast reactor research in the USSR, has been identified as being engaged in the development of a cesium ion engine. It is believed that this Institute is probably engaged in the development of a fast reactor heat source for space applications. Information obtained at the Corrosion Conference held in Vienna in 1962 indicated that the Obninsk Institute is studying the use of liquid lithium contained in a niobium loop as a possible reactor coolant system. However, it is estimated that the Soviet experience with the BR-5 fast research reactor will probably dictate the use of liquid sodium for the first space prototype reactor.

105. Thermoelectric generators for space power conversion offer the important advantage of static operation. This property permits simplicity in design and gives a generator with a high intrinsic reliability. Soviet development of thermoelectric materials has been well substantiated and is being conducted primarily at the Leningrad Physical Technical Institute. It is estimated that the Soviets are on a par with the most advanced nations in the West in the development of thermoelectric generators and could have a suitable thermoelectric device capable of generating about a kilowatt of electric power in 1964.

106. The turboelectric conversion system has the advantage of high efficiency which permits a reduction in the size of the radiator and is most suitable for high power systems on the order of 100 KWe. It is believed that the Soviets will utilize an indirect liquid sodium turbo-conversion system for their first large nuclear power source. Based primarily on the BR-5 experience and equipment, and assuming the development of suitable turbopumps, turbines and alternators, we estimate that this type system could be flight tested as early as 1965.

107. The Soviets have shown a widespread interest in thermonic energy conversion which permits heat to be directly converted to electrical energy by thermal excitation of charged particles at the surface of an electrode. Extensive studies on thermal ionization phenomena have been noted at several institutes, including the Obninsk Institute. The Institute for Ceramics and Special Alloys of the Latvian State University have furnished to the Obninsk group the high temperature materials suitable for use in a thermionic reactor. We estimate that a thermionic power supply will become available toward the end of this decade.

108. The heat rejection system for space power supplies is a major weight item in high-power systems. The various power institutes of the USSR have been conducting studies on radiant heat transfer and the effectiveness of various configurations. Soviet weight restrictions in space vehicles are currently less stringent than those of the US, therefore, the Soviets probably can afford to use somewhat larger radiators. This in turn suggests that the Soviets may be able to optimize a reactor-radiator system composed of more common materials.

III. FISSIONABLE MATERIALS PRODUCTION (See Figure 2)

Uranium Ore Procurement

109. The State Production Committee for Medium Machine Building procures uranium ores from mining combines directly subordi-

nate to it within the USSR and from contract operations probably under its supervision in the Bloc (except China, Albania, and Poland). A variety of deposits are exploited, including veins, sandstones, oil shales, limestones, subbituminous coals and iron ore slags. The US Geological Survey estimates that the Soviet Bloc has reserves of several hundred thousand tons of uranium in medium grade ore deposits and an even greater quantity in low grade deposits. No large-reserve deposit similar in grade to the Ambrosia Lake deposit in New Mexico or the Blind River deposit in Canada has, to our knowledge, yet been discovered in the Soviet Bloc. The significantly lower grade sandstone deposits in Thuringia are the closest analog. Thus, mining and ore concentration costs are high because of the relatively low grade of the ore bodies which the USSR has found to date.

110. There are three main uranium mining and ore concentrating areas in the USSR, the Central Asian area, the Krivoy Rog iron ore district in the Ukraine, and the Caucasus area. Most of the other producing areas are small operations, with the ore being shipped to concentration plants located in the main producing areas, or being shipped directly to feed materials plants for upgrading.

111. Ore concentration plants are well designed and have substantial capacities, usually of 500 to 1000 metric tons of ore per day, although several plants have larger capacities. For example, the recently completed concentration plant at Seelingstadt, Thuringia, in East Germany has a peak design capacity of 12,000 metric tons of ore daily. The newer plants are using modern ion exchange recovery methods; however, Bloc production of appropriate ion-exchange resins has apparently been inadequate both in quantity and quality to meet the entire needs of the Soviet atomic energy program. Concentration plants had previously been identified at Dneprodzerzhinsk and Zhelty Vody in the Ukraine; Leninabad, Maily Say, Kadzhi-Say, Min Kush, and Karabalty in Central Asia; and Pyatigorsk in the Caucasus.

112. It is estimated that the USSR is currently procuring uranium ore at the rate of about 20,000 metric tons per year in terms of recoverable metal and that this rate will gradually increase over the next five years to 25,000 metric tons per year. About half of these amounts are estimated to come from within the USSR itself. The estimated 190,000 metric tons of recoverable uranium procured through mid-1963 and the 300,000 metric tons estimated through mid-1968 are believed to be sufficient for the fissionable materials production estimated herein, and for a very substantial stockpile throughout the period of the estimate. Values estimated could be higher or lower by 50%.

Uranium Feed Materials

113. Uranium metal and other feed materials are produced at Elektrostal, near Moscow; at Glazov, just west of the Urals; and at Novosibirsk in Central Siberia. These installations also contain ore concentration plants as well as facilities at one or more of them for the production of the metallic calcium used in the Soviet uranium metal production process. The lack of visible ore stockpiles and the general correlation which exists between estimated uranium ore procurement and estimated amounts of fluorine available in terms of otherwise unused acid grade fluorspar suggest that surplus uranium is stockpiled as a semi-finished product such as uranium tetrafluoride or bulk uranium metal.

The extensive warehousing adjacent to the Novosibirsk plant supports this thesis.

Plutonium-Equivalent Production

114. Three major plutonium-equivalent production sites have been identified in the USSR. The earliest and largest is located near Kyshtym in the Urals and the second is collocated with the U-235 production complex at the atomic energy site north of Tomsk in Central Siberia. The third is located within the large atomic energy site northeast of Krasnoyarsk in Central Siberia. Review of all available information leads to the conclusion that there are no other major plutonium-equivalent production sites in operation in the USSR.

115. *Kyshtym.* Very little specific information is available on the plutonium production reactors at the Kyshtym site. Construction began at that site shortly after World War II, and a small production reactor went into operation in 1948. Others have been added since, but little information is available regarding their number, type, and size. The entire site is serviced by the nearby Argayash electric power plant and is also connected to the Urals electric power network. A major addition to the site's electric power supply in the 1955 to 1957 period indicates a major expansion at that time, such that the current total reactor thermal power is estimated to be about 6000 megawatts.

116. An estimate of plutonium-equivalent production at Kyshtym has been made from an analysis of available evidence regarding the site, and results in a mid-1963 cumulative availability from this operation of about 12,000 kilograms. The data permits this cumulative availability to range from a high of 15,000 to a low of 9000 kilograms as of mid-1963. Current annual production of plutonium-equivalent at Kyshtym is estimated to be about 1400 to 1500 kilograms.

117. *Tomsk.* 1957 photography of the reactor complex at the Tomsk atomic energy site shows one plutonium production reactor which we believe became operational in 1955 and two dual-purpose reactors under construction which probably became operational in 1958 and 1961. Also under construction was a large chemical separations plant. The two dual-purpose reactors are currently estimated to be operating at a power level of about 1200 megawatts, and the earlier single-purpose reactor at about 1500 megawatts.

118. Plutonium-equivalent production from the Tomsk reactors is estimated on the basis of cooling water availability from water treatment facilities taken in conjunction with detailed analysis of interior photographs of the first dual-purpose reactor installation, obtained at the Geneva Conference on the Peaceful Uses of Atomic Energy. It is estimated that the probable mid-1963 cumulative plutonium-equivalent production from Tomsk is 3800 kilograms. The data permits this cumulative production estimate to range from a high of 4500 kilograms to a low of 2000 kilograms as of mid-1963. Current annual production of plutonium-equivalent at Tomsk is estimated to be about 900 kilograms.

119. *Krasnoyarsk.* The construction of the large atomic energy site near Krasnoyarsk began in 1949 and, [redacted] was still not in operation by early 1956. [redacted] suggests weapons fabrication and stockpiling facilities were under construction as well as a large river water intake at the foot of a hill containing many tunnels and shafts. The earliest date for significant reactor operations consistent with available information is the first half of 1958. Additional reactor facilities were probably added in the 1959–1962 period. Current

electric power availability at the site is consistent with a total reactor thermal power of about 3000 megawatts. This results in a probable mid-1963 cumulative plutonium-equivalent production from the site of about 1900 kilograms, although the data permits values as high as 4000 kilograms and as low as 1000 kilograms. Current annual production at Krasnoyarsk is estimated to be about 500 kilograms.

120. *Future Production.* Available information, including projected increases in electric power availability in the Tomsk and Krasnoyarsk areas, indicates probable significant increases in reactor capability through 1968. It is thus estimated that future annual plutonium production will increase at a moderate rate consistent with performance during the period 1958 to 1962 through new construction, increasing the power levels of existing reactors, and as a by-product of the nuclear power and propulsion reactors. This latter source (included in Table II), will contribute in amounts increasing to about 600 kilograms per year in 1968. This could be used in weapons by mixing with plutonium produced at considerably lower irradiation levels and would also have other uses.

121. It is estimated, on the basis of the factors discussed above, that future annual plutonium-equivalent production will increase at a rate consistent with performance during the period 1958 to 1962 and result in a cumulative plutonium-equivalent production of 35,000 kilograms by mid-1968. Even with an extremely high priority effort the cumulative plutonium-equivalent stockpile would not exceed 45,000 kilograms by mid-1968. Alternatively the minimum likely cumulative production by that date will not be less than 25,000 kilograms of plutonium-equivalent.

U–235 Production

122. Three large gaseous diffusion isotope separation complexes capable of concentrating U–235 up to weapon-grade product are in operation in the USSR; one at Verkh-Neyvinsk in the Urals, one north of Tomsk in Central Siberia, and the third at Angarsk in the Lake Baykal region. A fourth large gaseous diffusion complex is under construction north of Zaozerniy near Krasnoyarsk. [ ]we believe that no undetected large gaseous diffusion U–235 plant is currently in operation. The continuing construction of large gaseous diffusion plants in the USSR suggests that significant Soviet U–235 production by the ultra-centrifuge and other methods is unlikely.

123. The electrical efficiency of the Soviet gaseous diffusion process in 1952 was calculated on the basis of information from German scientists who had worked on the program, and on the basis of estimates of electric power and barrier material then available. The value obtained was consistent with reasonable assumptions of compressor and motor efficiencies and was supported by the efficiency of Soviet gaseous diffusion plants given to an Austrian scientist as the performance with which he had to compete in his gas centrifuge development work in the USSR. Subsequent efficiencies have been extrapolated from this base, considering advances in Soviet compressor technology and changes in process building design and utility supplies observed in aerial photography to indicate the time, nature and magnitude of improvements.

124. Changes in process building design parameters indicate the use of an improved barrier starting in 1958. The efficiency of this barrier can only be approximated, since no data on its operating characteristics have been received. The resultant estimated efficiencies and other assumed process characteristics are, however, similar in many details and order of magnitude to values used by the Soviet physicist A. M. Rosen in a 1960 com-

putation leading to his estimate of the production of US gaseous diffusion plants.

125. The estimate of U–235 production is, [redacted] However, such data must be combined with information on plant operating characteristics that is less well known. Compressor and interstage flow parameters are chosen to be consistent with Soviet practice in other industries and are not based on actual practice at Soviet U–235 plants. Finally, data on feed materials concentrations is about six years old and may well have only rough correspondence to practice in later years. Thus, production estimates since 1958 must contain an increasing probable error dominated by these uncertainties on plant operating characteristics.

126. Eye witness reports, published information on the electric power industry and aerial photography have provided the basis for a detailed chronology of building construction and of the growth of the Soviet gaseous diffusion program. However, we now believe that the current pace and magnitude of the expansion is somewhat less than previously estimated, resulting in a slight downward revision in cumulative production values.

127. *Verkh-Neyvinsk.* This is the oldest of the Soviet U–235 plants. Construction commenced here early in 1946 and production of weapon-grade U–235 began in 1951. Construction continued through 1958 when the plant consisted of five separate areas (each containing several buildings). Its electric power was supplied principally by the nearby Verkhne Tagil Power Plant. The remainder of the power was supplied by other Urals power stations through the 220 KV Urals electric power grid.

128. Additional generating capacity was completed in mid-1962 at the Verkhne Tagil Power Plant which is directly connected with the Verkh-Neyvinsk plant. Since the increased electrical consumption at Verkh-Neyvinsk was accomplished without additional cooling water facilities or building construction [redacted]

129. Published power transmission line diagrams imply that the Beloyarsk nuclear electric plant will also supply Verkh-Neyvinsk and there is current information on the continued expansion of the Urals electric power grid. It is therefore estimated that additional construction will occur at the Verkh-Neyvinsk gaseous diffusion plant which will start drawing electric power about 1965.

130. *Tomsk.* Construction started on this second U–235 complex in June 1949 and in 1957 there were four operating buildings. Power was supplied by an on-site thermal plant with backup from the main power plant in Tomsk city.

131. As of 1957, the on-site power plant was being expanded and a nuclear-electric power station was being added. In 1962, the site was also connected to the Siberian power grid through Tomsk City. New construction at the U–235 plant [redacted] is believed to have been finished early in 1962 with the completion of a sixth building. It is estimated that installation of an improved barrier in the four older buildings will take place by mid-1964. There is no indication that future additions to the U–235 plant are intended, although available water supply would permit at least a 50% expansion.

132. *Angarsk.* Eyewitness reports indicate that construction of the Angarsk atomic energy site commenced in 1954 and that by early 1958 part of the first building was oper-

ating and the shell of a second building had been completed. The plant now contains four U–235 buildings each about 3000 feet long, with the fourth building not completely in operation.

133. The plant is supplied electric power from an on-site power plant, from the Irkutsk Hydroelectric Plant and from the Bratsk Hydroelectric Plant.

134. *Zaozerniy.* Construction is proceeding on at least two large U–235 buildings at the Zaozerniy site. Partial operation of the first building is expected in 1963–1964. The "Irsha-Borodino" thermal power plant is under construction near the site. The site will be connected in late 1963 or early 1964 to the grid running from Nazarovo to Bratsk.

135. Our estimate of total Soviet cumulative U–235 production is presented in Table II in terms of cumulative production of uranium enriched to 93 percent U–235 content. It includes the 93 percent equivalent of material produced at lesser enrichments. Estimated expenditures for weapon tests and non-weapon uses of U–235 especially for nuclear powered submarines have been subtracted from the value of cumulative U–235 production to give our estimate of equivalent 93 percent U–235 available for weapon use.

136. *Margins of Error.* It is estimated that the Soviet cumulative U–235 production for mid-1963 is 130,000 kilograms.[9] (See Table II). It is unlikely that actual Soviet mid-1963 cumulative U–235 production could be less than 80,000 kilograms or more than 180,000 kilograms. It is estimated that the mid-1968 cumulative production will be 380,000 kilograms and we believe, with a fair degree of confidence that the actual U–235 production would not be less than 190,000 kilograms or more than 570,000 kilograms.

Table II

ESTIMATED SOVIET FISSIONABLE MATERIALS PRODUCTION[13]

(Cumulative Production in Kilograms Rounded)

	U–235		
Mid-Year	(93%)[10,12] Total	Available for Weapon Use	Plutonium Equivalent[11]
1950	25	25	100
1951	160	160	330
1952	600	600	550
1953	1,550	1,550	1,000
1954	3,350	3,350	1,600
1955	6,300	6,300	2,200
1956	10,500	10,500	2,900
1957	16,500	16,000	3,800
1958	24,500	24,000	4,500
1959	36,500	35,500	6,000
1960	53,000	51,000	8,000
1961	72,000	70,000	9,700
1962	100,000	96,000	12,000
1963	130,000	125,000	15,000
1964	170,000	165,000	18,000
1965	210,000	200,000	22,000
1966	260,000	250,000	26,000
1967	320,000	310,000	30,000
1968	380,000	370,000	35,000

[9] The Assistant Chief of Naval Operations (Intelligence), Department of the Navy, believes that the lower limit of the estimated value for cumulative production of U–235 is the more nearly correct. He believes that the evidential base is insufficient to support the production efficiency which a higher cumulative total would require.

[10] Production of less highly enriched uranium is included as equivalent quantities of 93% material.

[11] Non-weapon uses of plutonium are expected to be negligible during the period of this estimate.

[12] See Footnote 9 for view of the Assistant Chief of Naval Operations (Intelligence), Department of the Navy.

[13] Our current and future estimates of cumulative production of fissionable materials represents some decrease from those estimated in NIE 11–2A–62. These changes are the result of further analyses and the acquisition of additional information. However, it should be noted that the margin of error involved in any one year's value of cumulative production is larger than the magnitude of these changes.

Other Nuclear Materials

137. *Thorium and U–233.* The Soviets showed moderate interest in the procurement of thorium-bearing minerals between 1946 and 1952. Quantities of rare earths were processed at the Experimental Plant of the State Institute of Rare Metals at Podolsk, especially the lanthanum chemicals required by the early Soviet plutonium separation process.

138. The only evidence of the production of U–233 from thorium is [

] and its utilization in small quantities as reported in the open Soviet scientific literature.

139. *Lithium.* The main sources of lithium ores in the USSR are Zavatinsk near Shilka in Chita Oblast, the Tadzhik SSR, and the Kazakh SSR. The Soviet literature also indicates discovery of lithium-bearing ore bodies on the Kola Peninsula in 1957, but their precise location is unknown.

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141. A sample of 92 percent lithium–6 purchased from the USSR contained mercury in amounts consistent with its manufacture by the mercury amalgam isotope separation process. The locations of Soviet lithium–6 isotope separation plants have not been positively identified but could be located in certain facilities at the Nizhnyaya Tura and Novosibirsk atomic energy sites.

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143. *Zirconium.* Soviet research on the development of a process for producing reactor grade zirconium (Hafnium-free) began in 1952 and was intensified in the mid-1950's. There is strong evidence that the Soviets adopted a purification process based on the electrolysis of fused salts followed by the volatilization of the zirconium as an iodide. This zirconium is then alloyed with 1 to 2.5 percent niobium to improve corrosion resistance and its mechanical properties. A plant for the production of reactor grade zirconium, whose location is not known, is believed to have been completed in 1957. Zirconium-clad fuel elements are used in the nuclear reactors of the icebreaker LENIN, and by implication in the nuclear submarine cores. It is believed that adequate capacity is available to meet the needs of the Soviet atomic energy program. The Soviets have a major deposit of zirconium ore near Zhdanov in the Ukraine.

144. *Beryllium.* The USSR possesses large reserves of beryllium ore at Izumrud in the Urals and established, in the pre-war period, a combine there to manufacture beryllium-copper and other alloys. It is believed that sufficient quantities of beryllium ore and metal producing facilities are available to support both the nuclear weapons and reactor programs of the USSR.

145. Returned German scientists have reported interest in beryllium metal shapes at the Elektrostal feed materials plant and atomic energy Research Institute No. 9 as early as 1946. Plant A of the State Institute of Rare Metals was involved from 1947 through 1952 in the production of beryllium oxide bricks for reactor research at Obninsk. In 1958 physicists from the Ukranian Physics Technical Institute, one of the leading nuclear physics research laboratories in the USSR, published on the preparation of pure beryllium in industrial quantities by a vacuum distillation method.

146. *Heavy Water.* Since 1945, the USSR has constructed heavy water (D_2O) produc-

tion plants at some eight locations (see Figure 2) using at least 4 different processes. Installed plant capacities are believed to be sufficient to produce about 90 metric tons of heavy water per year. It is believed cumulative production has been adequate for Soviet needs.

147. Starting about 1952, liquid hydrogen distillation units for the production of deuterium were installed at a plant in the USSR using hydrogen derived from water-gas synthesis units. Since 1960 the USSR has started on a program to replace electrolytic hydrogen production by natural gas as a source of hydrogen in its nitrogen combines. If these plans are carried out, some additional heavy hydrogen separation units must be installed in order to maintain current annual production rates.

148. The estimated annual and cumulative production of heavy water is shown in Table VI with an estimated cumulative production through mid-1963 of about 1100 tons of heavy water. The actual production could be up to 50% more than that estimated if the hydrogen distillation process were adopted at all catalytic exchange plants in the post 1952 period or if an unknown but large additional facility exists such as the possible one at Combine 16, Angarsk.

149. This estimate indicates that sufficient heavy water was produced by late 1952 to permit the stocking of the first heavy water moderated production reactor, believed to have been put into operation in this period at the Kyshtym reactor site with about 175 tons of heavy water. In addition to other usage, two additional heavy water moderated reactors using 200 tons heavy water each could have been installed by the end of 1958 (possibly at Krasnoyarsk). The total estimated consumption corresponds reasonably with estimated production.

Table VI
SOVIET HEAVY WATER PRODUCTION
Metric tons D_2O

End year	Annual	Cumulative
1947	3	3
1948	4	7
1949	33	40
1950	45	85
1951	48	130
1952	58	190
1953	69	260
1954	69	330
1955	87	420
1956	87	500
1957	87	590
1958	87	680
1959	87	760
1960	87	850
1961	87	940
1962	87	1,030
1963	87	1,110

IV. SOVIET NUCLEAR WEAPONS PROGRAM (See Figure 1)

Nuclear Weapon Research and Development Installations

150. *Sarova.* The oldest Soviet center specifically concerned with nuclear weapon research, design, and development is located at Sarova about 250 miles east of Moscow.

151. Photography has revealed here a large, elaborate, heavily secured installation containing laboratories, industrial-type structures suitable for the fabrication and machining of explosive and non-explosive components, a number of high explosive (HE) test points, and a ballistics test facility.

152. *Kasli.* A second nuclear weapon research and development center, near Kasli in the Urals, probably became operational late in 1959. The complex, while similar, is considerably smaller than Sarova.

153. *Supporting Institutes.* The Soviet nuclear weapon program has certainly also been supported by research conducted at a number of other institutes in the USSR probably in-

cluding the Institute of Atomic Energy, Moscow; the Physics Institute, Obninsk; Physical-Technical Institute, Sukhumi; and especially the Institute of Chemical Physics, Moscow.

154. *Kerch/Bagerovo.* The Soviet research and development establishment at Kerch/Bagerovo Airfield has probably been concerned since its establishment with nuclear weapon systems development, particularly those involving aircraft. It has probably provided the drop aircraft and crews for nuclear devices tested by airdrop.

155. *Nuclear Weapon Test Areas.* The Soviets have used two primary nuclear weapon test areas: the Semipalatinsk Proving Ground in Central Siberia (86 tests) and the Novaya Zemlya area in the Western Arctic (88 tests). In addition, they held 11 tests at the Kapustin Yar Missile Test Range (KYMTR) in Central Asia and, on 14 September 1954, they held a military effects test (JOE 8) in conjunction with military maneuvers near Totskoye, southeast of Kuybyshev in the eastern European section of the USSR. Of the 186 nuclear detonations[

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156. *Semipalatinsk.* The Semipalatinsk Proving Ground is located in northeastern Kazakhstan about 100 miles west of Semipalatinsk. From 1949 through September 1957 the majority of Soviet tests were held here. Since then, only low-yield tests have been held in this area.

157. Aerial photography prior to 1958 has revealed a variety of test operations including ground bursts, air drops and tower shots, as well as tests combining one or another of the foregoing methods with arrays designed to test effects of nuclear detonations on military equipment and probably, in a few instances, on entrenched personnel as well. Large scale grids to the west of the usual detonation area probably were constructed to study contamination effects from one-point safety tests, but may possibly have also served for the testing of radiological warfare devices. Although we have no specific evidence, we believe that ground tactical systems have probably been proof tested at Semipalatinsk.

158. On 11 October 1961 and on 2 February 1962, the Soviets held their first known underground tests (JOEs 100 and 120). While these two tests are included in the general category of Semipalatinsk tests, they were not conducted at the proving ground itself, but in a rugged hill area about 40 miles to the southwest. These tests probably permitted the Soviets to evaluate underground instrumentation techniques for obtaining diagnostic weapons data and to study seismic data obtained from the tests in connection with underground test detection problems.

159. *Missile Test Range Activities.* 1959 photography disclosed the existence of separate nuclear handling facilities at the rangeheads of the surface-to-air (SAM) and surface-to-surface missile areas of the Kapustin Yar Missile Test Range and at the Sary Shagan Anti-Missile Test Center (SSAMTC).

160. Prior to the end of 1958, the Soviets conducted three, probably four, nuclear/missile tests at the Kapustin Yar Missile Test Range. JOE 29 on 19 January 1957 and JOEs 73 and 74 on 1 and 3 November 1958 were carried by surface-to-air missiles. In addition, JOE 20 on 2 February 1956[ ]was probably also launched from Kapustin Yar, but is believed to have been the test of a warhead for a nominal 700 nm ballistic missile rather than for a SAM. During the

1961 test series, the Soviets continued their SAM warhead development with the test of JOE 79 on 6 September and began a series of high-altitude tests which they continued in 1962 probably to collect data relevant to their anti-ballistic missile problem.

161. We have no evidence of any nuclear/ICBM tests; however considering the status of the Soviet ICBM program, we believe that extensive warhead compatibility testing has been undertaken for these missiles. Similarly, we believe there has been warhead compatibility testing in connection with all other deployed missile systems having a nuclear capability.

162. *Novaya Zemlya Nuclear Test Ranges.* Three locations within the Novaya Zemlya area have been used since 1955 for nuclear tests. Mys Sukhoy Nos on the west coast has been used primarily for high-yield air bursts; the southwestern coastal waters near Krasino for air bursts and surface and underwater tests; and the eastern coastline north of Proliv Matochkin Shar for air bursts having a variety of yields. We believe that the majority of the air burst tests were delivered by medium and heavy bombers and that the most likely staging base for these aircraft would be the LRAF airfield near Olen'ya on the Kola Peninsula which has nuclear weapons handling facilities.

163. The Soviet Ministry of Defense announcements of the closure of the Novaya Zemlya area issued before the 1961 and 1962 test series were unique in that they indicated that the Rocket Forces as well as the Air Force and Northern Fleet would participate in the coming exercises. On the basis of these announcements and [ ] we believe that some of the 1961 and 1962 Novaya Zemlya tests involved operational missile systems; [ ]

Weapon Development Program (Low-Yield Devices)

164. [ ]

165. *Fission Tests, 1949–1958.* Through 1958, the Soviets conducted numerous tests of fission devices encompassing a variety of yields, compositions and physical sizes. [ ]

166. [ ] some fission weapons were designed with several yield options ranging from 30 to 200 KT. We believe these were different yields of the same weight warhead. [ ] nuclear warheads yielding from 5 to 30 KT in diameters suitable for their 310 mm guns, 420 mm mortar, and other delivery vehicles are in the Soviet stockpile. [ ]

167. *Low-Yield Tests 1961–1962.* Of the Soviet tests in the 1–200 KT yield range [ ]

168. The 1962 test series, where the majority of the low-yield tests were 10 KT or under, included the development of warheads of very low kiloton and possibly sub-kiloton yield.[

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(Thermonuclear Weapon Developments)

169. The geophysical signals from Soviet thermonuclear tests generally give more reliable yield values than are obtained for low-yield tests. [

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170. *Thermonuclear Tests, 1955–1958.* Be-

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171. *1961–1962 Test Series.* Of the 112 detected tests[ ] thermonuclear devices with yields ranging from about 150 kilotons to 63 megatons. During the 1961 series there was a preponderance of tests in the 1–5 megaton region and an absence of tests between about 5 and 20 megatons. In the 1962 series the tests were rather evenly distributed from 150 kilotons to 30 megatons, with more emphasis than in 1961 on the submegaton range and on tests yielding from 13–30 megatons. Analysis of these tests indicates that the Soviets have developed a highly competent thermonuclear weapon technology which, in some areas, differs from that of the US.[

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173. The two largest Soviet nuclear explosions (30 MT and 63 MT) were both clean thermonuclear devices. [

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174. *Lower Yield Thermonuclear Tests (150–1200 KT).* [

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175. *Intermediate Yield Tests (1.5–6 Megatons).* [

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[redacted]

176. [redacted]

177. [redacted]

178. [redacted]

179. *High-Yield Tests (13–63 Megatons).* Two 13 MT tests (JOEs 144 and 158) and two 24 MT tests (JOEs 147 and 148) were held in 1962.

180. [redacted]

181. [redacted]

182. [redacted]

[redacted]

183. [redacted] JOE 111 (63 MT), detonated in 1961, was probably a clean test of the much publicized 100 MT weapon, and was similar in many ways to JOE 124.

(High Altitude Tests)

184. JOE 79 on 6 September 1961 was the test of a 25 KT warhead probably delivered to a detonation altitude of about 50,000 feet by a surface-to-air missile, since its detonation point was in the SAM area of the KYMTR.

185. JOE 98 on 6 October 1961, was the high altitude test of a 200 KT warhead over the KYMTR, and is believed to have been detonated at an altitude somewhere between 100,000 and 200,000 feet. [redacted]

186. JOEs 105 and 109 of 21 and 27 October 1961 and JOEs 157, 160 and 168 of 22 and 28 October and 1 November 1962 were high-altitude nuclear detonations near the Sary Shagan Anti-Missile Test Center (SSAMTC) of devices carried by missiles from the KYMTR. These complex tests were apparently conducted to obtain both basic high-altitude effects data and data applicable to the anti-ballistic missile (ABM) problem.

187. JOEs 105 and 109 each involved the firing of two 1020 n.m. ballistic missiles from the Kapustin Yar rangehead approximately two and one-half minutes apart; the first missile in each case probably carried the 1-KT nuclear payload. JOE 105 was detonated at approximately 160 n.m. altitude and JOE 109 at 80 n.m. For JOE 105, a missile which appeared to carry a spectrometer device was fired vertically to a point about 100 nautical miles above the detonation point and subse-

quently descended through the nuclear cloud. A missile, possibly an ABM, was probably launched about four minutes after burst time, and a second vertical firing through the cloud occurred about half an hour after burst time. In the JOE 109 operation, two possibly downrange firings were noted.

188. The 1962 high-altitude tests, JOE 157 on 22 October, JOE 160 on 28 October, and JOE 168 on 1 November, resembled those of 1961, but appeared to be more complex. All three involved the firing of three 1020 n.m. missiles from the Kapustin Yar rangehead; in each case the second missile was launched about fifty seconds after the first, and the third about six minutes after the first. As in 1961, the nuclear payloads are believed to have been carried by the first missiles.

189. JOEs 157 and 160 each had yields of 200 KT. The former was detonated at an altitude of about 160 n.m.; the latter, at an altitude of about 90 n.m. [ ] For the JOE 157 event, a missile, which probably had a purpose similar to the first vertically fired missile of the JOE 105 operation, was fired from a downrange location.

190. JOE 168 had a 1.8 MT yield and was detonated at an altitude of about 30 to 70 n.m. Unlike the other high altitude tests, JOE 168 was not one of an obvious pair of devices having identical yields but tested at different altitudes. The yield of JOE 168 was similar, however, to that of the US 9 July 1962 STARFISH device (1.45 MT) detonated 216 n.m. above Johnston Island in the Pacific. It is noted that Soviet scientific expeditionary ships were positioned both in the vicinity of Johnston Island and in the conjugate area probably to collect data from STARFISH. We believe that JOE 168, which was detonated on 1 November 1962 at 30–70 n.m., could have served along with STARFISH to give the USSR some data on high altitude effects from a pair of 1.5–1.8 MT tests at different altitudes.

191. A unique feature of all three 1962 high-altitude tests was the apparent planned use of a satellite to collect basic physical data. COSMOS XI passed over the burst point of JOE 157 within minutes of the detonation; it was at the antipodal point for the JOE 160 test at the time of detonation; and it was near the magnetic conjugate point of the JOE 168 detonation at time of burst. There is some question whether COSMOS XI was still transmitting at the time of JOE 168.

Nuclear Weapons and Systems

192. A small number of individually produced weapons for interim use could be fabricated within a few months after device testing. However, the time lag between nuclear test device and initial stockpile entry of serially produced weaponized versions is about two years at a minimum. On this basis some of the new devices tested in 1961 could be entering stockpile during the latter part of 1963 if a priority development requirement is assumed. It is estimated, however, that this could only be done on a limited scale, and that, in general, the devices tested in 1961–1962 would be stockpiled in 1964 and 1965.

Delivery Systems Information

193. [ ] indicate that the warhead assigned to the tactical SS–1a missile has a yield spectrum of 30 to 200 kilotons. [ ] data from which the warhead yield categories associated with other Soviet tactical missiles in the SS–1, SSC–1 and SS–2 categories can be generally derived. There is evidence [ ] that nuclear warheads for Soviet tactical missiles and

free rockets are designed with both air-burst and ground-burst fuzing options.

194. Some of the newer air defense fighters are expected to achieve a nuclear capability when air-to-air missiles with improved semi-active radar homing systems and payloads compatible with substantially larger heavier warheads are deployed. However, there is no evidence that such later generation AAMs have as yet been deployed to operational air defense fighter units.

195. There are numerous references [ ] to naval torpedoes with nuclear applications. In the Soviet test program JOE 110, the 15 KT device detonated at the traditional naval proving area south of Novaya Zemlya on 27 October 1961, is a possible candidate for torpedo warhead application.

Weapon Production and Stockpiling Sites

196. The Soviet nuclear weapon logistic system includes three general classes of sites: (a) National Reserve Stockpile facilities with associated weapon production plants at interior locations; (b) National Assembly-Stockpile sites located near major order-of-battle concentrations; and (c) Operational and Regional storage sites at military bases for the direct support of military operations.

197. The Soviet stockpile program has developed in three rather well defined stages. Expansion has continued in each class of existing sites and addition of new sites has occurred. In its initial program the USSR activated between 1951 and 1955 a total of about 6 stockpile sites of all classes. In the second stage, covering approximately the next three years, at least 18 additional stockpile sites of all classes were activated bringing the total to about 24 at the end of 1958. This expansion was primarily to support a substantial increase in the nuclear capability of the Soviet strategic bomber force which was then rapidly converting to jet aircraft and a limited development of nuclear capability in Naval and Tactical Aviation and probably Ground and Naval forces as well. Since 1958, a third stage of rapidly accelerated construction has been evident. It has coincided with the deployment of strategic and tactical missiles with a nuclear capability, and with a wider distribution of nuclear weapons among Soviet military forces. We estimate that in this period, the USSR has substantially increased the capacity of previously existing stockpile sites. In addition, it has constructed a minimum of about 23 new stockpile sites of all classes bringing the total to at least 47 sites. [ ]

198. National Reserve Stockpiles associated with weapon production facilities and the National Assembly-Stockpile Sites are probably administered by the State Production Committee for Medium Machine Building. These national facilities have been consistently characterized by isolation, extreme security, hardened bunkers (either earth-mounded or underground) and self-sufficiency in housing and other services required by the permanent cadres. Some changes in detail of structures in the operations areas has been evident in the assembly stockpile facilities constructed after about 1958.

199. We believe that Operational and Regional military storage sites associated with military bases are operated by the Ministry of Defense. Most are located apart from other base facilities and are characterized by stringent physical security measures. [ ]

[redacted]

200. As a result of these developments the USSR now has a comprehensive system of hardened stockpile facilities extending back in successive echelons from forward operational storage sites at military bases to national reserve facilities at remote interior locations. This system seems clearly designed to support more than an initial strike.

201. In the future the expansion most likely to occur will involve an increase in the number of missile-related storage facilities (although the pattern of warhead storage for missiles is not yet clear) and some increase in the number of field sites directly supporting tactical air units. We are uncertain as to how fully the requirements of Naval Submarine and Surface Forces and of Air Defense Forces have been met but believe that some increase in nuclear weapons storage facilities for these forces will occur.

202. Nuclear weapon fabrication complexes have been identified in the Urals at Nizhnyaya Tura and at Yuryuzan. A possible third complex is located in Central Siberia near Krasnoyarsk. National reserve stockpile sites are collocated with these three complexes.

203. *Nizhnyaya Tura.* The first fabrication-stockpile complex constructed in the USSR is located near Nizhnyaya Tura in the North Central Urals. We believe that the first facilities of the complex began operation in the latter half of 1950. Some construction and expansion of the enterprise was continuing at least through 1959.

204. [redacted] this complex is probably the major nuclear weapon production center in the USSR. It contains facilities suitable for the fabrication of explosive and non-explosive components for nuclear weapons and for the final assembly and storage of the weapons. The size and the remote location of the high explosive (HE) test facility, which is probably used primarily for quality control, indicate that complete assemblies of HE may be tested here.

205. A new area which was under construction in July 1959 stands out as a separately staffed underground installation with its own support facilities. Although its precise function has not been determined, it appears to be an additional nuclear weapon fabrication and assembly installation, possibly producing weapons.

206. *Yuryuzan.* Another nuclear weapon fabrication-stockpile complex in the Urals is located near Yuryuzan, approximately 240 nm south of Nizhnyaya Tura. We believe that the complex probably became operational in 1955 or 1956. Although the Yuryuzan complex appears to be similar to the Nizhnyaya Tura complex, its production facilities are estimated to be smaller, while its stockpile capacity is probably greater than that of the latter.

207. *Krasnoyarsk.* The atomic energy complex near Krasnoyarsk in Central Siberia contains a probable national stockpile facility. Although a nuclear weapon fabrication installation has not been definitely identified, a fabrication facility at this location would logically support the eastward expansion of the Soviet nuclear weapons logistic system. Certain

aspects, such as the existence of a high explosive storage area, are suggestive of weapon fabrication facilities.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

IRBM/MRBM Support

220. [redacted] stated that at the launch sites there are storage facilities for the missiles, nose cones, and fuel, and have emphasized that an important part of the prelaunch procedures is nose cone checkout. It is assumed that any necessary checkout of the nuclear warhead occurs at that time. The facilities to be used for this checkout have not been identified.

ICBM Support

221. The basic pattern of nuclear support at Soviet ICBM complexes is probably similar

to that of the MRBM/IRBM sites, and we would expect at least some of the ICBM complexes to have on-base facilities for nuclear warheads.

Naval Nuclear Weapon Storage

222. A probable nuclear weapon storage facility has been recently identified in a Soviet naval complex [redacted] near Severomorsk on the Kola Peninsula. [redacted] The function of these buildings has not been determined. We believe the facility [redacted] must also include storage bunkers, probably in a secure area well back from the dock area. The naval complex containing the nuclear facility is associated primarily with Soviet missile carrying submarines which it evidently supplies with missiles and probably with nuclear warheads. [redacted] is the first apparent nuclear storage to be identified for either the submarine or surface forces of the Soviet Navy. We feel certain, however, that other nuclear storage facilities exist to support Soviet naval forces, and will be identified in due course.

223. We believe that Soviet Ground Forces require field storage facilities in addition to the regional depots already identified, that the NAF requires storage sites for its AS–2 (KIPPER) missile-carrying BADGERS, and that some nuclear storage may be required for the surface-to-air missiles of air defense forces. We have been unable, however, to identify any of these storage areas.

Soviet Nuclear Weapon Storage in the European Satellites

224. We have no firm evidence that Soviet forces stationed in the European satellites have acquired nuclear weapons. However, the Group of Soviet Forces in Germany (GSFG) have acquired short-range rockets and the GSFG have simulated nuclear weapon employment during maneuvers.

225. No nuclear warhead storage facilities have been identified in East Germany, nor is there definitive information that nuclear weapons have been deployed to the GSFG. If no permanent nuclear storage facilities exist in East Germany the rocket and missile-equipped units which have been assigned a nuclear delivery role probably would have to be supplied from forward stockpile sites [redacted] or [redacted] sites near the western border of the USSR.

Logistics

226. The Weapon Fabrication-Reserve Stockpile installations are all located within the interior of the USSR and can operate as self-sufficient complexes. However, because of location and transportation limitations, these installations apparently are not intended to support a specific grouping of forces on an immediate operational basis. Thus, the stockpile of weapons at these sites probably represents a national reserve to be employed during the later phases of a nuclear conflict.

227. The national assembly-stockpile sites, though incapable of a very rapid deployment of weapons unless airlift of weapons by helicopter is employed, provide direct support to and a strategic reserve for the operational sites. In addition, a forward base, such as Delyatin, can provide direct support to the Soviet forces in the Satellite countries.

228. The regional [redacted] facilities are located so that they can provide support to strategic missile launch sites and to the free rocket and tactical missile units in their specific areas. Thus it appears that the weapons stored in these facilities represent an operational reserve to be sent to forward areas as required.

229. The airfield storage sites represent an operational capability for use by the Long Range Air, Naval Air, or Tactical Air Forces at their associated airfields. In addition there is usually sufficient storage to provide support for other forces located in the area or for restrike missions by the forces based on the airfield.

230. The system of on-base storage sites to support LRAF and also probably NAF units is probably now about completed, although some increase in the number of sites supporting tactical air units may occur. The system of [redacted] sites constructed near regional military depots and at certain airfields to provide second echelon operational support on a regional basis now constitutes a rather substantial logistical backup for deployed Soviet nuclear forces in the crucial border military district of Western USSR, and although the number of such units may continue to increase we believe that the expansion will be quite gradual. The expansion in the system of national assembly-stockpile facilities now underway in the Western USSR is expected largely to satisfy the Soviet requirement for sites of this type for the immediate future. We have seen no evidence to indicate that the number of national fabrication-stockpile facilities will increase in the immediate future.

231. Since 1959, the Soviets have shown an increasing interest in developing an air logistics system. [redacted] have recommended that nuclear weapon storage sites should be situated near airfields so that their weapons can be transported rapidly by air to wherever they are needed. Helicopter transport to advance positions of simulated nuclear weapons for tactical systems, as well as of other supplies, has, in fact, occurred in Soviet military maneuvers.

232. Other evidence of improved handling procedures since 1957 is apparent [redacted]

Command and Control

233. *Decision.* [redacted] indicates that the stockpiling, movement, issuance and use of nuclear weapons in the USSR is subject to initial authorization of the Presidium of the Central Committee of the Communist Party, probably upon the advice of the Supreme Military Council. [redacted] indicated that command is exercised by Chairman Khrushchev through the Supreme High Command and implemented by the Minister of Defense and General Staff. The Supreme High Command, possibly a "shadow" organization in peacetime, has the primary responsibility for the allocation of strategic nuclear strikes and for the over-all planning and direction of the strategic nuclear attack. It also has direct control of certain reserves of nuclear weapons and forces to be committed in support of both strategic and tactical operations.

234. *Command.* The flow of orders from the Supreme High Command is arranged so as to achieve maximum control and minimum delay in action. In the Strategic Rocket Forces, for instance, orders pass through the Commander and his main Staff directly to regiments responsible for nuclear fire. In the case of Theatre Forces, once employment of nuclear weapons has been authorized, responsibility for alerting forces and ordering execution of nuclear fire is delegated to major joint service commanders at the Military District, Group of Forces, or Front level. The Commander at this level may allow his subordinate commanders down to Army level some discretion in authorizing the use of nuclear weapons, but it is evidently rare for

commanders below that level to have any such discretion. In the case of special nuclear attack groups of tactical missiles and artillery, the Joint Service Commander evidently issues the order to prepare and execute nuclear fire directly to the units concerned, and their immediate superiors merely supervise execution of the order. Presumably Long Range Aviation, the Naval Forces and the Air Defense Forces operate in similar fashion.

235. *Control of Nuclear Weapons.* Although ultimate authority resides with the Presidium of the Central Committee of the Communist Party, national stockpile facilities of both types are under the direct control of the State Production Committee for Medium Machine Building. The Ministry of Defense is believed to control operational stockpile facilities located at military bases. The Committee of State Security (KGB) is responsible for the security of all nuclear stockpile facilities, provides their guard force and is responsible for escorting movements of nuclear weapons to and from national stockpile facilities and military depots. There is some evidence that responsibility for the management of logistical functions, such as storing, maintaining and delivery of nuclear weapons in support of military operations has been assigned to organizations operating in direct support of the major force components of the Ministry of Defense. For example, it has been reported [redacted] that the Chief Artillery Directorate is responsible for the storing and supplying of both tactical missiles and their associated warheads. These are stored separately and brought together for mating and use only on proper authorization by higher authority. [redacted] in 1961 warheads and missiles allocated for use by the Strategic Rocket Forces were held separately until a rather advanced stage of an alert had been authorized through the Chief of Strategic Rocket Forces.

236. We have no evidence to indicate whether or not the Soviets have either considered or installed safeguards in their nuclear weapon control procedures (such as permissive links).

237. *Signs of Innovation.* There is abundant evidence that the USSR was seriously preoccupied with the problem of improving its command and control procedures for nuclear weapons from 1959 and through at least 1961. The introduction of strategic missiles had complicated the problem of central control and had made more rapid response an urgent necessity. In addition [redacted] Soviet theatre forces [redacted] under field conditions many of the logistical practices and procedures governing the issue and servicing of nuclear weapons were cumbersome and operationally impractical. Some streamlining of the control system has probably occurred by now, although precise details are not yet known.

V. FUTURE WEAPON DEVELOPMENT AND TESTING

238. The status of Soviet nuclear weapons technology, while highly sophisticated and in most respects apparently adequate for their present needs, is such that significant advances can still be made through further development and testing. We believe that the Soviets are continuing an aggressive weapon-development program. In the course of this program the Soviets will certainly experience a strong motivation to conduct further nuclear tests.

239. *Weapon Effects.* Probably one of the strongest requirements for further Soviet nuclear testing is in the area of high-altitude effects of nuclear weapons. Previous Soviet high-altitude tests, while highly sophisticated in their missile involvement and probably well instrumented (judging from their location near the Sary Shagan Anti-Missile Test Cen-

ter), apparently lacked some of the characteristics which would give them detailed information on warhead kill mechanisms and on communications-blackout effects. For example, the Soviets have not detonated a warhead in the vicinity of a re-entering missile nosecone, nor do we have firm evidence that the Soviets placed instrument pods near their high-altitude bursts, although we may not have detected such pods.

240. We have no knowledge of Soviet activities paralleling that of the US in providing information on effects upon hardened missile launch sites. The Soviets have had no near-surface testing experience at high yields since 1954. It is likely that they have a requirement for such a high-yield test.

241. Other areas where the Soviets require additional effects information may exist; in particular, the Soviets lack experience with very deep underwater bursts.

242. *Weapon Development.* If the Soviets have requirements for significantly larger yields for their present delivery systems than are available as a result of their recent tests, they will probably require further testing to obtain such yields. They could adopt present designs to meet the needs of future delivery systems, but might, judging from past practice, require nuclear proof tests of these systems. Significant improvements in yield-to-weight ratios would require further tests.

243. We believe the Soviets have continuing requirements for low-yield weapons. They conducted many low-yield tests during 1961 and 1962 which must have added considerably to their knowledge of low-yield devices, although their progress is difficult to define. Only preliminary analyses of 1962 tests are now available and, in any case, evaluations of low-yield tests are subject to considerable uncertainties. To the extent that their requirements have not been satisfied, the Soviets have a need for further testing in this area.

244. *Test Status.* We believe the Soviets are currently in a posture to resume nuclear testing soon after a decision is made. Evidence indicates continuing weapon development activity in the Soviet nuclear weapon development centers. There is no evidence that the Semipalatinsk Proving Ground is not being maintained in an active status and we estimate that testing, either in the atmosphere or underground, could be resumed there on short notice. Of interest is the construction of an unusual site at Semipalatinsk similar to an AMM site at Sary Shagan. This suggests that AMM nuclear systems tests may be intended. The Arctic Proving Ground at Novaya Zemlya is not maintained on a continuing active basis. Instead, testing is conducted there on a task force basis, and all the indications are that only a short build-up is required for test resumption. The main test period in the Arctic is normally in the late summer and fall.

VI. SOVIET TECHNICAL CAPABILITIES IN SCIENTIFIC FIELDS RELATED TO NUCLEAR ENERGY

245. *Chemistry.* Soviet chemical research relating to their atomic energy program has continued to advance, but remains generally behind the United States in scope and originality. Soviet chemists are emphasizing the preparation, study and analysis of high purity substances useful as nuclear reactor component and construction materials. Their research on the separation and identification of transuranium compounds, although not as extensive as that of the US, appears to be on about the same level of technology. They have developed satisfactory ion exchange techniques, patterned after earlier US developments, for separating pure rare earth oxides from ores. From these oxides they are preparing and studying pure rare earth metals and compounds for possible applications in nuclear science and technology, such as improved materials for reactor control rods, shielding, and burnable poisons. While the Soviets so far are not known to have developed these materials to practical use in advance of the United States, their intensive studies could result in original achievements in a few years. Their use of ion exchange techniques, however, is hampered by their inability to provide many of the more useful resins.

246. Ceramics, with special nuclear and high temperature properties, such as silicon carbide (carborundum), boroncarbide, and beryllium oxide are under continued study. Special materials such as light weight, porous beryllium oxide ceramics are being developed, possibly for applications in advanced nuclear reactors.

247. Electrochemical studies are underway to determine the corrosion resistance of various stainless steel, aluminum and zirconium alloys in water at the high temperatures and pressures encountered in nuclear reactor heat exchangers. The corrosive effects of molten sodium, lithium, and fused salts on metals are also being examined in this connection. The published Soviet experimental work on corrosion continued to be empirical in nature and does not appear to exploit the excellent research on the theoretical aspects of electrochemistry done in the USSR.

248. Radiation effects on many materials are also under study, and work has been done to develop radiation resistant materials for reactor applications. Attempts are being made to improve the activity of catalysts for chemical and petroleum processes by irradiation, and to utilize radioactivity as a direct source of polymerization. Radioactive isotopes are also used extensively in the USSR in chemical analysis, chemical tracer techniques, and in laboratory as well as chemical process control instrumentation.

249. *Nuclear Metallurgy.* The extractive techniques necessary for obtaining nonferrous metals and alloys of nuclear importance are adequately known in the USSR, as are methods of metal fabrication; however, there are no indications that Soviet process developments in these areas have resulted in significant advances over those of the West. The USSR has a comprehensive program of alloy systems investigations in force which may exceed that of the West in extent and is closely comparable in terms of quality. Their research on the more advanced materials including the refractory metals and their compounds is receiving strong emphasis, but Soviet programs of practical alloy development and evaluation generally are believed to follow the Western lead.

250. Soviet applied research involving the actual applications of special alloys for structural use in reactor construction is estimated to be making substantial progress but prob-

lems of corrosion, including corrosion in welds of stainless steels and corrosion due to radiation effects, continue to cause difficulties as they do in the West. In addition, the Soviets have continuing problems in the technology of fuel elements. The number of well-trained, experienced engineers available for this work is estimated to have increased substantially during the past several years, resulting in sufficient Soviet competence to meet the current metallurgical requirements of their nuclear program.

251. *Computers.* The M–20, M–2, KIEV, BESM I, BESM II, URAL, and STRELA models are typical of the computers the Soviets used to solve problems in nuclear energy research projects, the M–20 being the most advanced model mentioned in these applications. Although these computers are less advanced than Western production models used for similar applications, they appear to be adequate for the usual types of computation required in scientific and technical research. A wide range of electronic analog computers, including large high precision models like the Soviet MN–14, are also available to Soviet researchers. Large-scale, very high speed digital computers comparable to the most advanced Western models have not yet been revealed in the USSR, but the Soviets may have such advanced models under construction or in use in classified work especially for nuclear weapons calculations.

252. *Instrumentation.* The Soviets have developed a variety of instruments and recording equipment for use in their nuclear research program. On the basis of different kinds of instruments which have been displayed at various exhibits, the Soviet devices appear to be adequate for stated applications but are considerably less sophisticated than the devices used for similar applications in the West. Soviet instrumentation for reactor control systems also appears to be less elaborate and easier to design and construct than that in the US.

253. *Low Energy Nuclear Physics.* Within the last few years a number of "standard" 120 cm cyclotrons have been installed in educational and research institutions scattered throughout the USSR. Several heavy ion cyclotrons are now in operation, the newest being a two-meter cyclotron at Dubna capable of accelerating ions of carbon, nitrogen, and oxygen to an energy of 12.5 Mev per nucleon. A high flux, impulse reactor instrumented with a 1 kilometer time-of-flight neutron spectrometer has also recently been completed at Dubna.

254. Soviet physicists are competent in the standard laboratory techniques employed in nuclear spectroscopy and have developed refined and novel apparatus and techniques. Their research effort on the physics of heavy ions is intensive and highly competent. However, the Soviet effort in experimental low energy nuclear physics as a whole still lags substantially behind that of the US, with the main deficiencies being a frequent lack of high quality research equipment and an apparent inability to attract the necessary quality of Soviet physicists into this field.

255. *High Energy Nuclear Physics.* By 1961 the USSR had constructed a 680 Mev synchrocyclotron and a 10 Bev proton synchrotron at Dubna, a 7 Bev proton synchrotron in Moscow and several electron synchrotrons at various locations, of which three at 100, 260 and 680 Mev each are of quite high quality. Attempted operation of the 7 and 10 Bev proton synchrotrons disclosed a number of engineering difficulties such as poor foundations, a lack of randomization of the residual magnetic fields in the structural iron and a totally inadequate proton injection system.

256. The USSR is continuing an intensive construction program. Most of the engineer-

ing and construction problems encountered with their large proton synchrotrons have been corrected. A 6 Bev electron synchrotron is nearing completion in Armenia. A 70 Bev proton synchrotron being constructed at a site near Serpukhov is scheduled to be completed by 1965 and will be the largest high energy accelerator in the world.

257. The 1963 US Atomic Energy Commission delegation reports the existence of both a 2 Bev and a 400 Mev linear electron acclerators at a new site north of Kharkov. These accelerators were judged to be a prestige item and will be used to study interaction theory. Construction of these linear accelerators is expected to be completed in 1964.

258. Although the Soviet experimental program enjoys a high priority and has adequate funds and personnel, the experiments conducted in the program are, in general, unimaginative.

259. The USSR has a very strong theoretical program in high energy physics, but it seems apparent that the experimentalists often do not follow the research published by the theorists. This reflects a lack of coordination of ideas and efforts between the theorists and experimentalists, although the poor performance of some of the accelerators may be a contributing factor. Thus, Soviet over-all research in high energy physics has generally been inferior to that in the West.

260. *Controlled Thermonuclear Reactions.* Soviet research on controlled thermonuclear reactions (CTR) began at about the same time as in the US, and this early work was declassified at Geneva in 1958. During the 1950's the Soviet program grew rapidly but now has leveled off to an annual growth rate of about 10%. Except for the older machines, OGRA and ALPHA, the Soviets have not constructed full-scale machines, as has the US, but rather they have concentrated on small experimental devices to explore the basic physical phenomena of plasmas. At the present time the status of CTR research in the USSR is roughly comparable to that in the West. It is estimated that the USSR will not achieve a useful controlled reaction within at least the next 3–5 years and consequently will not attain commercially useful power from nuclear fusion within the next decade.

261. The Soviet theoretical plasma physics and CTR program is extensive, both in quantity and scope, and has attracted some of the best Soviet theoretical physicists. However, the Soviet theorists appear to have very limited access to electronic computers and a general lack of contact with the experimentalists. Thus little effort is made by the theorists to design practical experiments or to correlate and interpret experimental data.

262. In experimental research on CTR the Soviets have abandoned fast pinches and are concentrating on magnetic compression, injection into cusps, and radio-frequency heating and confinement. In plasma diagnostics, the Soviets have emphasized optical and microwave spectroscopy. They currently appear to prefer the concept of pulsed fusion reactors rather than the steady-state machines used in some of the United States programs. The guiding philosophy expressed by the Soviets in this field is to concentrate over the next few years on basic plasma phenomena using relatively small experiments in the hope of finding some way of suppressing or avoiding the inherent instabilities of a plasma confined by a magnetic field.

263. *Radiobiology and Medicine.* Since 1959, there has been an increase in Soviet emphasis on the industrial uses of radiation and on studies of the resulting biomedical effects. Radiobiology is one of the major fundamental areas of the Academy of Sciences, USSR, and an Academy-wide scientific council has been

established for coordination of this research. The major biological institutes involved are: the Institute of Biological Physics, the Institute of Radiation and Physico-chemical Biology, and the Biology Division of the Institute of Atomic Energy imeni Kurchatov. The last installation has recently acquired new research facilities and the size and type of laboratories, and excellent equipment indicate that it could become one of the better radiobiological research centers in the world. On the other hand, clinical research and practice pertaining to radiation are less advanced. The Soviets need more and better-trained radiologists, and equipment such as the betatron has been slow in coming into research and therapeutic use in the USSR. Betatrons now, or about to be, in use (at the Tomsk Medical Institute; Institute of Roentgenology and Radiology, Moscow; and Central Scientific Research Institute of Medical Radiology, Leningrad) are outdated, relatively crude in design and improperly shielded. Soviet clinical techniques for the use of radiation for diagnosis and treatment are often outdated.

264. Radioisotopes are widely used in research and industry and a nation-wide safety program for their transporation, use and disposal has developed. Soviet rules for maximum permissible levels of ionizing radiation and concentrations of radioactive substances in air and water now closely follow International Commission on Radiological Protection (ICRP) recommendations. Within the next three years it is expected that revisions will include even lower permissible exposure rates and times of exposure. Radiation safety regulations concerning construction and operation of particle accelerators, are similar to but not as strictly enforced, as those found in the US.

265. The USSR maintains a program for air sampling to detect natural and artificial radioisotopes present in the external environment and inside work premises. The Soviet Union submitted a report on its "fly-paper" fall-out program to the United Nations Scientific Committee on Effects of Atomic Radiation. The program as set forth in the report was a poor one by US standards and the Soviet Union subsequently withdrew its report. Although they have carried out several well-planned and well-executed studies on oceanographic analyses pertaining to radioactive waste disposal in oceans, the positions taken by the Soviets in the UN on this subject have apparently reflected political rather than scientific considerations.

266. Detailed studies are underway on changes in resistance after irradiation in plant and animal cells and micro-organisms. Soviet working hypotheses for estimating factors which influence primary potential damage and recovery effects approach current views expressed by Western investigators; but in general, the Soviet approaches have not presented anything new with respect to prophylaxis or therapy of radiation injury. Their apparent hope for the ultimate development of chemical substances for protection against radiation or treatment of radiation injuries, does not appear justified.

267. In general, the Soviets are following published US findings and procedures with respect to protection from radiation effects of weapons. They are engaging in some research, training, planning, stockpiling and target area preparations relative to medical defense against nuclear warfare. Special weapons defense in the USSR also includes specific preparation against various types of radiological-biological warfare combinations.

ANNEX A

Annex A

EVALUATION OF SOVIET NUCLEAR TESTS (1949-1962)

JOE No.	Date	Location [1]	Burst Height (ft) [2]	Yield (KT) [2]
1	29 Aug 49	Semi	Surface	20
2	24 Sep 51	Semi	Surface	30
3	18 Oct 51	Semi	Air	15
4	12 Aug 53	Semi	Surface	300
5	23 Aug 53	Semi	Air	25
6	3 Sep 53	Central USSR, Prob Semi	Air	8
7	10 Sep 53	Central USSR, Prob Semi	Air	8
8	14 Sep 54	Totskoye	1,000 / 1,500	35 / 100
9	3 Oct 54	Semi	Air	4
10	5 Oct 54	Semi	Air	5
11	8 Oct 54	Semi	<few 1,000 [3]	<20
12	23 Oct 54	Semi	Air	90
13	26 Oct 54	Semi	Air	4
14	30 Oct 54	Semi	Air	25
15	29 Jul 55	Semi	Poss. near Surface	4
16	2 Aug 55	Semi	Air	30
17	21 Sep 55	NZ	Underwater, Prob <600	6
18	6 Nov 55	Semi	3,500	200
19	22 Nov 55	Semi	4,500	1,700
20	2 Feb 56	Caspian Sea	Air	6
21	16 Mar 56	Semi	Surface	30
22	25 Mar 56	Semi	Surface	25
23	24 Aug 56	Semi	Tower	60
24	30 Aug 56	Semi	3,300	2,200
25	2 Sep 56	Semi	>1,500	100
26	10 Sep 56	Semi	1,500 / 3,000	90
27	17 Nov 56	Semi	7,800	2,700

See footnotes at end of table.

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Annex A (*Continued*)

JOE No.	Date	Location [1]	Burst Height (ft) [2]	Yield (KT) [2]
28	14 Dec 56	Semi	Air	50
29	19 Jan 57	KY	Air	3.5 [7] (7)
30	8 Mar 57	Semi	Air	15
31	3 Apr 57	Semi	Air	70
32	6 Apr 57	Semi	Air	70
33	10 Apr 57	Semi	6,800	1,300
34	12 Apr 57	Semi	Air	30
35	16 Apr 57	Semi	6,500	750
36	22 Aug 57	Semi	>2,000	500
37	7 Sep 57	NZ	Surface	25
38	13 Sep 57	Semi	Unknown	<20
39	24 Sep 57	NZ	5,000/10,000	3,200
40	26 Sep 57	Semi	Air	8
41	6 Oct 57	NZ	7,000	4,300
42	10 Oct 57	NZ	Underwater	10
43	28 Dec 57	Semi	Air	7 (14)
44	4 Jan 58	Semi	Unknown	<5 (5)
45	17 Jan 58	USSR-Prob. Semi	Unknown	<5
46	23 Feb 58	NZ	10,500	1,200
47	27 Feb 58	NZ	10,300	2,500
48	27 Feb 58	NZ	10,800	520
49	13 Mar 58	Semi	Air	<10 (1)
50	14 Mar 58	NZ	Air	30
51	14 Mar 58	Semi	Air	30
52	15 Mar 58	Semi	Air	10
53	20 Mar 58	Semi	Air	15
54	21 Mar 58	NZ	>7,500	1,000
55	22 Mar 58	Semi	Prob. Air	20

See footnotes at end of table.

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Annex A (*Continued*)

JOE No.	Date	Location [1]	Burst Height (ft) [2]	Yield (KT) [2]
56	30 Sep 58	NZ	2,500 6,500	1,200
57	30 Sep 58	NZ	7,000	2,100
58	2 Oct 58	NZ	Air	350
59	2 Oct 58	NZ	Air	50
60	4 Oct 58	NZ	Not Sub-Surface	5 (10)
61	5 Oct 58	NZ	Air	25
62	6 Oct 58	NZ	Uncertain	2.5
63	10 Oct 58	NZ	Air	200
64	12 Oct 58	NZ	4,500	2,100
65	15 Oct 58	NZ	<10,000	3,000
66	18 Oct 58	NZ	6,500	7,600
67	19 Oct 58	NZ	Air	35
68	20 Oct 58	NZ	Air	400
69	21 Oct 58	NZ	Above Surface	<5 (1)
70	22 Oct 58	NZ	7,000	6,100
71	24 Oct 58	NZ	6,000	2,200
72	25 Oct 58	NZ	Air	200
73	1 Nov 58	KY	Not Subsurface	3.5
74	3 Nov 58	KY	Air	9 (3)
75	1 Sep 61	Semi	Below Trop. [3]	55 (20)
76	4 Sep 61	Semi	Below Trop.	25
77	5 Sep 61	Semi	Below Trop.	30 (17)
78	6 Sep 61	Semi	Atmosphere	<10
79	6 Sep 61	KY	Prob. ~50,000	25
80	10 Sep 61	NZ	7,500	4,900
81	10 Sep 61	Semi	Atmosphere	<10
82	10 Sep 61	NZ	Below Trop.	20
83	12 Sep 61	NZ	4,500	2,000
84	13 Sep 61	Semi	Below Trop.	70 (40)
85	13 Sep 61	NZ	Below Trop.	15 (30)
86	14 Sep 61	NZ	6,500	2,000
87	16 Sep 61	NZ	4,000	1,600

See footnotes at end of table.

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Annex A (*Continued*)

JOE No.	Date	Location [1]	Burst Height (ft) [2]	Yield (KT) [2]
88	17 Sep 61	Semi	Below Trop.	35
89	18 Sep 61	NZ	6,000	2,300
90	19 Sep 61	Semi	Below Trop.	15 (7.5)
91	20 Sep 61	NZ	6,000	1,500
92	21 Sep 61	Semi	Atmosphere	<10
93	22 Sep 61	NZ	4,500	750
94	2 Oct 61	NZ	<10,000	570
95	4 Oct 61	Semi	Below Trop.	5 (8)
96	4 Oct 61	NZ	7,500	2,900
97	6 Oct 61	NZ	9,000	4,700
98	6 Oct 61	KY	50,000 / 150,000	200
99	8 Oct 61	NZ	Below Trop.	25
100	11 Oct 61	Semi	Sub-surface	~2–5
101	12 Oct 61	Semi	Below Trop.	30
102	17 Oct 61	Semi	Below Trop.	3 (5)
103	19 Oct 61	Semi	Below Trop.	5 (8)
104	20 Oct 61	NZ	4,500	2,700
105	21 Oct 61	SS	~160 (nm)	~1
106	23 Oct 61	NZ	13,000	20,000
107	23 Oct 61	NZ	Underwater	~20
108	25 Oct 61	NZ	2,000 / 10,000	850
109	27 Oct 61	SS	~80 (nm)	~1
110	27 Oct 61	NZ	On, or slightly above, the surface	15
111	30 Oct 61	NZ	13,500	63,000

See footnotes at end of table.

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Annex A (*Continued*)

JOE No.	Date	Location [1]	Burst Height (ft) [2]	Yield (KT) [2]
112	31 Oct 61	NZ	8,700	5,300
113	31 Oct 61	NZ	6,000	~1,500 (2,000)
114	1 Nov 61	Semi	Below Trop.	<5 (5)
115	2 Nov 61	NZ	~3,000 / 5,000	~200
116	2 Nov 61	NZ	Below Trop.	300
117	3 Nov 61	Semi	Atmosphere	<5
118	4 Nov 61	NZ	Below Trop.	~10
119	4 Nov 61	NZ	7,500	3,200
120	2 Feb 62	Semi	Sub-surface	30–60
121	1 Aug 62	Semi	..	5
122	3 Aug 62	Semi	..	3
123	4 Aug 62	Semi	..	5
124	5 Aug 62	NZ	13,000	30,000
125	7 Aug 62	Semi	Surface or Low Air	15
126	10 Aug 62	NZ	..	400
127	18 Aug 62	Semi	..	5
128	18 Aug 62	Semi	..	9
129	20 Aug 62	NZ	9,000	6,000
130	21 Aug 62	Semi	..	25
131	22 Aug 62	NZ	7,500	3,800
132	22 Aug 62	Semi	..	4
133	22 Aug 62	NZ	..	9
134	23 Aug 62	Semi	..	3
135	25 Aug 62	Semi	..	15
136	25 Aug 62	NZ	11,000	4,200
137	27 Aug 62	NZ	11,000	5,800
138	27 Aug 62	Semi	..	10
139	2 Sep 62	NZ	..	160
140	8 Sep 62	NZ	5,000	2,900
141	15 Sep 62	NZ	9,000	6,000
142	16 Sep 62	NZ	8,500	5,300
143	18 Sep 62	NZ	7,500	2,500
144	19 Sep 62	NZ	11,000	13,000
145	21 Sep 62	NZ	10,000	3,000
146	25 Sep 62	Semi	..	5

See footnotes at end of table.

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Annex A (*Continued*)

JOE No.	Date	Location [1]	Burst Height (ft) [2]	Yield (KT) [2]
147	25 Sep 62	NZ	14,500	24,000
148	27 Sep 62	NZ	14,500	24,000
149	28 Sep 62	Unk. Poss. Semi	..	Prob. <5
150	7 Oct 62	NZ	~5,000	500
151	9 Oct 62	Semi	..	5
152	9 Oct 62	NZ	..	20
153	10 Oct 62	Semi	..	8
154	13 Oct 62	Semi	..	~2
155	14 Oct 62	Semi	..	10
156	20 Oct 62	Semi	..	10
157	22 Oct 62	SS	~325 (km)	200
158	22 Oct 62	NZ	11,000	13,000
159	27 Oct 62	NZ	..	410
160	28 Oct 62	SS	~200 (km)	200
161	28 Oct 62	Semi	..	30 }
162	28 Oct 62	Semi	..	15 }
163	29 Oct 62	NZ	..	750
164	30 Oct 62	NZ	..	810
165	31 Oct 62	Semi	..	10
166	1 Nov 62	Semi	..	Prob. <5
167	1 Nov 62	NZ	..	220
168	1 Nov 62	SS	~50–75 (km)	1,800
169	3 Nov 62	NZ	..	1,100
170	3 Nov 62	Semi	..	10
171	3 Nov 62	NZ	..	35
172	4 Nov 62	Semi	..	30
173	14 Nov 62	Semi	..	10
174	17 Nov 62	Semi	..	15
175	1 Dec 62	Semi	..	3
176	18 Dec 62	NZ	..	150
177	18 Dec 62	NZ	..	220
178	20 Dec 62	NZ	..	10
179	22 Dec 62	NZ	..	30
180	23 Dec 62	NZ	..	Prob. <5
181	23 Dec 62	NZ	..	Prob. <5
182	23 Dec 62	NZ	..	1,200

See footnotes at end of table.

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Annex A (*Continued*)

JOE No.	Date	Location [1]	Burst Height (ft) [2]
183	24 Dec 62	NZ	5,000
184	24 Dec 62	NZ	11,500
185	25 Dec 62	NZ	..
186	25 Dec 62	NZ	5,000 10,000

[1] Semi = Semipalatinsk; KY = Kapustin Yar; NZ = Novaya Zemlya; SS = Sary Shagan.

[2] Values of burst height and yield are best values. (Trop. = Tropopause)

[4] Where a range of values have been reported they are written as minimum/maximum.

[5] Greater than: >; Less than: <; Approximately: ~; present, amounts not known; *.

[7] Alternate value. Analysis based on this assumed yield.

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