CHERNOBYL NUCLEAR ACCIDENT DOCUMENTS

CIA FILES

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CHERNOBYL NUCLEAR ACCIDENT DOCUMENTS

Chernobyl Nuclear Power Plant Accident CIA, Department of Defense, Department of Energy, Congressional, GAO, and Foreign Press Monitoring Files

4,010 pages of CIA, Department of Defense, Department of Energy, Congressional, GAO, and foreign press monitoring files related to the Chernobyl Nuclear Accident.

On Sunday April 26, 1986, at the Chernobyl Nuclear Power Plant near Pripyat, Ukraine, reactor #4 exploded. For the 25 years from 1986 to 2011, this incident has been referred to as the world's worst nuclear power plant accident.

THE ACCIDENT

According to reports filed with International Atomic Energy Agency (IAEA) on April 25, 1986, technicians at the Chernobyl plant launched a poorly executed experiment to test the emergency electricity supply to one of its Soviet RBMK type design reactors. The test was meant to measure a turbogenerator's ability to provide in-house emergency power after shutting off its steam supply. During the experiment the technicians violated several rules in place for operating the reactor.

During the experiment, the emergency shutdown system was turned off. The reactor was being operated with too many control rods withdrawn. These human errors, coupled with a design flaw that allowed reactor power to surge when uncontrolled steam generation began in the core, set up the conditions for the accident.

A chain of events lasting 40 seconds occurred at 1:23 AM on April 26.

The technicians operating the reactor put the reactor in an unstable condition, so reactor power increased rapidly when the experiment began. Subsequent analysis of the Soviet data by U.S. experts at the Department of Energy, suggests the power surge may have accelerated when the operators tried an emergency shutdown of the reactor. According to Soviet data, the energy released was, for a fraction of a second, 350 times the rated capacity of the reactor. This burst of energy resulted in an instantaneous and violent surge of heat and pressure, rupturing fuel channels and releasing steam that disrupted large portions of the core.

The surge destroyed the core of reactor unit four, containing approximately 200 tons of nuclear fuel. Some of the shattered core material was propelled through the roof of the reactor building. The hot core material of reactor 4 started about 30 separate fires in the unit 4 reactor hall and turbine building, as well as on the roof of the adjoining unit 3. All but the main fire in the graphite moderator material still inside unit 4 were extinguished in a few hours.

It was a day and a half before the people living in Pripyat were ordered to evacuate. The residents were told they would only be gone for several days, so they left nearly everything behind. They never returned. Soviet authorities made the decision not to cancel May 1, May Day, outdoor parades in the region four days later.

The graphite fire continued to burn for nearly two weeks carrying radioactivity high into the atmosphere, until it was smothered by sand, lead, dolomite, and boron dropped from helicopters. Despite the wide spread of radiation, Soviet officials at first said very little publicly about what happened at Chernobyl. It was not until alarms from radiation detectors in other countries, many hundreds of miles away, forced the Soviets to admit to the Chernobyl accident.

Radioactive material was dispersed over 60,000 square miles of Ukraine, Belarus, and Russia. Smaller amounts of radioactive material were detected over Eastern and Western Europe, Scandinavia and even the United States. The accident has left some nearby towns uninhabitable to this day.

Radioactivity forced Soviet officials to create a 30-kilometer-wide no-habitation zone around Chernobyl, sealing off Pripyat. Still, the power plant continued to generate electricity until it was finally shut down in December, 2000.

During the first year after the accident, about 25,000 people, mainly Soviet Army troops, were dispatched to the site to clean up the accident. Thousands of workers, called liquidators, were employed during the following years of the cleanup.

Around October, 1986 the construction of a 21 story high metal and concrete shelter was completed, enclosing the reactor and the radioactive material that remained. Almost 200 tonnes of melted nuclear fuel rods remain within the damaged reactor. This containment shelter was not intended to be a permanent solution for containing the radioactive material. Over time, the shelter has weakened; rain entering through holes and cracks has caused corroding.

By 2006 the plans for a new shelter was about 7 years behind schedule, with a completion target date of no sooner than 2012. In February of 2011 it was reported that construction of the shelter may have to be halted, due to a $1 billion dollar short fall in the funds needed to complete the structure.

A United Nations report released in February 2011 estimates the disaster caused thyroid cancer in 7,000 children in the affected area. The report said despite the high rate of cancer, only 15 fatalities in these 7,000 cases have occurred.

THE DOCUMENTS

CIA FILES

215 pages of CIA files dating from 1971 to 1991.The files cover the Soviet Union's atomic energy program; The effect of the Chernobyl accident on the Soviet nuclear power program; and the social and political ramifications of the accident in the Soviet Union.

A 1981 report covers the less publicized Soviet nuclear "accident" near Kyshtym in 1957-58.

Media reporting of a nuclear accident near Kyshtym first appeared in 1958. It was not until 1976, when the writings of Soviet dissent Dr. Zhores Medvedev began to appear, that wider attention was given to this subject. Medvedev, an exiled Soviet geneticist, claimed in several articles and books that a "disaster" occurred near Kyshtym in 1957/58. He alleged that thousands of casualties and widespread, long-term radioactive contamination occurred as the result of an explosion involving nuclear waste stored in underground shelters.

The general consensus today is that a combination of events, rather than a single isolated incident at Kyshtym nuclear energy complex caused the radioactive contamination in the area. A study of the claims by Medvedev can be found in the Department of Energy section, in the 1982 report "An Analysis of the Alleged Kyshtym Disaster"

U.S. GOVERNMENT FOREIGN PRESS MONITORING

900 pages of foreign media monitoring reports from 1986 to 1992, produced by the U.S. government's National Technical Information Service's U.S. Joint Publication Research Service. They contain information primarily from Russian and Eastern Block news agency transmissions and broadcasts, newspapers, periodicals, television, radio and books. Materials from non-English language sources are translated into English.

The reporting includes firsthand accounts of experiences during all points of the Chernobyl disaster. Topics covering the accident and its aftermath including domestic and international politics, sociological affairs, nuclear plant fire, evacuations, sealing the reactor, cleanup mobilization, health implications, and people returning to region.

DEPARTMENT OF ENGERY REPORTS

1,244 pages of reports dating from 1982 to 2009 produced or commissioned by the Department of Energy.

The agencies and institutions contributing to these reports include Los Alamos National Laboratory, United States Nuclear Regulatory Commission, Lawrence Livermore National Laboratory, Savannah River Nuclear Solutions, Oak Ridge National Laboratory, Brookhaven National Laboratory, Argonne National Laboratory, and the Pacific Northwest Laboratory.

Highlights include:

The 1986 *Report of the U.S. Department of Energy's Team Analyses of the Chernobyl-4 Atomic Energy Station Accident Sequence DOE/NE-0076*.

The U.S. Department of Energy (DOE) formed a team of experts from Argonne National Laboratory, Brookhaven National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest Laboratory. The DOE team provided the analytical support to the U.S. delegation for the August, 1986 meeting of the International Atomic Energy Agency (IAEA), and to subsequent international meetings. The DOE team analyzed the accident in detail, assessed the plausibility and completeness of the information provided by the Soviets, and performed studies relevant to understanding the accident.

The 1987 report *Radioactive Fallout from the Chernobyl Nuclear Reactor Accident*

The Lawrence Livermore National Laboratory performed a variety of measurements to determine the level of the radioactive fallout on the western United States. The laboratory used gamma-spectroscopy to analyze air filters from the areas around Lawrence Livermore National Laboratory in California. Filters were also analyzed from Barrow and Fairbanks, Alaska. Milk from California and imported vegetables were also analyzed for radioactivity.

Other report titles include: An Analysis of the Alleged Kyshtym Disaster; Workshop on Short-term Health Effects of Reactor Accidents; Preliminary Dose Assessment of the Chernobyl Accident; Internally Deposited Fallout from the Chernobyl Reactor Accident; Report on the Accident at the Chernobyl Nuclear Power Station; Radioactive Fallout from the Chernobyl Nuclear Reactor Accident; Radioactivity in Persons Exposed to Fallout from the Chernobyl Reactor Accident' Radioactive Fallout in Livermore, CA and Central Northern Alaska from the Chernobyl Nuclear Reactor Accident; Projected Global Health Impacts from Severe Nuclear Accidents - Conversion of Projected Doses to Risks on a Global Scale - Experience From Chernobyl Releases; The Chernobyl Accident - Causes and Consequences; Chernobyl Lessons Learned Review of N Reactor; Reconstruction of Thyroid Doses for the Population of Belarus Following the Chernobyl Accident; The characterization and risk assessment of the Red Forest radioactive waste burial site at Chernobyl Nuclear Power Plant; Estimated Long Term Health Effects of the Chernobyl Accident; and Environmental Problems Associated With Decommissioning the Chernobyl Nuclear Power Plant Cooling Pond.

DEPARTMENT OF DEFENSE REPORTS

816 pages of reports dating from 1990 to 2010 produced or commissioned by the Department of Defense.

The reports include: Chernobyl Accident Fatalities and Causes; Biomedical Lessons from the Chernobyl Nuclear Power Plant Accident; Nuclear

Accidents in the Former Soviet Union Kyshtym, Chelyabinsk and Chernobyl; Retrospective Reconstruction of Radiation Doses of Chernobyl Liquidators by Electron Paramagnetic Resonance; Neurocognitive and Physical Abilities Assessments Twelve Years After the Chernobyl Nuclear Accident; Simulating Wet Deposition of Radiocesium from the Chernobyl Accident; and Radiation Injuries After the Chernobyl Accident Management, Outcome, and Lessons Learned.

GAO REPORTS

184 pages of reports from the United States General Accounting Office, whose name was later changed to the Government Accountability Office. The four reports are Comparison of DOE's Hanford N-Reactor with the Chernobyl Reactor (1986); Nuclear Power Safety International Measures in Response to Chernobyl Accident (1988); Nuclear Power Safety Chernobyl Accident Prompted Worldwide Actions but Further Efforts Needed (1991); and Construction of the Protective Shelter for the Chernobyl Nuclear Reactor Faces Schedule Delays, Potential Cost Increases, and Technical Uncertainties (2007).

UNITED STATES CONGRESSIONAL HEARINGS

634 pages of transcripts from three Congressional hearings: The Chernobyl Accident Hearing before the Committee on Energy and Natural Resources, Ninety-ninth Congress, 2nd session on the Chernobyl accident and implications for the domestic nuclear industry, June 19, 1986; The Effects of the accident at the Chernobyl nuclear power plant hearing before the Subcommittee on Nuclear Regulation, United States Senate, One Hundred Second Congress, second session, July 22, 1992; and The legacy of Chernobyl, 1986 to 1996 and beyond hearing before the Commission on Security and Cooperation in Europe, One Hundred Fourth Congress, second session, April 23, 1996.

TOP SECRET

NATIONAL INTELLIGENCE ESTIMATE

Soviet Nuclear Programs

(Supersedes NIE 11-2A-69 and NIE 11-2B-69)

TOP SECRET

NIE 11-2-71

10 June 1971

№ 188

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

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

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

Concurring:

The Deputy Director of Central Intelligence

The Director of Intelligence and Research, Department of State

The Director, Defense Intelligence Agency

The Director, National Security Agency

The Assistant General Manager, Atomic Energy Commission

Abstaining:

The Assistant to the Director, Federal Bureau of Investigation, the subject being outside of his jurisdiction.

NIE 11-2-71

SOVIET NUCLEAR PROGRAMS

CONTENTS

SOVIET NUCLEAR PROGRAMS

THE PROBLEM

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

SUMMARY CONCLUSIONS

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

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

Testing

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

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

Weapons

E. [

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

]

F. [

]

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

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

Production of Nuclear Materials

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

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

Power and Propulsion

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

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

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

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

Peaceful Uses and International Cooperation

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

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

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

DISCUSSION

I. THE NUCLEAR WEAPONS PROGRAM

A. The Nuclear Test Program

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

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

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

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

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

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

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

B. Weapons Developed During the Period of Atmospheric Testing

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

7. [redacted]

Thermonuclear Weapons

8. [redacted]

C. Weapons Developed Since the Beginning of Underground Testing

13.

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

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

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

16.

D. Other Weapon Developments

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

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

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

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

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

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

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

E. Storage and Control of Nuclear Weapons

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

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

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

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

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

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

II. PRODUCTION OF NUCLEAR MATERIALS

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

A. Production of Plutonium-Equivalent

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

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

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

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

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

TABLE III

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

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

[a] Cumulative production figures have been rounded.

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

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

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

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

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

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

B. U-235 Production

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

37.

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

39.

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

TABLE IV

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

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

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

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

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

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

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

C. Uranium Procurement

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

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

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

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

III. NUCLEAR POWER AND PROPULSION PROGRAMS

A. Nuclear Power Stations

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

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

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

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

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

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

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

TABLE V

SOVIET NUCLEAR POWER STATIONS [a]

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

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

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

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

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

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

B. Marine and Naval Nuclear Propulsion

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

Submarines

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

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

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

Icebreakers

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

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

IV. ADVANCED NUCLEAR RESEARCH AND DEVELOPMENT

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

A. Aerospace Applications of Nuclear Energy

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

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

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

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

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

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

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

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

B. Controlled Thermonuclear Reactions

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

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

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

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

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

V. PEACEFUL USES OF NUCLEAR EXPLOSIONS

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

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

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

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

VI. INTERNATIONAL COOPERATION

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

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

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

]

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

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

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

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

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

GLOSSARY OF NUCLEAR ENERGY TERMS

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GLOSSARY OF NUCLEAR ENERGY TERMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ANNEX A

SOVIET UNDERGROUND NUCLEAR TESTS
MARCH 1964-MAY 1971

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ANNEX A

SOVIET UNDERGROUND NUCLEAR TESTS
MARCH 1964-MAY 1971

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

Footnotes at end of table.

ANNEX A (Continued)

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

ANNEX A (Continued)

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

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

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

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ANNEX B

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ANNEX B

CENTRAL INTELLIGENCE AGENCY

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SI M 77-10082
29 Aug 77

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The Soviet Nuclear Power Program

The Soviet nuclear power program has two basic types of nuclear power reactors in its inventory at the present time--the pressurized-water reactor (PWR) and the channel-type boiling water reactor (BWR). In addition, the Soviets are currently in the process of introducing the liquid-metal fast breeder reactor (LMFBR) into their reactor inventory.

The current Soviet nuclear reactor construction program is based on three reactors. The VVER-440, a medium-sized PWR, is in serial production in the Soviet Union. The VVER-440 has a gross electrical capacity of 440 megawatts (MWe) and is the standard Soviet PWR design both for export and for domestic power production (figure _/). The Soviets have sold 26 of these reactors for export, almost entirely to the Eastern European countries. The VVER-1000 is a large-sized PWR which incorporates more sophisticated technology and safety features than does the VVER-440. The VVER-1000 is a scaled-up version of the VVER-440 PWR and has a gross electrical capacity of 1000 MWe. The Soviets are obviously making some concessions to Western reactor safety standards. This is demonstrated by the fact that the VVER-1000 will be the first Soviet PWR to utilize a Western-style secondary containment building and an emergency core cooling system (ECCS). Serial production of the VVER-1000 is beginning, and this reactor probably will become the standard

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Soviet PWR in the near future. The RBMK-1000 is a large channel-type BWR and is the most sophisticated reactor of this type in the Soviet Union. It has a gross electrical capacity of 1000 MWe. One of the principle advantages of this type of reactor is that it allows for on-line refueling; i.e. the RBMK-1000, unlike Soviet PWRs, can operate at full power while its nuclear fuel is recharged.

Although the USSR was the first country in the world to build a power reactor, the Soviet nuclear power program has not progressed as rapidly as one would have expected. As of July 1977, the Soviet Union had an installed nuclear-electric generating capacity of only 7073 megawatts-electric. The Soviets have some 19,800 MWe of nuclear-electric generating capacity in various stages of construction at the present time and at least 11,000, and perhaps as much as 23,000, MWe of nuclear capacity is in an advanced stage of planning (table 1/). the locations of all the Soviet nuclear power stations--either operating under construction, or planned for construction to begin during the current Five-Year Plan--are shown in figure 2. An additional 13 nuclear power stations (26,000-30,000 MWe) are known to be in the planning stage but construction at these sites is not expected to begin until the next Five-Year Plan (1981-1985).

'In addition to the reactors which are in operation or under construction, the USSR has a number of other reactors under development. These include larger, 1500-MWe versions of the channel-type BWRs (RBMK-1500) and PWRs (VVER-1500) and large LMFBRs. Construction of the first nuclear power plant utilizing a RBMK-1500 reactor has begun in Lithuania. The design of the VVER-1500 is not as far along. The USSR has one LMFBR in operation, the BN-350, near Shevchenko on the Caspian Sea. A larger LMFBR with an alternate design is under construction near Beloyarsk. Soviet LMFBR research work is directed towards the production of a large, 1000 to 1600 MWe LMFBR.

The Soviet Union is among the many nations concerned about meeting their long-range energy needs. To meet the growing demands for electricity in the USSR, especially in the European part of the country, nuclear power stations are planned to offset a possible depletion of fuel for conventional power stations. At present, the Soviets' primary energy problem is one of distribution. About 85 percent of the Soviet fuel and hydro resources lie in Siberia, while about 80 percent of the electric power is consumed in the European part of the USSR. As the fossil fuel reserves in the European part of the USSR become depleted, nuclear power stations will become more competitive with conventional power stations, and the emphasis on nuclear power will increase.

By the end of 1975, the Soviet Union had an installed nuclear-electric generating capacity of 5,621 MWe. The Tenth

Five-Year Plan calls for the completion of an additional 13,800 MWe of nuclear-electric generating capacity by the end of 1980. An installed capacity of 100,000 MWe is planned for 1990. The Soviets predict that by the year 2000, nuclear power will account for 30 to 35 percent of total Soviet electric power generating capacity. This represents about 255,000 MWe of nuclear-electric generating capacity at that time (figure 3/). Soviet projections for nuclear power appear to be rather optimistic. It is likely that future Soviet projections will be scaled down, and it would not be surprising if the Soviet projected nuclear power program fell several years behind schedule.

Figure 3

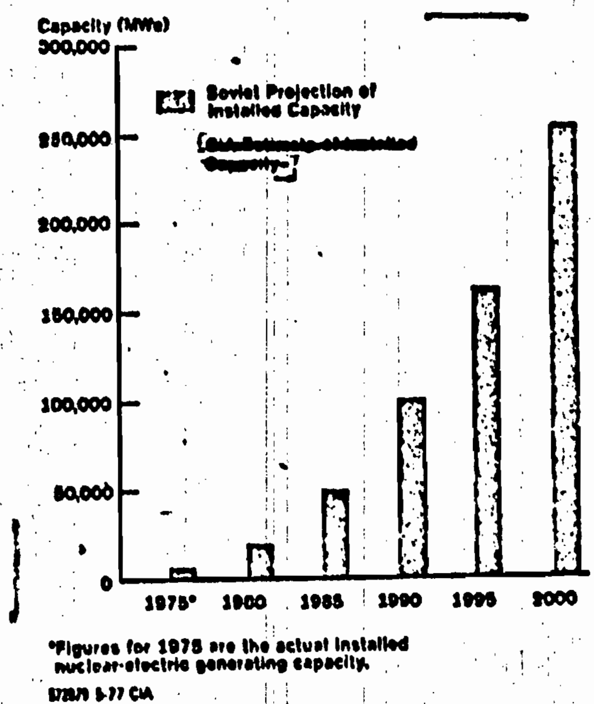

Figure 3 Projected Soviet Nuclear-Electric Generating Capacity (UNCLASSIFIED)

Table II

Nuclear Power Reactors in Operation, under Construction,

Item No.	Plant Designation	Location	Type of Plant	Ele Capa (M
1	Troitsk 1	Siberia	Graphite/Water	100
2	Troitsk 2	Siberia	Graphite/Water	100
3	Troitsk 3	Siberia	Graphite/Water	100
4	Troitsk 4	Siberia	Graphite/Water	100
5	Troitsk 5	Siberia	Graphite/Water	100
6	Troitsk 6	Siberia	Graphite/Water	100
7	Beloyarsk 1	Beloyarsk	BWR (channel-type)	100
8	Beloyarsk 2	Beloyarsk	BWR (channel-type)	200
9	Beloyarsk 3 (BN-600)	Beloyarsk	LMFBR	600
10	Novovoronezh 1	Novovoronezh	PWR	210
11	Novovoronezh 2	Novovoronezh	PWR	365
12	Novovoronezh 3	Novovoronezh	PWR	440
13	Novovoronezh 4	Novovoronezh	PWR	440
14	Novovoronezh 5	Novovoronezh	PWR	1000
15	BN-350	Shevchenko	LMFBR	350
16	Bilibino 1	Chukotka	BWR (channel-type)	12
17	Bilibino 2	Chukotka	BWR (channel-type)	12
18	Bilibino 3	Chukotka	BWR (channel-type)	12
19	Bilibino 4	Chukotka	BWR (channel-type)	12
20	Kola 1	Kola Peninsula	PWR	440
21	Kola 2	Kola Peninsula	PWR	440
22	Kola 3	Kola Peninsula	PWR	440
23	Kola 4	Kola Peninsula	PWR	440
24	Leningrad 1	Sosnovyy Bor	BWR (channel-type)	1000
25	Leningrad 2	Sosnovyy Bor	BWR (channel-type)	1000
26	Leningrad 3	Sosnovyy Bor	BWR (channel-type)	1000
27	Leningrad 4	Sosnovyy Bor	BWR (channel-type)	1000
28	Oktemberyan 1	Armenia	PWR	440
29	Oktemberyan 2	Armania	PWR	440
30	Kursk 1	Kursk	BWR (channel-type)	1000
31	Kursk 2	Kursk	BWR (channel-type)	1000
32	Kursk 3	Kursk	BWR (channel-type)	1000
33	Kursk 4	Kursk	BWR (channel-type)	1000
34	Chernobyl' 1	Chernobyl'	BWR (channel-type)	1000
35	Chernobyl' 2	Chernobyl'	BWR (channel-type)	1000
36	Chernobyl' 3	Chernobyl'	BWR (channel-type)	1000
37	Chernobyl' 4	Chernobyl'	BWR (channel-type)	1000
38	Smolensk 1	Smolensk	BWR (channel-type)	1000
39	Smolensk 2	Smolensk	BWR (channel-type)	1000
40	Smolensk 3	Smolensk	BWR (channel-type)	1000
41	Smolensk 4	Smolensk	BWR (channel-type)	1000
42	West Ukraine 1	Rovno	PWR	440
43	West Ukraine 2	Rovno	PWR	440
44	West Ukraine 3	Rovno	PWR	1000

Table 11

Reactors in Operation, under Construction, and Planned

Location	Type of Plant	Electric Capacity (MWe)	Year in Operation
Siberia	Graphite/Water	100	1958
Siberia	Graphite/Water	100	1958
Siberia	Graphite/Water	100	1958
Siberia	Graphite/Water	100	1958
Siberia	Graphite/Water	100	1958
Siberia	Graphite/Water	100	1963
Beloyarsk	BWR (channel-type)	100	1964
Beloyarsk	BWR (channel-type)	200	1967
Beloyarsk	LMFBR	600	UC
Novovoronezh	PWR	210	1964
Novovoronezh	PWR	365	1959
Novovoronezh	PWR	440	1971
Novovoronezh	PWR	440	1972
Novovoronezh	PWR	1000	UC
Shevchenko	LMFBR	350 ~~[equivalent]~~	1973
Chukotka	BWR (channel-type)	12	1973
Chukotka	BWR (channel-type)	12	1974
Chukotka	BWR (channel-type)	12	1975
Chukotka	BWR (channel-type)	12	1976
Kola Peninsula	PWR	440	1973
Kola Peninsula	PWR	440	1974
Kola Peninsula	PWR	440	UC
Kola Peninsula	PWR	440	UC
Sosnovyy Bor	BWR (channel-type)	1000	1974
Sosnovyy Bor	BWR (channel-type)	1000	1975
Sosnovyy Bor	BWR (channel-type)	1000	UC
Sosnovyy Bor	BWR (channel-type)	1000	UC
Armenia	PWR	440	1977
Armania	PWR	440	UC
Kurck	BWR (channel-type)	1000	1977
Kursk	BWR (channel-type)	1000	UC
Kursk	BWR (channel-type)	1000	Planned
Kursk	BWR (channel-type)	1000	Planned
Chernobyl'	BWR (channel-type)	1000	UC
Chernobyl'	BWR (channel-type)	1000	UC
Chernobyl'	BWR (channel-type)	1000	Planned
Chernobyl'	BWR (channel-type)	1000	Planned
Smolensk	BWR (channel-type)	1000	UC
Smolensk	BWR (channel-type)	1000	UC
Smolensk	BWR (channel-type)	1000	Planned
Smolensk	BWR (channel-type)	1000	Planned
Rovno	PWR	440	UC
Rovno	PWR	440	UC
Rovno	PWR	1000	Planned

28	Oktemberyan 1	Armenia	PWR	440
29	Oktemberyan 2	Armania	PWR	440
30	Kursk 1	Kursk	BWR (channel-type)	1000
31	Kursk 2	Kursk	BWR (channel-type)	1000
32	Kursk 3	Kursk	BWR (channel-type)	1000
33	Kursk 4	Kursk	BWR (channel-type)	1000
34	Chernobyl' 1	Chernobyl'	BWR (channel-type)	1000
35	Chernobyl' 2	Chernobyl'	BWR (channel-type)	1000
36	Chernobyl' 3	Chernobyl'	BWR (channel-type)	1000
37	Chernobyl' 4	Chernobyl'	BWR (channel-type)	1000
38	Smolensk 1	Smolensk	BWR (channel-type)	1000
39	Smolensk 2	Smolensk	BWR (channel-type)	1000
40	Smolensk 3	Smolensk	BWR (channel-type)	1000
41	Smolensk 4	Smolensk	BWR (channel-type)	1000
42	West Ukraine 1	Rovno	PWR	440
43	West Ukraine 2	Rovno	PWR	440
44	West Ukraine 3	Rovno	PWR	1000
45	Kalinin 1	Kalinin	PWR	1000
46	Kalinin 2	Kalinin	PWR	1000
47	Ignalina 1	Lithuania	BWR (channel-type)	1500
48	Ignalina 2	Lithuania	BWR (channel-type)	1500
49	South Ukraine 1	Nikolayev	PWR	1000
50	South Ukraine 2	Nikolayev	PWR	1000
51	South Ukraine 3	Nikolayev	PWR	1000
52	South Ukraine 4	Nikolayev	PWR	1000
53	Urals 1	Urals	BWR (channel-type)	1000
54	Urals 2	Urals	BWR (channel-type)	1000
55	Ivano-Frankovsk 1	Ukraine	BWR (channel-type)	1000
56	Ivano-Frankovsk 2	Ukraine	BWR (channel-type)	1000
57	Khmel'nitskiy 1	Ukraine	Unknown	Unknown
58	Khmel'nitskiy 2	Ukraine	Unknown	Unknown
59	Aktash 1	Crimea	Unknown	Unknown
60	Aktash 2	Crimea	Unknown	Unknown
61	Saratov 1	Saratov	Unknown	Unknown
62	Saratov 2	Saratov	Unknown	Unknown
63	Tsimlyansk 1	Volgodonsk	Unknown	Unknown
64	Tsimlyansk 2	Volgodonsk	Unknown	Unknown

NOTE: An additional 26 reactors (13 nuclear power stations) are known to be in the planning stage but constru[ction is not] expected to begin on ~~these reactors~~ (at these sites) until the next Five-Year Plan (1981-198[5]).

* UC = under construction

** This reactor has a rated capacity of 350 MWe; however, [illegible] 200 MWe is utilized to desalinate water from the Caspi[an]

Armenia	PWR	440	1977
Armania	PWR	440	UC
Kursk	BWR (channel-type)	1000	1977
Kursk	BWR (channel-type)	1000	UC
Kursk	BWR (channel-type)	1000	Planned
Kursk	BWR (channel-type)	1000	Planned
Chernobyl'	BWR (channel-type)	1000	UC
Chernobyl'	BWR (channel-type)	1000	UC
Chernobyl'	BWR (channel-type)	1000	Planned
Chernobyl'	BWR (channel-type)	1000	Planned
Smolensk	BWR (channel-type)	1000	UC
Smolensk	BWR (channel-type)	1000	UC
Smolensk	BWR (channel-type)	1000	Planned
Smolensk	BWR (channel-type)	1000	Planned
Rovno	PWR	440	UC
Rovno	PWR	440	UC
Rovno	PWR	1000	Planned
Kalinin	PWR	1000	UC
Kalinin	PWR	1000	UC
Lithuania	BWR (channel-type)	1500	UC
Lithuania	BWR (channel-type)	1500	UC
Nikolayev	PWR	1000	UC
Nikolayev	PWR	1000	UC
Nikolayev	PWR	1000	Planned
Nikolayev	PWR	1000	Planned
Urals	BWR (channel-type)	1000	UC
Urals	BWR (channel-type)	1000	UC
Ukraine	BWR (channel-type)	1000	Planned
Ukraine	BWR (channel-type)	1000	Planned
Ukraine	Unknown	Unknown	Planned
Ukraine	Unknown	Unknown	Planned
Crimea	Unknown	Unknown	Planned
Crimea	Unknown	Unknown	Planned
Saratov	Unknown	Unknown	Planned
Saratov	Unknown	Unknown	Planned
Volgodonsk	Unknown	Unknown	Planned
Volgodonsk	Unknown	Unknown	Planned

...own stations,
...s are known to be in the planning stage but construction is not
...se reactors until the next Five-Year Plan (1981-1985).
[illegible]

...tic capacity of 350 MWe; however, process steam equivalent
...to desalinate water from the Caspian Sea.

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USSR: Nuclear Accident Near Kyshtym in 1957-58

An Intelligence Assessment

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USSR: Nuclear Accident Near Kyshtym in 1957-58

Overview

Media reporting of a nuclear accident near Kyshtym has appeared occasionally since 1958. It was not until 1976, when the writings of Dr. Zhores Medvedev began to appear, however, that worldwide attention was focused on this subject. Medvedev, an exiled Soviet geneticist, claimed in several articles and books that a "disaster" occurred near Kyshtym in 1957-58. He alleged that thousands of casualties and widespread, long-term radioactive contamination occurred as the result of an explosion involving nuclear waste stored in underground shelters.

There is growing interest in both the United States and abroad in establishing whether this so-called accident or disaster was only a historical event in the development of nuclear energy or is, in fact, relevant to the current debate over nuclear technology safety

We believe that a significant radioactive contamination problem exists in the Kyshtym area of the southern Ural Mountains and that the origin of this contamination is the Kyshtym nuclear energy complex. We believe that this contamination problem is the result of a combination of events rather than a single isolated incident. We do not know the actual extent of the contamination zone, but we believe that an area about 1,000 square kilometers is affected; as much as 100 square kilometers contain high levels of radioactivity; the rest is contaminated with hazardous levels of radioactivity. A contributing factor in creating the contamination may have been the pressure to produce large quantities of nuclear materials quickly

There is evidence of five accidents or events in the Kyshtym area during the 1950s. The five events are listed in decreasing order of the amount of contamination they could have caused:

- A major release of high-level radioactive waste produced from early years of spent reactor fuel reprocessing probably occurred at a large waste pit and also possibly at a waste-filled ravine near the main production facility. We believe that a single major accident and/or a series of incidents at one or both of these sites created serious contamination conditions.

- Early reactor operations at the Kyshtym complex clearly created a chronic contamination problem of significant proportions in the Techa River drainage area. Radioactive products, which resulted from reactor fuel failures and irradiation of coolant impurities, flowed into the river after they were discharged to the lake that provides cooling water (intake and discharge) for the reactors. In the late 1950s bypass canals were constructed, isolating the lake from the river, to prevent further contamination of the river.

- An incident occurred in one of the reactor areas during the late 1950s and probably was the cause of the shutdown of the area during the 1960s and 1970s. The most likely cause of the incident was a failure of the core-cooling system or a sudden reactor power surge. This incident probably produced only intense, short-lived contamination near the reactor. But it also may have caused radiation injuries to maintenance and cleanup personnel at the facility as well as to inhabitants of the affected off-site areas.

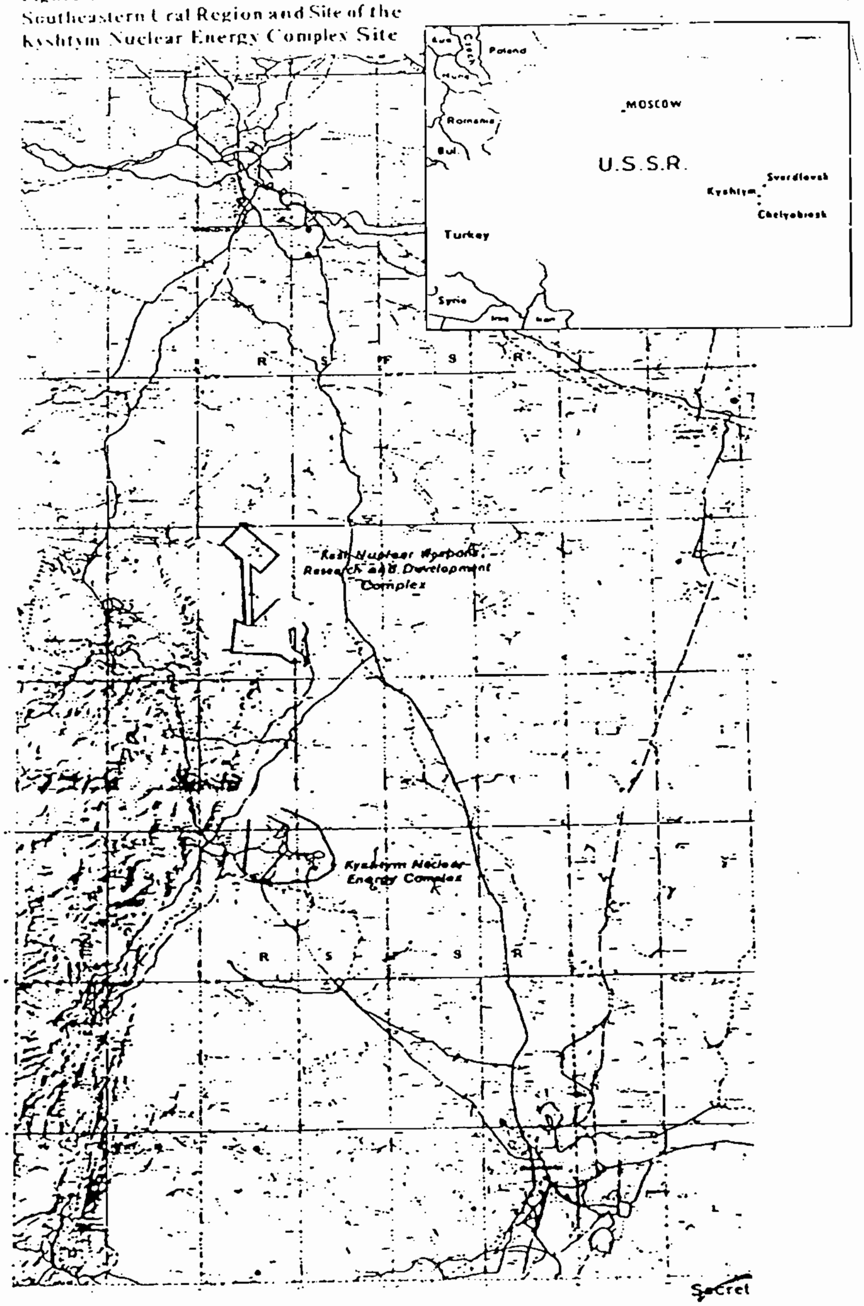
- An accident in the fuel reprocessing area, either a fire or chemical explosion within the area, probably was responsible for the shutdown of the area in 1957-58. Such an accident probably would cause local radioactive contamination and possibly radiation injuries to maintenance and cleanup personnel. An accident external to the area, such as a waste-pit explosion, also may have been responsible.

- A large explosion of stored chemicals may have occurred within the Kyshtym complex. Such an explosion and the subsequent fire could explain some of the events described in several reports. A large chemical explosion would not necessarily have had a direct impact on any of the facilities within the complex containing radioactive materials. At most, only minor, localized contamination would have resulted.

The events at Kyshtym have little relevance to current nuclear technology safety issues. The nuclear waste storage practices and technology, the fuel reprocessing technology, and the reactor technology now available are significantly different and/or improved relative to those in use at Kyshtym during the 1950s.

Contents

Figure 1
Southeastern Ural Region and Site of the Kyshtym Nuclear Energy Complex Site



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USSR: Nuclear Accident Near Kyshtym in 1957-58

Introduction

Since 1958 reports have indicated that a nuclear accident occurred in the southern Ural Mountains during the mid-to-late 1950s. Information in a majority of these reports points toward the involvement of the Kyshtym nuclear energy complex. It was not until September 1961, however, that satellite photography of the Kyshtym area provided our first look at the facility that had been associated with the reported accident

The complex is approximately 15 kilometers (km) east of the city of Kyshtym in the eastern foothills of the south-central Urals (see figure 1). The complex includes the oldest plutonium production facility in the USSR. Construction of the complex is believed to have been well under way as early as 1946. The outer perimeter security fence encloses an area roughly 140 square kilometers (km^2). The complex includes two major production facilities, a number of associated facilities for support and auxiliary functions, and housing areas.

The main production facility consists of three production reactor areas, a spent fuel reprocessing and waste disposal area, and various support areas. This production facility is separately secured and is located on the southern shore of Lake Kyzyltash. This lake serves as the source of cooling water for the reactors (see figure 2).

The second large secured area within the complex boundary is the Tatysh production facility located southwest of the main production facility on the shore of Lake Tatysh. This Tatysh facility has a number of laboratory-type buildings, a steam plant, two electrical substations, and a railroad siding (see figure 3).

A Technical Intelligence Report to be published in late 1981 will present an in-depth analysis of the Kyshtym accident

The absence of photography of the Kyshtym area during the crucial period between the late 1950s and September 1961 has been the most serious intelligence gap in our understanding of events surrounding the reported "accident." Over the last three years, however, new information has become available from in-depth analysis of Soviet radioecology literature, and satellite imagery. This information has provided new insight into possible accident events and radioactive contamination associated with the Ural "disaster."

Indicators of Radioactive Contamination Events

reports on the Ural nuclear accident suffer from the lack of any firsthand or even secondhand accounts of the event(s), the absence of scientific qualifications describing certain effects (for example, radiation burns), significant differences in the reported dates of an event (1956-63), and widely varying accounts of events and their aftermath. The reports, however, present a reasonably consistent localization of these events to the southern Ural area.

Roughly half of the reports indicate that an event occurred during 1957-58. Information in a majority of them clearly points toward the Kyshtym nuclear energy complex as the location of one or more events. Most of the reports refer to an explosive-type event. Some of the dramatic citations concerning the type of event are as follows:

- Explosion at the Kyshtym plant
- Atomic test . . . in Kyshtym.
- Atomic explosion in the (Chelyabinsk) area
- Large areas north of Chelyabinsk contaminated by radioactive waste from a nuclear plant
- Tremendous explosion . . . in one of the sections of the closed zone for the atomic center near Chelyabinsk.

Figure 2

Main Production Facility, Kyshtym Complex

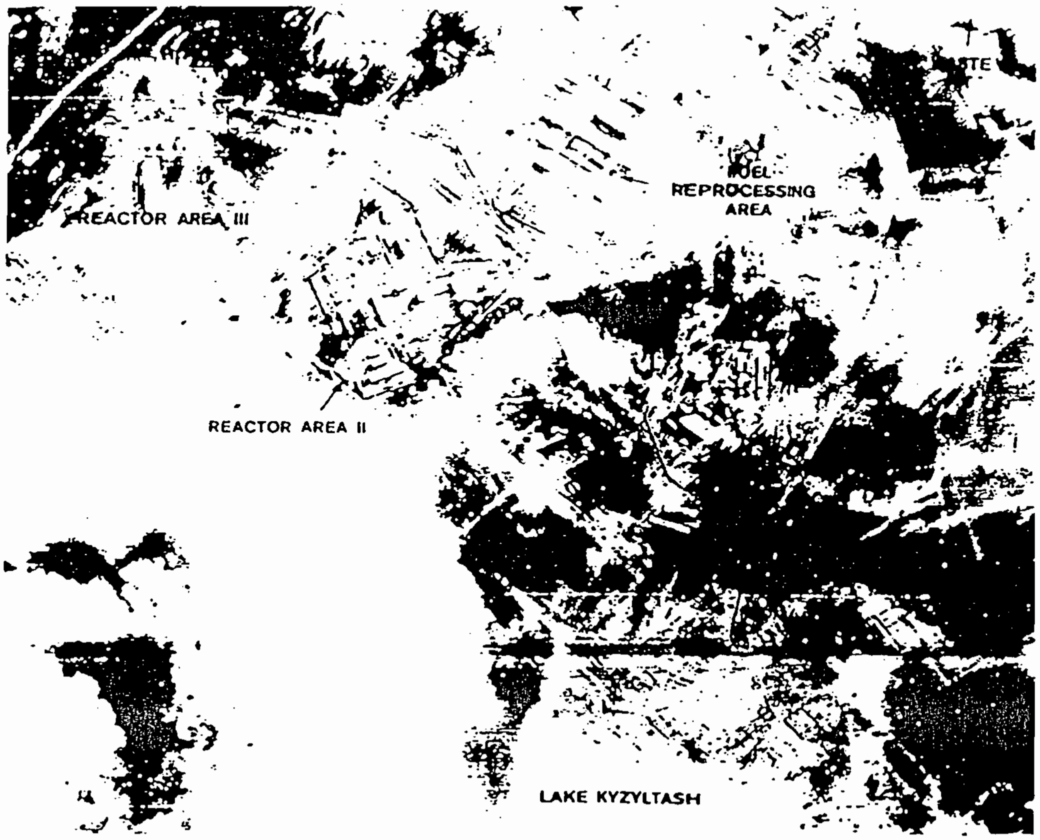

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Figure 3

Tatysh Production Facility, Kyshtym Complex

- Explosion at the atomic installation known as Chelyabinsk-40.
- Terrific explosion somewhere in Chelyabinsk Oblast.
- Atomic factory exploded in vicinity of Sverdlovsk.
- Enormous explosion occurred in a plant called Chelyabinsk-100.
- Nuclear test . . . occurred in an unspecified region of the Ural Mountains.
- Disaster, is still

Most of the reports also indicate an extensively affected area lying east of Kyshtym and between the cities of Sverdlovsk and Chelyabinsk. [ ]

[ ]

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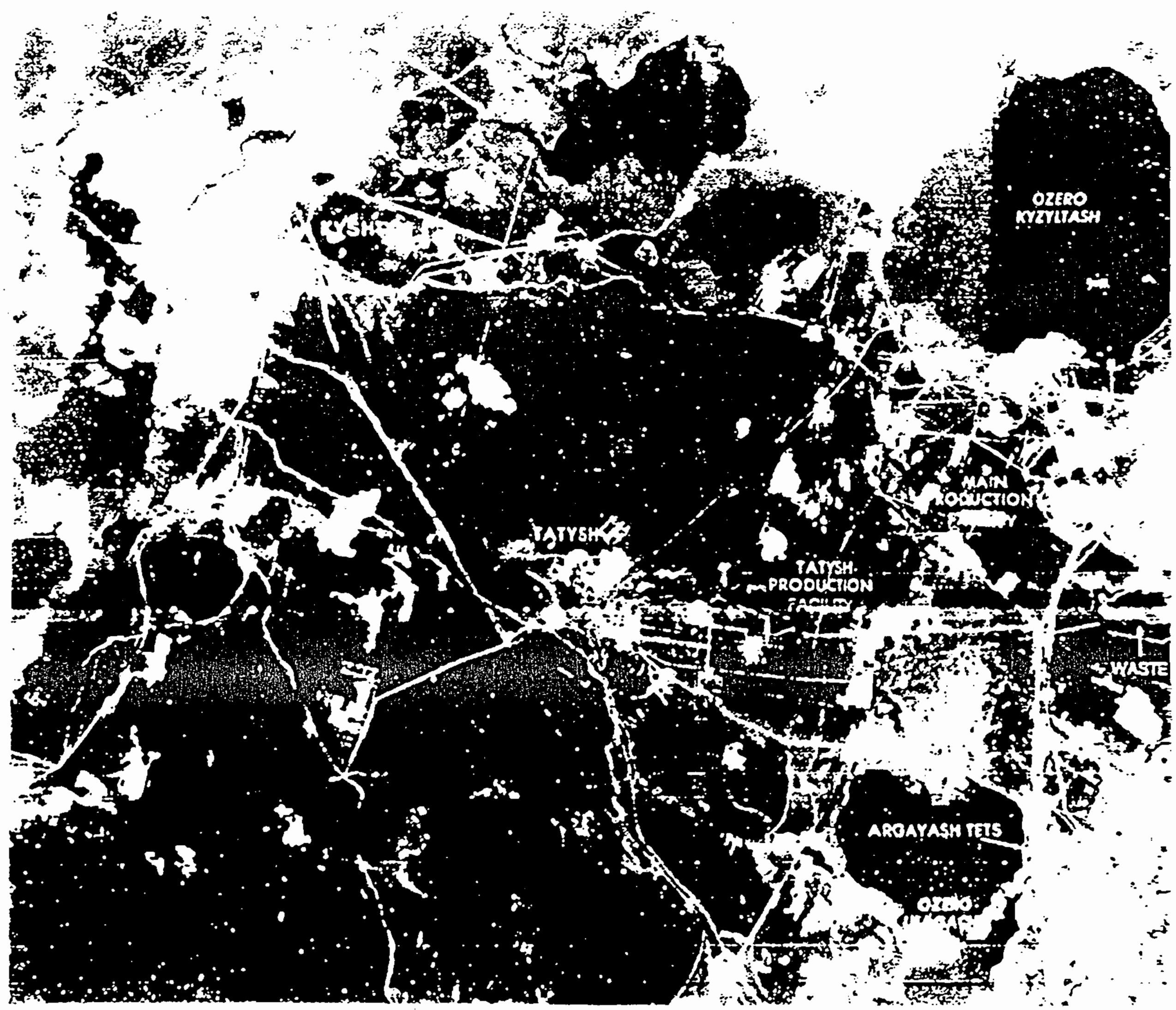
[redacted] None [redacted] provides any indication of the radioactivity levels or range of isotopes present in areas that are reported contaminated

Photography. In July 1959 a U-2 aircraft photographed the Kyshtym area for the first time, but the key areas of interest were almost entirely obscured by cloud cover. Satellite photography of the area obtained in September 1961 provided our first look at the nuclear facilities in the vicinity of Kyshtym. This absence of photography of the Kyshtym complex during the crucial period between the late 1950s and September 1961 has been the most serious intelligence gap in our understanding of events surrounding the accident. The 1961 photography reveals, however, several areas at or near the Kyshtym nuclear energy complex that are suspected of having a direct connection to the radioactive contamination that exists in the Ural Mountains. Among these are (1) the large retention basins east of the complex and the associated Techa River bypass canals, (2) the shutdown Reactor Area III, (3) the large waste pit and dammed ravine near the fuel reprocessing area, and (4) a long, narrow off-site "corridor," running from the complex perimeter in a northeasterly direction that appears to have been evacuated and declared off limits for the populace

The 1961 photography of the Kyshtym area showed that canals had been constructed to route the Techa River around Lake Kyzyltash. Also, two large cascaded basins whose combined area of approximately 49 km² had been created for retention and evaporation of drainage from the lake (see figure 4). The creation of these retention basins and construction of the bypass canals may have been necessitated by the continuing chronic release of significant fission and activation products from reactor operations (and from site runoff). Also, construction of the basins and canals may have been precipitated by a single major accident that resulted in substantial ground and/or water contamination in the vicinity of the site. Given the absence of any holdup cribs in the reactor areas to confine the majority of products released through fuel failures, it is probable that these continuing releases eventually forced the Soviets to isolate the water bodies associated with reactor operations in order to reduce the radiation hazard to the populace downstream

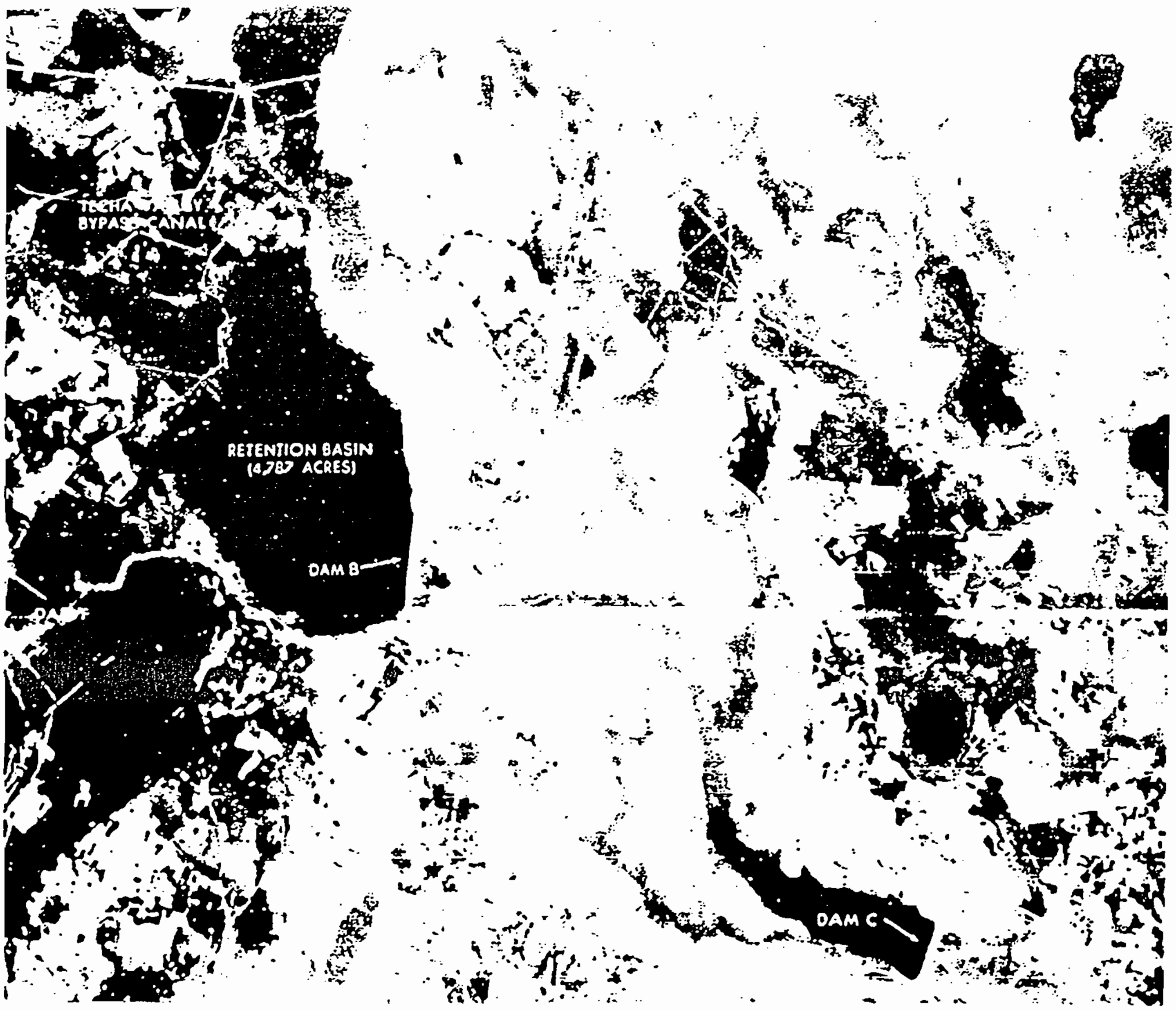
The photographic history of Reactor Area III indicates that a serious incident occurred at this site some time before 1961, probably in the late 1950s. From September 1961 until mid-1972, very little activity occurred within the area, and no reactor operations were under way. In mid-1972 a major decontamination and modification program was begun. After almost eight years, reactor operations at the renovated facility commenced in early 1980. It is difficult to reconcile the extended period of shutdown at Area III with anything less than a serious incident that precluded the resumption of reactor operations. Such a long cessation of operations is inconsistent with demonstrated Soviet practice in the operation of production reactors, if indeed there had not been an incident or one having a relatively short-term impact. If a serious incident had not occurred at Area III, it is likely that the Soviets would have made the effort necessary to repair and reactivate the reactor(s) in Area III as soon as possible after shutdown. The shutdown occurred at a time when there was a heavy demand for reactor products (plutonium and tritium) for the Soviet nuclear weapons program

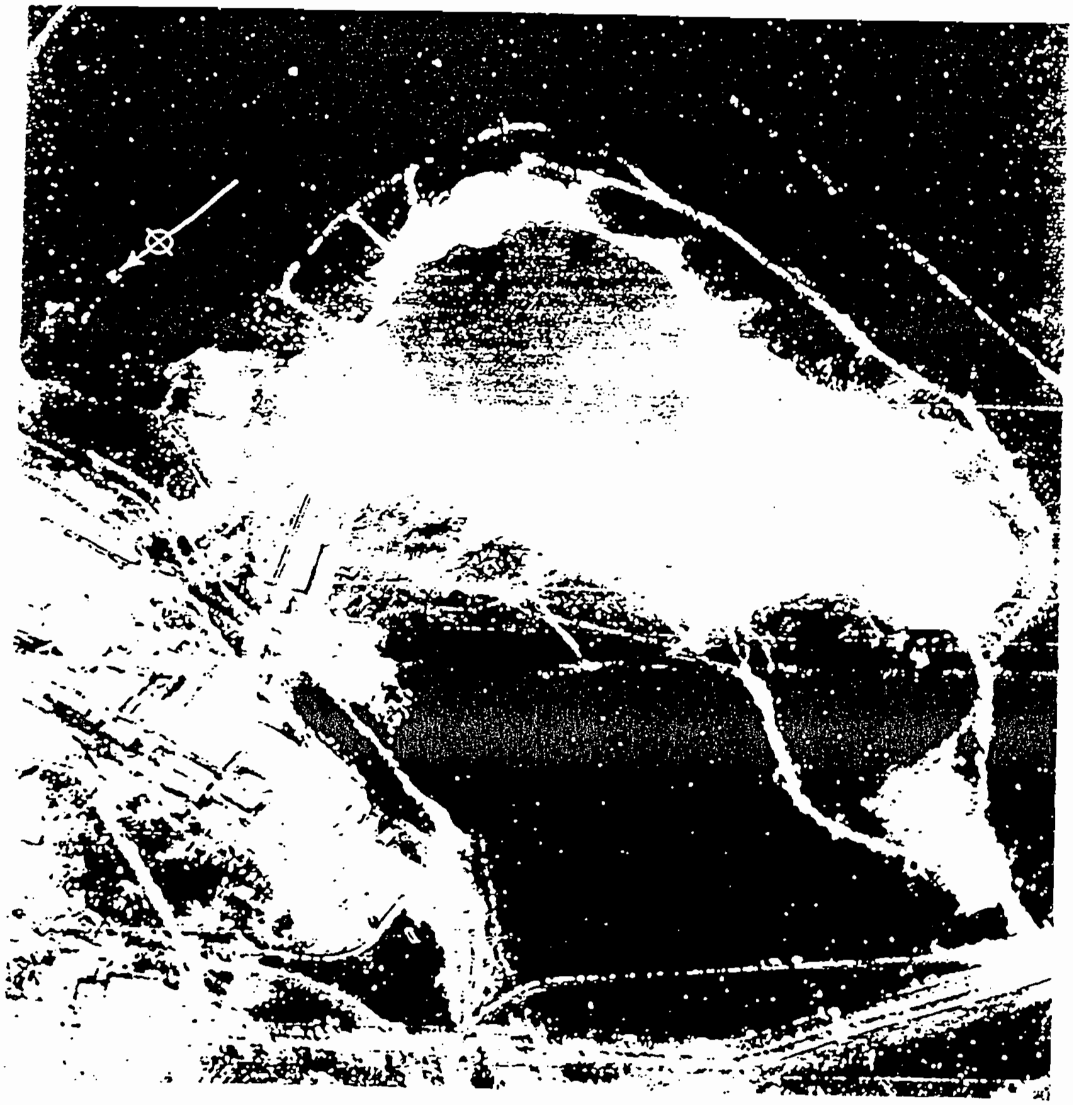
A comparison of the estimated volume of high-level radioactive waste generated at the Kyshtym complex during its first eight to 10 years of operation and the known capacity of the tank storage at the site has led us to conclude that most of the high-level waste generated by early fuel reprocessing at the Kyshtym complex has been discharged to the large open pit south of the fuel reprocessing area (see figure 5). Lesser amounts of high-level waste appear to have been discharged to the dammed ravine east of the fuel reprocessing area (see figure 6). This conclusion is further supported by information obtained through an examination of the photographic history of activity at these two sites



OZERO
KYZYLTASH
MAIN
TATYSH
TATYSH
PRODUCTION
WASTE
ARGAYASH TETS


OZERO
KYZYLTASH
RETENTION BASIN
(4,787 ACRES)
DAM B
DAM E
WASTE PIT


RETENTION BASIN
(4,787 ACRES)
DAM B
DAM C



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During the early-to-mid-1960s the Soviets began a massive earth-moving effort (still under way) to create a completely new, clean embankment for both the large pit and the dammed ravine. The liquid level in the pit and the ravine is kept fairly constant, and the discharge of high-level waste to these areas has ceased. Thus, the earth-moving operation would reduce the amount of high-level waste products transported into surrounding areas from the exposed banks, which were contaminated as a result of earlier waste additions and evaporation. The manner in which the Soviets are depositing the earthen material (presumably sand or gypsum) to create the new embankments is also rather revealing of the radiation hazard in the vicinity of these two sites. It is also apparent from the winter photography that the pit and the ravine generate heat, which is consistent with a site for high-level waste disposal

The inhabitants have been evacuated from an area roughly 5 to 10 km wide and about 70 to 80 km long northeast from the Kyshtym complex. The villages within the area have been razed, and large-scale cultivation of crops has been abandoned (see figure 7). Long narrow corridors of this type are typically the result of an airborne radiological release following an accident. Single events of this type tend to produce a narrow deposition plume with sharp boundaries. This is in contrast to the more widely affected area resulting from chronic operational releases, which tend to produce more diffuse, widespread depositions

Soviet Radioecology Literature. Analysis of unclassified Soviet radioecology literature indicates that an accident occurred in the Kasli-Kyshtym area during 1957-58 and involved the atmospheric release of reprocessed fission wastes. This analysis indicates the following:

- A major airborne release of radioactivity occurred within a 50-km radius of Kasli in the winter of 1957-58, involving moderate- to long-lived fission products having little cesium-137.
- An extensive area (at least 25 to 100 km^2) was contaminated with high levels of radioactivity—roughly 1 milliCurie per square meter of strontium-90. The total area estimated to have contamination levels significantly above fallout background may exceed 1,000 km^2.
- The incident appears to have involved the release of 10^5 to 10^6 Curies of strontium-90, with a minimum airborne contribution probably on the order of (0.3-1) x 10^5 Curies of strontium-90.
- It is impossible to determine from the radioecology literature alone whether the contaminated zone was created by a single event, several events (involving permutations and combinations of accidents and nonaccidents), or complex releases associated with a single accident

Figure [illegible]

Waste-Filled Ravine East of the Fuel Reprocessing [illegible]

Accident Hypotheses

The accident hypotheses suggested by the evidence from the five categories of information discussed above encompass (1) nuclear waste events, (2) production reactor events, (3) fuel reprocessing events, (4) nuclear weapon-related events, and (5) chemical shipment/storage detonation.

Nuclear Waste Events. It has been established that large volumes of high-level waste generated in the first several years (possibly 10 years or more) of operations at the Kyshtym complex were discharged to the large open pit (or pond) south of the fuel reprocessing area. A lesser amount apparently was discharged into the dammed ravine east of the chemical separations area

The accidents that possibly could result from using open pit reservoirs for storing high-level waste are chemical explosion, nuclear criticality, and dispersal of waste products from other causes (for example, wind and water transport). Detonation of dried waste is considered the most credible single major accident event for the open pit. Criticality (with a potential for supercriticality in an unlined earthen pit) theoretically has a great energy potential given reasonably high plutonium losses in separations. The neutron poisoning effect of various fission products in the waste solution and the severe demands on plutonium mass and configuration make a criticality or supercriticality event highly unlikely.

Dispersal of wind- and water-borne waste products from the pit area probably has been a chronic source of contamination in the vicinity whatever the number and severity of individual accidents. Clearly, the fission product inventory and isotopic characteristics of the high-level waste residing in the open pit (and dammed ravine), however dispersed, offer the best match to the Soviet radioecology data.

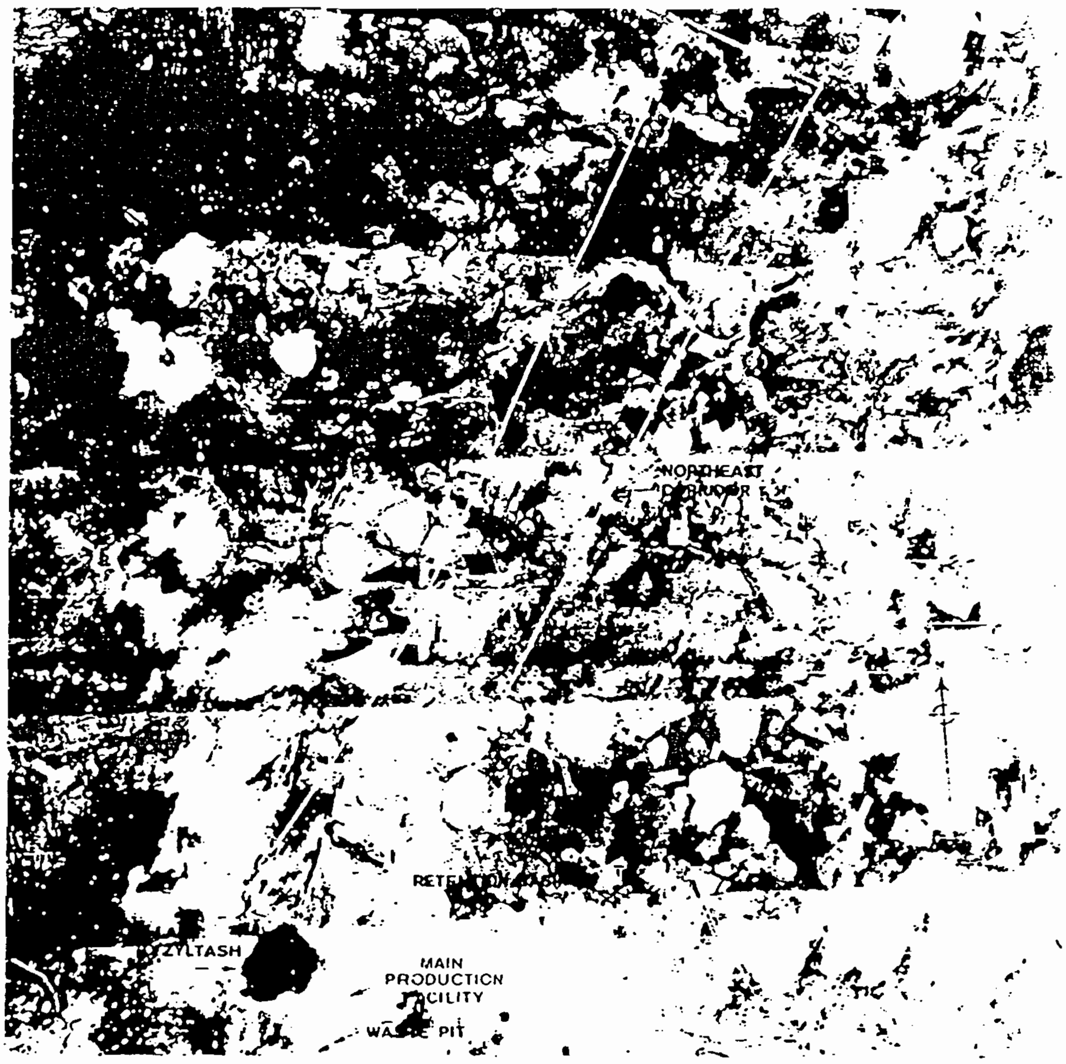
We conclude, therefore, that a major release of high-level radioactive waste products probably occurred at the large waste pit and possibly also at the dammed, waste-filled ravine. We further conclude that serious contamination conditions may have been created in the vicinity of the complex as the result of a single major accident, a series of incidents, and/or chronic releases associated with one or both of these waste disposal sites.

With respect to the few sites used for waste tank storage at the Kyshtym complex, accident categories considered were chemical explosion (hydrogen detonation, dried waste detonation), nuclear criticality, and tank rupture from other causes (bumping, corrosion, lifting from water table rise, and earthquakes). Dried waste detonation clearly has the greatest potential for producing widespread, high-level contamination. If the cesium-137 had been separated from the waste stream as a consequence of the separations chemistry or largely removed from the stored waste by, for example, tank rupture, then the contents of one large waste tank could provide both the inventory and isotopic characteristics consistent with the Soviet radioecology data. A viable set of conditions necessary to cause an explosion in the contents of a waste tank can be achieved, but photographic evidence does not support such an event at the Kyshtym complex.

Production Reactor Events. The types of production reactors considered in the analysis of events at the Kyshtym complex were heavy-water reactors (HWRs), single-pass (open cycle) graphite-moderated reactors (GMRs), and recirculating (closed cycle)

Figure 7

The Northeast Corridor



GMRs. HWRs and recirculating GMRs were considered the most likely reactor candidates for the initial system(s) in Area III, with single-pass GMRs clearly being the type of systems present in reactor areas I and II.

The photographic history of Area III and nearby offsite areas indicates the occurrence of some type of reactor incident at this facility before the first satellite photography of September 1961. Types of accidents considered were reactor power surges, loss of control, overpower operation, power-coolant mismatch, cooling failure, and nonnuclear energy release in the core. Reactor power surges and cooling failure are the two types of reactor events that appear to be most consistent with observations about Area III, particularly with respect to the types of events required to preclude relatively quick repair and reactivation of a reactor facility. Release of fission products resulting from power surges and cooling failures could be quite severe, especially in terms of short-lived activity, and most likely would produce a long, relatively narrow plume deposition pattern that is reasonably consistent with the shape of the northeast corridor. It should be noted, however, that this type of event would not produce quite the magnitude of release nor the isotopic characteristics indicated in the radioecology literature

In addition to the Area III incident, it is clear from certain [redacted] reports and site photography that chronic releases of fission products and activation products from the single-pass GMRs during early operations at the site created a serious contamination problem in the Techa River by the early-to-mid-1950s. Before the late 1950s, the radioactive products resulting from reactor fuel failures and irradiation of coolant impurities were free to flow into the Techa River after being discharged to Lake Kyzyltash. It was not until the late 1950s that Lake Kyzyltash was finally isolated from the Techa River flow by a system of bypass canals

Fuel Reprocessing Events. Accident hypotheses considered for the fuel reprocessing facilities include explosions and fires, criticality, radioactivity spills, and chronic releases. A fire and/or explosion, particularly in connection with the possible operation of a solvent extraction pilot plant, are the most likely causes of a serious incident within the fuel reprocessing area that would cause the shutdown noted in the [redacted] data. Such an event could cause severe contamination in the vicinity of the affected facilities. The magnitude of release even in this type of event would be relatively small because of the limited reactor fuel inventory in a fuel reprocessing plant operation. A major radioactivity spill, if occurring at a strategic location in the plant, would produce relatively little contamination away from the facility but could result in an extended downtime for cleanup. Criticality and chronic releases are considered much less serious in an accident sense, although injuries to plant personnel could result. It is possible that some reports of accident casualties being treated in Chelyabinsk hospitals were the result of overexposure and injury to maintenance and cleanup crews brought in to repair and reactivate a damaged fuel reprocessing facility.

It is likely, therefore, that either a fire and/or explosion or a major radioactivity spill caused the 1957-58 shutdown of fuel reprocessing at Kyshtym if, in fact, this shutdown was caused by an incident internal to the fuel reprocessing area. The evidence is insufficient to establish conclusively whether this shutdown was caused by an incident inside the fuel reprocessing area or an incident somewhere outside this area (for example, waste pit explosion

Nuclear Weapons-Related Events. Accident hypotheses considered for nuclear weapons-related events are (1) fallout from atmospheric tests, (2) accidental detonation of a device, and (3) releases from a weapon component fabrication plant. None of these events is a credible candidate for a major event and subsequent high-level contamination in the Kyshtym area. The low-level global fallout activity found in the environmental samples and the features of high-altitude meteorological phenomena argue against any significant contamination problem in the Kyshtym area being created by fallout from high-yield atmospheric tests at Novaya Zemlya or Semipalatinsk. There is no evidence for an accidental detonation of a device, nor do we believe that the Soviets would risk having an assembled device in the vicinity of the Kyshtym complex during the time frame of interest. The consideration of releases from a fabrication plant for weapon components was prompted by the suspected presence of such a facility in the Tatysh area of the Kyshtym complex. Neither chronic nor accidental single releases from such a plant are consistent with either the magnitude or the isotopic characteristics indicated by the Soviet radioecology data nor with the nature of the event as described in much of the reporting.

Chemical Shipment/Storage Detonation. Events relating to shipping, storage, and detonation of chemicals were considered as a possible explanation for some of the reporting of explosive events. One highly explosive chemical, ammonium nitrate, may have been stored in reasonably large quantities somewhere within the complex during the 1950s.[2] If the Soviets had been experimenting with an early Hanford-type solvent extraction separation process [3] during this time period, it is likely that ammonium nitrate (which is used as a process chemical) would have been stored on the site.

[2] Several disasters involving explosions of stored or in-transit ammonium nitrate have been documented

[3] REDOX-type process.

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Directorate of
Intelligence

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The Soviet/CEMA Nuclear Power Programs and Their Requirements for Enriched Uranium

A Research Paper

CIA HISTORICAL REVIEW PROGRAM
RELEASE AS SANITIZED
1999

This paper was prepared by and , Office of Scientific and Weapons Research. Contributions were provided by of the Office of Soviet Analysis and

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SW 84-10026
April 1984

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The Soviet/CEMA Nuclear Power Programs and Their Requirements for Enriched Uranium

Key Judgments

Information available as of 31 August 1983 was used in this report.

Total installed nuclear generating capacity in the Soviet Union and other CEMA countries increased from about 1,000 megawatts (electrical) at the start of the 1970s to over 22,000 megawatts by the end of 1982. Well-publicized, long-range Soviet/CEMA plans call for approximately 100,000 megawatts of installed capacity by 1990 in Soviet-designed and -fueled reactors.

We have examined in detail all available information from [redacted] of existing reactors, those under construction, and those in various planning stages. On the basis of this examination, we believe that a capacity of about 100,000 megawatts will not be achieved in 1990, but probably will be achieved at some time in the mid-1990s. We estimate that actual capacity as of 1990 could be as high as 88,000 megawatts, but is more likely to range from 60,000 to 70,000 megawatts.

The fraction of Soviet uranium enrichment capacity allocated to the Soviet/CEMA nuclear power program increased from essentially zero in the early 1970s to a cumulative total of about 15 percent of output—22,000-metric-ton separative work units (MTSWU)—by the end of 1982. We believe this demand will rise dramatically (to 80,000 or more MTSWU) by 1990, [redacted].

In addition to supporting its own nuclear power program and those of other CEMA countries, the Soviet Union operates a commercial toll-enrichment program through which it sells uranium enrichment services (not the uranium itself) to the nuclear power programs of various Western countries. The toll enrichment program began in 1973. Cumulative enrichment requirements from the program amounted to about 24,000 MTSWU by the end of 1982 and are expected to increase to about 50,000 MTSWU by the early 1990s.

Taken together, the Soviet/CEMA nuclear power programs and toll-enrichment program requirements for enriched uranium will account for [redacted] of total capacity by 1990. By the mid-1990s, we believe that total Soviet requirements for enriched uranium (including those for nuclear weapons and naval nuclear propulsion, as well as power reactors and toll enrichment services) will outstrip our projections of Soviet capacity. It is therefore likely that the Soviets will bring additional production on line between now and the early 1990s.

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The Soviet/CEMA Nuclear Power Programs and Their Requirements for Enriched Uranium

Introduction

The strong growth of nuclear power in the Soviet Union and other CEMA [1] countries in the 1970s will continue in the 1980s and early 1990s. All nuclear power stations in the Soviet Union and most of the existing and planned stations in the other CEMA countries are built around Soviet-designed reactors that use uranium fuel slightly enriched in the isotope uranium-235 (U-235). The Soviet Union provides the fuel for all these reactors, placing an increasingly large burden on its enriched uranium production capacity.

The Soviet uranium isotope separation plants that produce enriched uranium for military purposes (nuclear weapons and the naval nuclear propulsion program) must also supply the enriched uranium for Soviet/CEMA nuclear power and the toll enrichment program, a commercial endeavor in which the Soviet Union sells enrichment services (not the uranium itself) to Western nuclear power programs. Our estimates of the production capacity available to supply enriched uranium for nuclear weapons necessarily are based on subtracting nonweapon demand (particularly requirements for nuclear power programs) from estimates of total enrichment capacity.

Because of the complex variety of uranium enrichments necessary for various weapon and nonweapon applications, both enrichment capacity and enrichment demand are usually expressed in terms of separative work units (SWU) rather than quantities of material. The SWU is an internationally recognized measure, which quantifies the separative work involved in producing a given amount of enriched uranium for any given assay (enrichment level) of the uranium feed, product, and waste (tails). This report describes the requirements of each Soviet reactor type in terms of metric tons of material at various enrichments and then converts these quantities to metric ton SWU (MTSWU). The totals are discussed entirely in terms of MTSWU.[2]

Our analysis of these programs and their requirements for enriched uranium is based primarily on data available from open Soviet and East European publications, but our conclusions about future growth in nuclear power are strongly influenced by [ ].

Soviet Power Reactor Types and Their Separative Work Requirements

A modeling approach was developed to establish the separative work requirements of each class of Soviet reactor. The approach aims only at establishing the separative work requirements of a "typical" reactor within each class. Such an approach is necessary because the Soviets do not publish data on current or projected nuclear power program requirements for uranium, enriched uranium, or separative work. They have, however, published relatively detailed descriptions of each type of reactor. They also routinely announce the start of new reactors and publish their plans for construction of additional reactors. They publish information on the amount of power generated each year at the various operating nuclear power

[1] CEMA—Council for Mutual Economic Assistance: Council members which have or are scheduled to have Soviet power reactors are Poland, East Germany, Romania, Hungary, Czechoslovakia, Bulgaria, Cuba, and the USSR.

[2] SWU are usually characterized as kilogram-SWU (KGSWU) or MTSWU, depending on the units used for the equivalent amounts of material. In this report we use only MTSWU. For a more complete explanation of the concept of the SWU and its relationship to enrichment plant operation, see CIA Report ER 77-10468 (Unclassified), August 1977, *Nuclear Energy*.

Conversion of quantities of enriched uranium of a given enrichment to the equivalent in SWU involves calculations that are quite sensitive to the assumed assay (enrichment level) of the plant waste. For the calculations used in this report we used a tails assay value of 0.2 percentage point. [ ].

stations. There is no single document or publication that contains all of this information. The information instead must be assembled from an assortment of Soviet books, journal articles, scientific papers, and news items. From the reactor data, it is possible to determine the amounts and enrichment of the initial and replacement fuel loads and the amount of power generated before each refueling. The electric power data provide a basis for determining how long a typical reactor will operate before refueling. By totaling over time the typical reactor data of each type, it is possible to calculate overall fueling requirements.

There are two major types of Soviet-designed and -fueled power reactors: pressurized water reactors and boiling water reactors. The pressurized water reactors are designated by the Soviets as VVER. Two versions are being produced, a 440-megawatt (electrical) model designated VVER-440 and a 1,000-megawatt (electrical) model designated VVER-1000. Two earlier models are also in operation, the VVER-210 and the VVER-365. The boiling water reactors are of the graphite moderated pressure tube type and are designated RBMK. There are two important versions, 1,000- and 1,500-megawatt (electrical) models designated RBMK-1000 and RBMK-1500, respectively. Smaller versions exist but not in significant numbers. The VVERs are found in both the Soviet Union and the other CEMA countries. Because of publicly stated Soviet nonproliferation policy and the ability of the RBMK reactor to produce plutonium suitable for use in nuclear weapons, we do not believe these reactors will be built outside the Soviet Union. The VVER-440 and the RBMK-1000 are currently operational in sizable numbers. The VVER-1000 and the RBMK-1500 are just being introduced into service. (

In addition to these basic reactors, the Soviets are continuing to develop a third type—liquid-metal-cooled, fast-breeder reactors. Only two major breeder reactors are currently in operation: a 350-megawatt prototype designated BN-350 and a 600-megawatt prototype designated BN-600. Several small liquid-metal-cooled research reactors are also in operation. Currently, the impact of the breeder reactors on separative work requirements is of some significance because they are fueled with highly enriched uranium. On numerous occasions, senior Soviet nuclear officials have stated their intent to use plutonium to fuel their breeders. However, these statements generally refer to a time in the 1990s when breeders will be built on a commercial basis. They have never indicated if, or when, they plan to switch to plutonium fuel for the prototypes. In this paper, we assume that only uranium fuel is used in breeder reactors. (

VVER Pressurized Water Reactors

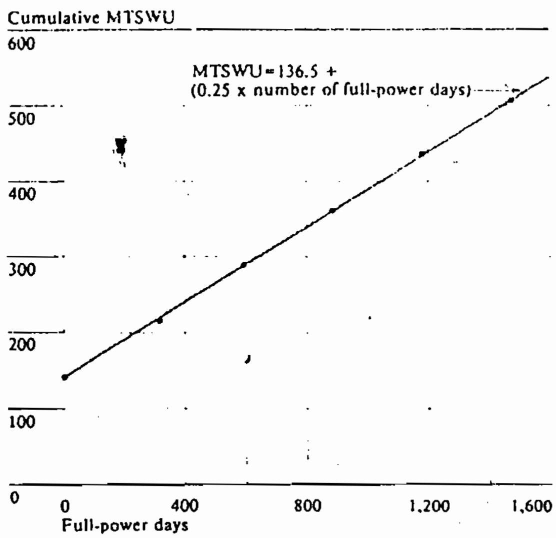
In the VVERs, the nuclear fuel is loaded in a lattice arrangement inside a steel pressure vessel. The fuel is cooled and the neutrons moderated by circulating water. The reactor is kept under high pressure to prevent the water from boiling within the reactor itself. Another large vessel called a pressurizer is used to maintain and regulate the pressure in the primary coolant loop (the coolant path through the reactor itself). Hot water from the reactor vessel is circulated through a steam generator (heat exchanger) where steam is produced for the turbines. (

VVER-440. The core of the VVER-440 consists of 349 fuel assemblies, each of which contains uranium dioxide equivalent to 120 kilograms of elemental uranium. Total core load is thus about 42 metric tons of elemental uranium. The degree of enrichment of the uranium contained in various parts of the core is varied systematically during the initial (transition) period of operation while the reactor is being brought to equilibrium (steady-state utilization of the nuclear fuel). The initial core usually consists of 114 assemblies with uranium enriched to 1.6-percent U-235; 133 assemblies with uranium enriched to 2.4 percent; and 102 assemblies with uranium enriched to 3.6 percent. (

According to published Soviet, East European, and Finnish data, the first fuel replacement in the VVER-440 occurs after the equivalent of about 320 full-power days of operation, with the 114 1.6-percent assemblies being replaced with a set consisting of 12 2.4-percent and 102 3.6-percent assemblies.[1] The second refueling occurs after about 595 full-power days, with 121 of the 2.4-percent assemblies being replaced with a set consisting of 19 fresh 2.4-percent assemblies and 102 3.6-percent assemblies. The third refueling occurs at about 890 full-power days, with 12 of

[1] A full-power day is 24 hours of operation at full-rated power. (

Figure 1
Separative Work Requirements for a Typical VVER-440



The points show the requirements for the typical VVER-440 fueling schedule described in the text, with the initial load requirement of 136.5 MTSWU at zero full-power days. The linear function shown by the orange line was used to calculate the separative work requirements of the VVER-440s as a class.

the 2.4-percent assemblies and 102 of the 3.6-percent assemblies being replaced with fresh fuel of these two enrichments. From this point forward, 12 of the 2.4-percent assemblies and 102 of the 3.6-percent assemblies are replaced approximately every 295 full-power days.

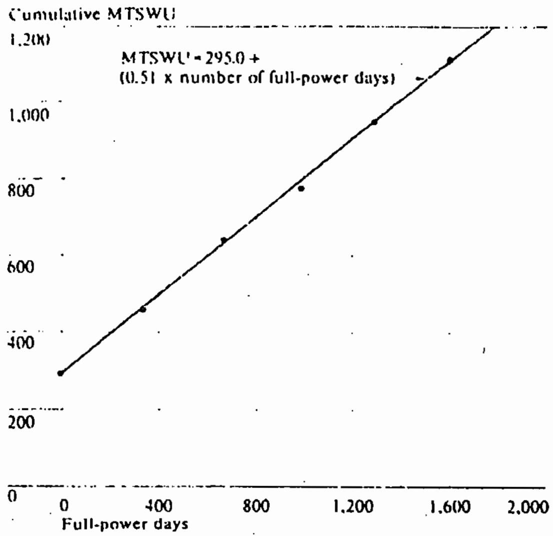
The separative work required to produce the various quantities and grades of enriched uranium for the typical fueling schedule just described is shown in figure 1 in terms of MTSWU versus full-power days of operation. The points on the graph show the requirements for the initial load and each reload. The initial load requires 136.5 MTSWU. Thereafter, the reactor requires an additional 0.25 MTSWU for each full-power day of operation during both the transition and equilibrium cycles.

The relationship between full-power days and calendar days will depend on the rate at which the reactor is operated. Data from actual Soviet operating experience suggest that a typical VVER-440 operates about 120 full-power days during the first year, about 220 full-power days during the second year, and about 255 full-power days during the third year. In the first three years of operating, the reactor produced electric power equivalent to about 600 days of full-power operation. Thereafter, if all goes as expected, the reactor should operate at a rate of about 75 percent (275 full-power days per year). Combining this information with the relationship between separative work requirements and full-power days shown in figure 1, the VVER-440 requirements can be summarized as follows:

Initial load:	136.5 MTSWU
First three years:	47.7 MTSWU per year (three-year average)
After three years:	68.8 MTSWU per year.

VVER-1000. The design core of the VVER-1000 consists of 151 assemblies, each of which contains uranium dioxide equivalent to 441 kilograms of elemental uranium. Total core load is about 66 metric tons of elemental uranium. Current Soviet planning indicates that most VVER-1000s will use a three-year fuel cycle with an initial core consisting of 54 assemblies with uranium enriched to 2 percent, 54 assemblies with uranium enriched to 3 percent, and 43 assemblies with uranium enriched to 4.4 percent. Based on detailed calculations, the refueling schedule for this reactor is as follows. After about 350 full-power days, the 54 2-percent assemblies will be replaced with 42 4.4-percent and 13 3.0-percent assemblies. After about 670 full-power days, the 54 3-percent assemblies will be replaced with 13 3-percent and 42 4.4-percent assemblies. The 43 4.4-percent assemblies originally in the core will be replaced after

Figure 2
Separative Work Requirements
for a Typical VVER-1000



The points show the requirements for the typical VVER-1000 fueling schedule described in the text, with the initial load requirement of 295.0 MTSWU at zero full-power days. The linear function shown by the orange line was used to calculate the separative work requirements of the VVER-1000s as a class.

approximately 980 full-power days with 13 3-percent and 42 4.4-percent assemblies. Thereafter, 13 3-percent and 42 4-percent assemblies will be added every 318 full-power days.

The separative work required to produce the enriched uranium for the VVER-1000 fueling schedule just described is shown in figure 2 in terms of MTSWU versus full-power days of operation. This figure is exactly analogous to figure 1 on the VVER-440. The initial load requirement is 295 MTSWU. The reactor requires an additional 0.51 MTSWU for each full-power day of operation during both the transition and equilibrium cycles. (

There are no statistical data on which to base an estimate of VVER-1000 rates of operation. For planning purposes, the Soviets probably assume values similar to those of the VVER-440. On this basis, the separative work requirements for the VVER-1000 can be summarized as follows:

Initial load:	295.0 MTSWU
First three years:	97.4 MTSWU per year (three-year average)
After three years:	139.6 MTSWU per year. (

RBMK Boiling Water Reactors
In the RBMK reactors, high-pressure tubing is embedded in a graphite block to form vertical fuel channels. The nuclear fuel assemblies are loaded into these channels and cooled by water pumped through the channels. The cooling water is allowed to boil to produce steam for the turbines.

RBMK-1000. The core of the RBMK-1000 contains 1,693 fuel channels. Each fuel assembly contains uranium dioxide equivalent to 113 kilograms of elemental uranium for a total core load of about 192 metric tons of elemental uranium. Although early RBMK-1000s used uranium enriched to 1.8 percent, operational reactors are using (as will future reactors) 2-percent enriched uranium. (

The fuel replacement schedule as the reactor is brought to equilibrium is much more complex than in the VVERs. In early RBMK reactors only 1,453 fuel channels were initially loaded with fuel assemblies; the remaining 240 channels were loaded with auxiliary rods containing neutron-absorbing material. These auxiliary absorbers were replaced with fuel assemblies at a rate of about 40 absorbers every 100 full-power days of operation until, after roughly 600 full-power days, all 240 had been replaced and the reactor was fully loaded with fuel. A varying number of the original fuel assemblies were also replaced. It is assumed that the same type of scheme is used in reactors loaded with 2-percent enriched fuel. Based on this assumption the reactor does not reach equilibrium (design utilization of the nuclear fuel) until after 1,500 full-power days, after which fuel replacement attains a more nearly constant rate of 394 assemblies about

Table 1
Fuel Replacement Schedule of a Typical RBMK-1000

Equivalent Full-Power Days [a]	Fuel Assemblies Replaced [b]	Total Extra Absorbers Remaining	Total New Fuel Assemblies Required
0 (initial load)		240	1,453
100	6	200	46
205	24	160	64
305	27	120	67
410	30	80	70
510	33	40	73
610	34	0	74
715	33		33
815	38		38
915	150		150
1,020	145		145
1,120	150		150
1,225	145		145
1,325	135		135
1,425	125		125
1,530	120		120
1,630	130		130

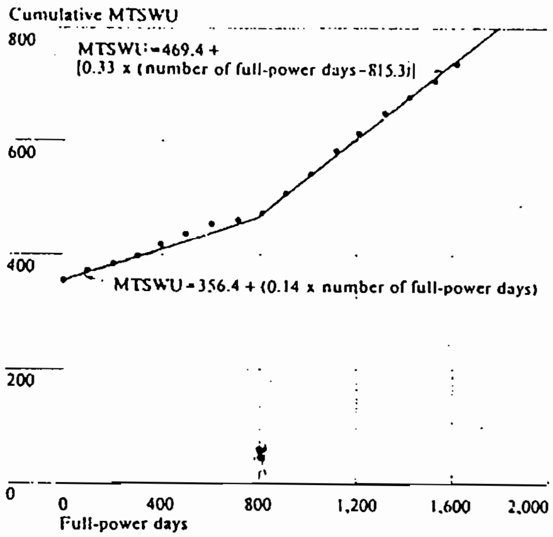
[a] Calculated from Soviet fuel burnup specifications and rounded to the nearest five full-power days.
[b] The RBMK-1000 is capable of being refueled while operating. It is not known whether the Soviets replace several assemblies/absorbers per day or wait until the reactor is not operating to perform the refueling. Because of this online refueling capability, the Soviets are not bound to a fixed schedule. The values in this table should be treated as representative only.

every 318 full-power days. Table 1 shows in greater detail the assumed replacement schedule for absorbers and fuel assemblies in a typical RBMK-1000.

The separative work requirements for the fueling schedule described in the table are shown in figure 3 in terms of MTSWU versus full-power days. The relationship is much more complex than in the two VVER reactors, but it can be adequately approximated for estimative purposes by two linear functions. The initial load requirement is 356.4 MTSWU. During approximately the first 800 full-power days, the reactor requires an additional 0.14 MTSWU per full-power day; thereafter, this requirement increases to 0.33 MTSWU per full-power day.

From published Soviet data, we know that RBMKs have shown somewhat better operating rates than VVERs: about 180 full-power days in the first year, 240 in the second, and 255 in the third. Thereafter, they seem to maintain about the same rate as the VVERs, that is, 75 percent. A typical RBMK will operate an average of 225 full-power days per year during the first three years and 275 full-power days thereafter. The separative work requirements of the

Figure 3
Separative Work Requirement for a Typical RBMK-1000



The points show the requirements for the typical RBMK-1000 fueling schedule described in the text, with the initial load requirement of 356.4 MTSWU at zero full-power days. The linear functions shown by the orange lines were used to calculate the separative work requirements of the RBMK-1000s as a class.

RBMK-1000 can be summarized as:

Initial load:	356.4 MTSWU
First three years:	31.6 MTSWU per year (three-year average)
After three years:	90.8 MTSWU per year. (s)

RBMK-1500. We have much less information on the RBMK-1500 than on the RBMK-1000, as none of the former are yet operational. Various Soviet publications indicate that the fuel enrichment will be the same (2 percent), the total uranium load about the same, the core configuration the same or very similar, and the degree of fuel utilization (burnup) the same as in the RBMK-1000. [

]

[ ]The initial load will be at least approximately the same as that for the RBMK-1000. Since the reactor is designed to produce 1.5 times as much power as the RBMK-1000 from essentially the same amount of fuel (at the same enrichment level and the same planned burnup), the separative work requirement to support the fuel replacement schedule should be higher by roughly the same factor. If we assume that RBMK-1500s will operate the same number of effective full-power days as current RBMK-1000s, then its separative work requirements will be as follows:

Initial load:	356.4 MTSWU
First two years:	44.0 MTSWU per year (two-year average)
After two years:	140.3 MTSWU per year.

Breeder Reactors

In Soviet fast-breeder reactors the nuclear fuel is cooled by liquid sodium metal. Sodium is an excellent heat transfer agent and has a high boiling point; thus, the reactor core of the fast reactor is much more compact, and the reactors are operated at a much lower pressure than either the RBMKs or VVERs. Since sodium becomes radioactive as it is irradiated in the reactor core and since it reacts violently with water or steam, an intermediate sodium loop is placed between the primary (radioactive) coolant loop and the steam/water loop.

Two large prototype fast breeders currently are producing a limited amount of electric power in the USSR: the BN-350 at Shevchenko, which provides heat for desalinization as well as electric power, and the BN-600 at Beloyarsk. The Soviets are planning to build a larger version (probably 800 megawatts) that will serve as a prototype for future commercial breeder reactors. This prototype cannot be operational until 1990 at the earliest. Both operating prototypes are currently fueled with enriched uranium, but the Soviets plan to switch the BN-600 to a mixture of plutonium and uranium oxide (mixed oxide) fuel at some future date. The proposed BN-800 as well as all commercial breeders will use mixed oxide fuel.[4] Plutonium for these reactors will be obtained by reprocessing irradiated fuel from VVER and RBMK reactors. The breeders will produce more plutonium than they consume, but requirements for plutonium to start up additional breeder reactors will greatly exceed production (in the breeder reactors themselves) through at least the mid-1990s. (

BN-350. The initial core of the BN-350 has two active zones: 109 assemblies (3.2 metric tons) of 17-percent enriched uranium and 90 assemblies (2.6 metric tons) of 26-percent enriched uranium. The reactor has axial and radial blankets containing 59.5 metric tons of natural or depleted uranium. The Soviets indicated that refueling should occur approximately every 65 full-power days. Initially, about one-third of the 17-percent fuel is replaced, probably with 26-percent fuel and about one-tenth of the blanket is replaced with new blanket assemblies. This process continues until there is significant utilization in the 26-percent fuel (at about 300 full-power days), after which the 26-percent fuel is gradually replaced. Operating this reactor at 275 full-power days per year would require about 247.5 MTSWU.

BN-600. Operation of the BN-600 is probably very similar to that of the BN-350. The initial core consists of 234 assemblies (5.0 metric tons) of 21-percent enriched uranium and 162 assemblies (3.5 metric tons) of 33-percent enriched uranium in the central region and axial and radial blankets containing a total of 40.6 tons of natural or depleted uranium. Fuel for this reactor probably is replaced about every 195 full-power days of operation. At 275 days per year of effective full-power operation, this reactor would consume 313.5 MTSWU.

Other Reactors

In addition to the large RBMKs, VVERs, and breeder reactors, the Soviet Union has operated two prototype VVERs, two prototype RBMKs, four small heat and electric reactors, and a small breeder reactor. The prototype VVERs consist of 210- and 365-megawatt units at Novovoronezh. A 100-megawatt RBMK and a 200-megawatt RBMK with super heating are in operation at Beloyarsk. Four 12-megawatt RBMK-type reactors producing industrial and home heat as well as electricity are in operation at Bilibino. A 60-megawatt experimental fast reactor, the BOR-60, is in operation at Melekess. The requirements for enriched uranium for these reactors are small compared to the other reactors, and the reactor-specific data will not be presented in this report. Assuming that these reactors operate about 275 full-power days per year, the total yearly requirement for enriched uranium would be approximately 130 MTSWU. (

The Soviets are planning to install a large number of reactors, which will produce heat for industrial and residential purposes. The first of a planned pair of these reactors is currently under construction at Gorkiy. When complete, this station will consist of two 500-megawatt (thermal) reactors. Data on the precise nuclear fuel characteristics of these reactors are not available, but their effect on total separative work requirements will be minor for the next decade because of their small numbers. (

Growth of the Nuclear Power Program

Official statements, [ ] indicate that the installed nuclear generating capacity in the Soviet Union increased from around 1,000 megawatts at the start of the 1970s to over 17,000 megawatts in 1982. Current capacity (not including miscellaneous small reactors) consists of nine VVER-440s, two VVER-1000s, 10 RBMK-1000s, and two breeder reactors. Publicized Soviet plans project increases, which, if achieved, would result in an installed capacity in the Soviet Union of up to 85,000 megawatts by the end of 1990

CEMA countries other than the USSR have 4,840 megawatts of installed nuclear capacity consisting of 11 VVER-440 reactors. Current plans call for an

[4] A breeder reactor is so named because it produces or "breeds" more fissionable fuel than it consumes. It does this by using excess neutrons from the fission of fuel to convert the U-238 isotope of uranium to plutonium. This plutonium is eventually recovered, purified, and fabricated into fuel. It is highly desirable that plutonium be used in the first fuel loading because it gives off more excess neutrons when it fissions, resulting in a much faster rate of conversion.

increase by the end of 1990 to as much as 37,000 megawatts, including uncertain plans for various Western-origin reactors. There is a lack of data as to the actual breakdown by country of this figure. Of the total, we can account for about 19,000 megawatts in terms of Soviet-designed and -fueled VVER-440 and VVER-1000 reactors nominally scheduled for completion by 1990. The Soviets are also committed to construct and fuel two VVER-440 reactors in Libya.[5] (Soviet-designed VVER-440 reactors in Finland are not included in these figures because their separative work requirements are accounted for under the Soviet toll enrichment program.)

Total installed capacity in Soviet-fueled reactors at home and abroad (other than in Finland) was thus about 22,000 megawatts at the end of 1982. If all of the goals discussed in the two preceding paragraphs were achieved, total installed capacity in Soviet reactors by 1990 would be about 100,000 megawatts, a figure frequently mentioned in Soviet public statements. (One recent Soviet projection stated that the total Soviet/CEMA program would be 100,000 to 120,000 megawatts by 1990. This value may include an indeterminate number of Western-origin reactors under consideration in Eastern Europe.) (s)

We have examined in detail all available information [ ]

This examination revealed that the Soviets and their CEMA allies (plus Libya) have at least 127 Soviet-origin reactors in the construction or planning stage. It is clear that there are specific plans to construct all or most of the planned reactors. The completion of all of these reactors would add about 120,000 megawatts to the current total, making a grand total at some time in the late 1990s or early 2000s of about 143,000 megawatts (70 percent in the Soviet Union, the remainder abroad). In the unlikely event that all construction schedules were optimally fulfilled, the total capacity by the end of 1990 would be about 88,000 megawatts, somewhat less than the Soviets' general planning figure of 100,000 megawatts. To meet even this reduced goal, the Soviets would have to place 75 reactors in operation over the next seven years. Historically, they have not met their announced nuclear power goals on time, and it is not at all likely that they will meet this formidable goal on schedule. Unless unforeseen circumstances intervene,[6] we believe that a capacity of about 100,000 megawatts will be achieved not in 1990 but probably at some time in the mid-1990s. We estimate that actual capacity as of 1990 could be as high as 88,000 megawatts but is more likely to range from 60,000 to 70,000 megawatts.

Total Separative Work Requirements of the Soviet/CEMA Nuclear Power Program

Total past and projected separative work requirements of the nuclear power program were calculated by combining the data in appendix A with the data given earlier on the separative work requirements of each reactor type. In performing the calculations, we allowed a nominal period of one year to fabricate the enriched uranium into fuel. To reflect this, we offset the requirements by one year, that is, we treated each year's requirement as though it fell due in the preceding calendar year. The resultant year-by-year requirements are given in appendix B in terms of annual MTSWU for each reactor type and in terms of cumulative MTSWU for reactors of all types.

The data in appendix B show that the separative work needed to support the Soviet/CEMA nuclear power programs increased from negligible amounts in the

[5] The Soviets have shown an interest in exporting additional reactors and have held general discussions with Finland, Yugoslavia, India, Turkey, China, North Korea, and Syria. [ ].

[6] Our projection of the Soviet/CEMA commercial nuclear program assumes that nuclear power will continue to receive a high priority in energy plans and top priority in the expansion of the electric power sector. There are, however, circumstances which could result in a much delayed nuclear program. For example, a nuclear power plant accident, in which a major design fault is revealed, could cause significant delays while flawed components are redesigned. Economic factors, such as severe capital investment constraints or reduced growth in electricity demand over an extended period also could result in slower-than-expected expansion of the Soviet/CEMA nuclear program.

early 1970s to about 3,000 MTSWU per year by 1982. Cumulative requirements through 1982 amounted to more than 22,000 MTSWU. These requirements will increase by large factors in the remainder of the 1980s. In the unlikely event that the Soviet/CEMA programs achieve the maximum of 88,000 megawatts by 1990, annual requirements will increase to about 14,000 MTSWU and the cumulative requirement through 1990 will be about 91,000 MTSWU. Achievement of what we regard as the more likely level of 60,000 to 70,000 megawatts in 1990 will still result in very large increases: to roughly 11,000 MTSWU annual and about 80,000 MTSWU cumulative as of the end of 1990.

Annual MTSWU values given in appendix B illustrate the rate of growth and the effect of the different reactor types on enriched uranium requirements as well as the manner in which this changes with time. In future years, the VVER-1000 will have a disproportionately large impact; by 1990 this one reactor type will account for well over one-half of the separative work requirements of the Soviet/CEMA nuclear power program. When considering the overall impact on Soviet enriched uranium allocation, cumulative values in appendix B are more significant than annual values. We have no way of knowing exactly when the Soviets may produce the material to satisfy any given annual requirement, that is, the extent to which they may have preproduced material in the past or may do so in the future. Thus, our estimate is the minimum amount of separative work expended for nuclear power. (

Accuracy of Soviet/CEMA Separative Work Calculations

The separative work requirements shown in appendix B for the period through 1982 are based on actual Soviet installed nuclear capacity. These values may be regarded as accurate, subject only to relatively minor error inherent in our method of calculating the separative work requirements of the two major reactor types currently in operation. This methodological error becomes increasingly important, however, in future projections. We emphasized in an earlier section that our method of calculating is essentially a modeling approach and that the results are valid only for a "typical" reactor of that class. In this limited sense, the calculated values probably are quite accurate for the VVER-440 and the RBMK-1000, because the fuel loading and replacement cycles of these two established classes are well known and their historical operating rates well established. Individual reactors operate at differing rates, and there is undoubtedly some variation in fuel replacement cycles from reactor to reactor. In general, however, our "typical" VVER-440 and RBMK-1000 reactors probably are well representative of their respective classes. Since almost all of the current capacity consists of these two types, the error in the cumulative separative work totals for the period through 1982 should be relatively small, but we are unable to calculate the error beyond that general statement.

Information on fuel loading and replacement cycles and operating rates of the new types, the VVER-1000 and RBMK-1500, is much more limited, rendering our "typical" models of these two classes somewhat speculative (particularly so in the case of the Soviet RBMK-1500). Since these two classes will assume an increasingly greater share of total capacity over the coming decade, errors in calculating separative work requirements of each reactor type will have an increasingly greater impact on total separative requirements. Uncertainties about fuel loading and replacement cycles have a potentially important impact on the future projections, not only because of our imperfect understanding of current fueling plans for the VVER-1000 and RBMK-1500, but because the Soviets may well change these plans over the next decade. (Conceivably, this could be done, not only with respect to the VVER-1000 and RBMK-1500 but also with respect to the VVER-440 and RBMK-1000.) We cannot now assess quantitatively the impact of uncertainty in this area, but it is not likely to decrease future requirements substantially. The Soviets have published studies on alternative power reactor loading schemes for both VVER and RBMK reactors. In general, Soviet thinking in this area seems geared to reducing the overall costs of producing electricity by reducing fuel fabrication costs. None of the alternative concepts appear aimed directly at reducing separative work requirements per reactor. (

Over the long run, nuclear power separative work requirements may be reduced as a result of reprocessing, that is, extracting the usable plutonium and uranium from the used nuclear fuel.

The Soviets stated that they intend to use the recovered plutonium in fast breeder reactors, sharply reducing the rate of increase of separative work requirements for this reactor type beginning in the mid-1990s. Recycling of recovered uranium could occur sooner, perhaps by the late 1980s. However, because of the long cooling period before spent fuel is shipped from the reactor (currently five years) and the rapid expansion in the number of reactors, the impact of reprocessing on Soviet separative work requirements over the next decade probably will be quite small.

The Toll-Enrichment Program

In addition to supporting its own nuclear power program and those of the other CEMA countries, the Soviet Union sells uranium enrichment services to the nuclear power programs of various Western countries through a commercial toll enrichment program. The uranium to be enriched is provided in all cases by the customer, not by the Soviet Union. Each sales contract specifies the waste (tails) assay, usually about 0.2 percent. The contracts are not classified and information on sales is generally available from commercial sources.

The Soviet toll enrichment program began in 1973 and grew rapidly through the 1970s to its present level averaging 2,500 to 3,000 MTSWU per year. (This provides a hard currency income of roughly $350 million per year.) Existing contracts call for continuation at roughly this level through the 1980s, declining to about 1,000 MTSWU in the early 1990s. Actual levels cannot be predicted much beyond 1990, however, because of uncertainty about potential new contracts. The cumulative total through 1982 amounted to about 24,000 MTSWU and, on the basis of existing contracts, is expected to grow to about 50,000 MTSWU by the early 1990s. A year-by-year listing of annual and cumulative totals is given in table 2. (U)

Table 2
Toll-Enrichment Contracts (MTSWU)

Year	October 1983 Annual	Cumulative
1973	328	328
1974	460	788
1975	332	1,120
1976	2,026	3,146
1977	3,639	6,785
1978	3,571	10,356
1979	4,995	15,351
1980	3,380	18,731
1981	2,981	21,712
1982	2,581	24,293
1983	2,824	27,117
1984	2,776	29,893
1985	2,709	32,601
1986	2,540	35,141
1987	2,563	37,704
1988	2,939	40,643
1989	2,908	43,551
1990	2,841	46,392
1991	957	47,349
1992	957	48,306
1993	957	49,263

Impact of Combined Requirements for Nuclear Power and Toll Enrichment

Taken together, the Soviet/CEMA nuclear power program and toll enrichment program requirements for enriched uranium will account for of total enrichment capacity by 1990. As figure 4 indicates, there are large uncertainties on our present estimates of enrichment capacity, reflecting the fundamental limitations of analyses .

Figure 4
Combined Nuclear Power Enrichment Demand and Estimated Capacity Cumulated Through Time
Cumulative MTSWU (in thousand)

the accelerating demand for enriched uranium (driven primarily by the expanding Soviet/CEMA nuclear power and toll enrichment requirements)[1] will outstrip our projections of Soviet capacity for the mid-1990s. We therefore believe that the Soviets will bring additional production on line between now and the early 1990s.

[1] Enriched uranium requirements for military requirements—nuclear weapons and naval propulsion—will be overshadowed by the burgeoning nuclear power/toll enrichment demands in the 1990s. We judge that military demand has leveled off (as with the United States) after many years of growth.

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Appendix A

Existing and Planned Nuclear Power Reactors in the USSR and Other CEMA Countries

All known Soviet-origin power reactors—those operational, under construction, or planned—are listed in this appendix. The startup dates for those reactors not yet operational reflect the assumption of *optimal schedule fulfillment*. These dates should be regarded in each case not as our best estimate but *as the earliest possible date*:

- All reactors, which might reasonably be expected to be complete by the end of 1985, are already under construction. [

  ].

- Those reactors expected to be completed after 1985 are either at nuclear power stations [ ] or at power stations announced by the Soviets but not yet begun. (All Soviet/CEMA power reactors are parts of nuclear power stations with multiple reactors.) In the first case, we have followed Soviet practice by estimating that each reactor at a given station will begin operations one to two years after completion of its immediate predecessor in the construction series. In the second case, we have assumed that the first reactor at the station will not be operational for at least seven years after its construction start is first announced by the Soviets and that each successive reactor will follow at an interval of one to two years.

- In a few cases, we have specific Soviet/CEMA projected dates that conflict with our methodology. In these cases, we used the Soviet/CEMA date only if it is later than the one produced by our methodology.

Table 3
Known Soviet-Origin Power Reactors

Name	Reactor Type	Actual or Earliest Operational Date •	Name	Reactor Type	Actual or Earliest Operational Date •
Bulgaria			**East Germany**		
Belene-1	VVER-1000	Mid-1990	Lubmin-1	VVER-440	Late 1974
Belene-2 •	VVER-1000	Late 1991	Lubmin-2	VVER-440	Late 1975
Belene-3 •	VVER-1000	Mid-1993	Lubmin-3	VVER-440	Late 1977
Belene-4 •	VVER-1000	Mid-1995	Lubmin-4	VVER-440	Mid-1979
Kozloduy-1	VVER-440	Late 1974	Lubmin-5	VVER-440	Mid-1984
Kozloduy-2	VVER-440	Early 1976	Lubmin-6	VVER-440	Late 1985
Kozloduy-3	VVER-440	Early 1981	Lubmin-7	VVER-440	Mid-1987
Kozloduy-4	VVER-440	Mid-1982	Lubmin-8	VVER-440	Early 1989
Kozloduy-5	VVER-1000	Early 1988	Niedergorne-1	VVER-1000	Early 1990
Kozloduy-6	VVER-1000	Early 1990	Niedergorne-2 •	VVER-1000	Mid-1991
Cuba			Niedergorne-3 •	VVER-1000	Late 1992
Isle-of-Pines-1	VVER-440	Mid-1988	Niedergorne-4 •	VVER-1000	Mid-1994
Isle-of-Pines-2	VVER-440	Early 1990	**Hungary**		
Czechoslovakia			Paks-1	VVER-440	Late 1982
Bohunice-1	VVER-440	Early 1979	Paks-2	VVER-440	Early 1984
Bohunice-2	VVER-440	Early 1980	Paks-3	VVER-440	Mid-1985
Bohunice-3	VVER-440	Early 1984	Paks-4	VVER-440	Mid-1987
Bohunice-4	VVER-440	Late 1984	Paks-5 •	VVER-1000	Early 1991
Dukovany-1	VVER-440	Mid-1984	Paks-6 •	VVER-1000	Early 1992
Dukovany-2	VVER-440	Late 1985	**Libya**		
Dukovany-3	VVER-440	Mid-1986	Sirte-1 •	VVER-440	Mid-1990
Dukovany-4	VVER-440	Mid-1987	Sirte-2 •	VVER-440	Early 1992
Mochovce-1	VVER-440	Late 1987	**Poland**		
Mochovce-2 •	VVER-440	Late 1988	Zarnowiec-1	VVER-440	Early 1989
Mochovce-3 •	VVER-440	Early 1990	Zarnowiec-2 •	VVER-440	Early 1990
Mochovce-4 •	VVER-440	Mid-1991	Zarnowiec-3 •	VVER-1000	Early 1992
Temelin-1 •	VVER-1000	Mid-1990	**Romania**		
Temelin-2 •	VVER-1000	Late 1991	Moldavia-1 •	VVER-1000	Early 1993
Temelin-3 •	VVER-1000	Late 1992	Moldavia-2 •	VVER-1000	Early 1995
Temelin-4 •	VVER-1000	Late 1993	Moldavia-3 •	VVER-1000	Early 1997
New-PWR-1 •	VVER-1000	Mid-1992	**USSR**		
New-PWR-2 •	VVER-1000	Mid-1993	Armenian-1	VVER-440	Late 1976
New-PWR-3 •	VVER-1000	Late 1994	Armenian-2	VVER-440	Late 1979
New-PWR-4 •	VVER-1000	Late 1995	Balakovo-1	VVER-1000	Mid-1985
New-PWR-5 •	VVER-1000	Mid-1996	Balakovo-2	VVER-1000	Early 1987
New-PWR-6 •	VVER-1000	Mid-1997	Balakovo-3	VVER-1000	Early 1988
New-PWR-7 •	VVER-1000	Mid-1998	Balakovo-4	VVER-1000	Early 1990
New-PWR-8 •	VVER-1000	Mid-1999	Bashkir-1	VVER-1000	Mid-1989

Table 3 (continued)
Known Soviet-Origin Power Reactors

Name	Reactor Type	Actual or Earliest Operational Date [a]	Name	Reactor Type	Actual or Earliest Operational Date [a]
Bashkir-2 [a]	VVER-1000	Mid-1990	Kostroma-1	RBMK-1500	Late 1990
Bashkir-3 [a]	VVER-1000	Mid-1991	Kostroma-2 [a]	RBMK-1500	Early 1992
Bashkir-4 [a]	VVER-1000	Mid-1992	Kostroma-3 [a]	RBMK-1500	Early 1994
Bashkir-5 [a]	VVER-1000	Early 1994	Kostroma-4 [a]	RBMK-1500	Early 1996
Bashkir-6 [a]	VVER-1000	Early 1995	Kharkov-ATETS-1 [a]	VVER-1000	Late 1992
Beloyarsk-1	RBMK-100	Mid-1964	Kharkov-ATETS-2 [a]	VVER-1000	Mid-1994
Beloyarsk-2	RBMK-200	Early 1968	Kursk-1	RBMK-1000	Late 1976
BN-350	BN-350	Mid-1973	Kursk-2	RBMK-1000	Early 1979
BN-600	BN-600	Mid-1980	Kursk-3	RBMK-1000	Late 1983
Chernobyl-1	RBMK-1000	Late 1977	Kursk-4	RBMK-1000	Late 1985
Chernobyl-2	RBMK-1000	Late 1978	Kursk-5	RBMK-1000	Mid-1989
Chernobyl-3	RBMK-1000	Late 1981	Kursk-6 [a]	RBMK-1000	Mid-1991
Chernobyl-4	RBMK-1000	Late 1983	Leningrad-1	RBMK-1000	Late 1973
Chernobyl-5	RBMK-1000	Early 1987	Leningrad-2	RBMK-1000	Mid-1975
Chernobyl-6	RBMK-1000	Late 1988	Leningrad-3	RBMK-1000	Late 1979
Chernobyl-7 [a]	RBMK-1500	Mid-1991	Leningrad-4	RBMK-1000	Early 1981
Chernobyl-8 [a]	RBMK-1500	Early 1993	Minsk-ATETS-1 [a]	VVER-1000	Early 1989
Chernobyl-9 [a]	RBMK-1500	Early 1995	Minsk-ATETS-2 [a]	VVER-1000	Early 1991
Chernobyl-10 [a]	RBMK-1500	Early 1997	Novovoronezh-1	VVER-210	Late 1964
Crimea-1	VVER-1000	Mid-1988	Novovoronezh-2	VVER-365	Late 1969
Crimea-2	VVER-1000	Mid-1989	Novovoronezh-3	VVER-440	Late 1971
Crimea-3 [a]	VVER-1000	Early 1991	Novovoronezh-4	VVER-440	Late 1972
Crimea-4 [a]	VVER-1000	Mid-1992	Novovoronezh-5	VVER-1000	Mid-1980
Ignalina-1	RBMK-1500	Early 1984	Odessa-ATETS-1	VVER-1000	Mid-1988
Ignalina-2	RBMK-1500	Late 1985	Odessa-ATETS-2 [a]	VVER-1000	Mid-1990
Ignalina-3 [a]	RBMK-1500	Mid-1989	Rostov-1	VVER-1000	Early 1987
Ignalina-4 [a]	RBMK-1500	Mid-1990	Rostov-2	VVER-1000	Late 1988
Kalinin-1	VVER-1000	Mid-1984	Rostov-3 [a]	VVER-1000	Mid-1990
Kalinin-2	VVER-1000	Mid-1986	Rostov-4 [a]	VVER-1000	Mid-1992
Kalinin-3 [a]	VVER-1000	Mid-1989	Rovno-1	VVER-440	Late 1980
Kalinin-4 [a]	VVER-1000	Mid-1990	Rovno-2	VVER-440	Late 1981
Khmelnitskiy-1	VVER-1000	Mid-1987	Rovno-3	VVER-1000	Late 1985
Khmelnitskiy-2	VVER-1000	Mid-1989	Rovno-4	VVER-1000	Late 1987
Khmelnitskiy-3 [a]	VVER-1000	Mid-1991	Rovno-5 [a]	VVER-1000	Early 1989
Khmelnitskiy-4 [a]	VVER-1000	Late 1992	Rovno-6 [a]	VVER-1000	Mid-1990
Kola-1	VVER-440	Mid-1973	Smolensk-1	RBMK-1000	Late 1982
Kola-2	VVER-440	Late 1974	Smolensk-2	RBMK-1000	Mid-1984
Kola-3	VVER-440	Early 1981	Smolensk-3 [a]	RBMK-1000	Mid-1987
Kola-4	VVER-440	Early 1984	Smolensk-4 [a]	RBMK-1000	Early 1989

Table 3 (continued)
Known Soviet-Origin Power Reactors

Name	Reactor Type	Actual or Earliest Operational Date [a]
Smolensk-5 [a]	RBMK-1500	Mid-1990
Smolensk-6 [a]	RBMK-1500	Mid-1992
South-Ukraine-1	VVER-1000	Late 1982
South-Ukraine-2	VVER-1000	Mid-1985
South-Ukraine-3	VVER-1000	Mid-1987
South-Ukraine-4 [a]	VVER-1000	Early 1989
Tatar-1	VVER-1000	Early 1989
Tatar-2 [a]	VVER-1000	Early 1991
Tatar-3 [a]	VVER-1000	Early 1992
Tatar-4 [a]	VVER-1000	Early 1994
Volgograd-ATETS-1 [a]	VVER-1000	Early 1994
Volgograd-ATETS-2 [a]	VVER-1000	Mid-1996
Zaporozhe-1	VVER-1000	Late 1984
Zaporozhe-2	VVER-1000	Late 1985
Zaporozhe-3	VVER-1000	Early 1987
Zaporozhe-4	VVER-1000	Mid-1988
Zaporozhe-5 [a]	VVER-1000	Early 1990
Zaporozhe-6 [a]	VVER-1000	Mid-1991

[a] Planned

Appendix B

Summary of Separative Work Units, by Year and by Reactor Type (Optimum Scheduling)

Year	Reactor Type	MTSWUs	Cumulative MTSWUs
1963	Beloyarsk-1	97	
	Novovoronezh-1	80	
Total		**177**	177
1964	Beloyarsk-1	10	
	Novovoronezh-1	35	
Total		**45**	222
1965	Beloyarsk-1	10	
	Novovoronezh-1	35	
Total		**45**	267
1966	Beloyarsk-1	10	
	Novovoronezh-1	35	
Total		45	312
1967	Beloyarsk-1	10	
	Beloyarsk-2	233	
	Novovoronezh-1	35	
Total		278	590
1968	Beloyarsk-1	10	
	Beloyarsk-2	35	
	Novovoronezh-1	35	
Total		80	670
1969	Beloyarsk-1	18	
	Beloyarsk-2	35	
	Novovoronezh-1	35	
	Novovoronezh-2	86	
Total		**174**	844
1970	Beloyarsk-1	18	
	Beloyarsk-2	35	
	Novovoronezh-1	35	
	Novovoronezh-2	25	
Total		113	957
1971	Beloyarsk-1	18	
	Beloyarsk-2	35	
	Novovoronezh-1	35	
	Novovoronezh-2	25	
	VVER-440	136	
Total		**249**	**1,206**
1972	Beloyarsk-1	18	
	Beloyarsk-2	35	
	BN-350	282	
	Novovoronezh-1	35	
	Novovoronezh-2	25	
	VVER-440	319	
Total		**714**	**1,920**
1973	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	171	
	Novovoronezh-1	35	
	Novovoronezh-2	25	
	RBMK-1000	356	
	VVER-440	413	
Total		**1,063**	**2,983**
1974	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	171	
	Novovoronezh-1	35	
	Novovoronezh-2	25	
	RBMK-1000	387	
	VVER-440	507	
Total		**1,188**	**4,171**
1975	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	171	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	62	
	VVER-440	486	
Total		**845**	**5,016**
1976	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	

Summary of Separative Work Units, by Year and by Reactor Type (Optimum Scheduling) (continued)

Year	Reactor Type	MTSWUs	Cumulative MTSWUs
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	774	
	VVER-440	711	
Total		1,858	6,874
1977	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	183	
	VVER-440	575	
Total		1,131	8,005
1978	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	954	
	VVER-440	889	
Total		2,216	10,221
1979	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	516	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	660	
	VVER-440	1,004	
	VVER-1000	295	
Total		2,848	13,069
1980	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	217	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	809	
	VVER-440	1,276	
	VVER-1000	97	
Total		2,772	15,841
1981	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	217	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,196	
	VVER-440	1,417	
	VVER-1000	97	
Total		3,300	19,141
1982	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	217	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	664	
	VVER-440	1,328	
	VVER-1000	392	
Total		2,974	22,115
1983	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,791	
	RBMK-1500	356	
	VVER-440	1,961	
	VVER-1000	531	
Total		5,325	27,440
1984	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,231	
	RBMK-1500	44	

Summary of Separative Work Units, by Year and by Reactor Type (Optimum Scheduling) (continued)

Year	Reactor Type	MTSWUs	Cumulative MTSWUs
	VVER-440	1,987	
	VVER-1000	1,513	
Total		5,461	32,901
1985	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,024	
	RBMK-1500	400	
	VVER-440	1,919	
	VVER-1000	1,311	
Total		5,340	38,241
1986	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,736	
	RBMK-1500	184	
	VVER-440	2,395	
	VVER-1000	2,727	
Total		7,728	45,969
1987	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,619	
	RBMK-1500	184	
	VVER-440	2,416	
	VVER-1000	3,351	
Total		8,256	54,225
1988	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	2,065	
	RBMK-1500	636	
	VVER-440	2,573	
	VVER-1000	4,691	
Total		10,651	64,876
1989	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,415	
	RBMK-1500	1,392	
	VVER-440	2,960	
	VVER-1000	6,436	
Total		12,889	77,765
1990	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,889	
	RBMK-1500	812	
	VVER-440	2,824	
	VVER-1000	7,165	
Total		13,376	91,141
1991	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,623	
	RBMK-1500	1,308	
	VVER-440	2,913	
	VVER-1000	8,880	

Summary of Separative Work Units,
by Year and by Reactor Type
(Optimum Scheduling) (continued)

Year	Reactor Type	MTSWUs	Cumulative MTSWUs
Total		15,410	106,551
1992	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,741	
	RBMK-1500	1,328	
	VVER-440	2,866	
	VVER-1000	8,218	
Total		14,839	121,390
1993	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,741	
	RBMK-1500	1,468	
	VVER-440	2,950	
	VVER-1000	9,953	
Total		16,798	138,188
1994	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,800	
	RBMK-1500	1,704	
	VVER-440	2,971	
	VVER-1000	10,125	
Total		17,286	155,474
1995	Beloyarsk-1	18	
	Beloyarsk-2	45	
	BN-350	247	
	BN-600	313	
	Novovoronezh-1	35	
	Novovoronezh-2	28	
	RBMK-1000	1,800	
	RBMK-1500	1,844	
	VVER-440	2,992	
	VVER-1000	10,385	
Total		17,707	173,181

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The Soviet Nuclear Power Program After the Chernobyl' Accident

A Research Paper

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June 1987

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The Soviet Nuclear Power Program After the Chernobyl' Accident

A Research Paper

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June 1987

The Soviet Nuclear Power Program After the Chernobyl' Accident

Key Judgments

Information available as of 1 May 1987 was used in this report.

The disruptions to the Soviet nuclear power industry through 1990 caused by the Chernobyl' accident will be minor when measured in broad economic terms and will not derail Soviet intentions to increase reliance on this energy source. The Soviets remain strongly committed to reducing dependence on oil and gas, antinuclear elements of public opinion will have only a weak effect, and the large investment and substantial infrastructure in the commercial nuclear program will ensure continued growth. Beyond 1990, however, some modification of the nuclear power program is likely; a few changes could set back the timetable by several years. These would probably involve the design and location of future nuclear plants and a shift in emphasis resulting from the competition of coal and oil interests for investment resources.

The USSR—and to some extent its CEMA partners—will bear a variety of energy-related costs because of the Chernobyl' accident. The loss of electricity generated by the Chernobyl' reactors and the increased use of fossil fuels in thermal power plants to partially offset the loss are key short-term consequences. Eastern Europe already had to bear some of the burden of electricity cuts during the 1986-87 winter period of peak power demand. During 1987 enough power plant capacity probably will be restored at Chernobyl' or brought on line elsewhere to alleviate this problem. Longer term consequences for the Soviet civilian nuclear industry include the investment writeoffs of at least three reactors at Chernobyl' and the costs of improvements to the safety of other Chernobyl'-type reactors. A rough total of these capital costs shows them to be the equivalent of two or three years' investment in the industry. Since the accident, Moscow has also spent about $80 million on Western equipment for use in the entombment of the destroyed reactor and in other aspects of the recovery.

Despite increased costs, we expect the Soviets will strive to minimize the impact of the accident on their long-term plans for nuclear power and will continue broadening the role of this energy source. We believe they will be largely successful in this damage-limitation effort. The fixes proposed for implementation over the next several years for Chernobyl'-type reactors are not likely to take them out of service for long, and the costs are manageable. Moreover, power plants with Chernobyl'-type reactors have long been slated to play a diminishing role in the Soviet nuclear program of the 1980s and 1990s as the emphasis shifts to other reactor types. These other types represent 80 percent of the nuclear energy capacity currently under construction or planned.

Longstanding problems in manufacturing components for nuclear power plants and delays in plant construction will account for the majority of the shortfalls in bringing new capacity on stream between now and 1990, overshadowing the impact of Chernobyl' on the growth of the USSR's commercial nuclear program. The cumulative effect of the Chernobyl' accident (both the direct effects and the turmoil caused by the recovery effort) will probably mean that only three or four fewer new nuclear reactors (out of 35 planned) will be completed during the 1986-90 plan period. The loss of these reactors and delays in the construction of others will mean that roughly 10 percent less electricity will be produced from nuclear power. We believe the USSR will have about 48,000 megawatts of commercial nuclear capacity by yearend 1990 (compared with 28,300 megawatts in 1985) and will produce some 260 billion kilowatt-hours of electricity at nuclear power plants in 1990 (compared with 167 billion kilowatt-hours in 1985).

The Soviets are likely to encounter only a minor domestic backlash against nuclear power. The psychological blow of Chernobyl' may be enough to catalyze some Soviet groups with reservations about nuclear energy and the supporters of other energy sources into challenging plans for some nuclear facilities. Advocates of other reactor types and other energy sources will use the accident to bolster their arguments. The plans most vulnerable to pressure for nonnuclear alternatives are those for eight Chernobyl'-type reactors where little construction has taken place and those for 20 units of a new type of nuclear plant designed to be sited near cities to provide a dedicated source of heat beginning in the 1990s

The Soviets have sought a high-profile involvement of the West in the postaccident events. Moscow chose the International Atomic Energy Agency (IAEA) as the forum in which to defuse Western concerns about radioactive contamination and safety in the USSR's nuclear program. The Soviets will probably continue to use the IAEA to certify that the proposed modifications to Chernobyl'-type reactors are adequate and that all Soviet reactors are safe—particularly types they hope to export.

Given the long-term need to monitor the environment and the leadership's intent to keep expanding its nuclear energy program, Moscow is likely to look to the West for radiation monitoring and decontamination equipment and, possibly, nuclear power plant components and services. A role for the West as supplier of plant components is more likely if Moscow chooses to accelerate construction of pressurized-water reactors to replace Chernobyl'-type reactors that may be canceled; Soviet equipment suppliers have not been able to meet the demand at the current pace of construction.

Any market in the USSR for Western nuclear vendors is likely to be highly competitive. Firms from the United States, France, Finland, West Germany, Sweden, Great Britain, and Japan can offer many comparable components and services.

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Contents

Scope Note

For several decades the Soviets have viewed nuclear energy as the key to growth in the electricity supply—and recently in the heat supply—in the European USSR. The Chernobyl' accident on 26 April 1986, however, has robbed the commercial nuclear power program of some momentum and challenged many Soviet concepts regarding its safety, reliability, and low costs. The special August 1986 meeting of the International Atomic Energy Agency showed that the Soviets were beginning to make changes based on their analysis of the accident. This meeting also revealed that the Soviets expect to study their nuclear program a good deal more, which means we are now getting only a first look at the possible changes

This report explores how the Chernobyl' disaster will probably influence the USSR's plans for nuclear power and heat supply and evaluates the implications for total primary energy production.

The Soviet Nuclear Power Program After the Chernobyl' Accident

Short-Term Consequences of the Accident

The accident that destroyed reactor unit 4 of the Chernobyl' nuclear power plant in late April 1986 had many and varied consequences—from the tragic human costs (see inset) to marginally greater fossil-fuel consumption, safety upgrades on Chernobyl'-type reactors, and some reexamination of the commercial nuclear program in the USSR.

The Accident: Prescription for Disaster
The Soviet accident report filed with the International Atomic Energy Agency (IAEA) indicates that the errors that doomed unit 4 began on 25 April when technicians started a poorly executed experiment to test the emergency electricity supply to the reactor. Major violations of the procedures for reactor operations were committed, such as switching off the emergency shutdown system and operating the reactor with too many control rods withdrawn. These human errors, coupled with a design flaw that allowed reactor power to surge when uncontrolled steam generation began in the core, set up the conditions for the accident.

The final moments of the accident occurred in a period of about 40 seconds at 0123 local time on Saturday, 26 April. Operator errors had put the reactor in an unstable condition, so reactor power increased rapidly when the experiment began. Subsequent analysis of the Soviet data by US experts suggests the power surge may have accelerated when the operators tried an emergency shutdown of the reactor.[1] According to Soviet data, the energy released was, for a fraction of a second, 350 times the rated capacity of the reactor. This burst of energy resulted in an instantaneous and violent surge of heat and pressure, rupturing fuel channels and releasing

[1] An expert team assembled by the Department of Energy has evaluated the final hours of unit 4. For details see DOE/NE-0076, November 1986, *Report of the U.S. Department of Energy's Team Analyses of the Chernobyl'-4 Atomic Energy Station Accident Sequence*

The Human Costs of the Chernobyl' Accident

The 31 initial casualties resulting from the explosion that destroyed unit 4 will ultimately account for only a minor part of the human toll of the Chernobyl' disaster. Two power plant workers were killed immediately, and burns and high radiation exposures eventually claimed the lives of another 29 people—most of them firemen and site emergency personnel. Soviet doctors reported that nearly 300 people received enough radiation to require hospitalization. These individuals will experience substantial additional risk of cancer.

Longer term health consequences in the USSR will result from radioactive contamination spread by the accident over an area of about 1,000 square kilometers. Many thousands of persons were exposed to this radiation (or will be exposed to residual amounts of radiation as daily routines are reestablished), increasing their long-term risk of cancer. This cancer threat poses unique medical and psychological problems, even though the overall statistical increase in cancer rates is likely to be minimal.

Soviet reactions to the accident included a massive evacuation and a cleanup effort that will probably be a long-term battle. An area with a 30-kilometer radius around the reactor was evacuated, and Moscow reported that about 135,000 people were moved. In addition to these official evacuees, perhaps as many as 270,000—mostly women and children—left cities (such as Kiev) in the region around the reactor site but outside the evacuation zone. The official evacuation started about 36 hours after the explosion and took about 10 days to complete. Most evacuees will never be able to return to their homes. Nearly all of the 135,000 evacuees have been resettled, about half in new homes

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steam that disrupted large portions of the core. Some of the shattered core material was propelled through the roof of the reactor building.

The hot core material that was released started about 30 separate fires in the unit 4 reactor hall and turbine building, as well as on the roof of the adjoining unit 3. All but the main fire in the graphite moderator material still inside unit 4 were extinguished in a few hours by the heroic efforts of firefighters. The graphite fire continued to burn for nearly two weeks—carrying radioactivity high into the atmosphere—until it was smothered by sand, lead, dolomite, and boron dropped from helicopters.

Unit 3 was shut down four hours after the destruction of unit 4. Units 1 and 2, located several hundred meters from unit 4, continued producing electricity for 24 hours after the accident. The Soviets reported considerable radioactive contamination of units 1, 2, and 3.

Electricity Losses and Increased Fuel Use

For five months following the destruction of the Chernobyl'-4 reactor, the plant's three surviving reactors were idled. This loss of generating capacity—roughly 10 percent of the total in the Ukraine—would have led, if uncompensated, to an average monthly deficit in electricity production of 2.4 billion kilowatt-hours (kWh). But, during the summer lull in electricity demand, the Soviets were in a favorable position to offset much of this potential deficit by stepping up electricity production from power plants burning fossil fuels. Beginning in September, however, the seasonal upsurge in demand for electricity probably eliminated most of the painless adjustment mechanisms.[2]

The Ukraine experienced electricity problems even during the summer lull in demand. Ukrainian party chief Vladimir Shcherbitskiy, in a July speech, called for additional energy conservation measures, and Ukrainian Council of Ministers chairman Aleksandr Lyashko noted that some enterprises needed to change to night shift work to reduce daytime electricity demand. These steps were a likely preparation for coping with the prospective shortage of electricity, since the Soviets were only able to restore two reactors at Chernobyl' to partial service by the onset of winter.

The effect on total fuel demand of the effort to offset Chernobyl'-induced electricity losses appears to have been minor. Given the fuel-use capability of the replacement plants, the Soviets were probably using an extra 45,000 barrels per day (b/d) of oil, 220 million cubic meters per month of natural gas, and 400,000 tons per month of coal.[3] During the five-month period when the Chernobyl' plant produced no electricity, the nationwide demand for fuel oil increased 1 to 2 percent, natural gas use grew 0.2 percent, and coal use rose by 0.3 percent.

In addition to the power losses at Chernobyl', the Soviets are expecting cuts in output during 1987 at the four other nuclear power plants operating RBMK (Chernobyl'-type) reactors. [redacted] fixes to improve safety will reduce power output at these plants by about 10 percent, or nearly 10 billion kWh, in 1987. Soviet [redacted] have not indicated whether this is a one-time loss in power generation due to temporary downtime or a derating of the capacity of these reactors.

Returning the Chernobyl' Plant to Service

As soon as the Chernobyl' accident was under control, Moscow began promoting a rapid recovery of power-generating capability at the idle plant, evincing concern for longer term considerations affecting the nuclear power program as well as for the immediate exigencies:

- Moscow desired to spare the economy the degree of electricity shortfall that would come in winter unless much of the Chernobyl' capacity was returned to service.

[3] The total monthly fuel bill was nearly 800,000 tons of standard fuel. A unit of standard fuel contains the energy equivalent of 7,000 kilocalories per kilogram, or 12,600 Btus per pound.

[redacted]

- With roughly half the Soviet nuclear power plant capacity in Chernobyl'-type reactors, restoration of confidence in these units was imperative.

- The leadership probably viewed the recovery of the Chernobyl' plant as an implicit test for the management of the nuclear industry—proof that nuclear power is reliable and that Soviet management is competent.

The Soviets restarted Chernobyl' unit 1 in late September and unit 2 in November, thereby missing their early optimistic goal.[4] Adequately decontaminating the site to resume operations tested Soviet ingenuity and resources (see inset on page 6). A major reallocation of managers and technicians was needed to solve problems such as the entombment of the destroyed reactor and decontamination of the highly radioactive turbogenerator hall, which houses the turbines of all four of the plant's units [redacted] Part of the price for this success was a slowdown in the construction of at least three reactors at other power plants due for startup in 1986. Intermittent operation of Chernobyl' units 1 and 2 through mid-December suggested that problems remained.

The fate of Chernobyl' unit 3 is still uncertain. Although entombment of unit 4 is now complete, the recovery of unit 3 will drag on for some time, especially if critical electrical and ventilation assemblies were damaged in the fires following the accident or if radiation contamination is too extensive for rapid cleanup. If the reactor of unit 3 is not fully recovered, Moscow will have to reassess the "shared facilities" design at RBMK reactors. Three nuclear power plants now use this type of design and one other such plant is at an early stage of construction.[5]

Meanwhile, the Soviets appear to have abandoned efforts to recover the partially constructed units 5 and 6. This was announced without elaboration by the chairman of the State Committee for Utilization of Atomic Energy, Andronik Petrosyants, on 25 April 1987. Factors in stopping construction probably include high radiation at the site, rising construction costs, and possibly difficulties in recruiting skilled labor to finish the project.[6]

Short-Term Economic Costs

The immediate economic costs of the accident include:

- The opportunity costs of using additional fuel oil in plants replacing electricity from Chernobyl' instead of selling the fuel oil for hard currency.

- Increased purchases of Western equipment to facilitate the cleanup after the accident.

- The diversion of construction labor, equipment, and materials to the tasks of decontaminating the Chernobyl' plant and surrounding area, entombing the destroyed reactor of unit 4, and building new housing for the evacuees.

The forgone hard currency earnings from reduced sales of heavy fuel oil at prevailing world-market prices during 1986 potentially amounted to roughly $100 million. This opportunity cost was halved when two Chernobyl' units were brought back on line in December 1986. Continued losses of potential sales of fuel oil (at the reduced level) will nevertheless equal nearly $10 million per month until another 2,000 megawatts (MW) of power plant capacity is brought into the power network, probably late this year

[4] Shortly after the April accident, plans were announced to restart Chernobyl' units 1 and 2 in June. During August the deadline for restart was shifted to October as the Soviets became more concerned about radiation exposures of operations staff.

[5] In order to save on plant investment and simplify designs, the Soviets construct RBMK plants to share facilities for functions such as reactor hall ventilation or water treatment. Although designs for Western nuclear power plants use similar logic, a much greater effort and investment are made to assure that the integrity of functions is maintained in the event of disruption at any one reactor.

[6] Unit 5 is 85 percent complete and unit 6 is 15 percent complete. In addition to decontamination and construction work on the power plants themselves, housing and basic amenities would need to be organized for the 10,000 to 13,000 workers needed to finish construction. These people and their families were displaced from the heavily contaminated town of Pripyat'

A Chronology of the Recovery Effort at the Chernobyl' Nuclear Power Plant

1986	
26 April	*Reactor unit 4 explodes, causing fires in that unit and some damage to adjoining unit 3. Radioactive contamination forces shutdown of undamaged units 1 and 2 and suspension of construction on units 5 and 6.*
28 April	*Soviets publicly acknowledge the accident.*
14 May	*Gorbachev appears on TV, describing the accident and announcing goals for recovery.*
15 May	*Tunnel for access to the area under the unit 4 reactor started; construction on entombment for unit 4 begun.*
22 May	*First recovery timetable announced, proposing to complete entombment and "prepare" units 1, 2, and 3 for operation by 15 June.*
2 June	*Restart of units 1 and 2 scheduled for October; restart of unit 3 put on hold.*
4 July	*Tunnel to unit 4 completed.*
19 July	*Special CPSU Politburo meeting discusses Chernobyl' investigation results, announces reorganization of nuclear power industry.*
25-29 August	*IAEA special meeting on Chernobyl' held in Vienna.*
29 September	*Unit 1 restarted; unit 2 restart promised in two weeks.*
10 October	*Plans for units 3, 5, and 6 announced—unit 3 restart scheduled for mid-1987; construction on units 5 and 6 to resume after unit 3 brought on line.*
13 October-8 November	*Unit 1 shut down for "adjustments."*
8 November	*Unit 2 reactor restarted; trial operation at low power.*
15 November	Pravda *reports entombment of unit 4 complete.*
5 December	*TASS announces that units 1 and 2 are on line and ready for normal service.*
1987	
11-16 January	*IAEA director Hans Blix inspects entombment and "verifies" its integrity.*
13 March	*Soviet press reports that units 1 and 2 are operating at full power.*
25 April	*The chairman of the USSR's State Committee for Utilization of Atomic Energy, Andronik Petrosyants, announces that units 5 and 6 will not be completed.*

Table 1
The USSR's Nuclear Program in an International Perspective

Country	Capacity (Yearend 1986 [a]) (*megawatts*)	Reactors (Yearend 1986 [a])	Output (1986 Total [a]) (*billion kilowatt hours*)	Percent Share of Total Power Output
United States	87,241	95	433.5	16
France	47,170	49	254.2	70
Soviet Union	29,312 [b]	42 [b]	161.0	10
Japan	24,686	32	164.8	29
West Germany	18,295	17	117.4	33
Britain	12,940	37	59.1	19
Canada	11,813	17	74.5	16

[a] Preliminary data.
[b] Does not include Chernobyl' units 3 and 4.

Announced changes in fuel enrichment at existing reactors will initially cost about 115 million rubles. There will also be hard currency costs; by September 1986 some $80 million had been spent on imported goods to aid the recovery. Much of the cost of these imports could be charged to the nuclear program because they were used in the entombment of the Chernobyl' unit 4 reactor. The eventual costs to the nuclear industry are likely to be much higher.[1]

The Soviets have made relatively small purchases from the West to facilitate cleanup after the accident, speedily return Chernobyl' units to use, and construct new housing for workers displaced from their apartments and homes by radioactive contamination. The Soviets bought a wide variety of products: remote-controlled robots and tunneling equipment for decontamination work and entombment of the unit 4 reactor, radiation monitoring equipment, radiation protection items for personnel, and prefabricated housing units. In addition, the USSR received from international contributors several million dollars worth of donations in the form of cash, medical supplies, and household items

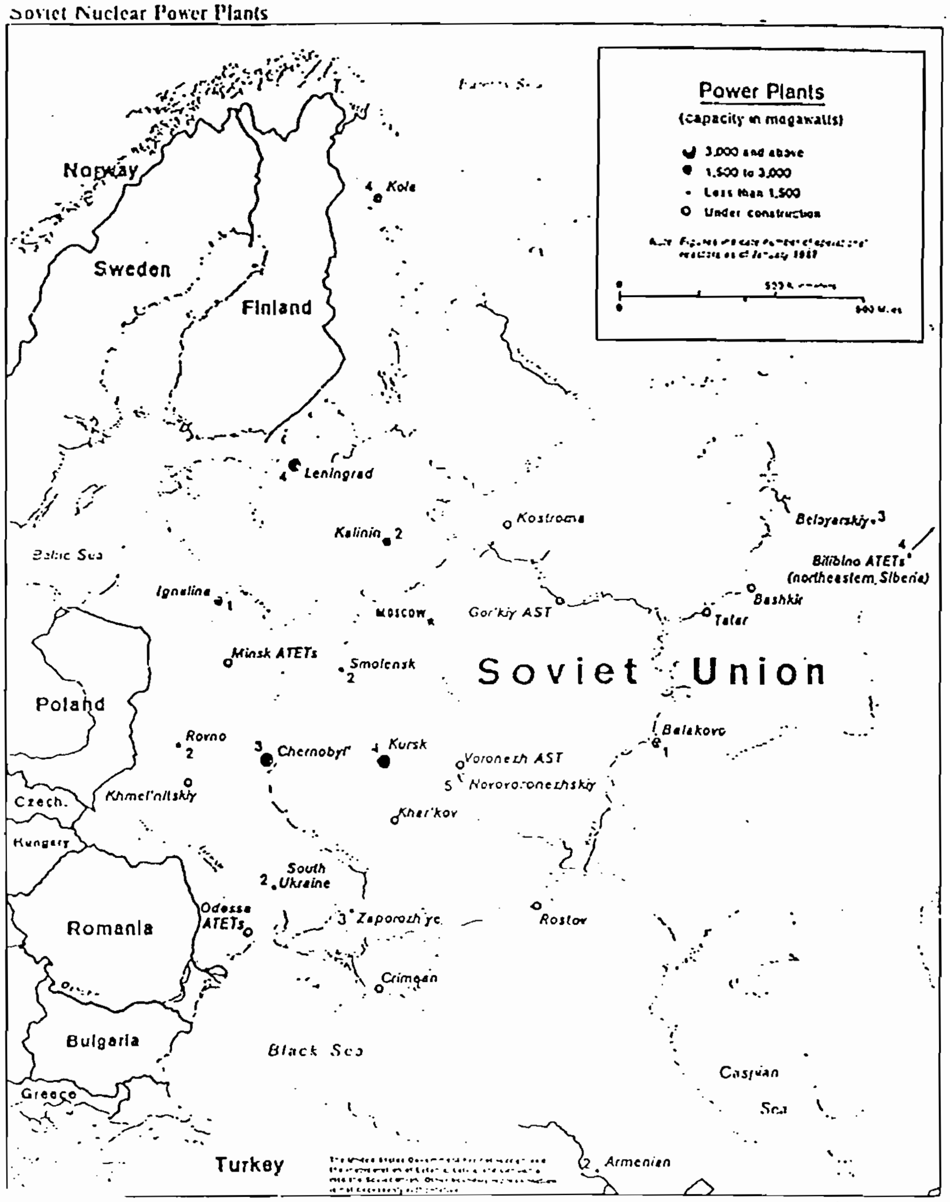
[1] Unconfirmed Soviet estimates of the cost of the Chernobyl' accident range from 2 billion to 25 billion rubles. The minimum estimate was quoted in the Soviet press during the summer of 1986 and probably accounts for only direct damage to the plant, immediate site cleanup, and possibly population relocation expenditures. The higher estimate was provided unofficially [ ] The upper estimate would probably cover a total accounting of the costs of cleanup and recovery and probably represents a projection of expenses through 1990

Managing the Nuclear Power Capacity

Background

The USSR ranks among the leaders worldwide in the development of peaceful uses of nuclear energy (see table 1). After a quick start as the first country to operate a nuclear power plant, the USSR fell behind the United States and, later, France. Soviet industry has not been able to meet in timely fashion the technological and logistic challenges of nuclear power plant construction, so plant startups are lagging three to five years behind original plans. The USSR, nevertheless, has managed ambitious nuclear power research that has yielded the world's largest capacity reactors used for commercial applications, one of the most advanced breeder-reactor programs, and numerous designs that Soviet energy planners hope to implement in future uses of nuclear energy in urban/municipal and industrial projects (see figure 2).

Soviet Nuclear Power Plants



USSR: Commercial Nuclear Reactor and Plant Types

RBMK. A graphite-moderated, boiling-water reactor currently used at the Chernobyl', Leningrad, Kursk, Smolensk, and Ignalina nuclear power stations. It is produced in two standardized capacities: 1,000 MW and 1,500 MW (electrical rating). Although boiling-water reactors are used outside the USSR, there is no close Western counterpart to the RBMK, which is operated only in the USSR

VVER. A pressurized-water reactor, in which the water is used as both a moderator and a coolant. It is produced in two standardized capacities: 440 MW and 1,000 MW (electrical rating). This reactor is similar to many Western designs. VVERs are operated in the USSR at the Armenian, Balakovo, Kola, Novovoronezhskiy, Rovno, South Ukraine, and Zaporozh'ye plants. VVER reactors are also operated in Eastern Europe and Finland.

BN. A fast-breeder reactor that, as its name implies, will produce or "breed" nuclear fuel for other reactors as it operates. This reactor is cooled by liquid sodium. The Soviets are running two prototypes: 350 MW and 600 MW (electrical rating). Plans call for the design, construction, and operation of 800-MW and 1,600-MW versions. Only a few other countries have mastered this technology on a similar scale.

AST, ATETs. These two types of nuclear plants are designed to supply heated water for centralized heating. The AST will use a specially modified reactor of 500 MW (thermal rating) that the Soviets plan to dedicate solely for centralized heat supply to cities. Production has just started on this reactor. Current plans call for its use at Gor'kiy and Voronezh by 1990 and eventually at many other cities. The ATETs plant will supply both electricity and heated water to cities. The ATETs will use a VVER-1000 reactor to power a steam turbine-generator, modified to permit release of heated water to the central heat network in cities. Although the ATETs design incorporates a standard VVER reactor model, the loss of energy to the heat network lowers the electrical rating of the reactor to 900 MW. Current plans call for startup of ATETs plants at Odessa, Minsk, and Khar'kov by 1990 and extensive use in the European USSR in later years.

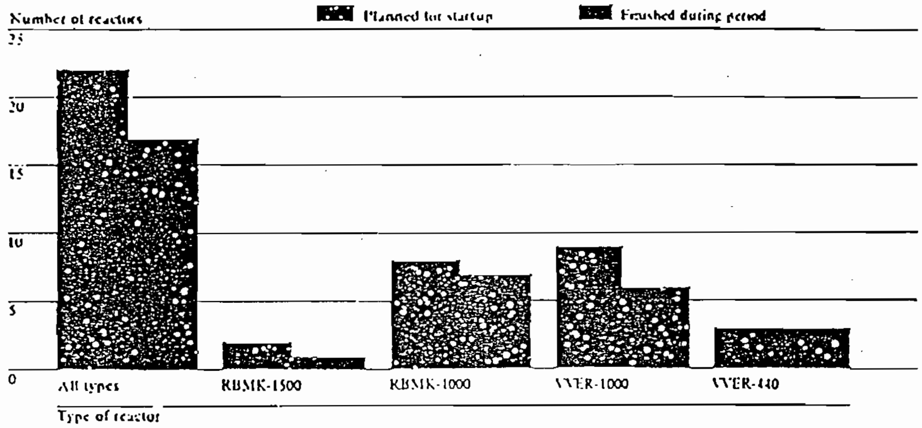
An important difference in viewpoint exists between the Soviets and the West on the economics of commercial nuclear power. In the West, the focus on the "bottom line" of financial projections means that the cost and revenue projections for an individual utility play the leading role in decisions on how much nuclear power capacity to build or, as more recently, in decisions to cancel nuclear projects. The Soviets, on the other hand, are less guided by the costs of individual projects than by the cost-benefit ratio of a proposed power plant with respect to Soviet fuel-supply logistics and the reliability and quality of electricity supplied to end users.[4] In the USSR, nuclear power plants are highly valued because they substantially reduce the burden of fossil-fuel production and transportation, and, until Chernobyl', nuclear plants were more reliable electricity producers than either fossil-fueled or hydroelectric plants. Although nuclear power plants are likely to become more costly as Chernobyl'-inspired design modifications are implemented, they will retain their attractiveness in the Soviets' broader economic evaluation.

Choice of Reactor Types

After making a commitment to nuclear power, Moscow turned to the RBMK graphite-moderated, boiling-water reactor in the 1960s and 1970s (see inset). This enabled the USSR to get substantial

[4] Inadequacies in electricity supply—including low voltage, AC frequency below established limits, and intermittent brownouts or cutoffs are chronic in the USSR

Construction of Soviet Commercial Nuclear Reactors, 1981-85



nuclear power capacity on line during the protracted period of tooling up to produce other types of reactors. The RBMK was less technically demanding to build than other large-capacity reactor types. Consequently, the RBMK-1000 and RBMK-1500 are the backbone of the current program. The Soviet pressurized-water model has two standardized capacities (VVER-440 and VVER-1000).[a] The larger version is scheduled to become the workhorse of the 1990s. Moscow hopes the prototype fast breeder reactor (BN-600) will become the model for expansion in the 1990s and beyond to increase efficiencies in the nuclear fuel cycle and to lower costs. Within the next year or so, the Soviets will probably begin operating a new reactor (AST-500), which will replace some fossil-fueled plants in supplying hot water to centralized heating systems

Maintaining the RBMK Option

The seriousness of the Chernobyl' accident has overshadowed the history of more than 80 reactor-years of RBMKs operating reliably and without serious incident, according to the available evidence. A number of positive characteristics of RBMK reactors, described in Soviet technical handbooks, are probably still valid and will contribute to a Soviet willingness to keep these reactors operating. The RBMK-1000 reactor in recent years has had a better record for on-time assembly than other large power reactors (see figure 3). Plants with this reactor can generate more electricity on an annual basis than either fossil-fueled or VVER-equipped power plants of equivalent capacity because the RBMK is subject to fewer unplanned outages.[b] Online refueling capability helps RBMK reactors to maintain high utilization rates.

[a] The numeric part of a power-reactor designation refers to the capacity of the reactor. For the VVER, RBMK, and BN reactors this capacity is expressed in megawatts of electricity generation capability. For the AST reactor, this capacity is expressed in megawatts of thermal (heating) capability

[b] In 1985, for example, the 14 RBMK-1000 reactors averaged 72-percent utilization of capacity, while the six online VVER-1000 reactors averaged 64 percent and a representative sample of fossil-fueled generating capacity averaged 70-percent utilization.

Because the 14 existing RBMK reactors compose 53 percent of the nuclear power plant capacity and provide 6 percent of all the electricity generated in the USSR (60 percent of nuclear-generated power), a prolonged safety-related equipment refitting of existing reactors could seriously disrupt the Soviet electricity supply. We believe Moscow is not planning extensive modification of RBMKs, although Soviet inquiries to Western companies suggest Moscow is considering a retrofit of additional equipment besides that mentioned in their accident report to the IAEA.[11] The Soviets appear to have rejected wholesale upgrading of RBMK containment on the grounds of technical difficulty and costs.[12]

The technical shortcomings of the RBMK reactor that contributed to the accident include a complex nuclear core that requires moderately sophisticated monitoring with computer-assisted control, and the potential instability of the nuclear reactions in the core during low-power operating conditions or if coolant is rapidly lost. These were known to Soviet specialists well before the Chernobyl' events. Reporting in the Soviet nuclear industry's technical journals showed that design engineers were working on these problems, so fixes may not require extraordinarily long downtimes or construction delays.

Another concern surfaced by the catastrophe is the possible vulnerability of Soviet nuclear power stations to multiple reactor failure. All five of the existing plants using RBMK reactors are built around pairs of reactors. The explosion at Chernobyl' unit 4 damaged components of unit 3, calling attention to the risk that other events such as major fires or large pipe ruptures in one reactor could endanger the other member of a pair. Modifications to reduce this risk of multiple reactor failure in future plants would require time-consuming redesign work, which would increase construction costs.

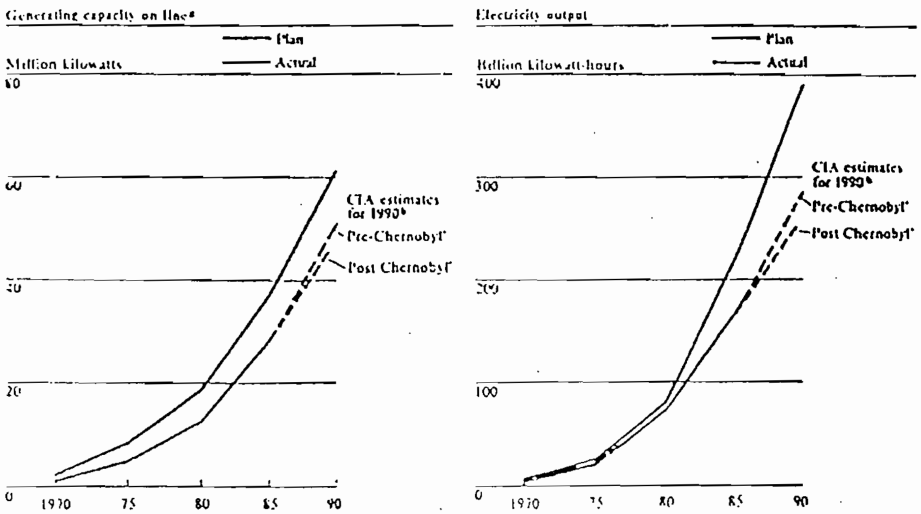
Modifying the RBMKs. Of the 29 RBMK reactors built or planned, the projects most vulnerable to cancellation if basic design flaws cannot be easily remedied are the eight reactors at the earliest stages of construction. These are located at the existing Kursk and Smolensk plants and at the proposed Kostroma plant. In an April 1987 announcement of the remaining RBMK projects, the Soviets implied, by omission, that the four reactors at Kostroma had been dropped. The Kostroma plant is in the earliest stages of design and site preparation work and could be canceled with the least disruption. The plans cited in the Soviet press call for construction of four 1,500-MW RBMK reactors at Kostroma, due to come on line at two-year intervals from 1992 to 1999. A power station operated on natural gas could be proposed as an effective alternative to the Kostroma nuclear plant, since large gas-fired power plants are already in existence in the region. A gas-fired replacement for Kostroma could be built with only minor delays to the plan for expanding power-generating capacity.

Replacement of Smolensk units 5 and 6 (RBMK-1500s) and Kursk units 5 and 6 (RBMK-1000s) would pose greater problems. Although assembly has just begun on some of these reactors, abandoning them would mean a costly writeoff of the construction infrastructure that is already being used to complete four other reactors at each location. Replacement electricity-generating capacity could be either conventional gas-fired or even nuclear, using VVER reactors. It is unlikely that the Power Ministry could complete the process of site selection, design, and construction of this replacement capacity in time to avoid a tightening of power supplies to the central region, because the units at Smolensk and Kursk were expected on line in the early 1990s.

[11] Western suppliers have been contacted about equipment for hydrogen monitoring and ignition to detect and prevent the formation of an explosive mixture that could result in the Chernobyl'-type destruction of a nuclear reactor. Other possibilities for retrofits may involve adding backup emergency core cooling and improving the automated reactor-control systems.

[12] The Soviets have already set a precedent on refusal to retrofit for containment. Soviet planners had decided by the mid-1970s to add containment to designs for pressurized-water reactors (VVERs). The containment function was incorporated in phases, with later model VVER-440 reactors receiving containment or localization of certain critical components. In 1980 the Soviets built their first reactor with full containment, equivalent to that used in the West. They did not, however, retrofit any of the eight earlier model VVER-440s with containments. The decision not to enforce the same safety standards at all VVERs was probably influenced by the technical difficulty of such extensive reconstruction and by costs, estimated by some Western experts to equal the original investment in the reactors

Soviet Nuclear Power: Performance Versus Plan



[a] Total capacity on line at end of five-year plan; 1990 capacity includes nuclear heating plants.
[b] Midpoints of established ranges.

Seven RBMK reactors are in later stages of construction, with four at an advanced stage, including the reportedly canceled Chernobyl' units 5 and 6. Modifications already proposed by the Soviets could probably be done on the remaining five without major extensions to completion times. If the Soviets decide to curtail the RBMK construction program sharply—following through on Petrosyants' announcement about the two Chernobyl' units—they still might be able to salvage some prestige. Moscow would be able to claim, with some justification, that they are only accelerating a long-planned shift to VVER reactors. The emphasis in construction of nuclear power plants has moved from RBMK reactors to VVER reactors over the last three five-year planning cycles. In the 1976-80 plan period, six of the 11 completed reactors were RBMKs, and in 1981-85 the share declined to eight of 17. The plan for 1986-90 shows only seven RBMKs among the 35 reactors due for completion.

Outlook for Achievement of Nuclear Industry Goals for 1990

Soviet targets for nuclear power plant capacity and output were out of reach even before the Chernobyl' accident shocked the nuclear industry (see figure 4). The targets call for starting electricity output or heat

Table 2
USSR: Plan for Additions to Nuclear Power Plant Capacity (Scheduled Startups, 1986-90) [a]

1986	
Kalinin 2	VVER-1000
Zaporozh'ye 3	VVER-1000
Chernobyl' 5	RBMK-1000
Ignalina 2	RBMK-1500
Rovno 3	VVER-1000
Balakovo 2	VVER-1000
Khmel'nitskiy 1	VVER-1000
Gor'kiy 1	AST-500
1987	
Zaporozh'ye 4	VVER-1000
Smolensk 3	RBMK-1000
Balakovo 3	VVER-1000
1988	
Kalinin 3	VVER-1000
Zaporozh'ye 5	VVER-1000
Chernobyl' 6	RBMK-1000
Rovno 4	VVER-1000
Balakovo 4	VVER-1000
Crimean 1	VVER-1000
Rostov 1	VVER-1000
Odessa ATETs 1	VVER-1000
Voronezh 1	AST-500
1989	
Zaporozh'ye 6	VVER-1000
Tatar 1	VVER-1000
Smolensk 4	RBMK-1000
South Ukraine 3	VVER-1000
Minsk ATETs 1	VVER-1000
Khmel'nitskiy 2	VVER-1000
Ignalina 3	RBMK-1500
Gor'kiy 2	AST-500
1990	
Rovno 5	VVER-1000
Crimean 2	VVER-1000
Rostov 2	VVER-1000
Odessa ATETs 2	VVER-1000
Khar'kov ATETs 1	VVER-1000
Kursk 5	RBMK-1000
Voronezh 2	AST-500
Totals	
New capacity	New reactors
32,000 MW (electrical)	24 VVER-1000s
2,000 MW (thermal) in ASTs	5 RBMK-1000s
	2 RBMK-1500s
	4 AST-500s
	35 All types

[a] Original plan, subject to annual revisions during 1986-90.

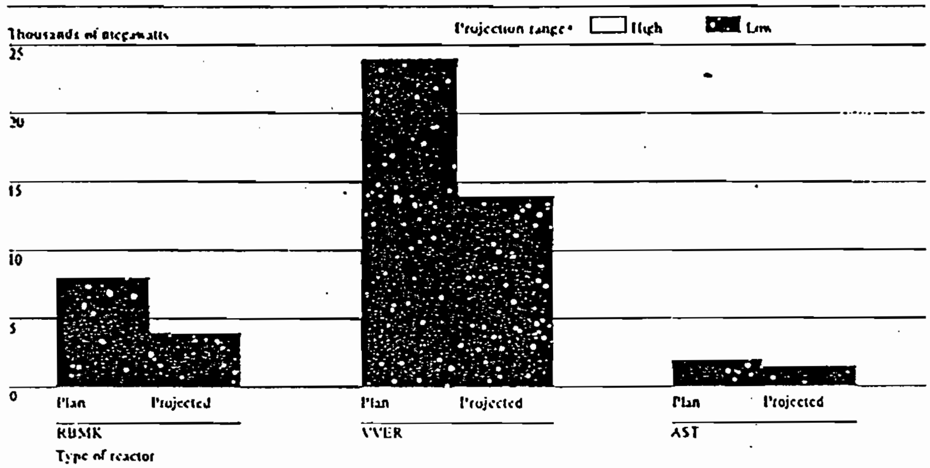
generation at as many as nine new reactors in a single year, 1988 (see table 2).[11] The 1990 electricity output goal for nuclear power is even more ambitious than the capacity goal—390 billion kWh, compared with the 167 billion kWh produced in 1985

[11] Soviet near-term plans for nuclear power were summarized in the 12th Five-Year Plan (1986-90). Full details of the plan have not been published, but the general goal is clear—a doubling of operational nuclear power plant capacity, from 28,300 MW in 1985 to about 60,000 MW in 1990. An alternative plan for 41,000 MW of new capacity, which would bring total nuclear capacity in 1990 to about 70,000 MW, has also been cited by Soviets in the nuclear industry. This total is not confirmed, however, in the literature on construction at individual plants. The 41,000-MW target probably represents both the capacity they hope to bring on line and the capacity in late stages of construction.

Before the Chernobyl' accident, we estimated that the Soviets would achieve good growth in both capacity and output but still fall short of plans for 1990. We projected that capacity would increase to about 50,000 MW and that electricity production would grow to about 285 billion kWh. Such an outcome would have been consistent with Soviet performance, which continues to fall short in component manufacture and plant construction.

As a result of the Chernobyl' accident (both the direct effects and the turmoil caused by the recovery effort), we estimate that by yearend 1990 nuclear capacity

New Capacity at Soviet Nuclear Facilities, Planned and Projected, 1986-90



[a]CIA estimates.

will reach only 48,000 MW and electricity output only 260 billion kWh. We expect that three or four fewer new reactors will be completed because labor and materials have been drawn from other nuclear plant construction sites to speed the Chernobyl' recovery (see figure 5). Indeed, Chernobyl'-induced delays are likely to affect much, if not all, of the construction of nuclear power plants. Such delays on unit 1 at the Odessa nuclear heat-and-power plant, unit 2 at the Voronezh AST, and possibly unit 5 at the Kursk plant could postpone startup of these units until the early 1990s.

In making these projections we assume that the Soviets will succeed in limiting the disruptions caused by retrofitting RBMKs and will not have to disrupt construction of the VVER-1000 reactors, including almost all of those due on line by 1990, for safety upgrades (see table 3). These assumptions are based on our observation that only a few individuals in the Soviet nuclear-power decisionmaking hierarchy (the CPSU, the scientific community, and involved ministries) have expressed reservations about the basic form of the nuclear program

Assuring the Future: VVER and AST Reactors
The VVER and AST reactors, representing 80 percent of the capacity under construction or planned, are the future of the Soviet nuclear program to the year 2000. The Soviets want to use these reactor types in power plants, in plants supplying heat to centralized municipal distribution networks, and in plants

Table 3
USSR: Actual and Projected Additions to Nuclear Power Plant Capacity, 1986-90

1986		1990	
Kalinin 2	VVER-1000	Rovno 4	VVER-1000
Zaporozh'ye 3	VVER-1000	Zaporozh'ye 5	VVER-1000
Rovno 3	VVER-1000	Rostov 2	VVER-1000
1987		Kalinin 3	VVER-1000
Balakovo 2	VVER-1000	Odessa ATETs 1	VVER-1000 [a]
Ignalina 2	RBMK-1500	Kursk 5	RBMK-1000 [a]
Gor'kiy 1	AST-500	Totals	
1988		New capacity	
Zaporozh'ye 4	VVER-1000	18,000 to 20,000 MW (electrical)	
Crimean 1	VVER-1000	1,500 MW (thermal) in ASTs	
Rostov 1	VVER-1000	New reactors	
Khmel'nitskiy 1	VVER-1000	14 to 15 VVER-1000s	
Voronezh 1	AST-500	1 to 2 RBMK-1000s	
Gor'kiy 2	AST-500	2 RBMK-1500s	
1989		3 AST-500s	
Ignalina 3	RBMK-1500	20 to 22 All types	
Balakovo 3	VVER-1000		
South Ukraine 3	VVER-1000		
Smolensk 3	RBMK-1000		

[a] Delay to 1991 possible.

that will provide both electricity and heat to municipal and industrial customers. Because these reactors are central to the expansion of the USSR's nuclear program, their involvement in a Chernobyl'-inspired safety review that resulted in major changes in equipment and procedures would have a larger impact on growth prospects for the nuclear industry than would changes to RBMK reactors alone. Such a safety review has already been suggested as a possibility by several leading scientists in the USSR's nuclear establishment

The nuclear power plants under construction that will use VVER and AST reactors are already caught up indirectly in the post-Chernobyl' activity. Construction of a VVER-1000 reactor at Rovno in the Ukraine was accelerated so that the loss of Chernobyl' to that region could be reduced. Despite some delays, this reactor started generating electricity in 1986 instead of in 1987 as we had projected earlier. Construction at several other plants, however, slowed as resources were drawn off to complete the entombment of the destroyed reactor at Chernobyl' or to accelerate the installation of safety modifications

Another set of postaccident concerns that could affect VVER and AST reactors relates to the number of reactors colocated at any one plant. Some Soviet specialists may challenge the wisdom of colocating multiple reactors that can be rendered inoperable for months or years by an accident in one unit. Plans made before the Chernobyl' accident call for most plants to colocate four to seven reactors. Reducing the number of reactors at plants would substantially slow the growth and increase the cost of the nuclear power program. The larger number of smaller plants would also reduce economies of scale in operation and maintenance.

In addition, the widespread radioactive contamination around Chernobyl' and the increased risks of cancer to people exposed to this radioactivity are likely to motivate Soviet specialists to reconsider the decision to locate nuclear heating plants in heavily populated areas. At present, in order to operate economically, plants supplying both electricity and heated water for central heating are located 25 kilometers or less from the heat-distribution network of a city. Plants that produce only heated water for heating are sited even closer—within 15 kilometers of the centers of major cities.[14]

Before the Chernobyl' accident, Soviet nuclear specialists had convinced critics in the USSR that the nuclear heating plants were equipped with safety backups adequate to ensure that their proximity to cities posed acceptable risks. Construction is under way on nuclear heating plants at Gor'kiy, Voronezh, Odessa, Minsk, and Khar'kov that are scheduled to come on line before 1990. Canceling or modifying these plants probably would be prohibitively expensive, according to Soviet calculations. The post-Chernobyl' safety reviews are likely, however, to reopen the discussion of site locations for the roughly 20 nuclear heating plants that exist only on paper in long-term plans.

Until the mid-1970s Soviet experts believed that the probability of a major accident in a nuclear power plant was so small that massive and expensive containment structures were unnecessary. All later model reactors (both RBMK and VVER), however, have some form of containment. The earlier uncontained reactor models may now come under closer scrutiny since Chernobyl' has shown the potential impact of what had been considered a low-probability event. If the Soviets decide to improve safety, the eight uncontained VVER reactors may be reviewed first because of the potential risks if the integrity of components is breached

Impact on Soviet Nuclear Energy Policy

At the time of the Chernobyl' accident, a distinctive Gorbachev imprint on the USSR's nuclear goals was not yet apparent. Gorbachev's new assignments at energy ministries were too recent to have had a visible effect on the nuclear program—the new Minister of Power and Electrification was appointed in March 1985. The new leadership in the various major energy ministries (oil, natural gas, coal, and power) apparently did not alter the long-term energy goals when the opportunity presented itself in late 1985. At that time, the plan for 1986-90 (pushing natural gas production and calling for sustained growth in oil output) and the existing Long-Term Energy Program (setting goals for expanded roles for coal and nuclear energy in the 1990s and beyond) were publicly endorsed without changes.

Early in 1986, however, there were signs that the Gorbachev energy team was considering some shift away from coal, with a corresponding greater emphasis on nuclear power in the longer term. A key element in the program for a coal resurgence—direct-current ultra-high-voltage (UHV) electricity transmission—was challenged on the grounds of high development costs and lack of progress in achieving new technical capabilities. The critics of coal argued that nuclear power plants are better suited to supplying electricity to the Urals than would be UHV transmission lines linked to distant coal-fired power stations.[15]

[14] Existing Soviet standards for nuclear plant locations—minimum distances of 3 kilometers (km) from any populated area, 25 km from cities with populations of at least 300,000, or 40 km from cities with populations of 1 million or more—were amended for nuclear heating plants (ASTs) following a review in the late 1970s.

Since the accident, a number of Soviet viewpoints relating to the effects of Chernobyl' on the USSR's nuclear program have been set forth in the Soviet media and expressed by Soviet officials in conversations with Western counterparts. There appears to be broad agreement on several judgments:

- The USSR's need for nuclear energy as the main alternative to fossil fuels was not changed by the Chernobyl' disaster.
- Operator error in performing tests at unit 4 was the chief, although not the sole, cause of the disaster.
- Soviet targets for completing nuclear power plants and for generating electricity in 1990 should not be changed.

Some disagreement among Soviet authorities is evident, however, on:

- The extent to which the basic design flaws in the RBMK reactor that contributed to the destruction of Chernobyl' unit 4 and damage to the adjoining unit 3 can be fixed.[a]

- The amount of work needed to restore reliable operation of Chernobyl' units 1 and 2 and provide housing and services to workers.

- The feasibility of returning Chernobyl' unit 3 to operation and whether construction could be resumed on Chernobyl' units 5 and 6 (a decision not to recover units 5 and 6 was apparently made in March/April 1987).

- The functions and authority of the several organizations that deal with nuclear energy.

[a] For example, the first official statements on the cause of the accident singled out operator error and poor management in the Power Ministry and State Committee for Safety in the Nuclear Industry. By 19 July the Politburo had extended its public criticism to include the firing of a key designer of the RBMK reactor, an official in the semisecret Ministry of Medium Machine Building. By implicating design shortcomings as at least a contributing cause of the accident, the Politburo had called into question not only the design integrity of existing and planned RBMKs but also possibly the design philosophy underlying the entire nuclear program. It was not until the August IAEA special meeting that the Soviets directly acknowledged that design faults were partly responsible for the seriousness of the accident.

Given the complexity of these issues, the contradictory viewpoints on some matters, and the number of bureaucracies involved in making the necessary decisions, Soviet policies on the nuclear program could remain unsettled for another year or more. The immediate attention of decisionmakers was directed at Chernobyl' cleanup activities, the effort to entomb unit 4, and the recovery of units 1, 2, and 3. Meanwhile, the nuclear industry has been rocked by reorganization and uncertainty about the authority of key players such as the Power Ministry, the State Committee for Nuclear Safety, and the new Ministry of Atomic Energy (see inset).

An Underlying Commitment to Nuclear Power

Nevertheless, Soviet spokesmen continue to affirm a strong commitment to the growth of nuclear energy. This commitment is bolstered by the large infrastructure dedicated to the nuclear industry—a factor that will carry considerable weight with policymakers as they review long-term plans for nuclear energy. Long-range goals for Soviet nuclear power to the year 2000 were defined in terms of their projected impact on economywide fuel use.

Specifically, Moscow had set goals for the development of nuclear energy during the 1986-2000 period that were designed to mesh with other energy programs so that:

- Consumption of oil and gas could be reduced.
- Retirements of obsolete power plants could be speeded.
- The quality of electricity supply could be improved.
- Fossil fuels could be conserved in increasing quantities by using nuclear energy in more applications.
- Growth in the demand for electricity in the European USSR could be met; nuclear power stations are concentrated in the area west of the Ural Mountains.

Our conversion of these targets to actual reactor construction goals implies that over 120,000 MW of power plants and about 20 nuclear heating plants would have to be added during the 1986-2000 period.

Reorganization of the Soviet Nuclear Program

After studying the results of the Chernobyl' investigation in July, the CPSU Politburo began a reorganization of the Soviet nuclear industry. It fired the head of the All-Union State Committee for Nuclear Safety and the main designer for RBMKs, as well as key personnel in the Ministry of Power and Electrification and in the Ministry of Medium Machine Building (probably for its role as overseer of RBMK design).[a] In addition, the Politburo set up a new Ministry of Atomic Energy and increased the party's influence on the operation of nuclear plants by assigning people from the central CPSU apparatus instead of local party representatives to each nuclear power station.

Major questions remain on which organizations and people will wield authority for such functions as operation of nuclear power plants, preparation and disposal of nuclear fuel, enforcement of safety rules, construction of nuclear plants, and fabrication of components. [redacted] *many areas of authority have yet to be clearly defined. The Ministry of Atomic Energy, for example, will assume responsibility for operating all nuclear power plants, taking over from the Ministry of Power and Electrification and the State Committee for the Utilization of Atomic Energy (staffed with nuclear experts from the Ministry of Medium Machine Building). Whether even more authority will be transferred from other key ministries to the new Atomic Energy Ministry is not now evident.*

[a] The responsibilities of the Ministry of Medium Machine Building include functions in both military and civilian nuclear programs. The civilian nuclear industry depends on this ministry for nuclear fuel, for design and construction work on the RBMK reactor, and for expertise in nuclear materials transportation, storage, and reprocessing

The Soviets appear to have begun work—ranging from preliminary paperwork on the plant designs to actual plant construction—on about three-quarters of the projects needed to meet the long-term goals (see table 4). More than half of these nuclear projects are in the earliest stages of development, however, and some 30,000 to 40,000 MW of the nuclear capacity needed to achieve the objectives for the year 2000 has not yet been approved at even the drawing-board stage.

Disagreement, moreover, is evident in the Soviet media on several aspects of nuclear energy development over the longer term. Among the points at issue are:

- The adequacy of Soviet nuclear safety standards and standards of enforcement.
- Whether reactor types other than the RBMK (VVER or AST) should receive thorough safety reviews.
- The need for a reevaluation of quality control in component manufacture for nuclear plants.
- The criteria for site locations of future nuclear plants.
- The feasibility of pushing ahead with more and larger breeder reactors.
- The need for development of an inherently safe reactor.

Before Chernobyl' the Soviet safety philosophy was based on a perception of the probability of certain types of accidents rather than on an evaluation of the consequences of both probable and unlikely occurrences. The Soviets believed that their nuclear plant designs, operating parameters, and rules for plant operations assured that any failures would be small events that could be contained safely. [redacted] stated that "as a result of the Chernobyl' nuclear accident, the Soviets have buried forever the fail-safe argument concerning nuclear power." If the Soviet nuclear industry is instructed to give greater weight to ensuring safety for even low-probability events with major consequences, this new philosophy will impact on plant site selection, designs, component manufacture, and plant operation.

Table 4
The Soviet Nuclear Program to the Year 2000:
Outlook Before Chernobyl'

	Capacity (MW)	Plants	Reactors
Total planned	170,000 to 180,000 [a]	60 to 70	230 to 250
Operating (generating power as of 24 April 1986)	28,312	15	41
Of which RBMK	15,500	5	15
Capacity at some phase of construction or planning	111,300 [a]	39	162
Of which RBMK	19,500	6/1 [b]	15
Construction at main facilities	35,000 [a]	16/8 [b]	36
Of which RBMK	7,000	3/0	6
Site preparation	19,300 [a]	11/3	18
Of which RBMK	4,500	3/0 [b]	3
Planning and design	31,000 [a]	12/5 [b]	29
Of which RMBK	8,000	3/0 [b]	6
Site proposals	26,000 [a]	18	38
Of which RBMK	None	None	None
Capacity awaiting go-ahead on site selection and design	30,000 to 40,000	6 to 15	30 to 45
Of which RBMK	Unknown	Unknown	Unknown

[a] Includes capacity partially or wholly dedicated to supplying heat for space heating and industrial-process applications.
[b] Number at left of diagonal (/) shows total of plants with activity in the category, number on right shows plants exclusively in the category.

We believe the Soviets will try to accommodate both old and new safety philosophies to minimize costs and delays. Existing plants and plants at advanced stages of construction would continue to be judged according to the current safety standards. The new safety philosophy would be phased in at plants on the drawing board and possibly at selected plants now in the earliest stages of construction. This approach to a more comprehensive safety philosophy would leave plans for new nuclear power plant capacity untouched in the 1986-90 period but could lead to delays in the 1990s. Support for this theory of Soviet reactions was evident [redacted] in December 1986. [redacted] construction of RBMKs would cease after the last two Chernobyl' reactors were completed (units 5 and 6, scheduled for the early 1990s). We believe the Soviet reference to a construction halt on RBMKs would still allow for completion of many of the remaining 15 reactors now at some phase of assembly.[c]

The plans for power plants based on VVER reactors will probably survive the post-Chernobyl' scrutiny, although some additional safety requirements could be mandated. However, the slowing of the Soviet

[c] If new safety measures that go beyond what has already been proposed make new RBMK reactors prohibitively expensive, the Soviets could drop as many as six RBMK reactors that are now in very early stages of planning. Such an action could be taken without a major impact on electricity supply if Moscow is willing to rapidly replace these reactors with conventional thermal power plants fueled by natural gas.

The Manufacturing Infrastructure for the Nuclear Power Industry

The manufacturing infrastructure for the Soviet nuclear power industry is divided into two more or less distinct subsets. One group, composed of over 500 major enterprises, makes components for RBMK reactors. The logistic nightmare of the RBMK support industry is a main reason this reactor has been scheduled for gradual phaseout. The other—and much smaller—group of support enterprises manufactures components for VVER reactors and is scheduled to produce for the breeder reactor program. In the latter group of enterprises are the Izhorsk Heavy Equipment plant near Leningrad and the Atommash plant outside Volgodonsk, two of the largest nuclear-component-fabrication facilities in the world. But the Atommash plant has shown a disappointing performance since production of VVER pressure vessels began in 1978. Far from being a showcase nuclear assembly plant, Atommash has been plagued with problems—poor management, production of substandard components, and plant damage from ground subsidence.

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nuclear program as well as safety reviews will probably mean that the economic rationale for a large-scale breeder-reactor program currently targeted to start in the late 1990s will be eroded.

The Influence of Nuclear-Industry Infrastructure

The large investment the Soviets have made in manufacturing plants that supply the nuclear industry will bolster their commitment to a growing and little-changed program (see inset). Plants manufacturing components for Soviet-designed reactors are located not only in the USSR but also throughout Eastern Europe. The Soviets have invested tens of billions of rubles and millions of dollars of hard currency imports in building and equipping their facilities. They have accomplished many of their goals for centralizing component production and for integrating the capabilities of the CEMA. The East European countries, for example, can produce nearly all the components for power plants using VVER-440 reactors—with the notable exception of nuclear-fuel assemblies. Moreover, VVER and RBMK nuclear power plants built in the USSR contain many key components manufactured in Eastern Europe.

Because it appears likely to Western observers that the failure of or an inadequate operational range of certain components could have contributed to the Chernobyl' accident, the absence of repercussions in the Ministry of Power Machine Building or the Ministry of the Electrical Equipment Industry is surprising. The IAEA special meeting on Chernobyl' provided insight on this matter. According to the Soviet account of the accident, improper designs, not poorly built components, explained entirely the inability of certain systems to perform as expected.[a] Thus, in a perverse way, the Chernobyl' accident is good news for the equipment manufacturing ministries because they were implicitly certified as competent. Indeed, it is possible that more resources will be assigned to them so that equipment for modifications can be produced quickly.

Antinuclear Voices in the USSR

Antinuclear movements as they exist in the West are not possible in the USSR. Moscow's control organs probably would effectively prohibit the organization of an antinuclear group of substantial size and almost certainly would prevent public demonstrations or circulation of publications containing views opposed to official policies on nuclear energy. The Soviets have also minimized the opportunities for an antinuclear lobby by mounting an effective pronuclear campaign that advertises the advantages of nuclear power: fuel savings, less environmental impact than coal, and lower overall costs.

Nevertheless, antinuclear sentiments exist in the USSR, and they receive some degree of official acknowledgment. Three groups that have questioned

[a] In the nuclear industry, as in other Soviet industries, responsibilities for designs of equipment and plants are handled by institutes and bureaus that operate nearly independently of the manufacturing and construction organizations that use the designs

the nuclear program are likely to respond to the Chernobyl' accident with increased activity: (1) specialists on ecology, (2) those regional Communist Party authorities who have shown reluctance to back nuclear projects, and (3) scattered individuals who reveal a grassroots expression of doubt and concern about the locations and operations of nuclear plants.

Although Soviet ecologists have generally supported the nuclear program as providing an energy source much less disruptive to the environment than fossil fuels, particularly coal, a few scientists have criticized the impact of nuclear energy. The most prominent of these critics has been Nikolai Dollezhal, original designer of the Chernobyl'-type reactors. In an article published in a leading Soviet journal in 1979, Dollezhal argued that a large nuclear program in the European USSR could eventually require withdrawal of lands from agricultural production, make excessive demands on water resources, and release ecologically threatening quantities of heat into the atmosphere. Dollezhal's solution (to consolidate nuclear power plants in large, remote complexes) could now gain more backing from ecologists, whose opinions recently have had increasing, though still minor, influence on policy formulation.[10]

Since the Soviets are unlikely to allow direct questioning of the safety of nuclear plants, the ecology issue could provide an acceptable surrogate for use by groups whose real concerns are safety and public health. A harder look at the ecological impact of nuclear power could jeopardize the extensive use of this energy source for central heating, because the reactors used for this purpose must be located close to populated areas. Moreover, ensuring that nuclear facilities are more ecologically benign probably would drive up the capital costs of most nuclear plants.

Many regional party and government organizations saw real advantages to nuclear power and supported nuclear power plant projects. A few regions (the Ukraine, for example) gambled heavily on the successful operation of nuclear power plants; nearly all new power plant construction there since the late 1970s has been nuclear. The leadership of the Georgian republic, however, opposed building nuclear plants until early 1986, when the construction of a power station was announced. The basis for opposition to nuclear plants in Georgia was not fully discussed in the Soviet press, but concern about radiological consequences on Georgian agriculture was evident. The Chernobyl' catastrophe is likely to revive the Georgian antinuclear lobby, which may now be more successful in arguing that untapped hydro resources and local coal deposits can meet future Georgian electricity needs.

Impact on Resource Allocation and Trade

The assorted production and research bureaucracies of the energy ministries that compete for resources with nuclear power (oil, gas, and coal) will use the Chernobyl' accident and its associated capital costs as an opportunity to promote their claims for investment resources at the expense of the nuclear industry (see inset). In the short term, the oil and natural gas industries may be the quickest to take advantage of the Soviet nuclear industry's setback. Oil and gas provided 70 percent of the USSR's energy production in 1986 and will remain the most important Soviet energy sources well into the 1990s. Spokesmen for oil and gas industry interests will be able to make the case that over the next several years these fuels will be even more necessary for the Soviet economy because the nuclear industry will fall short of plans while it is reorganizing and regrouping in reaction to Chernobyl'. The oil and gas interests will probably link this argument to a bid for increases in their already escalating requirements for investment and skilled labor, promising that they can meet the energy needs of the economy.

Coal is nuclear power's main long-term competitor. Coal-based energy strategies have backers in the State Planning Committee (Gosplan), in the Power

[10] The view that ecologists, or arguments couched in ecological language, have had influence on Soviet policymaking is supported by their role in recent events: the decision not to divert Siberian rivers, the followup to the Dnester River chemical spill, and the "nuclear winter" line in nuclear weapons debate.

Capital Costs of the Chernobyl' Accident

At a minimum, the nuclear industry will need to write off the 400-million-ruble reactor destroyed at Chernobyl'. If the Soviets must abandon Chernobyl' unit 3 and the work done on units 5 and 6 because they are too contaminated to recover, another 800 million rubles of investment would be lost. Additional outlays of hundreds of millions of rubles would be necessary if new rapid shutdown equipment for reactors is installed at all RBMKs. The VVER reactors, particularly the eight early, uncontained ones, may also need safety upgrades that, if extensive, could cost several hundred million rubles.

During 1981-85, yearly spending on equipment and construction for nuclear plants averaged nearly 2 billion rubles, almost 35 percent of all power industry investment. Additional sums, perhaps several hundred million rubles, are annually invested in infrastructure for the nuclear industry. A rough total of the capital costs of the accident (ranging from actual to possible) to be borne by the nuclear industry shows these to be the equivalent of two or three years' current investment.

Ministry, in the Coal Ministry, and in many research institutes. Expanded coal use is supported in the Soviet Long-Term Energy Program; planners are counting on coal, in conjunction with nuclear power, to supply nearly all new energy output once natural gas production levels off in the mid-1990s. However, the Soviets have not been devoting the resources needed to get the coal industry moving toward its ambitious goals. The industry's leadership is now in a strong position to bid for a larger resource share, using the argument that coal-fired plants will be able to deliver electricity more cheaply and safely than nuclear plants.

Soviet Purchases From the West

The Soviets are likely to continue to need Western equipment for monitoring radiation and health, amounting to several million dollars per year for at least a decade. Moscow probably hopes to meet these specialized needs through IAEA-sponsored donations, but will import what is necessary. Other products and services that the Soviets may want to purchase from the West are reactor simulators and teaching aids for training reactor operators and equipment for nondestructive testing of nuclear power plant components.

A more important role for Western imports is possible in the next few years if the Soviets want to accelerate their VVER program or decide to implement rapidly safety features used in reactors operated in the West. For example, the Soviets would probably need service contracts with Western machine-tool specialists to boost construction of VVER reactors because effective utilization of machine tools that have been purchased in the West is essential to the production of the major components used in these reactors. Many components of a generic nature (such as pipes, valves, and pumps) could also be purchased from the West, since these would require little modification to operate in Soviet plants.

Any market in the USSR for Western nuclear vendors is likely to be highly competitive. Firms from the United States, France, Finland, West Germany, Sweden, Great Britain, and Japan can offer many comparable components and services.

Soviet Nuclear Sales Abroad

Before the Chernobyl' accident, the USSR was stepping up its campaign to sell nuclear power plants in the West. The accident has dampened the prospects of all suppliers of nuclear power plants but may have a more lasting impact on Western suppliers than on the Soviets (see inset). The Soviets have tried to sell nuclear power plants with VVER reactors to new customers in 12 countries in the past two years. The Soviets agreed, several months before Chernobyl', to supply a nuclear power station to North Korea, hosted

Impact of Chernobyl' on Nuclear-Support Industries—Are the Soviets in Better Shape for a Comeback Than the West?

With the likely exceptions of France and Japan, most developed Western countries (including the United States) could suffer greater setbacks to their nuclear-support industries during the next decade than will the USSR as a result of reactions to Chernobyl'. While the nuclear industry in the developed West and several other countries—South Korea, Taiwan, the Philippines, and India—was in recession before Chernobyl', before the fall in oil prices, and even before the Three Mile Island accident, there were several immediate backward steps in the months after the Chernobyl' accident. Austria and the Philippines finally chose to give up their previously troubled nuclear programs. A number of planned orders for new stations—in Finland, the Netherlands, and Italy—were put on hold, permanently in some cases. Further postponing of orders for nuclear power plants is most likely to occur in the West as doubts about nucleor power increase. As a result, shakeouts and retrenchment in the developed West's nuclear-support industries are now more the rule than the exception: possibilities for new business are dwindling at home, and reactor-export possibilities are shrinking. In another five years or so, industrial capacity in the West devoted to supplying nuclear power plants could be greatly reduced.

In contrast, new orders for nuclear plants in the USSR continue. Because the state-operated nuclear power equipment industry of the USSR can weather this period of slack international demand for nuclear plants, the Soviet Union could find itself in a better position than most suppliers in the West to take advantage of a rebound in nuclear plant orders in the 1990s. Such a rebound currently seems remote. Nevertheless, selling nuclear power plants and equipment could again become lucrative if confidence in nuclear power is restored and conventional energy costs rise sharply

a Chinese visit to Soviet nuclear plants, sought Kuwaiti assistance as a broker for possible sales in the Middle East, and offered to sell nuclear plants to India, Egypt, Morocco, and Indonesia. Before Chernobyl' they also discussed constructing reactors in Syria, Iraq, and Libya, and planned to bid on plants for Finland and Yugoslavia. In the wake of the Chernobyl' disaster, the Soviets probably have lost some nuclear plant sales; Finland (with two operating Soviet reactors) and Yugoslavia immediately put their nuclear orders on hold, while other potential Soviet customers indicated that nuclear plans were being reviewed.

Before the Chernobyl' accident, Soviet nuclear plant marketers hoped to get several commitments for purchases of VVER reactors. Potential buyers in Finland and Yugoslavia seemed close to placing orders cumulatively worth roughly several billion dollars over the next five to seven years. Given the trade arrangements between each of these countries and the USSR, however, these transactions probably would have been largely barter agreements, with very little hard currency transferred to the Soviets. Although the Soviets were actively discussing contracts for commercial nuclear plants with a number of other non-Bloc potential buyers, this segment of business was at a preliminary stage.

The Soviets are jointly engaged with the East European countries (Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania) in marketing Soviet-designed nuclear plants to power industries inside and outside the CEMA area. These plants use the VVER pressurized-water reactor in either of two capacities: 440 MW or 1,000 MW. Reactors of the Chernobyl' type have never been offered for export. With the exception of nuclear fuel, all of the components for the VVER-equipped plants can be manufactured in Eastern Europe, largely in Czechoslovakia, East Germany, and Hungary. The 1,000-MW VVER reactors currently being marketed have full containment and other safety features functionally comparable to those used in the West. The Soviets are also jointly marketing a VVER-440 nuclear power reactor with a Finnish company that operates a plant of this model in Loviisa, Finland.

In public testimonials, a number of East European officials have reaffirmed their confidence in the safety and reliability of Soviet-designed reactors. Privately, however, East European energy experts concede that the Chernobyl' accident has increased concern about the safety systems engineered into Soviet designs (especially the older VVER-440s without even Soviet-type containment), but they expect that Soviet-designed reactors will continue to be operated, built, and ordered.

The East Europeans have a large stake in the success of Soviet-designed VVER models—19 reactors with a combined capacity of about 8,000 MW are now operating in these countries, and 50 others (some 36,000 MW) are under construction or on order. Although we believe that the East Europeans will follow through on plans for nuclear energy, their nuclear programs could experience delays (while public confidence is restored with safety reviews) and increased costs.

Director of
Central
Intelligence

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Monday
7 July 1986

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PHILIPPINES: **Attempt to Form Rival Government**

The naming of a rival government by Marcos supporters yesterday is an embarrassing irritant to the Aquino administration that was probably designed to drive another wedge between President Aquino and Defense Minister Enrile. b3

[redacted]

Arturo Tolentino, Marcos's running mate in the February presidential election, proclaimed himself acting president yesterday during a rally of Marcos supporters that included several hundred armed soldiers. Tolentino named several Marcos loyalists to his "cabinet" and said that he would retain Defense Minister Juan Ponce Enrile and Armed Forces Chief of Staff Fidel Ramos—the leaders of the rebellion that ousted Marcos and installed Aquino—in their positions. [redacted] b3

Under the command of officers loyal to Marcos and Tolentino, troops, estimated to number as many as 500, seized the Manila Hotel, the site of the demonstration [redacted] some of the troops supporting Tolentino may be from Regional Unified Command III, where many provincial commanders owed their positions to Marcos's crony Eduardo Cojuangco in the past. b3, b1

[redacted] b3

President Aquino, visiting Mindanao yesterday, announced that when she returned to Manila today, Tolentino would face sedition charges. Both Ramos—who was traveling with Aquino—and Enrile have publicly reaffirmed their support for Aquino. Enrile ordered government troops to surround the Manila Hotel and sent a three-man team of officers to negotiate a peaceful dispersal of the Marcos supporters. Two hundred soldiers have already surrendered, [redacted] leaving only former members of Marcos's presidential guard inside the complex. [redacted] b3

[redacted] Tolentino's gesture, presumably made at Marcos's direction, highlights the former President's continued efforts to harass and attack the legitimacy of the Aquino government. Tolentino himself is no real threat to Aquino; he lost much of his credibility by becoming Marcos's running mate earlier. The inclusion of Enrile in Tolentino's "cabinet" was almost certainly designed to worsen the growing tensions between Enrile and Aquino. Enrile's public support for Aquino, however, has prevented the defection of more government troops to Tolentino. If Enrile is able to resolve the incident without violent clashes, he could strengthen his position in Aquino's Cabinet and eliminate some of her distrust for him. [redacted] b3 b3

[redacted]

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NICARAGUA: **Government Crackdown Continues**

b1, b3

The Sandinistas' decision to expel another high-ranking priest—the second in less than a week [redacted]

Bishop Vega's expulsion on Friday followed a heavy proregime media campaign that chronicled his alleged support for the insurgents. The Bishop's Council has issued a statement criticizing the expulsion, and Cardinal Obando condemned the action in measured terms in his sermon yesterday. [redacted] b3

The Sandinista press [redacted] is already claiming the regime has evidence against key opposition political leaders. Despite these warnings [redacted] many dissidents remain determined to oppose the new security measures. b3 b3 b3

[redacted] b1, b3 b1, b3

The expulsion of Bishop Vega, combined with that of the Cardinal's chief spokesman last week, robs the hierarchy of its two best known voices. The moves will force the Cardinal to assume still more of the burden in opposing the regime and substantially increase his vulnerability to Sandinista retaliation. Bishop Vega was also important in maintaining support for the Cardinal's confrontational posture within the Bishop's Council. [redacted] b3 b3

Some in the civic opposition probably calculate they have little to lose in speaking out against the regime and will look for new opportunities to oppose the Sandinistas, but the new restrictions will sharply limit their ability to organize activities. Moreover, despite their joint statement, not all in the democratic opposition are likely to advocate confrontation, and internal debates will aggravate traditional personal rivalries. [redacted] b3

The Sandinistas almost certainly have selected their next targets, and extensive press attacks probably will be a key indicator of their likely moves. They will probably move gradually, however, perhaps calculating that, if they can force dissidents to leave without being forced to expel them formally, they can minimize international reaction and head off a politically damaging mass exodus. [redacted] b3

[redacted]

EASTERN EUROPE: **Economies Still Struggling**

Recently released data show Eastern Europe's economic performance for the first quarter of 1986 improved little over last year's poor showing. [redacted] b3

The hard currency deficit for the region was an estimated $900 million as increases in imports, especially from the West, outstripped export growth; in contrast, there was a slight surplus for the first quarter of 1985. The trade gap was particularly large for Hungary, Bulgaria, and Czechoslovakia. Officials in several countries have expressed disappointment with the trade figures, especially because economic plans had stressed reducing hard currency imports and expanding exports. [redacted] b3

First-quarter industrial growth fell below the annual rate for 1985. Encouraged by a relatively moderate winter this year, East European regimes hoped for stronger showings as they began new five-year plans. Official criticism of inertia in the Czechoslovak economy has been unusually harsh, and [redacted] Hungary's GNP might not increase at all in 1986. [redacted] b1, b3 b3

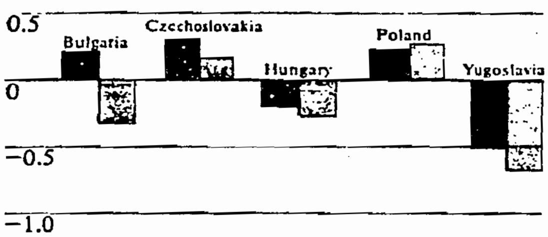
[redacted] Prospects for these economies over the rest of the year are not bright. Declining oil prices in the West have cut demand for the region's refined oil products and reduced the ability of Third World oil producers to buy from Eastern Europe. Tourism and food exports to Western Europe have also suffered since the Chernobyl' accident. [redacted] b3 b3

The slow industrial growth and the decline in hard currency trade performance indicate that the region's recovery from the economic stagnation and financial problems of the early 1980s is running out of steam. Further poor trade results may make bankers more cautious in lending to Eastern Europe. With the Soviets pushing Eastern Europe to increase economic growth and poor 1986 results already apparently throwing the new five-year plans off schedule, East European leaders will come under increasing pressure to take stronger actions in addressing economic problems. [redacted] b3 b3

Eastern Europe: Selected Economic Indicators

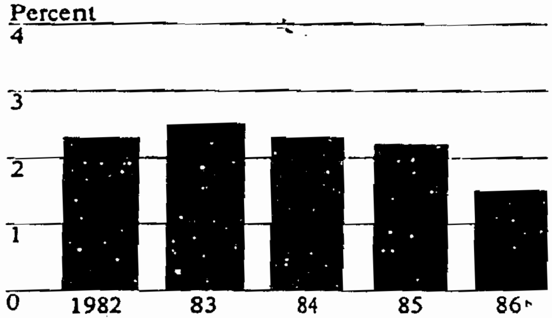
Hard Currency Trade Balances, First Quarter 1985 and 1986[a]

Billion US $ ■ 1985 □ 1986



Estimated Growth of Industrial Production, 1982-86

Percent



[a] Data for East Germany and Romania are not available.
[b] Data for first-quarter results adjusted to remove distortions of the winter of 1985.

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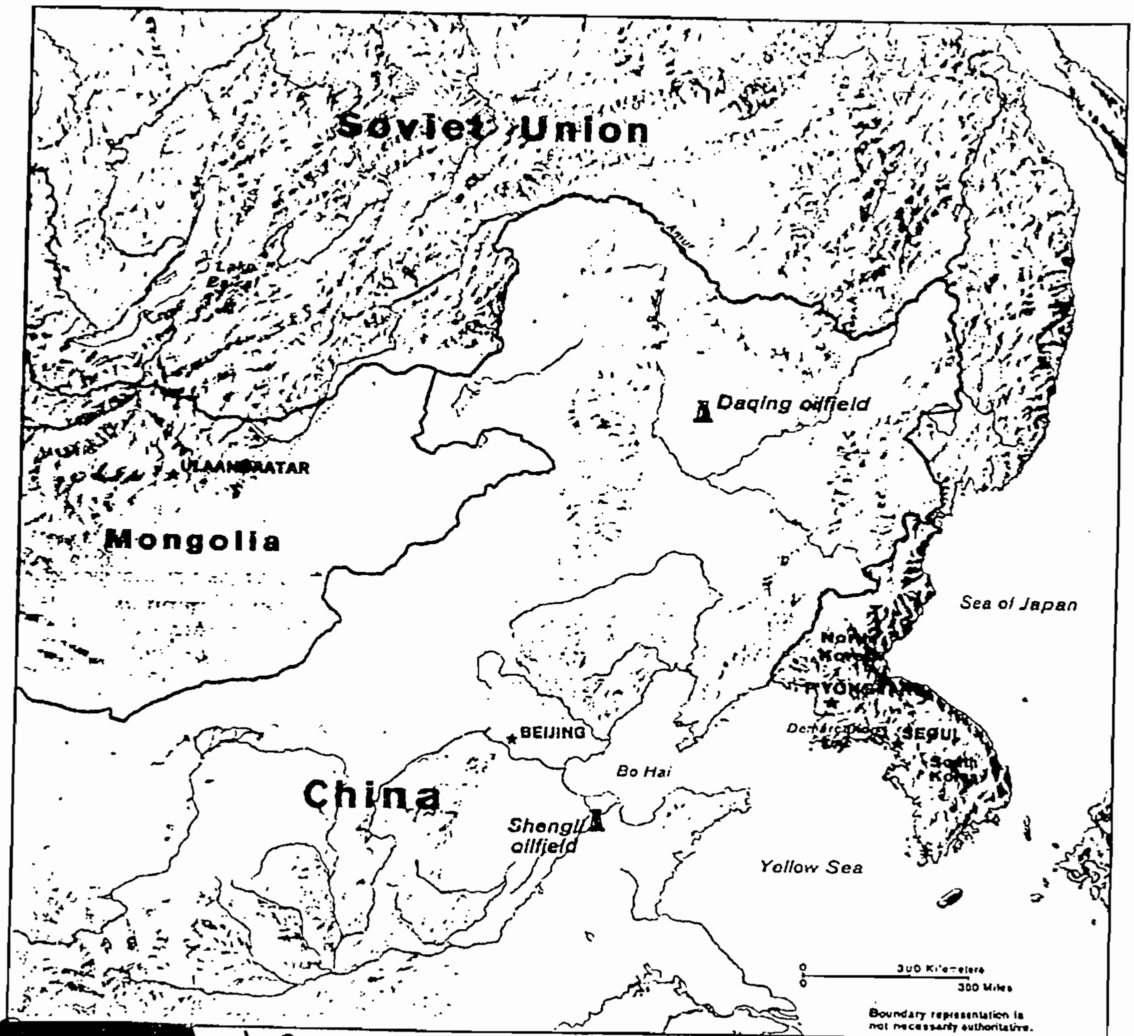

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CHINA: Oil Production Growth Slows

China produced 2.53 million barrels of oil per day during the first half of 1986, only 2 percent more than during the same period last year. Production at Daqing, China's largest field, declined 4 percent because an accident in January shut down one of the field's major power stations for several months [redacted]

b1, b3

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[redacted] The lower growth rate will have little effect on domestic oil supplies, which will benefit slightly from a drop in exports—down 11 percent in the first quarter. Nevertheless, Beijing will continue to ration domestic oil supplies tightly so it can expand exports if international prices rise. Significant new finds at Shengli probably will keep China's oil production growing through the rest of the decade. [redacted]

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CHINA: Currency Devaluation

China devalued its currency by 13.5 percent against the dollar on Saturday in response to continuing concerns about its balance of trade. In 1985 China ran a trade deficit of about $8 billion [redacted] Preliminary Chinese data indicate that the trade deficit in the first quarter of 1986 was about the same as in the same period last year. [redacted]

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[redacted] This devaluation, following a 7-percent devaluation in October, reflects Beijing's determination to improve its trade performance by using economic incentives rather than administrative directives. Premier Zhao Ziyang complained in March that, because of China's irrational price structure, the profits from domestic sales of many products are greater than profits from exports. The devaluation, by boosting the profitability of exports, will spur Chinese firms to divert more goods to foreign sales. At 3.7 yuan to the dollar, however, China's currency is still overvalued, and Beijing probably will devalue again before the end of the year. [redacted]

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[redacted]

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In Brief

South Asia

— Initial reporting indicates low turnout for **Pakistan** opposition leader Bhutto's nationwide demonstrations on Saturday . . . officials in volatile **Karachi** had banned rallies for two weeks . . . only one incident of violence reported. [redacted] b3

Middle East

— [redacted] Warsaw Pact members will help fund UN force in **Lebanon** to improve chance **Polish** troops will replace a **French** unit . . . UN seeking replacements from current contributors, no success yet. [redacted] b3 b1 b3

Americas

— **Nicaragua** to adopt conventional military ranks . . . guerrilla commandants to become majors and colonels . . . four grades of general authorized, President appointing top three . . . gives officers chance to equal or outrank **Soviet, Cuban** advisers. [redacted] b3

b1, b3 b1

— **Cuba** suspended interest payments to Paris Club members last Tuesday, [redacted] . . Havana refusing import cuts, reforms to reduce $436 million financing needed this year . . . strained talks probably will resume this month. [redacted] b3 b3

Europe

— [redacted] **East Germans** rankled by **Soviet** push for more open media policy . . . disliked Gorbachev's mentioning Soviet shortcomings at East German party congress . . . unhappy with Gorbachev's style. [redacted] b3, b1 b3

— **EC** court invalidated 1986 EC budget . . . ruled budget violated EC spending restraint agreement . . . ruling will increase financing gap from $3.9 billion to $4.5 billion . . . budget revisions this autumn likely to cut nonagricultural spending. [redacted] b3

— **EC** members expected to approve interim settlement of EC-US farm trade dispute this week . . . allows continued US corn exports to **Spain** this year . . . **France** contends agreement too favorable to US but unlikely to block. [redacted] b3

East Asia

b1, b3

[redacted] b1, b3

Eastern Europe: Indicators of Reaction to the Chernobyl' Accident of 26 April

	Bulgaria	Czechoslovakia	Hungary	East Germany	Poland	Romania	Yugoslavia
Initial press announcement	4/28	4/30	4/28	4/29	4/28	4/29	4/29
First admitted Soviet casualties		4/30	4/29	4/30	4/30	4/29	4/29
Medical warnings issued	5/1	5/6	5/2	5/7	4/29	5/2	5/1
Increased radiation announced	**[a]	**	**		**	**	**
Admitted economic losses	**	**	**		**	**	**
Accepted Western assistance					**	**	
Changed nuclear programs	**						**
Private statements of ire by officials	**		**	**	**	**	**
Requested compensation from Soviets			**		**	**	
Cited Voice of America as media verification					**		

[a] Double asterisk indicates date unknown.

[redacted] b3

Special Analysis

EASTERN EUROPE: Aftermath of Chernobyl'

The Chernobyl' accident has introduced new frictions into Eastern Europe's relations with the USSR. It has also provoked anger toward Western Europe over the EC's temporary ban on East European food exports. [redacted] b3

Soviet failure to warn Eastern Europe of the accident quickly and to share information, despite a CEMA agreement, angered leaders in many countries. Moscow has shown no willingness to accommodate the East Europeans' reported demands for compensation, however, and the ire expressed in some countries toward Western Europe has not slowed efforts to establish formal EC-CEMA relations. b3

[redacted]

Relations With the USSR

[redacted] b1, b3

b1, b3

[redacted] East European governments did not extend the customary formal condolences over the disaster to the Soviet Government. [redacted] b1, b3

Attempts to follow Moscow's line by minimizing the accident eroded the populace's already limited confidence in the governments of most East European regimes. [redacted] b3, b1

b3

Many people, distrustful of government information, assumed the threat to public health was worse than announced and relied on Western radio for news on the accident. The Polish regime even cited the Voice of America to calm the population's fears of health hazards. The accident also stimulated fledgling environmental and antinuclear groups, which will probably fuel political dissidence. [redacted] b3

Relations With the European Community

[redacted] Hungary, Poland, and Yugoslavia quickly denounced the EC import ban as a politically motivated move to protect domestic agriculture. The East Europeans claim the ban cost them more than $100 million in lost earnings in May, and financially troubled Poland and Romania have used the ban as an excuse for not making debt payments. [redacted] B1

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continued

Despite their anger, however, all East European countries responded positively to a recent EC proposal to pursue bilateral and CEMA-EC agreements simultaneously, [redacted] the Community will probably launch trade negotiations with Romania, Hungary, and Czechoslovakia in the near future. [redacted] b1, b3 b3

Outlook

The Chernobyl' incident appears unlikely to affect the East Europeans' relationship with Moscow in any fundamental way, even in the short run. [redacted] the Soviets and East Europeans discussed the compensation issue in Moscow [redacted] and [redacted] the East Europeans were determined to press the issue. [redacted] b1, b3 b1, b3, b1 b3

b1, b3

Compensation may also have been on the agenda of the unprecedented meeting Soviet leader Gorbachev had with East European party leaders following the regular session of the Warsaw Pact's Political Consultative Committee in Budapest that involved larger delegations. In public, however, the Soviets have avoided any hint they might compensate any country. [redacted] b3

The Soviets have disappointed East European hopes that Gorbachev would treat his allies more like equals than did his predecessors. The East Europeans believe themselves unfairly penalized by the accident, but they have little leverage with Moscow. At most, they may signal their displeasure by dragging their feet in future economic negotiations with the Soviets. [redacted] b3

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07 JAN 1988

The Chernobyl' Accident: Social and Political Implications

A Research Paper

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The Chernobyl' Accident: Social and Political Implications

A Research Paper

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The Chernobyl' Accident: Social and Political Implications

Scope Note

This research paper focuses on the societal and political implications of the first major domestic and international crisis under General Secretary Mikhail Gorbachev. It examines the impact of the Chernobyl' accident on the Soviet population, popular reaction to the event, and the effect on popular attitudes toward the Soviet bureaucracy and leadership. It provides the reader with a feel for how various strata of Soviet society reacted to this near-catastrophic event during a period of leadership-induced social ferment.

[redacted] The current study provides information on crisis decisionmaking under Gorbachev but does not deal in depth with the implications for the Soviet nuclear program. These issues have been treated comprehensively in the DI Research Paper *The Soviet Nuclear Power Program After the Chernobyl' Accident.*[2]

[2] DI Research Paper SOV 87-10032X [redacted] June 1987, *The Soviet Nuclear Power Program After the Chernobyl' Accident.*

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The Chernobyl' Accident: Social and Political Implications

Summary

Information available as of 5 December 1987 was used in this report.

The explosion of the Chernobyl' nuclear reactor in April 1986 presented a serious problem for Gorbachev's efforts to portray the new leadership as a reasonable and accountable government. The accident led to the emergence of nuclear energy policy as a significant public issue. Moscow's delay in reporting the accident to its people and neighbors left it open to charges of disregard for public health and eroded confidence in the regime. The psychological consequences of the Chernobyl' accident are likely to be long term and not limited to the immediately affected geographic areas.

Soviet citizens—in contrast to their counterparts in the West—have not mounted a successful campaign against the development of nuclear power, but antinuclear sentiment is growing in the aftermath of the Chernobyl' accident. Some members of the elite with policy influence have much less confidence in the safety of the Soviet nuclear system. Even ordinary citizens apparently worry that the regime's determination to rely more heavily on nuclear power will increase pressure on the nuclear sector to place growth above safety. They are reluctant to trust official assurances that safety alterations have been made and that existing safety rules will be enforced.

Regime claims that radiation fallout from Chernobyl' will not add significantly to the normal incidence of cancer have not silenced rumors and anxiety about health issues. A large segment of the population living in the European section of the USSR apparently believes it is in danger from radiation and continues to link genetic abnormalities, cancers, and poor health in general to the accident. These concerns are probably greatest among the 135,000 evacuees and more than 20,000 recovery workers—mainly military reservists—nearly all of whom are non-Russians.

We have evidence of considerable fear of contaminated food and water that is likely to continue. The effects of this fear were still being felt in the farmers' markets this past summer, and Moscow probably is concerned that this apprehension could result in workers' resistance to transfers to the Chernobyl' region, an inability to sell products from the region, and increased demand for medical services

Chernobyl' also had an adverse impact on the regime's credibility. More than a year after the accident, Soviet citizens continue to criticize top officials for initially concealing the Chernobyl' accident, and some think the regime's response to the disaster exposed the insincerity of Gorbachev's openness (*glasnost*) policy.

The regime brought many of these problems on itself by initially reacting with its traditional secrecy. Immediately after the accident, an information blackout was imposed until international pressure forced a grudging admission followed by a propaganda counterattack. Gorbachev himself remained silent until 14 May, almost three weeks after the accident, probably to minimize his personal responsibility and to wait for his experts to gain control of the situation.

Once Gorbachev got involved, however, he exploited the initial public relations setback to push his own reform agenda. By demonstrating that suppressing information about domestic problems can backfire, the accident gave added impetus to his drive for openness in the Soviet media. Several articles in *Pravda,* for example, pointed out that a lack of complete information had encouraged harmful rumors, and supporters of Gorbachev's policy criticized the domestic media's early silence.

Gorbachev also used the accident to eliminate some Brezhnev holdovers. He retired three elderly members of the Central Committee who were rumored to share some blame for the disaster. In addition, several ministry-level officials in the nuclear industry were fired, six Chernobyl' plant managers received jail sentences, and 27 party officials were expelled from the party either for contributing to the accident or for being inattentive to the evacuees' needs.

By laying the blame on local authorities, attacking the West for exploiting the disaster, and pressing forward with domestic reform, Gorbachev has so far largely avoided personal accountability. Gorbachev favored prompt publication of information but met resistance in the Politburo. However, this story conceivably was put out by his supporters to exonerate him.

The costs to regime credibility were especially serious in the Ukraine, Belorussia, and the Baltic. Dissatisfaction with the regime's handling of the Chernobyl' accident exacerbated longstanding popular frustrations in these regions:

- The nuclear radioactive contamination of Ukrainian and Belorussian territory and the dislocation of Ukrainian and Belorussian people provoked dissatisfaction with the Soviet policy of placing nuclear plants near populated centers and strengthened the environmentalist lobby in the Ukraine.

- Chernobyl' sparked demonstrations in the Baltic, where ecology-sensitive issues had already provoked anti-Russian demonstrations and Moscow's callup of reservists to clean up Chernobyl' was perceived as ethnic discrimination.

The new consciousness about environmental issues spurred by Chernobyl' has contributed to a climate of public activism that could contest Moscow's plans for nuclear power expansion in the next decade. Some 60 members of the Ukrainian Academy of Sciences signed a petition opposing the completion of units 5 and 6 at Chernobyl' because the project leaders had failed to adjust their plans to the new postaccident conditions. Reportedly, the petition was about to be made public when Moscow decided to shelve the expansion plans for the nuclear plant, conceivably in response to the arguments advanced by the Ukrainian group and possibly other public opposition.

Local Soviet press accounts indicate that concern about the safety of the nuclear industry is particularly high in areas with Chernobyl'-type reactors, like Kursk, Leningrad, Smolensk, Ignalina, and Chernobyl' itself. Demonstrations against the Ignalina and Leningrad nuclear plants were held in June 1986 as well as this year, and there is evidence that two nuclear projects have been recently shelved because of public reaction. Even though there have been greater efforts to reassure the public and perhaps some rethinking of the strategy for siting nuclear power plants, [redacted] the public's apprehension about the regime's commitment to make the necessary safety modifications remains well founded. [redacted]

Despite the fact that ministries responsible for nuclear industry have been given a formal mandate to achieve more stringent safety standards, there is no indication that public resentment will compel changes in the direction of Soviet nuclear power policy. The major bureaucracies resent public pressure and there are some signs of backtracking on *glasnost*:

- Despite Moscow's avowed openness policy, the July 1987 legal followup of the accident was conducted in secret, probably in an effort to avoid revealing technical testimony that addressed reactor design flaws.
- In the spring of 1987, Soviet reporters complained that the authorities were still tightly controlling information on Chernobyl', leaving the public largely in the dark.
- The official Soviet report presented to the International Atomic Energy Agency at the August 1986 meeting in Vienna, and made widely available to the West, was never released to the Soviet general public.

Soviet leaders probably hope that the consequences of Chernobyl' will fade from public view. Continued publicity poses difficulties because long-term environmental and health consequences will require further allocations of resources, which Moscow appears unwilling to make. A debate about the location and safety of nuclear plants is troublesome to a regime formally committed to nuclear energy and the economic benefits of building nuclear plants near highly populated areas. (

In an era of continued reform policies, another nuclear mishap, even a comparatively minor one, could unleash a backlash against nuclear energy that would be harder to ignore and might hasten the process of retiring the Chernobyl'-type (RBMK) reactor:

- The democratization campaign unveiled by Gorbachev, Yakovlev, and other senior leaders presupposes more sensitivity to public opinion.
- Legislation presented at the June 1987 Supreme Soviet on public referendums on local issues may give the people a mechanism to express their concerns.
- Public groups have been able to exert pressure on other environment-related issues through mass demonstrations.
- Some critics of current nuclear policy, including prominent journalists, probably can be more influential under *glasnost*.

In addition, the Gorbachev regime has issued a number of broader policy statements designed to curb pollution and improve health and appears willing to provide resources to support these policies. In July 1987, the CPSU Central Committee issued a sweeping resolution on ecology aimed at improving safety in the workplace and the quality of air and water. A month later, it announced a crash program to improve the medical system. The new Law on the Restructuring of Public Health stresses major reforms in the area of health through prevention and, given the growing concern with pollution and industrial safety, may be implemented more rapidly than usual.

Accommodation to popular frustration carries a danger for the regime and could make the situation worse by exciting expectations. The population will be more attentive to future regime performance in the areas of nuclear safety, public health, and ecology. There is increased discussion of these issues in the intellectual community, and social initiative groups are taking the issues to the street. These concerns are not likely to evaporate. As public dissatisfaction becomes more evident, the Chernobyl' accident may provide a focal point around which disgruntled citizens can organize, and Moscow may discover that Chernobyl' is a continuing irritant with a potential for social and ethnic tensions for years to come.

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The Chernobyl' Accident: Social and Political Implications

Regime Handling of the Chernobyl' Crisis

The accident at the Chernobyl' nuclear power plant on the morning of 26 April 1986 set off a sequence of events the Kremlin and Soviet populace are still grappling with. The belief in the safety of Soviet nuclear design had been widely shared among Soviet nuclear specialists, and most experts believed that an accident like the one at Chernobyl' could never happen, leaving them ill prepared to cope with a crisis of such magnitude.[3]

The government commission that investigated the accident concluded that the world's worst nuclear accident was caused by a bungled test at Chernobyl's unit 4 reactor, but Soviet media and reporting both indicate that more basic problems with reactor safety were also partly to blame. The top leaders were informed of the accident almost immediately and members of a government commission were on the scene within a few hours, but they apparently failed to give a high priority to prompt evacuation or the release of accurate information that could have stemmed rumors or facilitated more rapid public health precautions, like those taken in Poland.

The delay and uncertainty that characterized the regime's initial response can be explained in part by the magnitude of the Chernobyl' disaster, which would have been difficult for any government to handle. The leadership quickly recovered from this brief period of hesitation and effectively responded to control the radiation release, to evacuate and resettle 135,000 persons, to decontaminate most of the Chernobyl' environs sufficiently to permit workers to continue the recovery operations, and to reduce the public relations damage. The break in Gorbachev's political momentum appears to have been temporary, and, by laying the blame on local authorities, Gorbachev has avoided any personal accountability.

Formation of Decisionmaking Bodies

Moscow officials were at the scene of the accident within hours after the explosion occurred, according to nuclear physicist Boris Semenov, the Soviet delegate to the International Atomic Energy Agency (IAEA) board of governors. Semenov told IAEA board members in late May that Gorbachev and other members of the top leadership learned of the accident at Chernobyl' early in the morning of 26 April. A group within the Politburo under the direction of Nikolay Ryzhkov, chairman of the USSR Council of Ministers, was formed to deal with the accident. In addition, a special government commission headed by Boris Shcherbina, deputy chairman of the Council of Ministers, was formed that morning to investigate the causes of the accident.[4] This commission immediately took over direction of the emergency response and recovery effort.

Maj. Gen. Vladimir P. Pikalov, chief of the chemical troops of the USSR Defense Ministry and a decorated Hero of Soviet Union for his work at Chernobyl', told *Pravda* in December 1986 that he was summoned to the General Staff headquarters in the early morning hours and ordered by General Staff Chief Sergey

[3] In 1984, Academician Valeriy Legasov, a member of the presidium of the USSR Academy of Sciences and first deputy director of the prestigious Kurchatov Atomic Energy Institute, published an economic analysis on the acceptable level of risk in nuclear energy. He concluded that plants are designed and constructed so that there is no risk to human health not only during normal operation but even in an the event of a catastrophe, such as an earthquake or an aircraft crashing into the reactor. Legasov was one of the first to visit the scene of the disaster as a member of the government commission entrusted with the investigation of the Chernobyl' accident. He was clearly amazed by the scope of the devastation as were most specialists worldwide. "Frankly speaking," he said in a later interview, "I could never imagine that I would witness such an accident which was believed to be quite improbable by specialists in nuclear engineering."

[4] The on-site head of the commission rotated every two weeks starting 9 May 1986, with various deputy premiers serving their turn as its director. These included Ivan Silayev, Yuriy Maslyukov, Lev Voronin, Vladimir Gusev, Genadiy Vedernikov, and Boris Shcherbina

Laxity and Poor Design of the Chernobyl' Plant

The report of the investigation presented to the Central Committee of the CPSU stressed the Chernobyl' accident was caused by a "one-in-a-million" chain of events, but Western experts maintain that an accident was possible because of dangerous design characteristics that make the RBMK—a graphite-moderated reactor— vulnerable to accidents. Because many of these deficiencies cannot quickly and cheaply be remedied, the RBMK will continue to be considerably less safe than other type reactors, and planned safety enhancements will not raise these reactors to Western safety standards.

Construction of Soviet nuclear plants has been hampered by inefficient design bureaucracies, bottlenecks in component manufacturing, and overambitious planning that resulted in some substandard construction. The chief design engineer for the ventilation system of the Kursk and Chernobyl' nuclear power stations from 1974 to 1980 gave a good example of industry's use of inferior components. The Chernobyl' and Kursk ventilation systems were built from ungalvanized sheet steel to reduce cost. Similar problems with construction and workmanship halted work projects at the Rostov nuclear plant in April 1986, indicating that these conditions are widespread in the industry

On the eve of the accident, a Pripyat' resident, in an article published by the Ukrainian literary weekly Literaturna Ukraina, *attempted to draw attention to problems at Chernobyl's unit 5—then under construction—including shortages of skilled labor, inferior materials, unsafe shortcuts, and unrealistic building programs. Further revelations of precarious safety conditions prevailing at the plant were provided in a report from the trial of those responsible for the accident at Chernobyl'. At the July trial the technical commission of experts charged the experiment that commenced before the accident was a continuation of a series of similar and unsuccessful research projects, including a near mishap during a similar experiment in 1985. The Soviets told a Japanese visitor this September that the experiment was initially proposed at the Leningrad and Irkutsk nuclear power plants but was refused. It was then done at the Chernobyl' plant.*

Soviet Account of Accident to the IAEA in Vienna

The official Soviet version of the accident, as reported to the International Atomic Energy Agency (IAEA) in Vienna on 25-29 August 1986, is largely accepted in the West. Based on the conclusions of the Soviet Government commission investigating the accident, the world's worst nuclear accident was caused by a bungled attempt to test a minor part of the safety system of unit 4 of the Chernobyl' nuclear power plant. The experiment involved a scheme to use the rotational inertia of the turbogenerators to generate electricity to bridge a one-half minute gap between the loss of normal power and the beginning of auxiliary power supply in the event of the loss of normal supplies of electricity. The operators were under pressure to carry out the test, since another opportunity would not present itself until the next year.

According to the Soviet account at the IAEA meeting, the experiment was never officially approved and was not executed according to plan. The operators allowed the reactor to reach a highly unstable condition as a result of deliberately disabling some safety systems and a series of delays and mishaps. When the experiment began, the rate of cooling-water flow decreased, leading to increasing water temperature in the core and increased steam formation. Because of a design characteristic of the Chernobyl'-type reactors, the increased steam content in the core caused a power increase that quickly ran out of control. The power excursion ruptured fuel channels, and the pressure of the escaping steam blew apart the reactor's core and caused severe damage to the reactor building. Eyewitnesses report hearing a loud explosion and seeing sparks and burning chunks flying high into the night sky above unit 4 at 0123 hours on 26 April. The burning chunks fell back onto the roofs of surrounding buildings and started several fires.

Akhromeyev and Minister of Defense Sergey Sokolov to go to Chernobyl' and take charge of the chemical troops there. Within minutes of his meeting with these officials and less than two hours after the accident occurred, Pikalov alerted the mobilized military units in Kiev. He and the first brigade of chemical troops arrived in Kiev just over 12 hours after the explosion and, soon after, set up headquarters in the city of Chernobyl', 15 kilometers from the burning reactor. By the evening of 26 April the chemical troops were conducting radiological reconnaissance and continuous monitoring of radiation levels and weather data in the area surrounding the devastated Chernobyl' plant. According to General Pikalov, the health situation in Pripyat' had sharply deteriorated through the night of the 26th, and by 1000 hours on 27 April the planning to evacuate 47,000 persons from Pripyat' had begun.

Pikalov's account confirms Boris Shcherbina's statement at the 5 May press conference that he and other members of the commission were on the scene literally "within a few hours" of the explosion. This scenario strongly suggests that the leadership had the information channels it needed to evaluate the situation, despite the persistent Soviet line that "internal communication difficulties" had been the cause of the initial problems in dealing with the disaster. It also suggests that, while the decisionmakers began to react to the crisis by at least the afternoon of the 26th, safeguarding the population was not their first priority.

Evacuation and Decontamination

The Soviets initially responded to the accident as if it was a local emergency confined to unit 4 of the Chernobyl' nuclear power plant. Even after it was known that high levels of radioactivity were present, the accident was handled at first as a site emergency. Thousands of plant workers and their families in the city of Pripyat', located only 10 kilometers from the stricken plant, were neither informed about the accident, nor instructed to take precautions against radiation fallout. Evacuation was initiated 36 hours after the accident. Apparently there were no off-site emergency evacuation plans, and additional evacuation within the established 30-kilometer contamination zone continued for two weeks. The 2.5 million people living in Kiev, located less than 103 kilometers south of the reactor, were not warned publicly about the hazard until nine days later

The Evacuation of Pripyat'

The actual evacuation of the city of Pripyat' took place 36 hours after the initial release of radiation. What we know of Pripyat's evacuation is based entirely on Soviet retrospective accounts, since no television pictures or photographs of Pripyat' just before or after the dramatic evacuation have been released.

In later months, the press described the exodus as an orderly and efficient process. A caravan of more than 1,100 buses, mostly from Kiev, got under way on Sunday afternoon, carrying the townspeople in a line that stretched for almost 19 kilometers. The complete operation took less than three hours, a strikingly short time to move so many people.

Despite this impressive achievement, firsthand accounts of local officials directly involved in the evacuation present a picture of disorganization, supporting speculation there were no evacuation plans for an event such as the one unfolding at Chernobyl'. The Soviet press details how officials hastily decided on where to move such a large number of people; how to assemble the transportation; and what resources to tap to shelter, feed, and provide medical services for such a large number of evacuees. One Kiev Obkom official said that shortly before the evacuation an information group composed of oblast party officials, militiamen, and voluntary police (druzhinniki) *went from house to house informing the residents of the evacuation. The people were given less than an hour's advance warning, and no additional information was provided for fear of creating a panic.*

[redacted] *who visited the Chernobyl' site, the current Chernobyl' plant director said that after the accident people reacted "very emotionally," because they had no previous emergency exercises about what to do after an accident and stressed the need for such a public education program for people living around nuclear plants.*

The official figure on the number of people eventually evacuated from the Ukraine and Belorussia was 135,000, but the total number of those who left the area is probably much higher. In addition, some 400,000 children were evacuated from Kiev, and another 100,000 from points in Belorussia to Pioneer camps and summer resorts.

Initially, confusion seemed to reign among the officials on the spot, who seemed totally unprepared to deal with a catastrophe of such magnitude. In a later effort to explain the delay in the evacuation of Pripyat', Valeriy Legasov, presidium member of the USSR Academy of Sciences and the first deputy director of the prestigious Kurchatov Atomic Energy Institute, told a US visiting nuclear delegation that it was an appropriate precaution taken to protect the people because the radioactive plume had traveled over the likely evacuation route. Information released at the trial of the Chernobyl' plant managers this July, however, revealed that no effort was made by plant officials to check the radiation levels in the city in the immediate aftermath and that the nuclear plant had no off-site measuring capabilities. Court testimony also showed that the staff at the plant was ordered by plant officials to keep quiet about radiation levels and that they reported to their superiors lower levels of radiation than actually measured. As noted, the first comprehensive readings of radiation levels in Pripyat' were made on the evening of 26 April by the chemical troops who arrived earlier that day. As a result, schools and shops stayed open on 26 April and residents went about their business as usual

The Soviets responded relatively quickly to dispatch medical teams to surrounding areas to screen the population. According to the vice president of the Academy of Medical Sciences, there were 1,300 health care personnel involved, grouped into 230 medical teams, mostly from the Ukrainian and Belorussian medical services, with support from military mobile medical teams. Nevertheless, there were shortages of medical personnel, medical supplies and radiation-detection equipment, [redacted] As a result, the evacuees were forced to wait long periods of time to be processed at relocation centers, where they received a medical examination, a shower, and clean clothing.

Firemen's Effort to Contain Catastrophe

When the Pripyat' firemen responded to the fire at the nuclear power plant only minutes after the explosion released a radioactive cloud, they did not know the full extent of the accident. The chief of a MVD directorate, Maj. Gen. V. M. Korniychuk told Literaturna Ukraina *in May that the message alerting the firemen indicated only that there was a fire in the plant. When the firemen arrived on the scene of the burning reactor, within minutes of the accident, they found that the roof over the control room was burning and part of it had already collapsed. Fires had broken out at different levels of the 215-foot high structure housing the reactor and were threatening to spread to the other reactor. The firemen had no special equipment except for the face mask, breathing apparatus, and heavy heat-resistant outer clothing standard in a firemen's uniform.*

The first shift of firefighters fought for two and a half hours before reenforcements came from nearby towns. Col. Leonid P. Telyatnikov, the plant's fire chief and the only survivor of the group of firefighters who first scaled the roof to put out the fire, said that they worked until they weakened and collapsed from radiation exposure burns, although at that time he thought it was from physical exhaustion. Many of the firemen had received a lethal dose of radiation by the time the fire was extinguished at 0653 hours. All six firemen working alongside Telyatnikov died, giving their lives to contain a fire that, left unchecked, could have spread the nuclear disaster to the other reactors in the Chernobyl' plant.

Ground Forces units from the three military districts in the immediate vicinity of the accident—the Kiev Military District (MD), the Belorussian MD, and the Carpathian MD—played a key role in the evacuation. Military personnel performed traffic control, provided extensive medical support, assisted with transportation, and food distribution. Curiously, the Soviet civil defense, which is responsible for rescue and recovery from peacetime disasters in addition to its wartime responsibility, did not play a major role in the evacuation.

In the evacuation, some decisions may have unintentionally aggravated the potentially dangerous health situation, while others indicated that protection of its citizens was not always the top priority. For example:

- In the Pripyat' countryside, where another 20,000 persons lived, cattle and horses from the state and collective farms surrounding the city were evacuated first, beginning a day after the city was evacuated. People followed in buses about 24 hours later. According to the Kiev Oblast deputy chairman for agriculture, the animals were moved first because people were needed to load the 51,000 head of cattle.

- [redacted] indicate that people from some villages located 3 to 4 kilometers from the city of Pripyat' were not moved until 6 May, 10 days after the accident.

The 30-kilometer evacuation zone, established within the first 24 hours after the accident, was chosen because it encompassed the general population living around the reactor and did not necessarily correspond to the actual areas of high radioactivity. Legasov admitted to Western scientists that later radiation calculations showed a need to adjust the zone to make it correspond more closely to the actual distribution of radiation. Eleven villages in Polesskiy Rayon in Ukraine—where many of the Pripyat' people were initially evacuated—were forced to reevacuate after radiation levels were reassessed to be unsafe. Later, *Moscow News* criticized local officials for rushing to resettle these villages inside the zone to give an appearance of normalcy without proper consideration for the safety of the inhabitants.

Despite continuing concerns among scientists, no further evacuations were authorized. [redacted], a confidential report intended for Gorbachev established that some inhabitants of the Chernobyl' region were actually resettled in contaminated areas outside the 30-kilometer zone. The report was an attempt by Soviet scientists to alert Gorbachev to their discovery that the prevailing wind deposited radioactive particles from the radioactive plume in an irregular pattern. According to the source, isolated hot spots could be found 65 kilometers to the east of the power plant where many inhabitants of the Chernobyl' region were resettled (see figure 1)

Although [redacted] they considered a second evacuation, Soviet authorities did not exercise this option, probably because they wanted to avoid further dislocations. While some selective evacuation beyond the 30-kilometer zone was observed near Gomel' and Chernigov starting 9 May, a decision to expand the evacuation zone to 50 kilometers would have displaced an additional 75,000 civilians in southern Belorussia alone, at a time when the designated receiving areas were overflowing with Chernobyl' evacuees.

Moreover, the Soviets did no preventive evacuation, with the exception of the extensive evacuation of children in the broader region.[5] For example, although Mogilev Oblast in Belorussia, 320 kilometers northwest of Chernobyl', received sufficient radiation fallout from heavy rains on 27 and 28 April to prompt officials to close many wells, scrape and remove layers of contaminated soil, and ban sale and consumption of local milk and meat and vegetables, only the children were evacuated. Tens of thousands of people in the contaminated villages were not evacuated and received minimal information about the dangers of radiation, according to the rayon chief physician.

The evacuation of the nearby town of Chernobyl' and its environs—with a population of some 44,000—was begun only after radiation levels began to rise rapidly there on 3 May. Delaying the evacuation until then also allowed May Day festivities to take place in Chernobyl', as well as in Kiev, as if nothing unusual had happened. [redacted] the 500 buses and 200 trucks that came to evacuate Chernobyl' on 3 and 4 May were the same buses that came

[5] Starting 8 May, school-age children went to Pioneer camps, children between the ages of 3 and 6 were evacuated with the kindergarten teachers and medical workers, while children under 3 were evacuated with their mothers to vacation areas.

Figure 1
Evacuated and Repopulated Sites Surrounding Chernobyl'[a]

[a] Only selected evacuation and repopulation sites are shown.

from Kiev a week earlier to evacuate Pripyat'. They had been decontaminated and returned to Kiev in time for the two-day May Day celebration there. After the festivities were over, the buses returned to Chernobyl' to continue with the evacuation.

Trauma of Relocation. and some newspaper articles have admitted numerous foul-ups, suggesting the evacuation was far less orderly than the media first reported. An initial attempt to keep records was quickly abandoned, and later it was difficult for families to find each other because they were scattered to the farflung villages in the surrounding area. One Soviet documentary called it "a nightmarish situation," where children became separated from their parents and families were divided. For weeks some people did not know where family members were or how long they would have to stay in their new surroundings. Some officials complained in the press that they could not always tell the parents where their children were going because some camps were refusing to take the children from the Chernobyl' area.

Some individuals were even left behind in the confusion. According to a Soviet account, two elderly women were discovered in their house in Pripyat' two months later, apparently living on what was left in the house. They reportedly stayed because they did not want to abandon their domestic animals, which were not evacuated.

The dispersion of the Chernobyl' evacuees spread fear and rumors in a ripple effect far beyond the borders of the Ukraine and Belorussia to areas as far away as Siberia, Kirghiziya, Uzbekistan, and the Baltic republics. Many people resented the Chernobyl' refugees because they took scarce housing from local families and factories were compelled to take workers for whom there were no jobs. An engineer from the Chernobyl' plant spoke of the callousness and indifference he encountered while looking for a job after resettlement. Jokes circulating in the Siberian city of Omsk—where a large number of evacuees were resettled—reflected the resentment local people felt toward the refugees who exacerbated the chronic housing shortage there. For example, "Oh, Your apartment was taken from you? Do not worry, the resettlers have a high mortality rate.'

Many in the general population feared the Chernobyl' evacuees because of the widespread belief that radiation was contagious and that the evacuees could infect the healthy population. In Estonia, a rumor was spread that the normal death rate rose in Tallinn on the arrival of 3,000 Ukrainian and Belorussian evacuees. an elderly couple who arrived by train from Kiev in early May having trouble getting their Moscow relatives to take them in, even after they were checked by a dosimeter at the station. A letter from one Chernobyl' displaced person, which appeared in the press, perhaps best summarizes the feelings of the evacuated population: "In an instant, we lost our homes, our jobs, friends, surroundings, our whole microworld."

Reservists Shoulder the Burden of Decontamination. The recovery force at Chernobyl' consisted of tens of thousands of people. Most were military reservists and regular military and civil defense troops. Despite the high public profile that the Soviet media accorded the Chernobyl' volunteers, evidence indicates that a widespread callup of military reservists for a period of two to six months provided the main work force in the contaminated area

In addition to the evacuees, these recovery workers have been exposed to relatively high levels of radiation. According to their own statement, the Soviets initially permitted the workers to be exposed to 25 roentgen equivalent man (rem). According to the international guidelines for permissible levels for workers, a 25-rem dose is appropriate only for a very small number of people and, preferably, volunteers. Soviet nuclear officials told a visiting the zone in June 1987 that some 20,000 persons were still working in the zone, half of them military personnel. More recent guidelines indicate that these men are now being limited to a total dose of 5 rem—the internationally accepted dose—before being transfered.[4]

[4] The rem is a measure of radiation's effect on humans. Medical experts say that blood changes begin at a dose of about 25 rem. Sickness usually starts at 100 rem and severe sickness at 200 rem, with death coming for nearly everyone who has absorbed 1,000 rem. The 25-rem exposures are almost twice the average exposure of the civilian evacuees, hence these recovery workers will face a higher risk

Figure 2. a) Military reservists decontaminating one of the villages in Chernobyl' Rayon inside the 30-kilometer zone in August 1986.

b) A June 1986 photo of a military field camp for chemical troops working inside the contaminated zone. (U)

A Soviet reporter who wrote five unusually candid articles in the Estonian Komsomol newspaper *Noorte Haal* described the treatment of reservists from Estonian as brutal and their working conditions as dangerous and harsh. The articles stated that several workers became sick from high levels of radiation, and some men voluntarily exposed themselves to high levels to receive an early discharge (see figure 2).[1]

According to an account in a Stockholm daily, some Estonian conscripts avoided decontamination duties in the Ukraine by paying a bribe of 500 rubles to a high-ranking military official in Estonia, who has since been arrested. (Reportedly, this same official extracted twice that to escape duty in Afghanistan.) Although the claim that he has been arrested and executed has been denied by TASS, he had already been publicly named in the Soviet media for abuse of office.

Handling of Information

The Kremlin's silence of almost three days embarrassed the Soviet leaders at a time when they were just beginning to proclaim Gorbachev's new policy of openness. The official Soviet news agency TASS made the first brief announcement at 2100 hours, 28 April, and only after angry demands for information from Sweden, the first country to announce fallout detected from the stricken Chernobyl' plant. In many ways, Moscow's initial response to the Chernobyl' nuclear accident was similar to that in the KAL shootdown in 1983, when an information blackout was imposed until international pressure forced a grudging admission of the event, followed by a propaganda counterattack

In the initial period after the explosion, there were indications that differences among top Soviet leaders about how much information to provide the public may have contributed to delays and missteps [redacted] Gorbachev—at some unspecified time early in the crisis—reportedly met resistance from all Politburo members except KGB chief Chebrikov and Russian premier Vorotnikov, in his attempt to persuade the Politburo to release information quickly. Close Gorbachev allies—like Moscow party boss Boris Yel'tsin—were defensive about the initial delay. Party Secretary Dobrynin gave the impression [redacted] that the Politburo had been divided over how much to reveal and that Gorbachev was overruled when he recommended prompt airing of the news [redacted]

It is possible that rumors of tension within the leadership were orchestrated to minimize Gorbachev's personal responsibility. Reportedly, the Ukrainian party boss Vladimir Shcherbitskiy—a full Politburo member—had contacted Gorbachev within an hour of the accident asking for instructions and was directed to say nothing. In public, at least, Soviet officials have justified the delay on grounds that it was necessary to avoid public alarm. Thus, for example, the deputy director of the Institute of Power Engineering, Ivan Ya. Yemel'yanov, who was later fired for his prominent role in the RBMK reactor design, told the Italian Communist Party paper *Unita* in late May that it was not in the public interest to release critical information to the people. He told the interviewer the regime opted for selective release of information to prevent a tide of panic because "we could not cause terror in Kiev."

This logic was apparently prevalent among those on the scene. Some local officials, such as the health officers at the Pripyat' hospital, were alerted to the dangerous situation soon after the explosion, when the hospital began to receive the first casualties from the burning reactor [redacted] the health officers began monitoring the radiation levels at the hospital but failed to inform the city population. Pripyat' residents appearing in a Soviet documentary said these same health officers even denied that an accident had occurred when questioned by some citizens.

[1] [redacted]

The Civil Defense Role in Chernobyl'

The Chernobyl' accident provided the first opportunity to study the performance of the Soviet civil defense program when confronted with a large-scale nuclear accident. The civil defense program, a nationwide program under military control, is responsible for rescue and recovery from peacetime disasters in addition to its wartime responsibilities. On the basis of Soviet unclassified writing [redacted] *the program, we expected civil defense staffs and military civil defense units to play a leading role in the evacuation and cleanup of Chernobyl'. These staffs and units, however, did not respond as we had anticipated. Although military civil defense units were active throughout the cleanup effort, they appeared to perform support functions, while chemical defense staffs, MVD units, and various party and governmental organizations played the key roles. Civil defense units assisted in decontaminating, controlling traffic, coordinating logistics, and monitoring radiation levels; we do not think, however, that they were involved in the evacuation. More surprising is the lack of visibility of civilian civil defense staffs at the plant and in surrounding rayons. Although some civil defense personnel assisted in the cleanup, the staffs did not participate on the whole*

The fact that civil defense did not play a prominent role was reflected in Soviet media coverage of the accident. We expected the Soviets to use the accident as an opportunity to stress the importance of the program to the general population. The press has made few references to the actions of the civil defense forces. One article published in June 1987 revealed public criticism of the local civil defense authorities for their part in the response. At the same time, civil defense has not received outright criticism from the leadership and civil defense personnel have not been publicly charged with criminal action. Although we think that the replacement of the Chief of the USSR Civil Defense Staff a few months after the accident was part of Gorbachev's plans to revitalize the Ministry of Defense, the timing, as noted, was reportedly related to displeasure with the performance of civil defense forces in the cleanup.

We have not yet been able to resolve the various explanations for the limited civil defense participation. One theory is that civil defense personnel may have made serious errors in the initial stage of the accident, thereby requiring the military to take complete control. The immediate involvement of General Pikalov and the lack of criticism in the press, however, does not support this explanation. A second theory is that civil defense forces may not have been involved more because other assets were more readily available. Civil defense forces have responded to other peacetime disasters, but the scope of the Chernobyl' accident may have been beyond reasonable expectations of peacetime activity by the civil defense units. A third theory is that our expectations may have been inflated by incorrectly interpreting Soviet civil defense writing as describing the current civil defense mission instead of long-term, not yet realized goals.[a]

[a] Analysis of the civil defense role in Chernobyl' is continuing and will appear in a forthcoming SOVA paper

An attempt was made to keep Kiev, with its 2.5 million population, completely in the dark. Beginning 30 April, travel was cut off to the city for US and other diplomats [redacted] radiation-monitoring equipment was confiscated by the KGB from Kiev area institutes and laboratories, allegedly to control information and to keep the city population calm [redacted] immediately after the accident was announced, administrators of the Institute of Cybernetics, where the source worked, stopped colleagues from posting radiation levels saying such information was "secret." Such actions, however, only reinforced public concern, and the dosimeters and other equipment were returned in about two weeks. [redacted]

A deliberate show of normalcy prevailed under Shcherbitskiy, who was not an ardent exponent of *glasnost* at that time. The republic central newspaper on 28 April carried only the brief TASS announcement on the accident. Not even rudimentary information about the accident and the potential health hazards was made available to Kiev residents until several days later. The Ukrainian Health Minister Anatoliy Romanenko gave the first public health warnings to the citizens of the republic on 5 May—more than a week after the accident. In Belorussia such warnings were provided even later.

Some sources suggest that fuller information on the accident was available to local party and government officials, despite the initial reassuring tone of the media. For example, a former Russian journalist told a Western interviewer that his editorial office received a steady flow of alarming reports on the second day of the accident but was forbidden to print the information. Consequently, the office released only the official TASS reports.

Propaganda Counterattack

Once the Soviets realized they could not conceal the accident, they launched a public relations effort that bore the imprint of Gorbachev's *glasnost* policy. In addition to releasing a large amount of information about the Chernobyl' accident, Moscow employed several other tactics designed to minimize its responsibility for what happened, restore popular confidence in the regime, regain credibility abroad, and shift blame to the West for exploiting Soviet problems. The authorities have:

- Alleged that the reactor safety problems—until the Chernobyl' accident—have been more common and serious in the West.
- Depicted the mishap as a failure of a handful of people rather than of the system and highlighted the courage and self-sacrifice of the Soviet people in dealing with it (see figure 3).
- Denounced Western media for making political capital from Soviet misfortune and used the nuclear mishap to push Soviet arms control proposals (see figure 4).
- Played down in media accounts the long-term health risks and emphasized progress in decontamination and recovery operations.

Figure 3. Chernobyl' Victims as Heroes: The Soviet press consciously exploited the Chernobyl' disaster to marshal citizen support for regime policies. It was full of stories of sacrifice and heroism of workers engaged in the cleanup of Chernobyl', comparing their work with the heroic deeds of World War II soldiers. Those who died in the accident were given heroes' funerals and were posthumously awarded the title of "Hero of the Soviet Union." This photo, which appeared in Pravda Ukrainy *on 4 July 1986, depicts a monument erected at the Cherkassy Technical School for firemen in the Ukraine where some of the firemen who died were trained.*

Gorbachev himself remained silent until 14 May, almost three weeks after the accident. By lowering his own profile and allowing others to take the heat, he probably hoped to be associated with recovery rather than disaster and thus avoid blame. When he at last spoke on 14 May, he used the opportunity to present

Figure 4. The May 1986 issue of the Soviet Journal Ogonyok *carried this caricature of the West under the caption "Irradiation by Lies." The teeth spell out "gloating over other's misfortune"; the signs read "anti-Soviet agitation," and "anti-Soviet falsehoods and fabrications."*

to Western observers the compassionate, humane face of the Soviet Government during a tragic accident and to promote himself as a peacemaker. A recurrent theme has been that the accident demonstrates the need for removal of the nuclear weapons from Europe, where a conflict could unleash the radiation equivalent of dozens of Chernobyl's. He also used the occasion to announce an extension of the Soviet nuclear test moratorium.

Offering Up Scapegoats

To minimize its responsibility for what happened, the regime blamed lower level officials for mishandling the situation in order to insulate top leaders from criticism. Minister for Power and Electrification Anatoliy Mayorets, the official directly responsible for the power plant, was sharply reprimanded. Several other senior officials were fired outright for their incompetent performance, including the Chairman of the State Committee for Safety in the Nuclear Power Industry, Yevgeniy Kulov, for "failing to ensure compliance with safety regulations." Several local functionaries were also removed for being inattentive to the needs of the evacuees (see table)

Meanwhile, plant officials have been tried for their involvement. At the Chernobyl' trial in July 1987—initially open to international press and subsequently conducted behind closed doors—the former director of the Chernobyl' nuclear plant, Victor Bryukhanov, his chief and deputy chief engineers—Nikolay Fomin and Anatoliy Dyatlov—and three less senior managers were convicted of safety regulations violations that led to loss of life. They received sentences in labor camps, ranging from two to 10 years. As a further admonition to bureaucrats that they will be held accountable for their actions, the regime reportedly plans to bring to trial the people responsible for the design flaws in the reactor

The easing out in 1986 of three Central Committee members, rumored to share some blame for the accident, suggests Gorbachev also used the nuclear disaster to eliminate some elderly holdovers from the Brezhnev era:

- President of the USSR Academy of Sciences Anatoliy Aleksandrov—who reportedly had a part in the reactor's design—retired October 1986. Although he was well above retirement age and rumors about his prospective retirement circulated for some time, he publicly criticized his own performance and hinted that mistakes he made regarding Chernobyl' helped prompt his retirement.

- The 88-year-old Minister for Medium Machine Building Yefim Slavskiy, whose organization is responsible for the military nuclear program and for handling nuclear fuel for civilian reactors, also retired in November 1986, several months after his first deputy was fired because of the accident.

- Deputy Defense Minister responsible for civil defense Aleksandr Altunin—whose organization apparently was ill equipped to deal with the crisis—retired sometime during summer 1986.

Despite Gorbachev's interest in using the accident against the old guard, one top Brezhnev protege—Ukrainian party leader Vladimir Shcherbitskiy—has so far managed to survive, despite rumors that Gorbachev wanted to use Chernobyl' against him [redacted] Shcherbitskiy was able to escape blame for the accident, and we have no evidence that

Political Fallout From Chernobyl'

Political Fallout From Chernobyl' (continued)

[redacted]

the mishandling of the evacuation has been laid at his doorstep [redacted] he was treating Gorbachev's reported instructions to keep quiet after the accident, which came in a cable, as insurance against an attempt by the General Secretary to force him into retirement. [redacted] Shcherbitskiy had refused to sign an approval for activating the Chernobyl' nuclear plant at its completion, requesting instead that the permit be signed by Moscow. This maneuvering may have helped Shcherbitskiy avoid blame for the catastrophe. Gorbachev could still use the accident as one point in a bill of indictment, should he decide to move against Shcherbitskiy or other officials linked to Chernobyl', but this becomes progressively less likely as more time passes.

The Costs of Chernobyl'

In terms of domestic public opinion, the regime clearly paid a price for the accident. Its handling of the event, at least initially, created a credibility gap for the leadership and has heightened public apprehension about the safety of nuclear power, public health, and the environment. It also gave new impetus to environmental groups, highlighting the strong environmentalist bent of intellectuals who constitute a growing lobby. Moscow's callup of mostly non-Russian reservists to clean up Chernobyl' sparked some nationalist dissent. Although the economic disruption is expected to be only short term, the cost of cleaning up and safety modifications will have a minor adverse effect on Gorbachev's economic modernization effort and will make it harder for the regime to deliver on its promises of better health care, more housing, and safer work conditions.

Damage to Regime Credibility and Reputation

In the short term, Moscow's failure to disclose information about the Chernobyl' nuclear accident to its citizens, thousands of whom have been affected in some way, exacerbated fears, created widespread alarm, and started the rumor mill churning. A Kiev resident told [redacted] in September that she was outraged at the authorities for withholding timely information and accused officials of deliberately postponing public announcement of the disaster until after the May Day celebration to show happy Kievans dancing in the streets. A joke circulating in the city some time later shows that public opinion reflected this citizen's feelings toward the authorities: "On May Day, the faces of demonstrators in Kiev were radiating." Residents also cite the international annual bicycle race—which was permitted to take place through the city streets one day after the May Day celebration, despite the possible health hazards and withdrawals of some foreign competitors—as an example of leadership callousness. A radiologist in Kiev sent his wife and children to Moscow because he believed the authorities would issue false radiation levels.

Soviet citizens received no immediate instructions on how to protect themselves against radiation, but neighboring countries such as Poland and Finland were warning their people. Residents of Kiev and other Soviet citizens found this particularly reprehensible. Many in Kiev heard that Poland, for example, had dispensed iodine pills for children under 16 in its northwestern provinces to protect them from radioactive iodine-131. The Kievans reportedly resorted to their own version of an iodine—wine, and vodka cocktail—according to rumor.

Public resentments were probably further fueled by rumors that the party elite was taking special precautions. [redacted] Ukrainian party boss Shcherbitskiy had ordered the evacuation of members of the ruling strata and their families before any of the ordinary citizens in Kiev heard about the disaster. Many city residents said that they realized that something very serious occurred at Chernobyl' when families of party members suddenly left for "vacation" on 28 April. [redacted] that party members were the first to be evacuated

Faced with the initial information blackout, some Soviet citizens turned to Western radiobroadcasts, others relied on connections to party and government

"Warning": A Documentary Film

One of the most extraordinary examples of Gorbachev's glasnost *policy to date came from two Soviet journalists assigned to cover the accident at Chernobyl'. Lev Nikolayev and Aleksandr Krutov reported on the accident almost from the very beginning and subsequently produced a documentary film from the daily coverage of the immediate aftermath called "Warning." The film, which was shown to Soviet citizens on the first anniversary of the accident, captures in honest and unsparing detail the "unthinkable" catastrophe.*

The documentary opens with a panoramic shot from a helicopter of the destroyed reactor; the red glow from the burning graphite is still clearly visible on the morning of the 28th of April. In one of the sequences, the film shows the clinic at Pripyat', which received the first casualties suffering from radiation sickness and burns. The commentator asks the chief physician why he did not warn the people of Pripyat'. "It was not my sphere of action," the doctor replied. A Pripyat' health worker is seen telling the commentator that local officials covered up the accident and turned away people who offered their assistance, saying that nothing had happened. She also said that the "management" had emergency plans available, yet, they did not even tell us to close the windows and doors, and allowed our children go to school."

officials who had more complete information or personal contacts with foreigners to tell them what was happening.

Gorbachev's subsequent openness and domestic reform measures have deflected public attention from Chernobyl' to a considerable extent, and the heavy play given to alleged foreign overreaction to the catastrophe had some success in shifting public anger to the West. Many citizens accepted Soviet propaganda that the West was responsible for the panic and hysteria surrounding Chernobyl' and that the accident presented less public danger than the Three Mile Island accident or the Bhopal toxic gas leak that killed more than 2,000 persons

Although many Soviet citizens not directly affected by the accident appear to have accepted the regime's explanation, those in the affected regions continue to fault top officials for initially concealing the Chernobyl' accident, and some think the regime's response to the disaster showed the insincerity of the new openness policy. A strongly worded indictment of incompetence, which appeared in the June 1987 monthly *Yunost'* in the form of public letters, accused local officials at Pripyat' and Kiev of criminal irresponsibility for their role in the coverup. The fire chief, Leonid Telyatnikov, who risked his life putting out the fire at the plant on the night of the explosion, was quoted by the Soviet magazine *Smena* as saying he was ashamed of local Communist party officials who failed to use their power to protect the population after the disaster.

Some Soviet intellectuals were angry with the regime for failing to be honest. However, they blamed the technocrats for the accident, believing that the traditional arrogant attitude of nuclear bureaucracies—willingness to take risks for the sake of scientific progress at the expense of the people—has been the root cause of the Chernobyl' disaster. Some ordinary citizens share this point of view with the intellectuals. Because they believe that this attitude is pervasive among the Soviet technocrats, the public is reluctant to accept the regime's assurances that the safety of the Soviet nuclear plants has been improved in the aftermath of Chernobyl'

Health Problems

Despite Gorbachev's success in overcoming the initial embarrassment and, even to some extent, turning the issue to his favor, there have been real long-term human costs, particularly in the affected region. The chaotic nature of the evacuation alienated a number of the evacuees and stirred fear and resentment among the general population, thus broadening the psychological impact of the accident. The handling of the evacuation has contributed to public anxiety about health issues, which the regime has been unable to allay fully. Moscow's concern that public fears will have serious economic consequences including resistance to transfers of workers to the region, inability to sell products from the region, and increased demand for medical services by fearful people have already been borne out

Although the final human toll from the effects of radiation will be difficult for scientists to predict, many of the 135,000 evacuees from the 30-kilometer zone have been exposed to sufficiently high levels of radiation to increase their risk of long-term health problems. The regime apparently acknowledged this fact when it blamed local party leaders and ministry officials at the recent trial of Chernobyl' plant managers for failing to properly protect the population from the effects of radiation fallout and for delaying the evacuation.

As preoccupation with the massive evacuation eases, attention has turned to the impact of Chernobyl' on the long-term health of the general populace. Some Western estimates claim that over the next 70 years Chernobyl' could be responsible for up to 10,000 additional cancer deaths in the Soviet Union. The Soviets have publicly assessed a much lower figure and have assured their citizens that the radioactive fallout from Chernobyl' will not significantly add to the normal incidence of cancer. Although most official Western estimates agree with the Soviet figures, the public remains skeptical, and anxiety over health issues persists. In an open letter to *Pravda* addressed to Gorbachev, a resident of Pripyat'—the father of three—protested the slow evacuation from the city and blamed the authorities for jeopardizing his family's health.

Given the psychological reaction to the disaster of many Soviets who probably have not suffered measurable health effects of radiation, the accident's full impact on social attitudes has been out of proportion to the actual risk. Despite evidence to the contrary, a large segment of the Soviet population believes there will be dire health consequences from the accident and continues to link its poor health to the Chernobyl' radiation fallout.

Articles in the Soviet press indicate that anxiety about radiation fallout has not completely subsided in the general population, and the rumor mill is still churning. In December 1986, letters to the Belorussian daily *Sovetskaya Belorussiya* criticized the behavior of the authorities following the accident for failure to inform the population about the risk to which they were exposed, and demanded to know why children were not evacuated from towns in Belorussia just within the 30-kilometer zone.

The psychological consequences of the Chernobyl' accident are likely to be long term, for the public will continue to link even unrelated cancers, genetic abnormalities, and other illnesses to the disaster:

- A year after the accident, doctors from the new Center for Radiation Medicine in Kiev reported that much of the population is affected by a syndrome of radiophobia, and that many of those who took part in the cleanup show clinical changes described as situation neurosis unconnected with radiation.
- Kiev physicians have come up against the psychological consequences of the Chernobyl' accident. Kiev radio announced on 21 April 1987 that, in the span of several days, more than 25,000 city residents requested complete medical checkups at Kiev's clinics.
- [redacted] a famous Soviet athlete recently pressured the RSFSR sports committee to transfer his daughter, an Olympic medalist from Kiev, to another city. She had a child who was sick, and she believed that her son would not get better as long as they remained in Kiev in the "radiation-polluted atmosphere."

Rumor Mill

In the absence of factual information, some Western reporters estimated the immediate death toll in the thousands, with thousands more soon to follow. They also speculated that the water supplies serving the 2.5 million people in Kiev were contaminated. Stories filtering back into the USSR via Western radiobroadcasts were matched by those spread by the Soviet citizens themselves. A good example is the well-publicized story by a former Soviet dissident who lived in Kiev at the time of the nuclear accident. He insisted that Soviet authorities covered up the deaths in Kiev hospitals of some 15,000 persons from the town of Pripyat' who died shortly after the accident from radiation sickness. Rumors circulated that:

- *Kiev was being evacuated to Moscow, and all the roads leading from Chernobyl' were clogged with refugees fleeing the explosion.*
- *The streets of Chernobyl' were full of dead bodies and animal carcasses.*
- *There was no food or water in the Ukraine.*
- *Many people died before they could be evacuated and had been thrown into common graves and buried by bulldozers.*

- Citizens as far away as Leningrad worried about whooping cough and diphtheria among the children last winter because they feared that their resistance may have been lowered due to the radioactive fallout from Chernobyl'.

- A doctor told [redacted] who was diagnosed as having a malignant brain tumor in August 1986—that her cancer might be related to the effects of radiation from Chernobyl'. The diagnosis—medically unlikely, even though there are fast-growing brain tumors—indicates that trained professionals may be subject to the same overreaction.

Local officials appear to be aware of the public mistrust but have been unable to stem it. In an interview with Western journalists last December, Ukrainian Health Minister Romanenko said some people in the Chernobyl'-Kiev area are asking for a blood test every 10 days, "three times more often than recommended." (The blood test measures changes in the bone due to radiation exposure.) Although authorities brush aside such public concern as rumor and ignorance, they admit that, even a year later, the population remains skeptical and refuses to be reassured by officials. Romanenko expressed his frustration during a press conference on Chernobyl's first anniversary, saying that many still continue to stay indoors as much as possible, refuse to open windows, and avoid eating many foods, despite assurances that there is no longer a need for such precautions.

Responding to continued popular anxiety and discontent, *Pravda Ukrainy* on 23 November 1986 announced the formation of special centers in Kiev and Chernigov Oblasts as well as the major health care centers in the city of Kiev to handle the questions about health risks from radiation. The creation of such centers eight months after the accident indicated regime recognition that public trust has eroded.

Moscow is sensitive to the credibility gap created by public anxiety about health issues and has tried to counter by vigilant monitoring of information released to the public. Although Moscow has admitted 31 deaths—all within the first three months of the incident—grounds for public doubt remain. When the Soviet weekly journal *Nedelya* disclosed in its May 1987 edition the death of the filmmaker Vladimir Shevchenko from radiation exposure received while making a documentary "Chernobyl': A Chronicle of Difficult Weeks," the regime reacted quickly.[7] Leonid Il'in, vice president of the USSR Medical Academy,

[7] Shevchenko died sometime in March 1987 but has not been included in this official toll. The regime maintains that there have been no additional deaths from the accident since June 1986 when the official death toll was put at 31, and that only the 237 members of the initial group of plant workers and firemen had radiation sickness.

Estimates of Chernobyl's Impact on Health

According to a draft report from a US Government task force presented at a meeting of the Nuclear Regulatory Commission (NRC) on 6 February 1987, the release of radiation from the Chernobyl' explosion and fire may cause up to 4,000 cancer deaths in Europe and 10,000 additional unanticipated cancer deaths in the Soviet Union during the next 70 years. The interagency government task force, chaired by Harold R. Denton of the NRC, also estimated that the accident may eventually cause mental retardation in up to 300 newborn babies in the Soviet Union. These were infants born of women who were pregnant at the time of the accident and who lived within 30 kilometers of the nuclear reactor. NRC officials said that the figures represent the US Government's best assessment at that time of the long-term health toll from the disaster.

A more recent unofficial study claims 39,000 may die of cancer in the next 50 years, most of them outside the Soviet Union. According to our experts, this study does not use reliable or complete data, but may further contribute to public uncertainty in the USSR and Western Europe.[a] The Soviets are estimating an increase of 1,000 to 3,000 cancer deaths over the next 50 years in the Soviet Union or less than 0.4 percent of the natural death rate.

[a] *This information is from the monthly journal* Science, *8 May 1987, "Recalculating the Cost of Chernobyl'," pp. 958-59. The chief author of the report is Marvin Goldman of the University of California at Davis*

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told the Ukrainian republic newspaper that Shevchenko suffered from a fatal illness before his involvement in filming cleanup operations between May and August 1986. Il'in also denied *Nedelya's* statement that some of Shevchenko's cameramen are now in the hospital with radiation sickness.

Clearly, Moscow is concerned that revelations such as the filmmaker's death will reinforce suspicion among the Soviet population that the regime is not being candid in its treatment of the health risks. Fear is probably high among the families of the tens of thousands of military and civilian personnel who were ordered to the zone for decontamination work and the evacuees. Health problems among the reservists, most of whom are non-Russians, could increase social tension and anti-Russian sentiments.[10]

Anxiety Over Food and Water. In addition to concerns about overall health risks, there is evidence that considerable fear of contaminated food and water is likely to continue. The effects of this concern were still being felt in the farmers' markets as recently as this summer. According to the USSR Ministry of Health, all produce on sale until August 1987 had to have a stamp certifying the product had passed inspection for radiation. Shoppers reportedly continue to suspiciously question the vendors about the origin of the food and frequently ask to see the vendor's passport to be certain the produce was grown outside the Chernobyl' region.

Fear of radiation-contaminated food was not limited to the affected regions. People reportedly avoided eating meat and drinking milk as far away as Leningrad. A resident of the city traveling abroad said, although meat was abundant in Leningrad during the summer of 1986, people were afraid to buy it. Similarly, powdered milk became scarce because people were buying it instead of fresh milk. The source also reported it was necessary to call in soldiers from a nearby military division to butcher livestock in a Leningrad meat factory because the workers refused to do the work, believing the livestock to be contaminated with radioactive material.

Chernobyl' Area Kolkhoz Markets

The official banning of anything grown in the Chernobyl' region has given way to rumors that Chernobyl's irradiated vegetable gardens and orchards produce apples and tomatoes of unusual size. Many jokes capture the citizens' continued fears and skepticism regarding official reassurances of the safety of the food they eat. One particularly cynical joke making the rounds is a good illustration: An old woman at a Moscow collective farm market shouts; "Apples from Chernobyl', apples from Chernobyl'!" A visitor asks her aghast, "Who would buy such apples?" She replies, "They are very popular—some buy them for their wives, mothers-in-law. . . ."

Belorussian kolkhoz markets were also affected. Shoppers reportedly avoided buying plums from Belorussia, fearing the fruit came from the Ukraine. [redacted] *11 percent of a total of 270,000 food samples taken this May in southern Belorussia contained radioactive matter* [redacted] *no radiation-related illnesses have been reported in Belorussia since the accident.* [redacted] *the massive banning of foodstuffs—the second most important pathway of exposure to cesium, the first being ground deposits—probably reduced the overall level of exposure by a factor of 10 to 20*

Despite repeated official assurances by the Health Ministry and the Medical Academy that the foodstuffs and water are carefully checked for radiation and are completely safe, renewed fear gripped the Chernobyl' region during the 1987 spring floods. People worried that the runoff from the melting snow could threaten to contaminate the water supply with radiation. [redacted] Kiev in

[10] Our judgment that most of the reservists at Chernobyl' were non-Russians is based on [redacted] by the identity of the operational units mobilized for the cleanup effort. They came from throughout the Soviet Union—including Ukraine, Belorussia, Estonia, Kirghiziya, and Siberia

Protecting Water Supplies

The marshy portion of Poles'ye region west of Chernobyl', which received the highest level of radioactive contamination, is not a major agricultural area, but it contains the headwaters of Pripyat' River, which flows into the Kiev Reservoir. The reservoir, also supplied by the Dnepr River, provides water to some 32 million people.

The Soviet report to the International Atomic Energy Agency in August 1986 conceded that high levels of cesium-137 are expected to be relatively persistent in the marshes of Belorussia and the Ukraine in the next few years. As long as the radioactivity remains in the marsh's plants and soil, the water supplies are in danger of contamination.

To protect water resources against contamination, in September 1986 the Soviets began to install nonoverflow dams, filtering dikes with a fill of a special material to prevent the possibility of radionuclides being washed into the river in hazardous quantities. Pravda *said at the end of October 1986 that a 29-kilometer network of such barriers had been built around the Chernobyl' nuclear power plant water supplies at a cost of 11 million rubles.*

March 1987 reported that rumors circulated about a reevacuation of area children, and bottled water stocks were wiped out all across the region as people stocked up for the perceived emergency

In November 1986,

that a new water supply pipeline was being constructed for the inhabitants of Kiev. Although Kiev's existing water supply from the Dnepr River was found to be safe from contamination, concern by the government regarding the possibility of residual contamination led to the construction of an alternative water source from the Desna River

this assessment was not made public for fear of causing a further bout of panic among the local population. Since then, the water supply from the Dnepr has been resumed, and continued reports confirmed that the water in the Kiev Reservoir remains safe.

Strain on Health Care System. Medical resources diverted to treat the Chernobyl'-related medical problems are likely to further strain the Soviet health care delivery system and intensify public frustration. Soviet health care even before Chernobyl' was inadequate to deal with many medical problems associated with contemporary industrial society and has been the object of recent criticism from top leaders, including Gorbachev.

The medical costs of monitoring and treating as many as 500,000 people—an official Soviet figure—for radiation effects will burden the health care system. A team of Soviet physicians visiting the United States in October 1987 told an audience of American physicians that the medical cost of treating the Chernobyl' victims and screening the population has reached 16 billion dollars (see figure 5).[11]

The accident exposed widespread shortages in medical supplies and equipment. To fill the gap, the Soviets have been relying heavily on Western medical equipment. Much of this Western medical technology will be used in the new Kiev Center on Radiation Effect on Humans.

This new All-Union Scientific Center for Radiation Medicine of the USSR Academy of Sciences—established in Kiev—has set up an all-union registry to monitor the radiation effects and cancer development in the 135,000 evacuees and other people under medical supervision exposed to radiation, but by early 1987 it had not yet been allocated enough money to carry out the program

[11] Boris Shcherbina, head of the government commission, told a Western newspaper on 28 April 1987 that all the people who were in the contamination zone are under medical supervision and gave the total number of 500,000. The breakdown of this figure was provided by the Ukrainian Minister of Health this September: 20,000 in hospitals, more than 200,000 adults and almost 100,000 children.

[redacted]

Figure 5. Radiation burns on a Chernobyl' fireman, one of the 500,000 persons now being monitored for long-term effects of radiation.

[redacted] it is not clear which organization is handling the program, what data the Soviets have collected, or what they are planning to do. This suggests that the program has little direction from Soviet leadership, and that the prospects for adequate long-term care for the Soviet citizens who were put at risk by the nuclear accident—mostly Ukrainians and Belorussians—are not guaranteed.

The cost of the nuclear accident is likely to be reflected not only in impaired health of evacuees but also in poorer health care provided to areas losing health care personnel as a result of the exodus of people from the Chernobyl' area. Although the initial transfer of Ukrainian and Belorussian medical teams to deal with Chernobyl'-related patients had only a short-term impact on the health delivery systems, the loss of health professionals to permanent relocation has created shortages in this sector in the Ukraine and Belorussia, according to the Kiev Oblast officials.

Opposition in the Republics

The most significant long-term cost of the accident may be the exacerbation of longstanding tensions and resentments among the non-Russian minorities. This is particularly true in western non-Russian republics of the USSR—the Baltic, Belorussia, and the Ukraine.

The Baltic. Moscow's requisitioning of food, housing, and summer places for the Chernobyl' evacuees and the conscription of reservists for decontamination aroused great resentment among ethnic nationals in the Baltic republics and led to active protests:

- [redacted] some 300 Estonian conscripts, who were sent to help decontaminate the Chernobyl' 30-kilometer zone, conducted a work stoppage when they were told in June 1986 that their tour had been extended from two to six months. [redacted] a demonstration was held in Tallinn in support of the work stoppage and to protest the forcible use of military reservists for decontamination work.

- [redacted] a demonstration at a Soviet military base in Estonia over perceived ethnic discrimination in the conscription of non-Russians for military duty at Chernobyl'.

- In Latvia and Estonia, where ethnic populations constitute only a bare majority, citizens reportedly protested the resettlement of Ukrainian and Belorussian Chernobyl' refugees because they viewed these Slavic "immigrants" as further evidence of Moscow's desire to dilute Baltic nationalities.

- In Lithuania [redacted] reported active demonstrations in June 1986 against the construction there of another reactor similar to the one at Chernobyl'.

- [redacted] workers went on strike for three days in an optics factory in June 1986, demanding that food in the cafeterias be checked for radioactivity and that wages be raised.

The widely held belief that many Baltic conscripts were sent to Chernobyl' against their will is bolstered by persistent—though contradictory—rumors of soldiers being shot by the Soviets for refusing to do decontamination work. Even if untrue, the rumors still merit attention as an indication of the intense fear felt by those engaged in the cleanup of Chernobyl' and the degree of opposition to the regime's handling of the crisis. For example:

- The Chairman of the Estonian Refugees Committee of Solidarity in Sweden reported that 12 Estonians were executed in June 1986 for refusing to take part in decontamination.

- A [redacted] his employees reported that 10 Soviet soldiers had been executed for trying to run away from the decontamination site.

[redacted] there had been resentment among the Estonians over the use of reservists for this activity, but was told that it was not true that people had been shot.

Belorussia and the Ukraine. The accident does not appear to have fueled as much antiregime or anti-Russian protest in the Ukraine or Belorussia as it did in the Baltic, but some groups have expressed strong dissatisfaction with the regime regarding Chernobyl':

[redacted] reported that chemical plant workers in that city held a sitdown strike in May 1986 over mandatory pay deduction for the Chernobyl' Aid Fund. The workers reportedly shouted that they were in no less danger (from chemical contamination in this case) than the people of Chernobyl'.

- Citing unidentified Soviet sources, a Western newspaper reported hundreds of residents in Kiev used the first anniversary of the the accident for a public demonstration to demand compensation for damages they had allegedly suffered.

Some Christian believers in the Ukraine expressed fear over the nuclear contamination of the 800-year-old Ukrainian town of Chernobyl', viewing the unprecedented event in religious terms.[12] A widely circulated rumor, reportedly started by Ukrainian Baptists, reached the West through *samizdat* sources, linking the events at Chernobyl' to the apocalyptic tale of a star by the same name *chernobyl'*—"wormwood"—which heralds the end of the world in the Book of Revelation.

Ukrainian officials are probably concerned with the religious dimension because of the continuing problems with the Protestant sects and the outlawed Ukrainian Catholic Church.[13] In a religious connection with Chernobyl', people have been flocking to a small Ukrainian village—some 530 kilometers southwest of Chernobyl'—where a schoolgirl reportedly saw a vision of the Virgin Mary on the anniversary of the Chernobyl' nuclear disaster. According to an August 1987 article in *Literaturnaya gazeta*, more than 100,000 people converged on the village in the first month after the sighting. Since then, authorities have locked up the church where the vision reportedly appeared in an effort to discourage visitors. Despite that, the paper revealed that some 40,000 to 45,000 faithful visit the site daily, and even a Soviet journalist covering the story admitted seeing the vision (see figure 6)

[12] Chernobyl' was founded in 1160 as a princedom and has existed since then, thus occupying an important place in the national historical consciousness

[13] Moscow displayed sensitivity to the religious issue when it allowed Mother Teresa, the Nobel laureate and Roman Catholic nun, to visit the Chernobyl' area this August. She requested to set up a charity mission. Their granting of her request would represent a significant shift in the official attitude toward religious activity in the Soviet Union

Figure 6. "Miracle in Grushevo"—the Western Ukrainian village in L'vov Oblast where a young girl reportedly saw a vision of the Virgin Mary on the first anniversary of the Chernobyl' accident. In August 1987, Literaturnaya gazeta *reported daily crowds of 40,000 to 45,000 persons converged on the site.* (

Although evidence of popular demonstrations and protest in the Ukraine and Belorussia is generally lacking, the accident fueled strong criticism among intellectuals, who were already upset about the siting of so many nuclear reactors in the region. At a recent writer's conference sponsored by the literary journal *Druzhba narodov*, Ukrainian writer and poet Vladimir Yavorovskiy implicitly blamed Moscow by noting that his people paid the price for the accident at Chernobyl': "There is a dead slice of Ukrainian and Belorussian land from which the people have departed." The Belorussian writer Ales' Adamovich—who has been a strong proponent of more openness and public control over the nuclear power decisions, told an audience attending a film festival in Berlin that a 2,000-megawatt nuclear plant under construction near Minsk had been converted to a thermoelectric plant because of public protest. The large Minsk nuclear heat and power plant, which is scheduled for completion in 1992, is a particularly sensitive public issue because it is situated close to the city with a population of 1.5 million. Legasov confirmed in November 1987 that the Minsk nuclear plant has been shelved because of public opposition."[14] (

Chernobyl' has even been invoked by the Russian nationalist group *Pamyat'* as part of its anti-Semitic arsenal to "cleanse" Jewish influence from the Soviet Union. They blamed the accident on the Zionists. Such sentiments show Chernobyl's continuing potential to inflame ethnic and social tensions that hinder Gorbachev's efforts to unite public opinion behind his domestic reform program.

Antinuclear Sentiment

The accident has further raised public consciousness about environmental issues that have received prominent media attention under Gorbachev. Environmental concerns have contributed to a climate of public activism that could contest Moscow's plans for accelerated nuclear power expansion in the next decade. The Ukraine, for instance, is still scheduled to increase the number of plants in the 1990s from four—one of which is Chernobyl'—to 10, each with multiple units. Many of these will be built near cities of a million or more, including Kiev, Khmelnitskiy, Kharkov, Odessa, Rovno, and Zaporozhye

Concern among scientists about the impact of nuclear plants in the Ukraine existed even before Chernobyl'. A week before the accident, the president of the Ukrainian Academy of Sciences, Boris Paton, publicly called for a review on siting and distribution of reactors in the republic and recommended the Ukrainian Academy of Sciences coordinate environmental protection programs in the republic. Since the accident, Paton has expressed his view that large industrial complexes should be held accountable for ecological disasters and that they should be required to maintain stringent safety measures ensuring "absolute reliability" of their technology.

On the first anniversary of the Chernobyl' accident, Vitaliy Chumak, head of the Radiological Ecological Center at the Institute of Nuclear Research of the Ukrainian Academy of Sciences, criticized the Soviet nuclear industry in the English language weekly *Moscow News* for continuing to base their decisions on where to build nuclear plants mostly on logistical considerations—existing roads, labor resources, water resources—without fully considering public safety or the environment. Chumak's concern about siting several nuclear power stations close together near heavily populated areas had been raised by Soviet scientists as early as 1979. In June 1987, the popular literary weekly *Literaturnaya gazeta* published an article by the Ukrainian poet Boris Oleynik, specifically blaming the planners and designers of Chernobyl' for not heeding the warnings of scientists and economists and siting the giant nuclear power plant on a river flowing into a major water supply reservoir and in a flood plain of the Poles'ye region. More recently, a Western press account reported that an unofficial club called Svetlitza was gathering signatures in Kiev protesting the presence of nuclear power plants in heavily populated areas. Another example was provided by [redacted] a petition, reportedly circulating in Moscow, calling for the shutting down the Chernobyl' nuclear plant, halting construction of other nuclear plants, and changing the policy of siting nuclear plants near large cities. Reportedly, the petitioners are particularly disturbed with the construction now in progress on the nuclear power plant in Crimea, a popular and widely used resort area.

In the Caucasus, where the republic elites are not enthusiastic about nuclear energy, the Chernobyl' accident revived hopes among proponents of small-scale hydroelectric power plants (GES). Such plants powered the Soviet Union in the reconstruction years (1945-65), but in the last 15 years have been overshadowed by large thermal plants. According to recent press reports, Georgia, which has fought having a nuclear plant on its land, is also arguing strongly for more small-scale hydroelectric plants. These reports confirm the republic's commitment to pursue this option. This October, some 2,000 Armenians demonstrated in Yerevan for the closure of the nuclear power plant and a chemical factory that they say has polluted the area for 40 years

While Soviet citizens—in contrast to their counterparts in the West—have not mounted a major protest against the development of nuclear power, antinuclear sentiment is growing as noted by the Armenian demonstration and the formation of the Svetliza group. Nuclear energy has also become more of a public issue after the regime's attempts to minimize the effects of the nuclear accident. Local Soviet press indicates that concern is particularly high in areas with Chernobyl'-type reactors (RBMKs) like Kursk, Leningrad, Smolensk, and Ignalina in Lithuania. The Leningrad nuclear plant is located in Sosnovyy Bor, 70 kilometers northwest of Leningrad, near Estonia, and residents of both Leningrad and Estonia are worried about the safety of the plant. Recently, an unofficial environmental group, formed in opposition to the nuclear plant in Sosnovyy Bor, has asked to join a Leningrad coordinating organization for various environmental groups. The citizens of Sosnovyy Bor may have already won certian concessions from their city executive party committee (*gorlspolkom*) regarding the ecology-sensitive project. According to *Pravda*, a promise was extracted from city officials to consider public opinion and environmental factors in future city planning.

[redacted] more emphasis has been placed on reactor safety in the USSR since the Chernobyl' accident, probably as a result of public concern. However, Soviet citizens are apparently reluctant to trust official assurances that safety alterations in the other Soviet nuclear facilities have been made or that existing safety rules will be enforced. They worry that a greater demand for energy to make up the loss caused by Chernobyl' will increase pressure on the nuclear sector to place growth above safety. Throughout the summer of 1986, officials found it necessary to assure the public that the repairs on all remaining 14 graphite-moderated reactors have not been waived to overcome electricity shortfalls and that extensive safety checks were carried out even in a nongraphite nuclear reactor like the one in Armenia.

While it is unlikely that public opinion will alter the Soviet commitment to nuclear power, debate on the location and safety in the nuclear industry should continue to grow, particularly in the present atmosphere of greater openness. For example, in April 1987, some 60 members of the Ukrainian Academy of Sciences signed a petition opposing the completion of units 5 and 6 at Chernobyl'. Reportedly, the petition was about to be published by *Literaturnaya gazeta* when Moscow decided to shelve the expansion plans, conceivably in part as a response to public opposition.

Environmentalists have also successfully protested against the construction of new nuclear power plants. In November, the head of the government commission investigating the accident, Valeriy Legasov, told the Western press that public pressure caused the cancellation of the Minsk and Odessa nuclear power plants, and other reporting indicates the Soviets have suspended plans to operate the Gorkiy nuclear plant for the same reason.

Consumer Dissatisfaction

While the most serious costs have been to regime credibility, the need to divert state funds into containing the disaster may result in some readjustments to Gorbachev's initiatives for social programs, including better housing and health care, and may undermine the regime's ability to deliver on its promises.

Moscow announced in December 1986 that a total of 800 million rubles were budgeted for direct compensation in housing and short-term subsidies for the Chernobyl' victims. The rest of the cleanup operation—entombing the damaged fourth reactor, decontaminating the remaining reactors and plant environment, and protecting the water and soil from contamination—was initially projected to cost 2 billion rubles, or 0.2 percent of GNP for 1986, but Gorbachev told [redacted] in December that this estimate was too conservative. A Soviet engineer attached to the Chernobyl' government investigation commission estimated the cost of cleanup to be 25 billion rubles, or more than 2 percent of GNP for 1986.[1]

The evacuation has aggravated housing shortages in some areas. A large number of those who were evacuated to cities far away from the republic, such as Frunze in Kirghiziya, stayed there. Housing was built for them and they were integrated into the work

[1] Disruption to the Soviet nuclear power industry through 1990 will be relatively minor and will not delay Soviet intentions to increase reliance on this energy source [redacted]

[redacted] DI Research Paper SOV 87-10032X [redacted] June 1987, *The Soviet Nuclear Power Program After the Chernobyl' Accident*

Incidents in Soviet Nuclear Power Plants

Accidents in Soviet nuclear power plants were rarely discussed before Chernobyl'. The Soviets have consistently denied that such accidents had occurred. In part, this is a problem of the Soviet definition of a nuclear accident, which is so narrow that even the Chernobyl' accident may not qualify. However, the Soviets do report "incidents involving the nuclear plants" to the International Atomic Energy Agency. Some of the incidents reported include:

- *A leak of primary-cooling water through the pressure-vessel-heat flange seal in unit 3 of the Kola nuclear reactor in 1983.*
- *Damage to one of the main circulation pumps in unit 1 of South Ukraine nuclear plant in 1983.*
- *Corrosion-erosion damage caused steam-generator tubes to leak in unit 3 of Novovoronezh nuclear power plant in 1983.*
- *Corrosion-erosion damage suffered by the reactor vessel at Kolskaya nuclear power plant in 1983.*
- *Shutdown of Kalinin's unit 1 because of malfunction of pilot-operated relief valve of the pressurizer in 1985.*
- *A primary coolant leak into a steam generator at the Rovno nuclear power plant in 1982, which damaged the units's steam generator and shut down the plant.*

Reportedly these incidents did not involve the reactor core nor caused any radiation damage.

There have been more serious accidents at Soviet nuclear power plants, according to Pyotr Neporozhnyy, the former Minister of Power and Electrification, including an explosion and a radiation leak. He said to a US Congressman in 1987 that one accident involved a rupturing of a coolant line, and another an explosion that spread radioactive steam to other parts of the unit.

Other sources have reported fires and other accidents at plant facilities:

- *there was a fire in the Armenian nuclear power plant in 1980-81.*
- *In a series of fictional short stories, which appeared in the November 1986 monthly journal* Neva*—but reportedly were based on the personal experience of Grigorij Medvedev, a senior engineer at a Soviet nuclear facility—the author describes slipshod safety practices, dangerous cleanup techniques, and a reactor power surge, similar to the one that actually happened at the Chernobyl' plant, resulting in several deaths.*

Medvedev admonished the planners against placing the Chernobyl' plant near Kiev more than a decade ago.

On 11 September 1987, Sotsialisticheskaya Industriya *gave a list of 368 accidents in Soviet nuclear and conventional plants that happened between 1981 and 1984. They were all caused by plant operator error, according to the paper. It did not say how many accidents of the total took place in a nuclear plant and how many in a conventional plant, or list other nonoperator-caused accidents.*

force. Soviet sources say some 120,000 persons have been completely and permanently rehoused (see figure 7). In addition, many fled on their own from nearby cities such as Kiev, Chernigov, and Gomel. A *samizdat* letter from the Ukraine, which appeared in the Paris emigre paper *Russkaya Mysl'*, puts the number of those who left Kiev on their own at 150,000. Housing assigned to the Chernobyl refugees have added to the chronic shortages in Kiev, Chernigov, and other cities. The former Premier Aleksandr Lyashko said that upward of 13,000 apartments will be needed to be replaced in the city of Kiev alone

Figure 7. *Thousands of evacuees were resettled in or near Kiev, many in hastily built settlements like the one depicted behind a displaced Chernobyl' woman.*

The sudden loss of hundreds of thousands of people from the affected area is already having repercussions in social services and the agricultural labor force. Kiev Oblast party boss Revenko last December said the area faces serious shortages of specialists for state farms, schools, stores, and hospitals because most of the people who left the area after the accident have not returned and may never return. In addition, people are apparently reluctant to work in the contaminated zone where Chernobyl' nuclear plant units 1, 2, and 3 are now in operation. The new director of the plant and other experts expressed concern about shortages of workers—now at about half the preaccident strength.

Moscow eased part of the pinch on its coffers by forcing the population to bear some of the costs of the cleanup. Decontamination duty was assigned wherever possible to the military, whose wage costs are less because civilian cleanup workers received double wages. The regime also defrayed costs through so-called voluntary contributions made to a special Chernobyl' Aid Fund. The 530 million rubles, collected from the deduction of one day's wages from every Soviet worker, offset about one-fourth of the lowest official estimate but, as noted, cost was probably much higher. Many Soviet citizens told [redacted]s that the contributions were mandatory and were demanded even from retired elderly people on meager pensions. While many Soviets—possibly even a majority—welcomed an opportunity to help, the de facto compulsory nature of the contributions probably generated some resentment.

Other involuntary costs imposed by the government were also unpopular. The cost for the apartments "borrowed," presumably on a temporary basis, from various enterprises and local soviets in different republics to house the evacuees was mostly borne by these enterprises. Some of the cost for the evacuation of large numbers of children and their mothers to Pioneer camps and vacation resorts was borne by various trade unions and local soviets, but the greatest cost was shouldered by individual families. Throughout the Soviet Union, parents had to find alternate summer places for their children and ways to finance them. Many regular planned vacations in Soviet resorts were canceled. The Black Sea coast was reportedly completely closed to all but Chernobyl'-area evacuees.

Implications for Regime Policy

Gorbachev's drive for increased open criticism of shortcomings in Soviet society and his announcement of domestic reform, *glasnost*, and democratization has already begun to divert domestic and foreign attention from Chernobyl'. Despite this, however, the Chernobyl' accident continues to pose several longer term

Relocation

Moscow announced the evacuation of 135,000 persons: approximately 30,000 from Belorussia's Gomel' Oblast and the remaining 105,000 from the Ukraine. Reportedly, thousands more left the nearby cities on their own. By the end of the summer of 1986, it was clear that most of the evacuated population would not be returning for the winter and more permanent resettlement was needed. Belorussia resettled 10,000 families in hastily constructed prefabricated houses in Gomel's northern rayons.

The Ukraine resettled upward of 27,000 people in the 56 new villages built just outside of the 30-kilometer zone. Many evacuees are still living in very crowded conditions, however. According to Kiev Oblast officials, there are plans to build another 3,000 homes and 1,500 apartments to alleviate the crowding.

The new homes have modern facilities, are completely furnished, and constitute a great improvement over the overwhelming majority of the housing stock left behind in the Chernobyl' countryside, according to local officials. Still, some evacuees refused to resettle there. Local officials say it is because of the remoteness of the area, but the real reason for their reluctance may be the nearness of the new settlements to the contamination zone.

Only 300 evacuees from the Ukraine have been permitted to return to two of the decontaminated villages in the zone. Further north of the site in Belorussia, the inhabitants of 10 villages—about 1,500 persons—have gone back to their dwellings. The rest have been permanently resettled elsewhere with their possessions and livestock.

Plant operators have been allocated 8,000 apartments in Kiev and Chernigov and another 6,000 apartments in other rayons and towns of Kiev Oblast. About 3,000 online operators at the recently restarted reactor units 1 and 2 shuttle between Kiev and Zelenyy Mys—the partly completed settlement on the banks of the Dnepr River—in a two-week rotation.

In October 1986, plans for the construction of a new city called Slavutich were advanced by the Central Committee of the Communist Party. Slavutich will be located in Chernigov Oblast and will house 20,000 power engineers and plant operators at its completion in two years, according to Soviet press (see figure 1).

problems. The public's confidence in the nuclear system has been shaken, and there is skepticism about the leaderships's commitment to guarantee safety. The growing popular resentment and concern about environmental protection and individual safety is forcing the regime to give a higher priority to these issues, putting pressure on the nuclear ministries and departments and ultimately on national resources.

Chernobyl' and the *Glasnost* Debate

Gorbachev successfully exploited adverse Western publicity to the accident to extend his domestic *glasnost* campaign—which was only in its infancy when the accident occurred. The disaster spurred Gorbachev's move to open up discussion of social and economic problems. [ ]

Gorbachev hoped Chernobyl' would shake up the party establishment so that it will henceforth comply with his demand for more openness and honesty in internal party communications. The initial public relations debacle strengthened the argument for greater media openness in discussing domestic shortcomings. Several articles in *Pravda*, for example, pointed out that a lack of complete information had encouraged harmful rumors. Supporters of Gorbachev's *glasnost* policy, like the noted journalist Fedor Burlatskiy, criticized the domestic media's early silence as costing the regime credibility [ ]

Gorbachev said the precise means that can protect the party from errors in politics are openness, criticism, and self-criticism. "The price of these errors is known to all of us," he added, which no doubt in large part, applied to the Chernobyl' information coverup.

Since April 1986, on several occasions the Soviet media have promptly reported on accidents causing loss of life and publicized punitive measures taken against the officials responsible. Soviet media treatment of the sinking of the Admiral Nakhimov passenger liner in August 1986 because of gross negligence—apparently drunkenness—and the firing of the responsible minister and prosecution of its captain and his deputy is a striking example. Other disasters, such as a collision of two passenger trains that killed 40 persons because one of the engine drivers was asleep, the spectacular methane coal mine explosion in the Ukraine late last year, and the more recent one in Chaykino mine in Donetsk have been reported immediately.

A year after the accident, however, there are signs that the Soviets are again being less direct about Chernobyl' and that the openness in the months following the accident may have found its limits. Despite signs of popular concern, the regime has not taken steps to give the public more of a say on these issues. The major bureaucracies are resisting public pressure, and there are some signs of backtracking on *glasnost*:

- Two Soviet journalists complained this April in the Soviet weekly *Moscow News* that information on Chernobyl' is being withheld and is increasingly difficult to obtain, noting that information reported to the International Atomic Energy Agency is not being given to the public.

- The official Soviet report presented to the IAEA at the August 1986 meeting in Vienna, and made widely available to the West, was never released to the Soviet public. A 20-page summary was eventually published in the November issue of *Atomnaya Energiya*, and *Elektricheskiye stantsii*, both highly technical journals with a limited distribution.

- Despite pledges of cooperation at the outset, the Soviets have been reluctant to share the research on radiation data they have collected since the accident, according to the US Department of Energy and the Nuclear Regulatory Commission. In addition to the traditional reluctance of the Soviet Union to disclose information, the Soviets may fear new data will disagree with the information they have already made public or will prove embarrassing if future casualties appear among those being monitored, since they have claimed the health effect will be insignificant.

The *Moscow News* article suggests the traditional argument that public opinion has no role in the scientific and technical sphere is still being used to justify the restrictions. Many in the affected bureaucracies, and even some senior leaders, have a vested interest in ensuring the consequences of Chernobyl' disappear from public view. They would like to avoid a real debate on the direction of the Soviet nuclear energy policy and on the location and safety of existing and future nuclear plants. Such a debate is troublesome to a regime formally committed to nuclear energy and the economic benefits of building nuclear plants near highly populated areas. Moreover, continued publicity will leave the regime open to criticism if it is unwilling to allocate further resources to deal with long-term environmental and health consequences.

The news blackout during the three-week trial of plant officials in July was further indication that authorities are tightly controlling information on Chernobyl'. Shortly before the trial, Soviet Foreign Ministry officials described it as open and indicated Western reporters could attend. On the second day of the proceedings, however, foreign reporters were barred from the courtroom, and the trial continued behind closed doors. The decision to conduct the trial in secret, possibly in an effort to avoid revealing technical testimony that addressed reactor design flaws, demonstrates Moscow's sensitivity to issues that can feed the growing domestic concerns about the safety of the Soviet nuclear industry

Criticism of official suppression of open discussion on Chernobyl' was voiced at the April All-Union Writer's Plenum by the Ukrainian poet Boris Oleynik. In his speech, he expressed his frustration with the central press, saying he has been denied access to the media to publish his reservations about the completion of units 5 and 6 at Chernobyl'. He told *Literaturnaya gazeta* he repeatedly tried to speak out but was not permitted to do so. Another prominent Soviet literary figure, Yevgeniy Yevtushenko, told *Izvestiya* there were attempts by unspecified ministries and departments to suppress the production of the Chernobyl' documentary, "Kolokol Chernobyl'ya," because the film was critical of nuclear technocrats.

Nuclear Energy Policy
While popular support for nuclear power in the West has been eroded further by the Chernobyl' disaster, Moscow's formally stated nuclear energy goals remain unchanged, despite signs of public anxiety. However, it is attempting to be responsive on the safety issue, creating an internal tension in regime policy.

The nuclear energy bureaucrats remain firm in their determination to rely more heavily on nuclear power. Minister of Atomic Energy Nikolay Lukonin announced in April 1987 that Moscow's plans to double electricity output at nuclear power stations by 1990, as compared with the 1985 level, and more than treble it by 1995 remain unshaken. According to Andronik Petros'yants, the recently retired head of the State Committee for Utilization of Atomic Energy, after the RBMKs already under construction are completed, the graphite-moderated reactor will be phased out in the Soviet Union, and future construction of nuclear plants will be based on water-cooled, water-moderated reactors. This change has not gone far enough to satisfy those among the Soviet environmentalists who demanded the closing of all Chernobyl'-type reactors, but energy needs and high cost apparently rule out this option.

The regime has meanwhile publicized new measures to ensure reactor safety, including a new decree on nuclear safety by the USSR Council of Ministers in July. In the same month, the Politburo passed a resolution for the development of automated systems at nuclear power stations. What impact on safety these changes will have is not yet clear. The new decree designed to strengthen safety inspection regulations for the State Committee for Safety in the Atomic Energy Industry focuses primarily on new nuclear power stations. And more rigorous operator training and a few hardware modifications proposed by the Ministry of Atomic Energy will do little to improve the existing RBMKs reactors and the earlier pressurized water reactors (VVERs), which have significant safety problems. Decommissioning or extended shutdowns of these reactors may be the only safe solution, but not one that the Safety Committee is now capable of executing.

Since the accident, the nuclear energy industry has undergone an extensive reorganization designed, among other things, to make it more responsive to the public concerns of safety. The reference at the Chernobyl' trial to the secrecy of nuclear engineering is an implicit criticism of the industry's wholly technocratic approach, which had traditionally given little weight to social concerns. There is also renewed discussion on the siting of future nuclear plants in more remote areas, stressing ecology as a major consideration. However, it is too early to judge what actual changes these measures will bring.

Another Nuclear Accident?
Western analysts agree that the RBMK reactors—nearly half of the Soviet nuclear power capacity—have fundamental deficiencies that no reasonable modification can eliminate and pose a continued safety hazard, remaining vulnerable to severe accidents.[17] The Soviet Union now has more experience and is better prepared to deal with a nuclear power plant accident than any other country in the world. Still, another nuclear catastrophe would deliver a serious blow to Soviet nuclear policy and could produce high-level political shakeup—including in the Central Committee and ministries responsible for

[17] Although a serious accident in another Chernobyl'-type reactor would pose considerable social and political repercussions for the Soviets and could mean the end of RBMKs, a major accident in a VVER reactor would have far graver implications for Soviet confidence in nuclear reactor design because the water-moderated reactor is slated to be the workhorse of the 1990s, while the RBMK was being phased out even before Chernobyl'

Reorganization of the Nuclear Industry

Since the accident, the nuclear energy sector has undergone an extensive reorganization designed to make it more responsive to the concerns of safety. Currently, the ministries and Soviet organizations responsible for nuclear power in the USSR are as follows: (a) the Ministry of Atomic Energy (newly formed since July 1986 and headed by Nikolay Lukonin) assumed responsibility for operating all nuclear power plants, taking over some authority from other ministries; (b) the State Committee for Safety in the Atomic Power Industry; (c and d) the Ministry of Power and Electrification and the State Committee for the Utilization of Atomic Energy—which earlier controlled some plants but now have diminished authority; (e) the Ministry of Heavy Power and Transport Machine Building—which combined the responsibilities of the now defunct Ministries of Power Machine Building and of Heavy and Transport Machine Building; (f) the Ministry of Medium Machine Building; (g) and the Ministry of Health—which will follow up on the radiation risks.

Out of the previously existing bodies, the State Committee for Safety in the Nuclear Power Industry has undergone the most significant changes. It has a new director, Vadim Malyshev, and a larger number of field engineers to conduct inspections since Chernobyl'. Its old director, Yevgeniy V. Kulov, was fired. The committee's power has been spelled out and includes the authority to stop an operation if a violation of regulations occurs. Whether this authority will be exercised is still an open question

nuclear industry, which have been given a mandate to bring the Soviet reactors to more stringent safety standards

A segment of the Soviet population—including some members of the elite with some policy influence—has much less confidence in the regime's capacity to guarantee safety. Another nuclear mishap, even a comparatively minor one, could unleash a backlash against nuclear energy and the regime that might be hard to ignore. Another accident would probably provoke public demonstrations of the sort increasingly used by independent groups as a platform for political and social issues.

These demonstrations have already had some effect on regime policy and have sometimes taken on an anti-Russian cast. The actions of the growing environmental lobby—like the well-organized groups in Leningrad, which led a demonstration of 10,000 persons to successfully press for the closure of a chemical complex polluting the environment in Kirishi, or the public campaign in northern Georgia to halt the Trans-Caucasus railway planned to tunnel through the Caucasus Mountains—could serve as a model. The regime is not likely to maintain a business-as-usual attitude the second time around, and major changes in the nuclear industry would have to be considered.

Outlook

Certain factors point to the potential for public opinions playing a greater role on nuclear power decisions in the future:

- The democratization campaign unveiled by Gorbachev, Yakovlev, and other senior leaders presupposes more sensitivity to public opinion if it is to be taken seriously. Some informal environmental groups have apparently been able to get their candidates on the ballot in Leningrad, and the new law on public review of legislation provides for discussion of the construction of new enterprises—presumably including nuclear power plants—and environmental issues.

- The views of some of the critics of nuclear power, like Boris Paton, a full member of the Central Committee, and some prominent journalists probably carry more clout under *glasnost* and have a better chance of keeping the pressure on the nuclear power industry.

- Finally, the Gorbachev regime would be embarrassed by a repeat of the Chernobyl' disaster, or even an accident on a much smaller scale, given the effort it has put into cultivating a positive image abroad.

Although there is no guarantee that public resentment will translate into policy changes on nuclear power—evidence now points in the opposite direction—it may mean greater efforts to reassure the public and, perhaps, some rethinking of the strategy for siting nuclear power plants.

Chernobyl' has created a degree of public disillusionment in the regime's capacity to guarantee personal security and its commitment to provide for the public well-being. Under the greater latitude of public debate in the Gorbachev era of *glasnost*—spurred in part by Chernobyl'—the Soviet citizenry is challenging national and regional authorities to solve longstanding societal problems, and there are signs of leadership support for giving a higher priority to these issues. Chernobyl' awakened public interest in the safety of industrial facilities and hightened public awareness of health and environmental issues. As noted, public demand to address some of these concerns has already led to specific action by the authorities, like halting construction of a hydroelectric plant in Latvia this spring, after the public protested its harmful impact on the environment.

In addition, the Gorbachev regime has issued a number of broader policy statements designed to curb pollution and improve health, and Gorbachev appears concerned about providing resources to support these policies. In July 1987, the CPSU Central Committee issued a sweeping resolution on ecology aimed at safety in the workplace and improving the quality of air and water. A month later the Committee announced a crash program to improve the health care system. The new Law on the Restructuring of Public Health stresses major reforms in the area of public health through prevention and may be implemented more rapidly than usual, given the growing concern about pollution and industrial safety.

Accommodation to popular frustration carries a danger for the regime, however, and could make the situation worse by exciting expectations. The population will be more attentive to future regime performance in the area of nuclear safety, public health, and ecology. There is increased discussion of these issues in the intellectual community, and social initiative groups are taking issues to the streets. These concerns are not likely to evaporate. As public dissatisfaction grows, the Chernobyl' accident may provide a focal point around which disgruntled citizens can organize, and Moscow may discover that Chernobyl' is a continuing irritant with a potential for social and ethnic tensions for years to come

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Central Intelligence Agency

Washington, D.C. 20505

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MEMORANDUM FOR: See Distribution

SUBJECT: Problems With Radioactive Waste at Soviet Defense Sites

The attached memorandum was prepared at the request of the Department of Energy to support the upcoming visit of nuclear waste management experts to the Soviet Union. The information used is widely available in the Soviet Union and is the focus of the current public debate on Soviet defense waste management practices.

Director
Scientific and Weapons Research

Attachment:
SW M 90-20028

CIA/SW 90-20028 M

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Central Intelligence Agency

Washington D C 20505

DIRECTORATE OF INTELLIGENCE

30 May 1990

USSR: Problems With Radioactive Waste at Defense Sites

Summary

Environmental problems caused by radioactive waste exist at the Soviet plutonium production complexes at Chelyabinsk-40 and Tomsk. Complete disregard for the potential hazards of radioactive waste in the late 1940s and continuing until the 1960s created contamination problems in extent and severity that are rivaled only by the Chernobyl' disaster. At the plutonium production site at Krasnoyarsk, there is controversy over a plan to inject radioactive waste from a power reactor fuel reprocessing plant into the ground.

* * * * *

CIA SW 90-20028 M

This memorandum was prepared by , Office of Scientific and Weapons Research. Comments and questions may be directed to OSWR

SW M 90-20028

Background

The Soviet Ministry of Nuclear Energy and Industry, which was established in the summer of 1989, controls the sites producing defense waste. Before the Ministry's formation, all aspects of the nuclear fuel cycle, all defense-related nuclear sites, and a few power reactors were under the Ministry of Medium Machine Building (MSM). The remaining power reactors had been operated by the Ministry of Atomic Power since 1986. Until then, when control was shifted in response to the Chernobyl' accident, the Ministry of Power and Electrification had owned and operated most Soviet power reactors. Although Yevgeniy P. Velikhov urged that the MSM name be retained for sentimental reasons, the expanded organization was renamed the Ministry of Nuclear Energy and Industry. Although the ministry name change occurred almost a year ago, discussions in local papers and debates still refer to the defense nuclear sites as being run by the MSM.

Problems with the handling and disposal of wastes at three defense sites currently are being debated. At Chelyabinsk-40, near Kyshtym, and at Tomsk, the problems are with stored defense waste from plutonium production. At the plutonium production site at Krasnoyarsk, the controversy is over a plan to inject radioactive waste from a power reactor fuel reprocessing plant into the ground.

Chelyabinsk-40

Chelyabinsk-40 is not marked on maps of the Soviet Union. Once the city bore the name of Beria. Today, the city, and the adjacent defense enterprise, the Mayak (Banner) Chemical Combine, are usually called Chelyabinsk-40. It was at this site that Igor Vasilyevich Kurchatov, working under Beria, built the Soviet Union's first plutonium production reactor. Here also, Academician V. G. Khlopin and workers from the Radium Institute completed the first chemical plant for the separation of plutonium from irradiated uranium.

The first reactor, "A" reactor, was graphite moderated with 1,168 channels. (In comparison, the first US plutonium production reactor, B-Reactor at Hanford, has 2,004 channels.) "A" reactor, sometimes referred to as "Anna," began operation on 19 June 1948. The reprocessing plant began operation later that year. The second reactor at Chelyabinsk-40 was heavy water moderated. Shortly after this reactor, which was designed by Academician Abram Alikhanov, began operation, the heavy water in the two heat exchangers froze. Yefrim Pavlovich Slavskiy, then complex chief engineer and later Minister of Medium Machine Building, claims he had to enter the radiation area and place his hand on one of the heat exchangers to convince the designers that the heavy water had frozen.

A total of five graphite-moderated reactors were built at Chelyabinsk-40. The 701 reactor, a small 65-megawatt (MW) reactor with 248 channels, began operation on 22 December 1951. On 15 December 1952 the 501 reactor began operation. The "A" reactor and the 701 reactor were decommissioned in 1987. Two other larger graphite-moderated plutonium production reactors are located in a separate area of the complex. One of these reactors was decommissioned on 12 August 1989. That reactor, which has 2,001 channels, is larger than the "A" reactor.

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A nuclear fuel reprocessing and storage factory for power reactor fuel, submarine reactor fuel, and fuel from nuclear icebreakers also is located at the complex. Radioactive waste from this plant is converted into special glass, placed in stainless steel containers, and stored in cans in a special storage facility at the site.

Discharge of Waste into the Techa River

According to the official report, "During the first years of the operation of the enterprise in this branch of industry there was no experience or scientific development of questions of protecting the health of the personnel or the environment. Therefore, during the fifties there was pollution of individual parts of the territory and around the enterprise." These bland words actually mean that from its beginning in 1948 through September 1951 all radioactive waste from the radiochemical plant that reprocessed irradiated fuel and recovered the plutonium was discharged directly into the Techa River.

In 1951, after radioactivity was found as far away as the Arctic Ocean, a new solution was adopted. Instead of discharging the radioactive waste into the Techa River, the wastes were dumped into Karachay Lake. The Techa River and all its floodlands were excluded from use. The inhabitants of some settlements were evacuated, in other affected settlements, work was performed to supply people with water from other sources. A series of artificial reservoirs were created to isolate water from the most contaminated areas. The first reservoir was erected in 1951 and the fourth in 1964.

Lake Karachay

Beginning in 1951 "medium-level activity" waste, including nitrate and uranium salts, was discharged into this natural lake. The lake eventually accumulated 120 million curies of the long-lived radionuclides cesium-137 and strontium-90. In the 1960s it was discovered that radioactivity from the lake was entering the ground water. Efforts to eliminate the reservoir began in 1967. The lake still exists, although its area has been reduced. Today, radioactivity in the ground water has migrated from 2 to 3 kilometers from the lake. On the lake shore in the region near the discharge line, radioactivity is about 600 roentgens per hour.

Waste Explosion in 1957

For two years radioactive waste had been stored in 300--cubic-meter vessels were called "permanent storage containers." These containers had walls that were 1.5 meters thick and lined with stainless steel. The containers had a special ventilation and cooling system. The cooling failed in one of the containers, however, and the waste began to dry out. Nitrates and acetates in the waste precipitated, heated up, and, on 29 September 1957, exploded. The meter-thick concrete lid was blown off, and 70 to 80 tons of waste containing some 20 million curies of radioactivity were ejected. About 90 percent fell out in the immediate vicinity of the vessel. The remaining 2 million curies formed a kilometer-high radioactive cloud that was carried through Chelyabinsk, Sverdlovsk, and Tumen Oblasts. About 23,000 square kilometers were contaminated. Radiation levels within 100 meters of the crater exceeded 400 roentgens per hour. At a kilometer the levels were 20 roentgens per hour, and at 3 kilometers the levels were 3 roentgens per hour. Guards received the largest reported dose, about 100 roentgens.

There were 217 towns and villages with a combined population of 270,000 inside the area contaminated to 0.1 Curie-per-square-kilometer or greater (map). Virtually all water-supply sources were contaminated. Calculations indicated that the cumulative dose over the first month for the three most contaminated villages would range from 150 to 200 roentgens. These villages, in which about 1,100 people lived, were evacuated, but evacuation was not completed until 10 days after the accident.

The next wave of evacuations was conducted over a half year period beginning about one year after the accident, from areas where the strontium-90 contamination exceeded 4 Curies-per-square-kilometer. These people consumed contaminated foods for three to six months without restriction and continued to consume some contaminated food until their evacuation. Inhabitants of 19 populated areas, about 10,000 people, were evacuated.

The maximum average dose of radiation received before evacuation reached 17 roentgen equivalent man (rems) from external radiation and 52 rems of equivalent effective dose. One-fifth of the people living in the area affected by the release showed reduced leucocytes in the blood, and, in rare cases, thrombocyte levels also were reduced. No deviations in the incidence of diseases of the blood and in the incidence of malignant tumors have been registered.

1967 Contamination Event

In 1967 wind dispersed radioactivity from the shores of Lake Karachay around the reactor site, creating strontium-90 levels of up to 10 curies per square kilometer.

The Situation Today

Parts of the site have a dose rate of up to 15 milliroentgens per hour. The average value for the remainder of the site is in the range of 10 to 30 microroentgens per hour. The Techa River is cordoned off with a wire fence and people are forbidden to catch fish, pick mushrooms or berries, or cut the hay. There are 450 million cubic meters of radioactive water in open reservoirs.

The South Urals Project

The South Urals Nuclear Power Station is, in the words of Selskaya Zhizin, "in a bright birch grove, which guards the secret of the Ural [radioactive] trace." The nuclear station was being built by the Ministry of Medium Machine Building. Two BN-800-type liquid-metal-cooled, fast-breeder reactors were under construction and a third was planned. The nuclear power station was intended to provide employment for the skilled workers who have lost or will lose their jobs as plutonium-producing reactors are shut down.

The production complex, by consuming contaminated water for its needs, regulates the water level in the lakes. With three reactors shut down and two others to close, a new danger was identified--overfilling the reservoirs with natural water and possibly even failure of the dams, sending contaminated water into the rivers of the Ob basin. The South Urals nuclear power station was to avert this sort of catastrophe by using radioactive water to cool turbine condensers, thus increasing evaporation.

Public protests and questions raised by Oblast officials have at least temporarily halted construction, although some critics claim that the real reason is that the Ministry ran out of funds. In the public mind, constructive dialog on the nuclear power station is impossible without learning the truth about the ecological impact of Mayak Chemical Combine, particularly the 1957 explosion.

Tomsk

The closed city of Tomsk-7 is the location of the Siberian Atomic Power Station. In 1955, at the International Conference on Peaceful Uses of Atomic Energy, the Soviets described the reactors at this station as being solely for electric power generation. In 1981, A. M. Petrosyants, then Chairman of the State Committee for Utilization of Atomic Energy, admitted that these reactors served a dual purpose--plutonium production and power generation. Not until 4 May 1990 did the Soviets reveal that the reactors were at Tomsk. The reactors described in 1955 were graphite moderated, water cooled, and with 2,101 channels. Thus, they are slightly larger than the reactor shut down in 1989 at the Chelyabinsk-40 complex.

Problems with defense waste at Tomsk date back to the 1970s. At that time, a senior engineer for "monitoring stocktaking and storage of special output" discovered a "vast quantity of radioactive output" at the plant. Izvestiya claims that his letter to the Central Committee and L. I. Brezhnev only resulted in his reprimand and threatened expulsion from the party. Not until 18 April 1990, when Tomsk-7 radio warned that people had been contaminated, did the public learn of this problem.

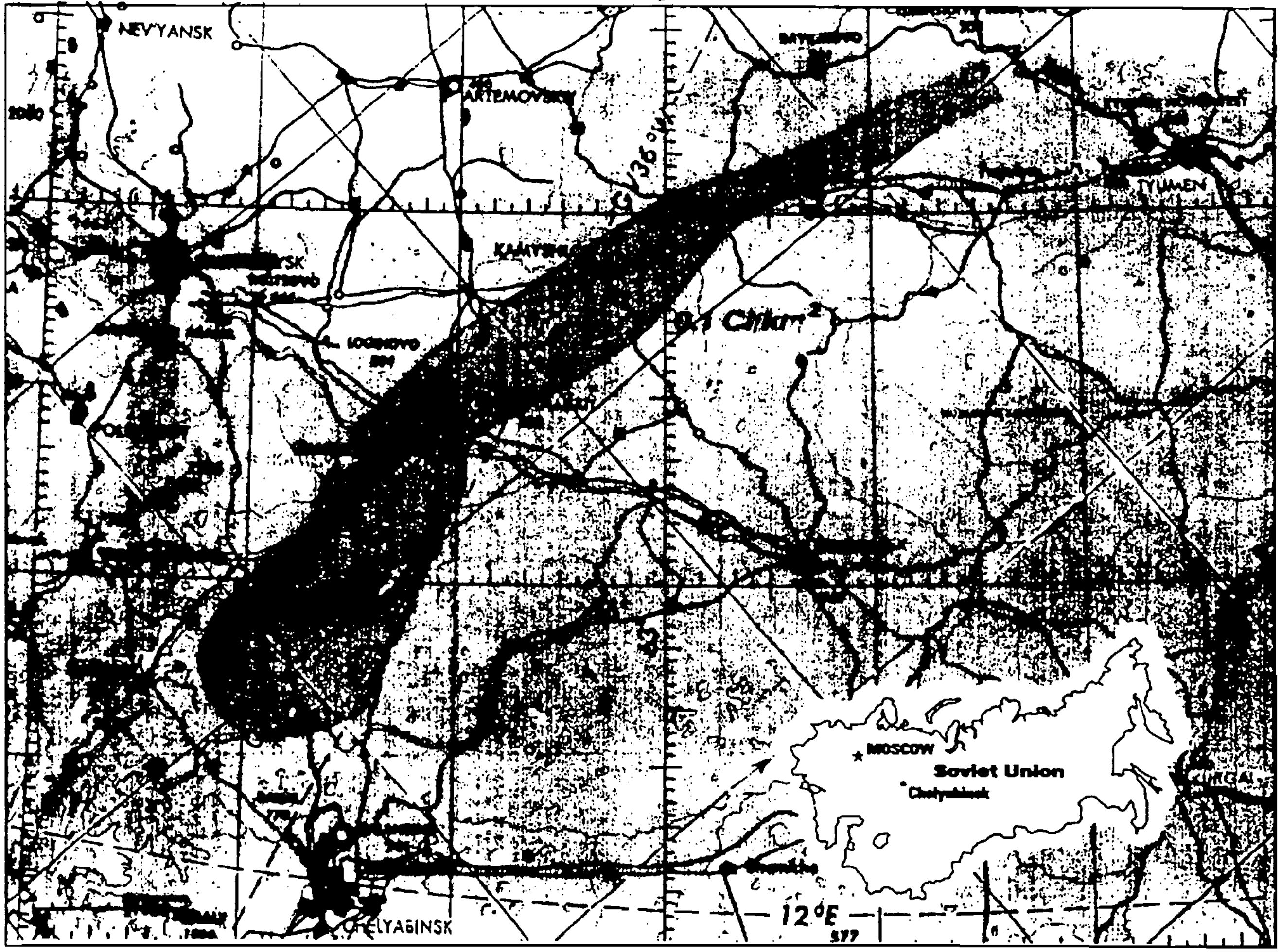
Izvestiya also reported that the radioactive waste burial site is poorly fenced and contaminated water areas are not fenced at all. Elk, hare, duck, and fish are contaminated, and 38 people were found to have higher than permissible levels of radioactive substances in their body. Of these 38, four adults and three children have been hospitalized.

Krasnoyarsk

In the early 1950s, Stalin authorized the building of a "radiochemical enterprise" for producing plutonium on the mountainous shores of the Yenisey River in the Siberian taiga. Thus was born the mining-chemical combine and, along with it, a closed city.

Fifteen years ago it was resolved to add an irradiated fuel-storage facility and a reprocessing plant for 1000—MW pressurized water reactor fuel (VVER-1000) and "other" reactors at this site. Controversy about the 1,500-metric-ton-per-year reprocessing plant, known as site 27, has resulted in the project being postponed. In June 1989, Komsomolskaya Pravda reported that some 60,000 people in Krasnoyarsk signed a protest. In part, they were angered by the revelation that the scientific study justifying the appropriateness of the site was actually produced nine years after construction started. The site is about 30 percent complete and was originally scheduled to start reprocessing in 1997.

Radioactive Contamination Near Chelyabinsk



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A key feature of the site is the method of handling radioactive waste. According to Moscow Trud, waste is to be injected between layers of clay at a depth of 700 meters. The injection location is some 20 km from the site of the reprocessing plant on the opposite side of the Yenisey River. Some 50 meters under the river, a tunnel has already been completed to carry the waste. It is the tunnel and the decision to inject liquid waste into the ground that is the focus of the controversy.

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Directorate of Intelligence
26 December 1991

Ukraine: Who Will Manage Chernobyl?

Summary

A pressing challenge for leaders in the newly independent Ukraine will be to reconcile the public to the fact that, although the republic may now control its political destiny, it will have to continue to defer to Russia on some economic and technical decisions. One such decision is the emotion-charged issue of the management of the Chernobyl nuclear power plant and the republic's overall nuclear energy industry. In the summer of 1991, the Ukrainian parliament passed a resolution asserting Kiev's right to exercise primary authority over atomic installations in the republic. Indeed, when a serious fire broke out at the Chernobyl nuclear power station a few months later, Kiev took the lead

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This memorandum was prepared by [redacted] the Office of Leadership Analysis. Comments and queries are welcome and may be directed to the Chief, RC Division, on [redacted]

[redacted]

in dealing with the incident, rather than allow Moscow to handle the political and physical fallout as it had during the Chernobyl disaster in 1986.

Although the magnitude of this recent incident was only a fraction of the earlier one (no radiation was released), the fire was nonetheless a close-call reminder that Ukraine by itself could not yet cope economically or technically with another serious accident, and that it might, therefore, be unwise—or impossible—for Kiev to sever in the near future all ties to central nuclear authorities. In signing the historic Commonwealth pact with Russia and Byelarus on 8 December 1991, Ukrainian leaders openly acknowledged this interdependence by consenting to a separate clause calling for a "special agreement" on Chernobyl. We believe this clause will allow for Russian technical access to and control of the plant while decontamination and containment operations continue, probably for years after the shutdown of the reactors, which is scheduled for 1993. [redacted]

Ukraine Tries to Take Control

Ukraine has had de facto jurisdiction over its nuclear power facilities since at least mid-1991, when the republic's parliament, responding to enormous political pressure stemming from the earlier Chernobyl accident, initially set a closure date of 1995 for the Chernobyl atomic energy station (AES). Ukraine has not yet ruled on the fate of four other nuclear power stations currently in operation, but it has declared a moratorium on new plant construction. [redacted]

Republic leaders have postponed a decision on a proposal by the former USSR Ministry of Atomic Power and Industry (MAPI)— the Moscow-based government agency that previously owned or oversaw all nuclear facilities—that would enable central authorities to retain some operational control. The proposal acknowledges republic ownership of former MAPI nuclear plants but p[redacted]vides for a centralized agency to service and run the power stations through a joint-stock state corporation. The arrangement would almost surely rankle Ukrainian sensitivities because it epitomizes the pervasive influence over the republic's nuclear sector exercised by Russia, where MAPI support facilities and know-how are concentrated. As the experience of the Baltic nations shows, that influence will probably continue for some time: even Lithuania, which has achieved complete political independence, still relies on a contingent of Russian personnel to run its Chernobyl-type reactor at Ignalina.[redacted]

The importance of these jurisdictional issues was illustrated in the accident that occurred on 11 October 1991 at the Chernobyl AES. That evening, an electrical malfunction in an operating unit of the plant sparked a serious fire, which caused a large section of the roof to collapse into a main generator room. No radiation was released because Ukrainian firemen, who were the first on the scene, extinguished the blaze in about three hours. Had the fire gone unchecked, however, it could have threatened the reactor itself, which would have required massive assistance that was beyond the republic's capability.[redacted]

Anticipating the political uproar this close call might generate, the republic government seized the lead by immediately appointing a 14-member commission to investigate. Headed by veteran politician Viktor Gladush, the team included government officials, firemen, engineers, public health officers, and experts from the Ukrainian Ecology and Nuclear Institutes. Ukrainians with considerable experience in nuclear matters—including followup issues from the Chernobyl accident five years ago—helped constitute a highly visible Ukrainian majority among those dealing with the aftermath of the fire.[redacted]

Moscow Plays it Down—But Not Out

To minimize the public's perception of danger and to forestall charges of interference in republic affairs, the Moscow-based MAPI kept a low profile in dealing with the accident. Nonetheless, it formed its own commission of inquiry and quietly set up a center at the AES to manage the fire cleanup. The MAPI, which has monitored incidents at all nuclear power stations throughout the former USSR, assigned a midlevel spokesman to issue information bulletins to reassure the public that there was no danger from radiation. [redacted]

The Chernobyl Fires—Then and Now

The October fire showed that some fundamental leadership and policy management changes have occurred since the Chernobyl disaster in 1986:

- Authority to make technology-driven decisions that have strong political ramifications has shifted from central, industry-oriented organizations or individuals to local political bodies. In 1986, the republic's leadership was powerless against the central nuclear bureaucracy. In October 1991 the populace targeted the Ukrainian Council of Ministers and the parliament as the authorities best able to take action.

- The public is now demanding and getting honest answers. Unlike central authorities who tried to clamp a news blackout on the 1986 Chernobyl disaster, Ukrainian officials made a full disclosure to the public of circumstances contributing to the October accident, and they kept citizens informed throughout regarding the extent of danger. The story broke internationally within a few hours, and even the cautious Moscow press reported it on national television the morning of the 12th.

- Now, environmentalists constitute a strong and vocal political force. At the time of the catastrophe in 1986, there was no active environmental movement, much less one with clout. People who are environmentally conscious are no longer on the outside looking in; they often hold policymaking offices. Capitalizing on the publicity surrounding the October fire, environmentalists secured the endorsement of officials from nearby West European countries and neighboring Soviet republics and agitated for immediate closure of the station. On 29 October the Ukrainian parliament voted to shut down the station by 1993, instead of phasing it out gradually. [redacted]

Willing, But Able?

Much as Ukraine would like to decide the future of its nuclear industry without having to consider its neighbors, we believe it is inextricably linked to them by economic and technical bonds. [redacted]

Why They Cannot Go It Alone

Numerous obstacles hinder Ukraine from gaining self–sufficiency in nuclear power or doing away with it altogether:

Economic Constraints

- *One–fourth of Ukrainian electricity is AES generated.*
- *Remaining energy sources are indigenous coal production (down one–third since 1990) and imports of Russian oil (expected to rise in price).*
- *Ukraine, in the past a significant exporter of electricity, has slashed energy exports, and the country currently is renegotiating foreign contracts to bring hard currency earnings under republic control and to cushion against oil price hikes.*
- *To meet near–term energy needs, republic leaders may commission three nearly completed nuclear plants that had been put on hold.*

Technical Factors

- *Ukraine lacks the trained personnel, computer codes, and essential design information to sustain a nuclear industry.*
- *Most scientists, engineers, and designers are Soviet trained and indoctrinated in an industry culture biased toward centralization of authority and expertise.*
- *Technical documentation is in Russian; the official language for AES operations is Russian.*
- *Ukraine has no significant nuclear manufacturing. Because its reactors are Russian built, Russia is the logical spare-parts supplier and equipment integrator.*
- *Tasks such as data collection and dissemination on AES incidents and operations are routed through Moscow. The top research institutes are in Russia.*

[redacted]

Ukrainians would prefer to seek technical assistance for their nuclear industry from the international community rather than from Moscow, and their chances of getting foreign help are good. Western firms are eager to deal with the republic, especially if they can help stabilize its nuclear industry. Notwithstanding the West's willingness to provide assistance, however, Kiev faces serious financial constraints that limit its ability to pay for Western technology and equipment; the republic will therefore be forced to rely on central—in effect Russian—experience and knowhow for the foreseeable future. [redacted]

Ukrainian leaders must determine, therefore, how much interaction between the republic's nuclear industry and Moscow is politically palatable; one issue, for example, is whether the republic will join the joint-stock corporation proposed by MAPI. Ukrainian concurrence is essential for the plan to be workable because the republic is second only to Russia in its number of nuclear power plants. Local leaders may resist signing on, however, because of overwhelming public sentiment that Ukraine control its own industrial facilities. Moreover, republic leaders have expressed how little they trust central authorities to run the nuclear power sector in the best commercial or environmental interests of Ukraine. Backing for the plan would most likely come from the republic's nuclear industry workers and officials, who would probably judge this measure of central control and coordination a necessary evil to reduce the chances of a severe nuclear accident or to cope with one, should it occur. Given these conflicting points of view, Ukrainian leaders will have to maintain a balancing act because joining the corporation may provide their only access to the technical expertise they need until they develop their own nuclear infrastructure or obtain sufficient Western help. [redacted]

Outlook: Reluctant Partners

The landmark 8 December Commonwealth accord, signed by Ukraine, Russia, and Byelarus, contained a separate provision (Article 8) on dealing jointly with the continuing effects of the 1986 Chernobyl disaster. Ukrainian leaders thereby implicitly acknowledged that, unassisted, they are unable to cope with the residual effects of that first accident. We believe the recent Chernobyl fire was a stark reminder to them that another majo[redacted]ccident would overwhelm the fledgling nation and could threaten its economic and political viability. We expect Ukrainian leaders to incorporate the Article 8 arrangement into an ongoing gentlemen's agreement with vestigial central nuclear energy authorities to help protect against such a threat. We believe the agreement will be one in which the republic continues to work with existing organizations for as long as necessary (allowing for continued Russian technical access and control) but keeps the collaboration as unpublicized as possible. For at least the near term, Kiev must remain Moscow's cooperative—even if reluctant—nuclear partner.[redacted]

Appendix A
Players in the Aftermath of the Chernobyl Fire

Described below are the most prominent players associated with the October fire. Most are Ukrainian officials or public figures, but two Moscow MAPI officials who were responsible for the power plant at the time of the accident are also included [redacted]

The Establishment

The ranking Ukrainian official was State Minister for Industry, Transport, and Energy **Viktor D. Gladush**. A longtime party official, he was named chairman of the republic commission investigating the fire. Gladush had served since June 1990 as head of a USSR Council of Ministers commission charged with taking the AES out of service by 1995. He had also coordinated regional responses to previous emergency situations, including supervision of Ukrainian assistance to victims of the 1988 Armenian earthquake.

[redacted]

Gladush's deputy on the investigation commission was Nikolay A. Shteynberg, chairman of the Ukrainian State Committee for Nuclear Safety since its establishment in August 1991. Shteynberg was assigned to the Chernobyl AES in the mid-1980s, but he left just before the 1986 accident because of a personality conflict with the plant director. When the disaster occurred, he returned to the AES on his own initiative, assumed a position of authority, and participated in early cleanup operations. As a consequence, he was named deputy chairman of the USSR State Committee for Nuclear Safety, a title he held until assuming his current post. [redacted]

The top MAPI official involved was **Erik N. Pozdyshev**, chairman of the Ministry's commission of inquiry into the causes of the fire and the measures needed for repair of the plant. He was the MAPI deputy minister in charge of all AES maintenance, operations, and accident coordination. Pozdyshev knows the Chernobyl station well; he was its director from right after the 1986 accident until probably mid-1989, when he was named deputy minister. His MAPI colleague, Chernobyl AES chief engineer **Nikolay A. Sorokin**, heads the center set up on 12 October to manage the fire cleanup. Both men have exercised a low-key response to the potential hazards of the fire, and both have stayed out of the spotlight focused on Ukrainian officials. [redacted]

The Greens

Environmental activists **Yuriy N. Shcherbak** and **Vladimir A. Yavorivskiy**, on the other hand, have been vocal critics of the Chernobyl AES. Shcherbak is Ukraine's Minister for Environmental Issues and also chairman of Green World, the Ukrainian environmental group that played a large role in eliciting public demands that the station be closed. Although Shcherbak concedes that economic imperatives will probably keep the Chernobyl AES on line for a while longer, he has faulted Ukrainian power officials for failing to develop alternative energy sources. A physician for more than 30 years, he treated Chernobyl accident victims. Shcherbak published a series of articles and a documentary novel during the late 1980s describing the medical and environmental effects of the Chernobyl disaster. He said he felt compelled to unveil what he believed to be a massive propaganda coverup of Chernobyl's consequences. Shcherbak served as chairman of the Nuclear Ecology Subcommittee of the USSR Supreme Soviet during 1989-90. [redacted]

Yavorivskiy is a well-known Ukrainian novelist and poet who has focused his writing since 1987 on the nuclear accident at Chernobyl. He was one of a group of literati who founded the intensely nationalistic People's Movement of the Ukraine for *Perestroyka*—known there as Rukh—in March 1988, and he later served as its chairman. He tried unsuccessfully to enter the Ukrainian presidential race, but he could not get the required number of signatures to become a candidate. Yavorivskiy is chairman of the Ukrainian Supreme Soviet standing commission on Chernobyl accident issues, and following the recent fire, he agitated for an immediate shutdown of the station. [redacted]