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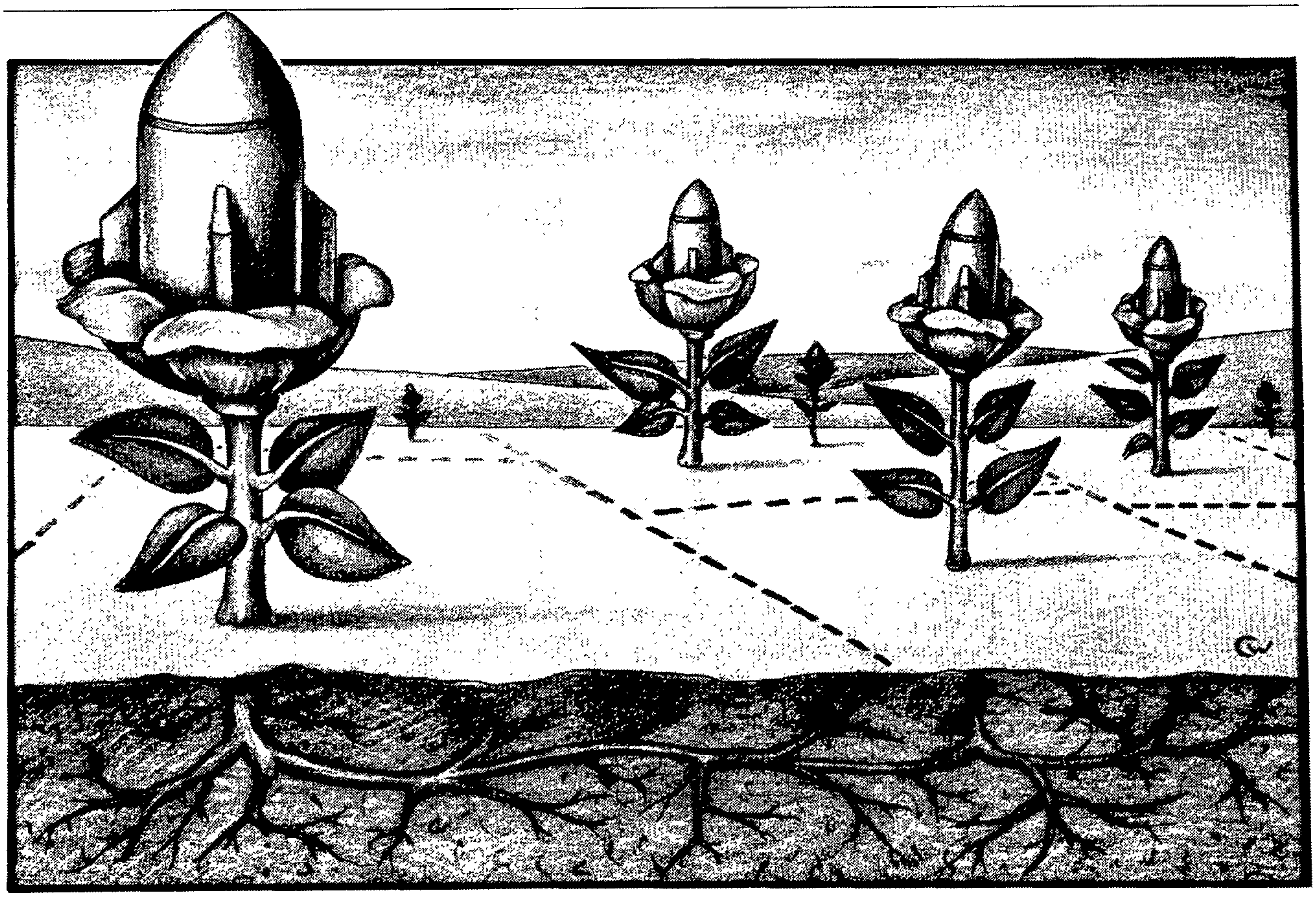

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MAKING ▲ WARHEADS

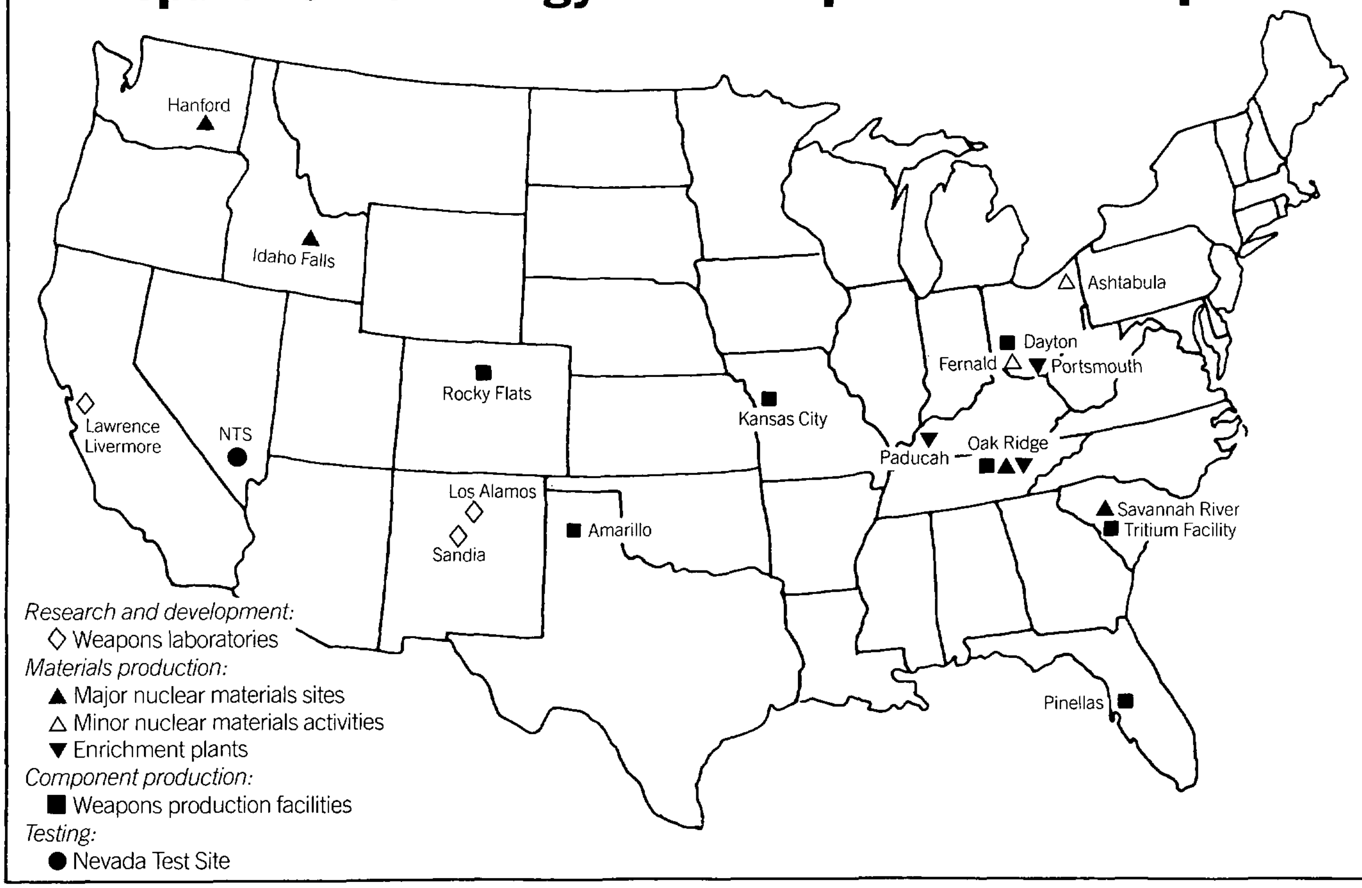
U.S. nuclear weapons production: an overview

Plans for a nuclear buildup, set in motion in the late 1970s, have come up against the limitations of the Energy Department's aging warhead-producing facilities, constructed largely during the 1940s and 1950s.

The U.S. Department of Energy's nuclear weapons complex is in trouble. The Reagan administration expects to continue and even increase production of the nuclear materials used in warheads. But the plants that produce these materials—plutonium, tritium, and weapon-grade uranium—are currently either shut down or operating at reduced capacity. Recent studies and declassified documents cite safety and environmental problems that have long been ignored by the self-policing Energy Department. The cost of dealing with these problems will be enormous. Meanwhile, Congress is being asked to fund one or two new reactors and will soon have to decide on a site for disposing highly radioactive wastes. The following nine articles provide background for those decisions. We thank guest editor David Albright of the Federation of American Scientists for his valuable assistance and advice in putting together this forum. —*The editors*

Thomas B. Cochran directs the Nuclear Weapons Databook *project at the Natural Resources Defense Council in Washington, D.C., where Robert S. Norris is a senior research associate. William M. Arkin directs the Arms Race and Nuclear Weapons Research project at the Institute for Policy Studies in Washington and is a contributing editor of the* Bulletin. *This article is adapted from "The Warhead Production Complex: An Overview,"* Nuclear Weapons Databook, *vol. 2:* U.S. Nuclear Warhead Production *(Cambridge, Mass.: Ballinger, 1987).*

Department of Energy warhead production complex



by Thomas B. Cochran, William M. Arkin, and Robert S. Norris

THE UNITED STATES has been engaged in the design, testing, and manufacture of nuclear warheads since the early 1940s. Together, the four agencies that have overseen these activities have spent approximately $89 billion, or $230 billion in current dollars. Meanwhile, the Defense Department has spent an estimated $700 billion ($1.85 trillion in current dollars) on delivery systems and other support costs for these weapons.

When the Atomic Energy Commission (AEC) was created in 1947 it not only developed and produced nuclear warheads, but it had physical custody of the weapons, even at deployment sites. Only if the weapons were to be used would custody be relinquished to the military. Even today U.S. policy is to separate the developer and producer of nuclear warheads from the military forces that would employ them. But the relationship between the civilian producer of warheads and the military consumer of the weapons has changed.

In the early days the AEC held a predominant influence on warhead policy. Over the years the commission lost physical custody over deployed warheads, its status diminished, and its responsibilities were redefined. Now its successor, the Energy Department, works in unison with the Defense Department on every aspect of the life cycle of a nuclear warhead. Each is assigned distinct responsibilities. But today, even with its huge production complex, capable of designing a nuclear warhead for virtually any kind of system, Energy's role has been reduced to that of providing engineering support to meet Defense's demands. Those requirements have fluctuated over the years. Although the planned nuclear weapons buildup, initiated by President Carter and greatly augmented by President Reagan, never achieved its goals, it still is straining the now aging production system, most of which was put in place by the mid-1950s.

THE ENERGY DEPARTMENT is responsible for the design, testing, manufacturing, assembly, and retirement of warheads. It produces the special material—uranium, plutonium, tritium—and warhead components, and certifies the technical quality of the stockpile through constant monitoring. Along with the Defense Department, Energy reviews safety standards and logistic procedures.

Warheads are produced in a complex of government-owned, contractor-operated facilities spread over 13 states, covering 3,900 square miles and employing some 90,000 people. [See map.] The complex conducts four basic activities:

• *Weapons research and design.* Two laboratories—Los Alamos National Laboratory in New Mexico, and Lawrence

Glossary

Beta emitters: radioactive elements that release beta particles as part of the radioactive decay cycle. Beta particles cannot penetrate even a thin sheet of metal, but they can burn skin. If inhaled or ingested, beta particles can cause radiation sickness, genetic damage, cancer, or death.

Curie: one curie is the rate of disintegration of one gram of radium: 37 billion disintegrations per second.

Depleted uranium: uranium from nuclear reactor spent fuel or enrichment plant tailings that contains a lower percentage of fissile uranium 235 than does natural uranium.

Enrichment: a concentration process to increase the proportion of a specified isotope. For example, natural uranium is enriched to increase the amount of uranium 235.

Fissile: able to be split by a low-energy neutron. A uranium 235 atom, for example, is fissile.

Half-life: time required for a radioactive substance to lose 50 percent of its radioactivity by decay.

Heavy water: ^2H_2O, water containing predominantly deuterium, a heavy isotope of hydrogen. It is used as a moderator in nuclear reactors because it can reduce the energy of fast neutrons.

High-level waste: highly radioactive material, containing fission products, traces of uranium and plutonium, and other transuranic elements, that results from chemical reprocessing of spent fuel.

Highly enriched uranium: uranium enriched to over 20 percent uranium 235.

Isotopes: atoms having the same number of protons in their nuclei, and hence the same atomic number, but differing in the number of neutrons, and therefore in atomic weight: for example, uranium 235 and uranium 238.

Moderator: a material used in a nuclear reactor to slow neutrons, thus increasing their chances of being absorbed by fissile atoms.

Rad: "radiation absorbed dose." One rad is the amount of ionizing radiation that deposits 100 ergs of energy in each gram of exposed material.

Radiation: the production and transmission of energy in the form of electromagnetic waves or particles. Electromagnetic radiation is generally classified as to frequency (infrared, visible light, ultraviolet, X-rays, and gamma rays). Alpha and beta radiation are particle emissions from the nuclei of atoms.

Radioactive decay: a process in which unstable nuclei release excess energy in order to become more stable. Uranium 235, for example, undergoes 15 separate transformations until it finally becomes nonradioactive lead. The energy released may take the form of alpha or beta particles, or gamma rays.

Rem: "Roentgen equivalent, man." This measurement takes into account the varying biological effects of different kinds of radiation and attempts to express them on a common scale.

Reprocessing: the means by which spent fuel from a nuclear reactor is separated into waste material for disposal and material to be reused, such as uranium and plutonium.

Spent fuel: used nuclear fuel that can no longer sustain a chain reaction.

Target rods: in a nuclear production reactor, tubes that hold lithium 6 or depleted uranium. Neutrons are "fired" at the lithium targets to produce tritium (see "How Tritium is Made," page 40), or at depleted uranium to produce plutonium.

Transuranic waste: any waste material containing elements with atomic numbers greater than uranium—neptunium, plutonium, americium, and curium, for example. It is produced primarily from reprocessing spent fuel and from use of plutonium in fabricating nuclear weapons.

Weapon-grade plutonium: plutonium composed of about 93 percent or more plutonium 239. Weapons can also be fabricated from lower-grade material.

Weapon-grade uranium: uranium that has been enriched to over 90 percent uranium 235. Natural uranium contains only about 0.7 percent uranium 235. Weapons generally use weapon-grade uranium, although nuclear explosives can be made with any highly enriched uranium.

Livermore National Laboratory in California—design nuclear warheads and conduct basic research on weapons systems and military applications of atomic energy and advanced sciences. A third establishment—Sandia National Laboratories in New Mexico and California—provides engineering support to Los Alamos and Livermore for the design of non-nuclear warhead components. Army, navy, and air force laboratories supplement these activities, conducting research on delivery techniques, nuclear effects, and safety.

• *Nuclear materials production.* Six principal nuclear materials are used in nuclear weapons: uranium 235, uranium 238, plutonium 239, tritium, deuterium, and lithium 6. During the Manhattan Project to develop the first atomic bombs, huge complexes were built at Hanford, Washington; Oak Ridge, Tennessee; and various other supporting facilities to produce these materials.

For some time after World War II nuclear materials were in limited supply. Building more warheads required more highly enriched uranium and plutonium. To the original three Manhattan Project reactors at Hanford were added five more between October 1949 and April 1955. When President Truman decided to proceed with the hydrogen bomb it was thought that huge amounts of tritium—an isotope of hydrogen that fuses with deuterium, another hydrogen isotope, in a thermonuclear reaction—would be needed. So the Savannah River plant was built near Aiken, South Carolina, to produce both plutonium and tritium. In the early 1950s uranium enrichment and processing facilities were expanded and added at Oak Ridge; Paducah, Kentucky; and at Portsmouth, Fernald, and Ashtabula, Ohio.

Savannah River and Hanford are now the mainstays of nuclear materials production, with facilities at Fernald, Ashtabula, Oak Ridge, and Idaho Falls, Idaho, playing key supporting roles in the production cycle. Only plutonium and tritium are currently being produced. [See sidebar]. Other materials requirements are satisfied from existing inventories.

• *Warhead component production.* Facilities to mass produce nuclear and non-nuclear warhead components were built in the late 1940s and early 1950s at the Mound facility in Miamisburg, Ohio; the Kansas City plant; and the Rocky Flats plant near Denver, Colorado. Two final assembly plants—in Burlington, Iowa, and the Pantex plant near Amarillo, Texas—were built in 1947 and 1951 respectively.

Nuclear warhead components are now manufactured at seven facilities. Rocky Flats processes plutonium and assembles plutonium and enriched uranium cores used as fission weapons and as fission triggers in thermonuclear weapons. The Y-12 plant in Oak Ridge manufactures uranium components for weapons and the lithium deuteride and uranium components of the thermonuclear stages of weapons. Tritium is produced, processed, and made into components for nuclear weapons at Savannah River. Mound makes detonators and various parts of the firing circuits. The Pinellas plant in St. Petersburg, Florida, manufactures neutron generators that initiate the chain reaction. Kansas City makes electronic and other non-nuclear parts. All of these components are shipped to Pantex, which manufactures chemical high-explosive components and assembles all the components into finished warheads.

• *Testing.* Currently U.S. (and British) nuclear explosive devices and finished warheads are tested at the Nevada Test Site. The nearby Tonopah Test Range is used to test mock warhead performance such as bomb drops with parachutes and the ballistics of artillery shells and rockets. Supplementing these facilities are the Defense Department's test ranges in Florida, California, and New Mexico.

THE STOCKPILE IS constantly in flux, with warheads being produced, retired, or modified every day. The capacity of the complex and the tempo of the activity have varied greatly over the past four decades. The current capacity to produce, retire, or modify—each activity is approximately equivalent in terms of labor, space, and time—is 3,500 to 4,000 warheads per year. The Energy Department budget for these activities for fiscal 1988 is about $7.8 billion. That exceeds, in current dollars, the spending during the Man-

A military nuclear fuel cycle primer

U.S. nuclear warheads contain at least a few kilograms of weapon-grade plutonium or highly enriched uranium, sometimes called "fissile" materials.

Most U.S. nuclear warheads also contain tritium. Its use has led to smaller and more efficient warheads. Tritium is also required in "neutron" warheads, being largely responsible for this weapon's ability to produce more neutron radiation than do standard warheads of the same explosive power.

Each year 5.5 percent of the tritium decays radioactively into helium. As a result, it must be replenished in weapons. Plutonium and weapon-grade uranium essentially last forever because they decay so slowly that they do not have to be replenished in this way.

The Energy Department currently produces plutonium and tritium in a "military nuclear fuel cycle" at six major sites that comprise an area about one-and-a-half times the size of Rhode Island (see nuclear materials sites and activities on the map).

Plutonium and tritium are produced in production reactors that are as large as commercial nuclear power reactors. Four of these—P, K, L, and C (now shut down due to cracks in its structure)—are at the Savannah River plant near Aiken, South Carolina. The fifth U.S. production reactor, the N reactor on the Hanford reservation near Richland, Washington, was used as a "dual-purpose" reactor to produce plutonium and to generate electricity for sale to local utilities. It is now shut down for safety modifications.

Inside the nuclear reactors, uranium 235 in the fuel fissions into two lighter, highly radioactive atoms or "fission" products, releasing neutrons and a great deal of heat. Some of the neutrons strike and fission other uranium 235 atoms, thereby perpetuating the fission reaction. Others are absorbed by uranium 238, transforming it into plutonium, or by lithium, transforming it into tritium.

Plutonium is separated from the highly radioactive fission products, transuranics, and leftover uranium in heavily shielded and remotely run "reprocessing" facilities—the F canyon at Savannah River and the PUREX (plutonium-uranium extraction) plant at Hanford. PUREX was restarted in 1983 after an 11-year shutdown.

Tritium is extracted from irradiated lithium in a special facility at Savannah River and transferred to the Savannah River tritium facility where it is loaded into containers for subsequent insertion into weapons.

Not all of the plutonium separated at the reprocessing facilities is weapon grade. Much of the plutonium separated at PUREX is fuel grade, a lesser-quality plutonium that was produced in the N reactor until 1982 and accumulated in spent fuel during the period when PUREX was shut down.

The separated fuel-grade plutonium is sent to Savannah River, where it is converted to weapon-grade plutonium by blending it with super-grade plutonium which Savannah River production reactors have been making since the early 1980s.

Weapon-grade plutonium from both Hanford and Savannah River is sent to Rocky Flats, Colorado, where it is shaped into forms suitable for weapons. Rocky Flats also recovers plutonium from old warheads.

After the plutonium and weapon-grade uranium are shaped into forms suitable for nuclear weapons, they are sent to the Pantex plant outside Amarillo, Texas, where along with components produced in facilities located in Florida, Ohio, and Missouri, they are assembled into nuclear warheads. The warheads are delivered to the military, which deploys them to many sites around the globe.

—adapted from David Albright and Martha Fell, "The Military Nuclear Fuel Cycle," Greenpeace Disarmament, *Winter 1986–87.*

hattan Project and approaches the peak spending of the late 1950s and early 1960s.

While the budgets are at near-record highs, however, the production rates are not. In the late 1950s and early 1960s the warhead production complex was operating at peak capacity in more than 20 facilities. Between 1959 and 1961 warheads were being produced at the rate of 5,000 to 6,000 a year. Nuclear materials production peaked between 1961 and 1963 at some 60 tonnes (metric tons) of highly enriched uranium and 7.5 tonnes of plutonium equivalent (plutonium and tritium) per year.

Early in the Kennedy administration a decision was made to scale back materials production. In 1964 President Johnson proposed to the Soviets a staged cutback in the production of highly enriched uranium and weapon-grade plutonium. The Soviets rejected the offer, but because of abundant stocks the United States shut down 10 reactors between 1964 and 1971. Uranium enrichment activities were greatly decreased during this period. After the enormous warhead buildup of the 1950s and 1960s—the numerical high was reached in 1967—the stockpile stabilized in numbers and underwent qualitative changes. By 1977–78 only a few hundred warheads a year, of a single type, were being produced.

While budgets are at near-record highs, production rates are not. The warhead complex was operating at peak capacity in the late 1950s and 1960s.

Beginning in the late 1970s several political and international factors led to renewed activity in the production complex. The waning of détente, the Soviet invasion of Afghanistan, the U.S. failure to ratify SALT II, and the election of Ronald Reagan each influenced decisions to increase the capacity of the warhead production complex. At the same time new goals and guidelines were established for the use of nuclear weapons (Presidential Directive 59, signed by President Carter in 1980). These were used to justify new warheads as well as to rationalize those in development.

Cruise, MX, Trident I, and Pershing II missiles, as well as neutron weapons and new bombs, were scheduled for deployment between 1979 and 1986. Some who studied these plans in the late 1970s concluded that there would not be enough fissile materials or sufficient capacity in the complex to produce them. The Senate and House Armed Services committees visited Energy Department facilities and found the department lacking a comprehensive program to meet the pending warhead schedule. The department provided a five-year plan to correct deficiencies, and a joint Defense/Energy planning group was directed to develop plans to upgrade and expand the production complex over the next 20 years.

President Carter bequeathed to Ronald Reagan an already increased set of production goals and programs. Upon entering office Reagan increased these further, adding $300 million to Carter's Atomic Energy Defense Activities request and increasing the materials production request from $837 million to $931 million. Reagan revived some weapons and increased goals for others, although there were decreases in a few programs. Enhanced-radiation (neutron) weapons would be produced, new naval nuclear weapons were envisioned, and Pershing II and ground-launched cruise missiles became top priorities to meet a December 1983 deployment deadline.

While the numbers of warheads projected in Reagan's force plans were not significantly higher than Carter's already increased goals—only 380 more for the first five-year period—a different mix of warheads coupled with technological developments drove projected nuclear materials production requirements higher. Smaller warheads with higher yields require additional plutonium, and more tritium would be needed for enhanced-radiation warheads.

"As a matter of policy, national security requirements shall be the limiting factor in the nuclear force structure," the president stated in approving his second nuclear force plan. He added: "Arbitrary constraints on nuclear material availability . . . shall not be allowed to jeopardize attainment of the forces required to assure our defense and maintain deterrence."

Also apparently included in this secret plan, issued in November 1982, were requirements for creating "sufficient reserves" of special nuclear materials. These reserves were said to be needed "as insurance against unforeseen [special nuclear materials] production interruptions and to allow for [a warhead production] surge capacity."

Several initiatives are underway to augment further the supply of nuclear materials and to assure production into the next century. The Energy Department could resume the production of highly enriched uranium as early as fiscal 1990 to meet new requirements for weapons. Projected demand for tritium has lessened since early in the Reagan administration, but substantial quantities will be required for existing warheads, to compensate for radioactive decay. The administration says it will continue to produce plutonium to meet increases in stockpile numbers, create additional reserves, and accommodate designs that require more plutonium per warhead.

At Savannah River, the department is planning to introduce new reactor fuel to increase the efficiency of plutonium production. The N reactor at Hanford, now shut down for safety improvements, will reach the end of its projected operating life in the mid-1990s, even if it is refurbished. Plans are to restart the N reactor and to build either one or two new production reactors for plutonium and tritium. The Energy Department also plans to build a special isotope separation plant at the Idaho Nuclear Engineering Laboratory, to begin operation in 1995. This plant would use laser isotope technology to enrich fuel-grade plutonium to weapon-grade plutonium for warhead use. □