Title
INTRODUCTION TO THE JOURNAL OF GLENN T. SEABORG, CHAIRMAN OF THE U.S. ATOMIC ENERGY COMMISSION, 1961-1971

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Publication Date
1989-03-09

PUB-651

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

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G.T. Seaborg

December 1988

NUCLEAR SCIENCE DIVISION

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098.

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PUB-651

Introduction to the Journal
of
GLENN T. SEABORG
CHAIRMAN OF THE U.S. ATOMIC ENERGY COMMISSION
1961–1971

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December 1988

This serves as an introduction to the 25-volume detailed daily diary kept by Glenn T. Seaborg during the time he served as Chairman of the U.S. Atomic Energy Commission. It is a brief synopsis of some of the major issues and accomplishments of that period, 1961–1971, of U.S. nuclear history. It is expected that the diary itself will be printed as a Lawrence Berkeley Laboratory report during the next year.

This work was supported by the U.S. Department of Energy under Contract DE-AC03-76SF00098.

XBB 732-892

Visit of President John F. Kennedy to the U.S. Atomic Energy Commission Headquarters, Germantown, Maryland, February 16, 1961.

USAEC Chairman Seaborg giving President Kennedy a lesson in basic atomic and nuclear structure.

INTRODUCTION

This introduction to my journal of 1961–1971, covering my years of service as Chairman of the U.S. Atomic Energy Commission, is written from the perspective of 1971, in order to reflect the attitudes expressed in my journal, which was written on a daily basis during that period. Thus, I express the points of view of that time rather than those of today (1988), which might occasionally be somewhat different.

I served as AEC Chairman from March 1, 1961 until August 17, 1971, ten and a half years. President Kennedy appointed me first to a two and a half year term, the time remaining on the appointment of John McCone, whom I replaced as chairman. Kennedy reappointed me to a full five-year term when the initial appointment expired in 1963. President Johnson reappointed me in 1968, limiting the appointment, at my request, to a two-year term. When President Nixon reappointed me in the summer of 1970, it was with the understanding that I would return to my professorial post at Berkeley a year later. The termination date of this appointment, August 17, 1971, occurred while I was in the Soviet Union leading a group of U.S. nuclear scientists, engineers, and administrators on visits to Soviet nuclear establishments and laboratories. The president asked me to continue with the visit and to serve in September as head of the U.S. delegations to the Fourth U.N. Conference on the Peaceful Uses of Atomic Energy (in Geneva) and the Fifteenth General Conference of the IAEA (in Vienna).

President-Elect Kennedy first offered me the position in a telephone call from Boston on January 9, 1961. I had never met Kennedy, although I attended the Democratic National Convention in August 1960 and heard him give his eloquent acceptance speech.

Upon my arrival in Washington I was greeted cordially by outgoing AEC Chairman John McCone, who introduced me to his key staff, including his administrative assistant Howard Brown, his chief secretary Mildred Cecil, his driver James Haddow and his general assistant Cecil King. On McCone's recommendation I asked all of them to stay on. I also met my new colleagues, fellow commissioners John S. Graham, Loren K. Olson, and Robert E. Wilson, the Commission's General Manager Alvin R. Luedecke, Deputy General Manager Robert E. Hollingsworth (who became General Manager in 1964), Secretary Woodford B. McCool, the six Assistant General Managers (Dwight A. Ink, E. J. Bloch for Operations, Spofford G. English for Research and Development, George F. Quinn for Plans and Production, Algie A. Wells [Acting] for International Activities, and Harry S. Traynor for Administration), the Division Directors, and other principal staff. Many of these individuals I had known from previous contacts with the AEC. During my first meeting with President Kennedy, in the reviewing stand for the inaugural parade in front of the White House on January 20, 1961, he suggested that I find a scientist to fill the vacancy in the five-member Commission. I suggested Leland J. Haworth and he was appointed soon after I became Chairman.

The composition of the Commission and its officers and of my staff changed throughout my ten and one-half years as chairman. The Commissioners who served as my colleagues on the Atomic Energy Commission are listed in Appendix A—a total of 13 in all. Marie Janinek soon joined me as a lead secretary and remained with me during the entire ten and one-half years. When Mildred Cecil left to join the Regulatory staff in the spring of 1967 she was replaced by Helen Gearin. My administrative and technical assistants at various times over the years included, besides Howard Brown, Chris Henderson, Arnold Fritsch, Victor Schmidt, Julius Rubin and Justin Bloom. My principal speech writers were Dan Wilkes, John Napier, and especially Stanley Schneider. Among those assisting me with writing assignments were Benjamin Loeb, Betsey McFadden and Sydney Gaarder.

Although the commissioners operated pretty much as a collegial body, we did use a system of "lead" commissioner, in which individual commissioners paid special attention to certain areas of the AEC's program. For example, John Graham and Robert Wilson specialized on civilian nuclear power; Loren Olson on regulation; Leland Haworth, Gerald Tape and Clarence Larson on weapons and research (and attended meetings of the Federal Council on Science and Technology); James Ramey on regulation and civilian nuclear power; John Palfrey on international activities; Samuel Nabrit and Polly Bunting on life sciences and education; Theos Thompson on weapons and civilian nuclear power; and Wilfrid Johnson, on civilian nuclear power.

Congressional oversight was a very serious fact of life for the AEC. In our case it was exercised primarily by the Joint Committee on Atomic Energy, a unique body established by the Atomic Energy Act. Under the statute, we were required to keep the JCAE "fully and currently informed" on all our activities. In addition, the AEC's budget had to be authorized in detail by the JCAE before it could be acted upon in the normal appropriations process. Much of my time and that of the other commissioners and principal staff was spent testifying at hearings held by the Joint Committee on various aspects of the AEC's program. The record of these hearings provide a valuable source of information on the agency's programs throughout its history. According to a custom established by the committee itself, its chairmanship alternated each Congressional session between a House member and a Senate member. During my tenure the post was filled alternately by California Congressman Chet Holifield and Rhode Island Senator John Pastore. By and large, we had smooth relations with the JCAE and the White House. These sometimes required a difficult balancing act by the AEC.

Soon after I came, I initiated Information Meetings (held in the Chairman's Conference Room), informal sessions of commissioners and staff, to deal in an expeditious manner with day-to-day operational and administrative matters. These sometimes dealt with as many as 30 or 40 agenda items. They were in addition to the long-established, more formal Commission Meetings (held in the Commissioners' Conference Room), in which the commissioners and staff dealt with policy matters and more long-range business, usually with the help of staff papers submitted by the general manager stating a problem, possible solutions, and recommending an action. During my tenure I presided over some 1700 Information Meetings and some 850 Commission Meetings. About 500 of the Information Meetings and 100 of the Commission Meetings dealt exclusively with regulatory matters.

From its inception the AEC had a profusion of advisory committees. I was familiar with the nine-member General Advisory Committee (GAC), having served as a charter member when the committee was established in 1947 The GAC [see Appendix B] met about four times per year and advised the Commission on major scientific and technical questions. Another important committee was the Advisory Committee on Reactor Safeguards (ACRS), which was charged with various safety studies and with the responsibility for reviewing licensing applications in the civilian nuclear power field. The ACRS met monthly and, later in the decade, as the applications for licenses burgeoned, created subcommittees that met several times a month. The Military Liaison Committee (MLC), whose responsibility was to assure adequate liaison between the Commission and the military services, had been very active in the AEC's early days, when policies concerning nuclear weapons were being debated. By 1961, however, the MLC's importance had diminished and, during my chairmanship, it met with us only about once a year. There were more than a dozen other committees advising the AEC on particular subject areas and some of these occasionally met with the Commission.

Since 1957, the AEC's official headquarters was at Germantown, Maryland, some 30 miles from downtown Washington. This made for great inconvenience for those of us who needed to transact business at the White House, the Executive Office Building, Congress, and government departments and agencies in Washington. Therefore, an alternative headquarters had been established in rented space at the Matomic Building (1717 "H" Street, NW) two blocks from the White House, where my fellow commissioners and I, secretarial and key staff, spent most of our time. Still, we regularly held forth in Germantown as well. This gave rise to serious logistical problems because all of our files had to accompany us as we moved from one office location to the other. Adding to the cumbersome arrangement was the fact that the Regulatory people were quartered in still a different location, namely in rented space in Bethesda.

At one of my first meetings with Budget Director David Bell he suggested that we should try to move toward replacing the five-member Commission with a single administrator, a position that I would presumably fill. The other commissioners were amenable, and on May 16, 1962, we sent him a letter. We argued that, due to changed circumstances, the initial concern over concentration of too much power in a single individual had become relatively less important than the need for a more efficient decision-making process. This was a remarkable step---a government administrative body was recommending its own demise. An additional reason why the White House wanted this change was to reduce the leakage of confidential administrative information to the JCAE. There had been many such leaks.

Attempts to get the support of the Joint Committee on Atomic Energy, which would have had to provide the necessary legislation to effect the change, were without success. Congressman Holifield, a powerful force in the JCAE, was adamantly opposed. Several later attempts, including some during the Johnson Administration, were similarly unsuccessfull. I was not too disappointed with this result. I found the Commission form of administration, although somewhat cumbersome, to have many advantages for attacking the numerous knotty problems we faced. Five minds were potentially better than one.

Worthy of special note was the role of Admiral Hyman S. Rickover, head of the joint Navy-AEC naval reactors program. The commissioners and I had good rapport with Rickover, but we couldn't claim that we gave much direction to his program. Brilliant, articulate and irascible, Rick was his own man. No more than by the AEC could he be controlled by the Department of the Navy, and largely for that reason, successive naval secretaries tried to get rid of him, especially after he reached the nominal retirement age. Navy Secretary Paul Nitze tried especially hard, but met with no more success than other secretaries. The prime reason was that Rick had enormous influence in Congress, which always insisted on his reappointment as Admiral and as head of the naval reactors program. The other commissioners and I visited him on occasion at his buildings on the mall just off Constitution Avenue. He, of course, attended Commission Meetings whenever he had an issue to propose or defend.

I recall that in February 1962, Rick invited me and my whole family to Norfolk and Newport News, Virginia, to visit the cruiser Long Beach, the first nuclear-powered surface ship, to attend the launching of the nuclear submarine Thomas Jefferson, and to have lunch on the nuclear submarine Sam Houston. On other occasions I took an overnight cruise with him on a nuclear submarine (where my fellow commissioners and I held a regular Commission Meeting), made an exciting, tight landing on the nuclear aircraft carrier Enterprise, and spoke at the commissioning of the nuclear-powered submarine Sturgeon at the U.S. Naval Submarine Base at New London, Connecticut.

During my decade as chairman Rick led the development at his Westinghouse Bettis Laboratory in Pittsburgh, at the AEC's National Reactor Testing Station (NRTS) in Idaho, and at other research facilities of more efficient, new, powerful and compact reactors for the propulsion of naval vessels. During the decade an extraordinary number of nuclear-powered naval vessels was built and launched. Thus, construction was begun on 43 attack submarines, 32 Polaris missile submarines, two aircraft carriers and three guided missile cruisers. Forty-four attack submarines, 38 Polaris missile submarines, one aircraft carrier and three guided missile cruisers were commissioned.

Rickover also ran an important show in the civilian nuclear power field. He utilized the pressurized water reactor technology developed for naval propulsion as a basis for design of the Duquesne Power and Light Company's Shippingport Atomic Power Station near Pittsburgh, which in 1957 became the world's first commercial nuclear power plant. Rick used this reactor as a basis for the development of the thermal neutron breeder reactor, the Light Water Breeder Reactor (LWBR) (the "Seed and Blanket" concept), and he continually encouraged the Commission to support this project.

As AEC Chairman, I was a member of a number of interagency committees that existed for all or part of my tenure. Foremost of these was the Committee of Principals, which advised the president on arms control policy. Established by President Eisenhower, this group was expanded and achieved new prominence under President Kennedy, continued to be important in the Johnson administration, but was abandoned by President Nixon in favor of more closely held White House control. Other committees that I or my designated representative attended included the Federal Council of Science and Technology (FCST, 1961-1971, composed of scientific representatives of federal agencies that had a science component in their operations); the U.S. Intelligence Board; the Federal Radiation Council (1961-1969); the President's Committee on Equal Employment Opportunity (1961-1965); the President's Science Advisory Committee (PSAC), as an observer and as an alumnus of this Committee; the National Aeronautics and Space Council (1961-1971); and the National Council on Marine Resources and Engineering Development (1966-1971). Vice Presidents Johnson, Humphrey and Agnew served as chairmen of the Space Council, Humphrey and Agnew of the Marine Council—I first became well acquainted with Lyndon Johnson because of his service as chairman of the Space Council.

I also found time while I was chairman to publish some books. In 1962, my book <u>Man-Made Transuranium Elements</u> appeared. Intended as part of the high school CHEM Study program (which I continued to serve as chairman of the Steering Committee), it turned out to have much wider appeal. In 1964, Earl K. Hyde, Isadore Perlman and I came out with the two-volume treatise (long in preparation) <u>The Nuclear Properties of the Heavy Elements</u>. Volume I was entitled <u>Systematics of Nuclear Structure and Radioactivity</u> and Volume II, <u>Detailed Radioactivity Properties</u>. Also, in 1964, Daniel Wilkes and I, with the help of Benjamin Loeb, produced <u>Education and the Atom</u>, which was used as a U.S. presentation volume given to the delegates of all countries at the Third Geneva Conference on the Peaceful Uses of Atomic Energy. The year 1969 saw publication of <u>Oppenheimer</u> with co-authors Isidor Rabi, Robert Serber, Victor Weisskopf, and Abraham Pais. And in 1971, there was <u>Man and Atom: Building a New World Through Nuclear Technology</u> with co-author William R. Corliss, a U.S. presentation volume at the Fourth Geneva Conference on the Peaceful Uses of Atomic Energy. Also, the AEC published several volumes of my speeches in paperback form.

I, of course, had close operating relationships with the presidential science advisors---Jerome Wiesner in the Kennedy Administration, Wiesner and Donald Hornig in the Johnson Administration, and Lee Du Bridge and Edward David in the Nixon Administration. Wiesner had an excellent working relationship with Kennedy. The role of the science advisor faded under Johnson and due in part to the attitude of Henry Kissinger deteriorated even further under Nixon. Du Bridge, for example, was completely frozen out of discussions on arms control policy. Although I had known Nixon since February, 1948 (when we met in Chattanooga, Tennessee, as members of the Junior Chamber of Commerce's "Ten Outstanding Young Men of the Year") my relations with him as president were less close than those I had with Kennedy and Johnson. I was not, like Du Bridge, cut off entirely from arms control matters, but my information came secondhand through the staff of our Division of International Affairs. Nixon's attitude seemed to be mirrored in a comment he made after I offered an opinion at a meeting about a SALT proposal. He said that he would look to me for scientific, but not for political, advice.

There were several episodes during the Nixon Administration that led to difficulties for me. During the early period when there was a push for the installation of an ABM system in the United States I was asked by Nixon's aides to make supporting speeches. This I declined to do. (Later, Nixon, to his credit, revised his own position and began the negotiations with the Soviet Union that led to the ABM Treaty.) I had a brush with Attorney General John Mitchell in connection with a charge that fissionable material had been diverted to Israel from a processing plant in Pennsylvania. He wanted me to revoke, without a hearing, the security clearance of the key individual involved. This I refused to do, as a matter of principle and because I was convinced that the charge was false.

I was pleased when President Kennedy volunteered in 1961 to make the presentation of the AEC's Fermi Award ($50,000, a medal and a certificate) in a White House Oval Office ceremony to the eminent Cornell physicist, Hans A. Bethe. Kennedy repeated this for the presentation to Edward Teller in 1962 and President Johnson continued the practice with his presentation to J. Robert Oppenheimer in 1963 and to subsequent award winners during his Administration, Admiral Hyman G. Rickover for 1964 , and John A. Wheeler for 1968. The Commissioners and I presented the Award in 1966 to Otto Hahn and Fritz Strassman in Vienna and I, to Lisa Meitner in Cambridge, England. No Awards were given in 1965 and 1967. I made the presentations to Walter H. Zinn in 1969 and Norris E. Bradbury in 1970 because President Nixon refused to carry on the tradition started by Kennedy and Johnson.

With Presidents Kennedy and Johnson I was given the privilege of appealing to the President some of the adverse budgetary decisions made by the Bureau of the Budget. With Kennedy this was done in White House meetings and with Johnson in meetings (in December) at his ranch in Texas. Here I defended my requests for budget restorations in debates with the Director of the Bureau of the Budget before the President. I was singularly successful in winning the approval of President Johnson. In my one opportunity to present an appeal to President Nixon I didn't win a single point. Thereafter, I was asked to present my appeals through the OMB director (Office of Management and Budget, the changed name from BOB), the person who had already ruled against me; this procedure led to no appeal victories for me.

The sections that follow provide an historical summary of the major activities and events with which the Atomic Energy Commission was associated during the period of my chairmanship (1961- 1971). This is done in a topical manner, i.e., by describing in summary form the accomplishments in each of a selected number of subject areas over the ten-year period. This is in preference to dividing the account into three parts, covering the Kennedy, Johnson and Nixon administrations, which would inevitably result in a good deal of repetition in thus describing each of the subject areas three times.

I have chosen to touch briefly (not in any order of priority) on the following subjects:

- I. The Limited Test Ban Treaty (LTBT)
- II. The Nonproliferation Treaty (NPT)
- III. Arms Limitation
- IV. The Cuban Missile Crisis
- V. The program of international cooperation, including my visits to 60 countries
- VI. Support of research
- VII. Los Alamos Meson Facility and 200 Bev Accelerator
- VIII. The National Transplutonium Production Program
- IX. Civilian nuclear power
- X. Raw Materials Program
- XI. Gas Centrifuge Program
- XII. Cutback in production of fissionable materials
- XIII. Regulation
- XIV. Radioisotopes Program
- XV. Nuclear power in space
- XVI. Nuclear weapons tests
- XVII. Plowshare
- XVIII. Controlled thermonuclear research (CTR)
- XIX. Nuclear education and training
- XX. Technical information
- XXI. Civil Defense

I. The Limited Test Ban Treaty (LTBT)

The United States, United Kingdom, and USSR began serious negotiations on a test ban treaty late in 1958. They were impelled to the bargaining table in part by a worldwide concern over radioactive fallout from nuclear tests. The negotiations soon became bogged down over disagreements about the details of a control system. Essentially, the United States wanted extensive controls because of a suspicion that the Soviets would cheat; the Soviets resisted controls because of a suspicion that we would use them for espionage. Nevertheless, a compromise agreement was almost reached in the spring of 1960 on a treaty that would have barred all tests considered to be verifiable; namely, all except underground tests producing signals of less than 4.75 on the Richter scale. Shortly before a Big Four summit at which it was thought such a treaty might be signed, however, the U-2 incident occurred and the way this was handled ended hopes of any agreement during the Eisenhower administration.

President Kennedy was deeply committed to achieving a nuclear test ban treaty with the Soviet Union and he pursued this goal persistently, despite numerous discouragements, showing sensitivity and patience in his diplomatic relations with both the Soviet Union (meaning, basically, with Nikita Khrushchev) and with the United States Senate. Discussions within the Committee of Principals, in which I participated, to define a U.S. position began immediately, in February 1961, and negotiation with the Soviet Union, within a matter of weeks thereafter, in March 1961. A draft treaty was introduced by the U.S. and U.K. in April 1961. It would have banned all but smaller underground tests; offered a moratorium on such tests; and allowed the Soviets to inspect devices we proposed to use for seismic research or for AEC's Plowshare (peaceful nuclear explosions) program. We also agreed to a Soviet suggestion that the number of onsite inspections on the soil of each party be limited to an annual quota. The most serious disagreement was over the size of this inspection quota: we proposed it be 20, the Soviets, while contending that no inspections were necessary, offered to accept three as a political concession to Kennedy. Over the ensuing two years we several times modified our quota demand until in February 1963 our chief negotiator was authorized to produce the number six as a final fall-back offer. But the Soviets would go no higher than three.

In August 1961 the Soviets surprised us by breaking an informal test moratorium begun three years earlier and launching a massive series of atmospheric tests. After some hesitation, President Kennedy authorized a series of U.S. atmospheric tests which took place in the Pacific between April and November 1962. (See Section XVI.)

President Kennedy's extraordinary commencement address at American University on June 10, 1963, finally set the stage for the high-level negotiations with the Soviet Union. Kennedy chose W. Averell Harriman, the experienced American diplomat, who had the respect of the Soviet leadership, to lead the U.S.-U.K. negotiating team in Moscow. On the specific issue of a test ban, Harriman was instructed that the achievement of a comprehensive test ban remained the U.S. objective. If that was unobtainable, he was to seek a limited treaty in three environments, (atmosphere, water and space) along the lines of a Western draft treaty of August 1962. Khrushchev made it clear before the emissaries arrived, however, that he was prepared to accept only a limited test ban, not the comprehensive agreement Kennedy wanted.

Harriman made an unsuccessful attempt to negotiate a Comprehensive Test Ban Treaty, then went on to negotiate the details of the Limited Test Ban Treaty. In 12 days of intensive negotiation in July, which Kenendy supervised on a daily basis, Foreign Minister Gromyko and Averell Harriman, leader of the small U.S. negotiating team, with minor British participation reached agreement on a treaty. It banned all tests in the atmosphere, outer space, and under water, environments where verification was feasible without onsite inspection. In order to achieve agreement with the Soviets, Harriman had to give up the U.S. peaceful uses of nuclear explosives (the Plowshare) provision in exchange for Soviet acceptance of a withdrawal clause.

I was pleased to be a member of Secretary of State Dean Rusk's delegation, which flew to Moscow for the signing, on August 5, 1963, exactly 18 years after Hiroshima, of the Limited Test Ban Treaty. We met with Soviet Chairman Nikita Khrushchev for an hour in his office in the Kremlin in the morning to discuss the significance of the Treaty, the future of East-West relations, etc. The Treaty was signed at 4:30 p.m. in the Kremlin's Catherine Hall by Rusk, Soviet Foreign Minister Andrei Gromyko and British Foreign Minister Lord Home.

To help assure a large favorable vote in the Senate, Kennedy agreed to four national security "safeguards" put forward by the Joint Chiefs of Staff as conditions for their support. These required the president to commit himself to a vigorous underground testing program, high-level maintenance of weapon laboratories, continued readiness to resume atmospheric testing, and improving our ability to detect Soviet violations.

The treaty was referred for study to the Committee on Foreign Relations, which began hearings on August 12, four days after the Senate received the President's message. The first three witnesses before the Foreign Relations Committee—Secretary of State Dean Rusk, Secretary of Defense Robert McNamara and I—were each separately questioned, each for an entire day. Without doubt, the most important aspect of my testimony of August 14 had to do with the effect of the treaty on the AEC's Plowshare program for peaceful nuclear explosions. Reassured by the safeguards and by forecasts (some by me during my day-long testimony) that peaceful nuclear explosion experiments would be permissible under the treaty, a number of senators who had been leaning against voted in favor. On September 24, 1963, the momentous vote on the treaty was taken. Every able-bodied senator was present. The treaty was approved by a vote of 80 to 19. This was 14 votes more than the required two-thirds majority, a margin that satisfied the President's desire for a strong endorsement. The treaty entered into force on October 10.

II. The Nonproliferation Treaty (NPT)

It was fear of the further spread of nuclear weapons more than any other consideration that prompted President Kennedy's push for a comprehensive test ban. Kennedy was so concerned about China acquiring the bomb that he authorized Averell Harriman, when the latter was in Moscow negotiating the Limited Test Ban Treaty, to feel out Khrushchev on the subject of launching a joint preemptive strike on China's nuclear facilities. Khrushchev shrugged off the suggestion—he said he didn't think China would be a serious nuclear threat.

By the time Lyndon Johnson became president, the Arms Control and Disarmament Agency had adopted nonproliferation as its number one objective. This position conflicted with another objective, which had strong support in the State Department, namely, the establishment of a NATO naval force, manned by personnel from several nations, and equipped with U.S. nuclear weapons, the so-called Multilateral Force (MLF). The purposes of the MLF included giving NATO countries, particularly Germany, a greater role in planning their own defense, thereby helping to dissuade them from wanting to be independent nuclear powers; preserving allied cohesion in the face of the Soviet threat; and encouraging the budding movement toward a united Europe. While it could be, and was, argued that the MLF and a nonproliferation treaty were not inconsistent, the former tended to exclude the latter because of the Soviet Union's attitude. The Soviets were fiercely hostile to a scheme that seemed to place a revengeful West German finger on the nuclear trigger. They made it clear they would not join in an NPT unless we abandoned the MLF.

Germany, and to a lesser extent Italy, seemed interested in the MLF from the start. The British were opposed—they didn't think this was any way to run a navy. Other NATO allies were indifferent at best. President Kennedy was himself rather cool toward the idea, although he was willing to go forward if the allies showed a clear desire to do so. Later, after France began to distance itself from NATO, Kennedy showed more interest because of a desire to give the Germans an alternative to nuclear cooperation with France. But there was strong opposition in Congress to sharing U.S. weapons with anybody, and to do so would have required Congressional approval in the form of an amendment to the Atomic Energy Act.

Despite the political problems, technical work on the MLF went forward, and when Johnson became president he was immediately subjected to strong pressures from MLF advocates in the State Department. Following some intense discussion within the administration he authorized a campaign to sell the idea to our allies, hoping to reach agreement by the end of 1964.

But then, on October 16, 1964, my journal contained the following entry:

> "The big news today is that at 3 a.m. Washington time the Red Chinese exploded an atomic bomb in the atmosphere."

Our analysis of the debris convinced us, to our surprise, that the Chinese had detonated a ^{235}U device of sophisticated design, not a plutonium bomb such as the other four nuclear powers had used for their first tests. I reported these findings to a Cabinet meeting on August 20.

The Chinese test had long been expected, but the actual occurrence nevertheless shook up the whole international equation. Potent forces in India immediately began agitating for an Indian bomb to match China's. This made the Pakistanis edgy. The Australians began to stir. Proliferation seemed to be in the air. The need for an NPT seemed more urgent.

President Johnson had to confront the MLF issue seriously in December 1964. The occasion was a visit by British Prime Minister Harold Wilson. The principal item on the agenda was the MLF, and the British had made no secret of their opposition. But it was probably the runup to the meeting rather than the meeting itself that had the biggest effect on the President's mind. In five days of intensive meetings with his principal advisors, Johnson grappled with the MLF question, seeking a policy position of his own. In the end he determined that the United States, while not opposing the MLF, would no longer actively try to bring it about.

The president's new position, by seeming to remove the MLF obstacle, really energized the diplomatic quest for an NPT. In August 1965 the United States unfurled a complete draft at the Eighteen Nation Disarmament Conference (ENDC). The draft did not fully rule out a future MLF, however—die-hards in State had managed to keep it alive—so the Soviets promptly rejected the draft. The Soviets wanted to outlaw any transfer of nuclear weapons whatever—their position seemed to bar even existing NATO arrangements by which U.S. weapons were stationed in Europe. Then Secretary McNamara devised a substitute for the MLF—the idea of a consultative committee to devise NATO nuclear strategy. This seemed to satisfy the motive of giving Germany and other NATO allies a voice in their own nuclear defense.

The situation now seemed ready for forward movement on an NPT. The missing ingredient was presidential involvement. President Johnson had become somewhat disengaged from arms control matters because of his preoccupation with the Vietnam War following the major escalation early in 1965. Pressures to get him to focus again on the NPT came from a number of directions. One was a Senate resolution in May 1966 that urged "additional efforts by the president. . . for the solution of nuclear proliferation problems." Next, some inside the administration managed through Bill Moyers, to get to the president and make the case on the urgency of getting an NPT. The break seemed to come on July 5, 1966, when, in answer to a question at a news conference, the president stated: "We are going to do everything within the power of our most imaginative people to find language which will bring the nuclear powers together in a treaty which will provide nonproliferation." Secretary of State Rusk, previously quite removed form the issue, now became for the first time an active and very effective NPT advocate.

Just to allay any doubts there might have been about where he stood, President Johnson stepped up the pressure in a speech at the National Reactor Testing Station on August 26, 1966. Speaking of the NPT negotiations, the president said, "I believe that we can find acceptable language on which reasonable men can agree." The search for such language was underway in hard and intense and private negotiation between the U.S. and Soviet sides.

On October 10, 1966 Foreign Minister Gromyko showed up at the White House in a visit full of smiles, indicating that the process had borne fruit. On December 5, 1966, the two sides unveiled the text of the first two articles of an NPT. Article I forebade states having nuclear weapons from transferring them "to any recipient whatsoever." Article II forebade States not having nuclear weapons from accepting their transfer or manufacturing them. Article I essentially ruled out the MLF. The United States, however, prepared a series of interpretations which we told the Soviets would be submitted to the Senate with the treaty. Most important of these was that the treaty would not prevent a federated European state, if one ever developed, from inheriting the nuclear weapons of Britain or France, or both. Apparently, the Soviets considered this eventuality sufficiently remote that they were willing to take a chance on it.

After the breakthrough on Articles I and II, there was still one other important matter to clear up. This concerned so-called "safeguards," meaning inspections and other mechanisms for detecting on a timely basis any diversion of nuclear materials from peaceful to weapons uses. In this matter the AEC became embroiled in a dispute with other parts of the U.S. government. We wanted safeguards, preferably administered by the International Atomic Energy Agency, to be made mandatory. Our European allies resisted mandatory safeguards, ostensibly because they did not like the idea of inspectors from other countries roaming around in their nuclear plants. They were supported in this attitude by elements in our State Department. The ACDA, bowing to allied and State Department pressure, at first introduced in Geneva a miserably weak treaty provision specifying merely that the parties to the treaty would "cooperate in facilitating the application of safeguards." The AEC bitterly protested the weakness of this provision, and our position won support from the Joint Committee on Atomic Energy. In fact, the JCAE implied that any treaty that did not have mandatory safeguards would be in trouble in the Senate. This helped tilt the balance and mandatory safeguards for all non-nuclear weapon countries soon became the U.S. position.

It did not, however, settle the question of who would administer the safeguards. In deference to our European allies, the U.S. argued in Geneva for a formula specifying "International Atomic Energy Agency or equivalent" safeguards. "Or equivalent" was a reference to safeguards already being applied to its members by the European Atomic Energy Community (EURATOM). Several allied countries very much preferred EURATOM to IAEA safeguards. Their argument was that IAEA inspectors might make off with industrial secrets about their growing nuclear businesses.

But the Soviets stated that "self-inspection" by EURATOM of its own members was unacceptable. Various compromise proposals were then thrown into the mix, all seeking some way that EURATOM safeguards could remain, at least for a while, subject to some verification of their adequacy by the IAEA. At length, informal talks among negotiators from the two sides produced basic agreement on a compromise solution. This was that each non-nuclear party to the treaty would within a specified time reach a safeguards agreement with the IAEA. This formula allowed for the possibility of continued EURATOM safeguards in that the agreements could be negotiated either individually or together with other countries.

A key step to soften allied opposition to the proposed safeguards article was taken on December 2, 1967, when President Johnson announced that the United States would accept the application of IAEA safeguards to all its own peaceful nuclear activities at the time that such safeguards were generally applied to other nations under the NPT. This announcement was the culmination of a series of prior suggestions and events in which the AEC had played a key role. The British immediately followed our example. These actions tended to cut the ground from under previous allied objections based on presumed commercial disadvantage. The allies then agreed to the text of the safeguards article and, after some last minute haggling with the Soviets over wording, the agreement was announced in Johnson's State of the Union message in January 1968.

The first three article of the NPT (Articles I and II setting out the basic obligations of nuclear-weapon states not to transfer, and nonweapon states not to acquire nuclear weapons, and Article III prescribing safeguards) pretty well encompassed what the superpowers hoped the final treaty would be. Not so the non-nuclear countries who were the main object of the treaty. There was very great resentment among them about what they considered the draft treaty's discriminatory nature. They felt they were being asked to renounce a future means of defense and without any compensation.

Ultimately three articles were added to the treaty in an effort to appease the non-nuclears. Article IV stated the right of all countries to pursue the peaceful atom without discrimination. It also announced the obligation of more advanced countries to provide technical assistance in peaceful uses to others, particularly to those in "the developing areas of the world."

Article V referred to a technology that has since declined in importance, namely, the use of nuclear explosions for peaceful purposes like excavation, mining, and research. Both Brazil and India objected to the draft NPT on the grounds that it would preclude their independent development of such explosives. In a trip to Brazil in 1967 I spoke to Brazilian officials at length about this. I pointed out to them that the USAEC stood ready under an NPT to provide a peaceful nuclear explosives service to them at a fraction of what it would cost them to provide it for themselves. I found that they were generally not well informed about the issues and that their arguments did not hold up. I became convinced that their avowed interest in peaceful nuclear explosions was mainly a cover to keep alive a nuclear weapons option. Nevertheless, to meet such objections as the Brazilians advanced, an Article V was added to the NPT providing for such a nuclear explosives service as I had described to them.

The most clamorous demand of the non-nuclears was that, in exchange for their abjuring nuclear weapons, the superpowers must do something to halt their bilateral arms race, which was regarded as a threat to everybody. The tide of revolt on this issue ran very strongly--so much so that the superpowers felt that if they did not give ground they might lose the treaty. They therefore added an Article VI pledging "to pursue negotiations in good faith on effective measures regarding cessation of the nuclear arms race and disarmament..." Later they were forced by the efforts of Sweden's Alva Myrdal to agree to an amendment requiring that these negotiations take place "at an early date."

Formal UN debate on the NPT began in the General Assembly on April 24, 1968. It was approved on June 12 by a vote of 95 to 4, with 21 abstentions. The treaty was opened for signature on July 1, 1968, in Washington, London, and Moscow. It was signed on that day by the Big Three and more than 50 other countries. Senate hearings began on July 10 with supporting testimony by Secretary Dean Rusk, ACDA Director William Foster, Deputy Defense Secretary Paul Nitze, Joint Chiefs Chairman Earle Wheeler, and me. My own testimony concentrated on IAEA safeguards, and the provision for a peaceful nuclear explosions service. There was little opposition, but the Foreign Relations Committee did not vote out the treaty until September 17. On October 11, with the presidential election campaign in full swing, the full Senate voted to postpone action. After Nixon's election, he made it clear that he wanted action still further deferred, until after his inauguration. On February 5, 1969, President Nixon recommended ratification in a special message to the Senate. The Senate gave its consent on March 13, and two days later, having been ratified by the requisite number of countries (the Big Three plus 40), the Treaty on the Nonproliferation of Nuclear Weapons entered into force.

III. Arms Limitation

On July 1, 1968, the very day they signed the Nonproliferation Treaty, President Johnson and Soviet Premier Kosygin announced their intentions to enter into talks on the limitation and reduction of offensive and defensive nuclear weapons.

This was by no means the first approach to this subject, but it may have been the first serious one. During the previous four years the United States and the Soviet Union had batted back and forth a series of proposals, some of which were obviously unacceptable to the other side and probably intended mainly for propaganda effect. In January 1964, President Johnson proposed a "verified freeze on the number of strategic nuclear offensive and defensive missiles." As details of this idea were worked out in Washington, it proved quite complex, much more so than its simple statement by the president would have indicated. The Soviets never took it seriously, possibly because verification of the freeze would have required intrusion into some of the most secret Soviet facilities.

One week after Johnson's freeze proposal the Soviets proposed that the major powers destroy all their bombers. This was obviously unacceptable to the United States, which held a large lead in number of bombers. The United States responded with a proposal that both superpowers destroy an equal number of bombers. The Soviets promptly rejected this since it would have increased the proportional U.S. advantage.

The superpowers also flirted briefly during Johnson's term with reductions in military budgets as an approach to arms limitation. Late in 1963 Chairman Khrushchev announced a 4.3 percent cut in planned Soviet military expenditures for 1964. President Johnson then announced a small reduction in the U.S. defense budget for fiscal year 1965. After both sides announced they intended to make additional cuts the process was aborted by the sharp escalation in the Vietnam War initiated by Johnson early in 1965. From that time forward, military spending by both superpowers resumed an upward course.

Section XII of this introduction describes the cutback in capacity to produce fissionable materials carried through by President Johnson. Though the president succeeded to some extent in surrounding these actions with the aura of arms control, they were prompted largely by the excess of materials production capacity built up during the 1950s. This same excess contributed to some U.S. proposals that both sides transfer already produced stocks of weapons grade U-235 to civilian use. In August 1963 the United States formally offered to transfer sixty thousand kilograms of such U-235 if the Soviet Union would transfer forty thousand kilograms. There was scant risk in this since our stockpile at the time was about five times that of the Soviets. Early in 1964 President Johnson suggested a halt in production of fissionable materials for weapons purposes and offered to act quickly on our past offer of a transfer to peaceful purposes in a 60-40 ratio. The Soviet response on both occasions was cold. They claimed that the amounts transferred would not diminish the U.S. nuclear potential, because we had excess weapons, that the verification procedures would require the most intrusive controls, and that, in general, the proposals amounted to "control without disarmament." To meet the last objection, we proposed that the transferred material be obtained from destruction of weapons chosen by each side from its stocks. U.S. efforts on behalf of such proposals reached their peak in 1965 and early in 1966. We ceased to press them thereafter, in part because our lead over the Soviets in stockpiles of fissionable materials was diminishing rapidly.

Meanwhile, both sides had been adding new and better weapons to their arsenals. One aspect of the continuing arms race appeared particularly alarming to serious-minded individuals. This was the deployment, first noticed in 1964, of an antiballistic missile system around Moscow, and rising pressure within the United States to deploy similar systems, then under development, to protect American cities.

In March 1966, Secretary of Defense MacNamara tried to still the clamor for an American ABM by stating it would not be capable of defending against a Soviet attack, although it might be effective against a lesser Chinese attack. He suggested that funds already authorized for an ABM system not be spent until arms limitation was explored with the Soviet Union. President Johnson agreed and was strengthened in this belief by a climactic meeting of his advisers held in Austin, Texas, in December 1966. He wrote to Kosygin in January 1967 setting forth the situation quite bluntly: if the Soviets deployed an ABM, we would follow suit, and also would increase our capabilities to penetrate their system. They would then increase their offensive and defensive capabilities and both sides would have incurred "colossal costs without substantially enhancing...security.." Johnson therefore suggested that some of the two sides' "highest authorities" meet to "carry the matter forward."

In response to the president's initiative, conflicting signals came from Moscow. Kosygin made public statements defending the Soviet ABM. This was in keeping with the Soviet military doctrine's emphasis on defense. At length, a month after the president's letter, the Soviets replied, stating their willingness to exchange views on strategic weapons but without suggesting a date. Meanwhile, discussions began within the U.S. government about the position we should take in the talks. The Joint Chiefs wanted any agreement to take the form of a treaty and that it both assure continued U.S. strategic superiority and allow future development of an American ABM. State and ACDA were less obdurate.

Preliminary discussions with the Soviets about arms limitation took place at a hastily arranged summit meeting between Johnson and Kosygin at Glassboro, New Jersey on June 23 and 24, 1967. The climax of the meeting was a passionate effort by MacNamara, over lunch, to persuade Kosygin that the security interests of both sides required some limitation of strategic arms. Kosygin appeared not to respond, continuing to argue that defense threatened no one. Yet there was evidence that he and his aides were indeed impressed with the logic and force of the American presentation.

They were not impressed enough to schedule strategic arms talks, however, and in the absence of such talks weapons developments continued apace. In September 1967, at the end of a long speech in which he argued the futility of a "heavy" ABM system to protect against the Russians, MacNamara announced a "light" one (SENTINEL) to defend against the Chinese. In December it was revealed that the United States was developing MIRVs.

President Johnson continued to pressure the Soviets to schedule talks and on July 1, 1968, as indicated above, the two sides announced their intention to enter into near-term talks "on limitation and reduction of offensive strategic nuclear weapons delivery systems as well as systems of defense against ballistic missiles." Still no date was announced.

Now the task of preparing a U.S. position began in earnest. A staff in the Pentagon prepared a draft treaty. Essentially it proposed a quantitative, but not a qualitative, freeze on strategic missile launchers, and an agreement to limit ABMs to an equal, but as yet unspecified, number. An ominous limitation of the proposal was that, at the insistence of the Joint Chiefs, it did not restrict MIRVs. Thus, while the number of missile launchers might be held steady, the number of warheads could increase substantially.

On August 19, the Soviet Union finally agreed to schedule a summit conference that would launch SALT, the strategic arms limitation talks. The date was to be in the first ten days of October, the site probably Moscow. On the night of August 20, however, a few hours before the joint announcement was to be issued, news came of the invitation of Czechoslovakia by Warsaw Pact forces. Anticipating a popular outcry, President Johnson felt he had to call of the scheduled announcement.

In the remaining months of Johnson's administration, some efforts were made to get the summit conference back on the rails. These were finally defeated by President-elect Nixon, who made it clear that he would not be bound by the results of such a meeting involving his predecessor.

The Nixon administration took several months to prepare before indicating a willingness to initiate SALT. A variety of options were considered. ACDA's new director, Gerard Smith, advocated an across-the-board freeze of the number and characteristics of strategic weapons. This "Stop Where We Are" proposal, which I supported, would have banned MIRVs on both sides. It would also have saved vast sums of money. The Joint Chiefs opposed this, and any other, limitation on technology.

The options were considered in a series of White House meetings in June 1969 which I attended. At one of these President Nixon stated with great emphasis that he would personally make all decisions regarding U.S. policy, setting the stage for very close White House control of the negotiations to follow. Discussions continued in coming months but before a more limited group, from which I and White House science adviser Lee DuBridge were excluded. President Nixon and Security Adviser Henry Kissinger apparently did not feel that the advice of scientists was of much use in matters like this.

SALT did not in fact begin until November 1969. There was early agreement on the desirability of limiting ABMs. But the assymetry between the forces on the two sides led to difficulties in reaching agreement on an offensive arms. The Soviets then sought to limit negotiations to ABMs, but the United States, fearing unlimited growth in the Soviet Union's burgeoning ICBM arsenal, insisted that offensive weapons be included as well. After a prolonged deadlock, it was decided to negotiate a permanent treaty limiting ABMs and, as a holding action, to add an interim agreement (not a treaty) restricting the growth of offensive arms for five years.

IV. The Cuban Missile Crisis

Periodic intelligence reports since late August of 1962 had revealed the off-loading of military equipment from Soviet ships and an increase in military construction activity at several locations in Cuba. Although the AEC was not a "collector" of intelligence, it did serve as an evaluator and interpreter of nuclear-related intelligence data collected by the CIA, the Department of Defense, and other elements of the intelligence community. I served as a member of the U.S. Intelligence Board, the highest intelligence estimating body in the government. Commencing in October, the AEC's Director of Intelligence Charles Reichardt, often accompanied by Assistant General Manager for Administration Harry Traynor and General Manager Alvin Luedecke, came to my office in the early morning nearly every day to give me the latest reports and estimates on developments in the Cuban situation. Many of these reports bore classifications above top secret.

The crisis broke on Monday, October 15, when analysis of photographs from reconnaissance overflights by U-2 planes disclosed evidence of a medium-range missile site, though not yet the missiles themselves, in Western Cuba. Now a nuclear confrontation with the Soviet Union over Cuba appeared to be a distinct probability.

The president immediately established a top-level group, later formally named the Executive Committee of the National Security Council (EXCOM), to consider policy alternatives and make recommendations to him. By Wednesday, October 17, launchers and missiles could be seen in U-2 photographs, and it was clear that the missiles could be fired within two weeks. EXCOM discussions began to focus on two options: 1) a swift air strike to take out the missiles, or 2) a naval blockade while diplomatic pressure was exercised to get the missiles removed.

It is necessary to recall that, almost from its inception, but especially since the Korean War, the AEC had maintained a readiness plan for continuity of essential operations in the event of hostilities. Indeed, when the new headquarters of the AEC was constructed at Germantown, Maryland, in 1957 (as part of President Eisenhower's plan for the dispersal of critical government functions), a reinforced structure replete with sophisticated emergency communications systems was built into the underground structure of the new complex. It was known as the Emergency Relocation Center (ERC), and was built with compartmentalized sleeping facilities to house 120 people with sufficient water and food to meet their needs for several weeks.

Periodically, mock exercises were held in the ERC during which imaginative efforts were made to write a realistic scenario. For most of the key officials who participated, these exercises, were a bit of a nuisance, interrupting their busy schedule. In mid-October 1962, however, the exercises commenced to assume a new reality.

The ERC was meant to house, in the event of a war emergency, the Initial Cadre, consisting of the Chairman, the commissioners, and those members of the AEC staff essential to operation of the agency in such an emergency situation. It was also contemplated that the members of the Initial Cadre might be accompanied by their families, although the feasibility of this was in doubt and subject to much debate.

By Friday, October 19, the blockade concept appeared to have won out over the air strike in the deliberations of EXCOM, but with the proviso that an air strike would follow if diplomacy failed. The president's address to the nation on radio and television, which revealed the extent of the crisis to the world for the first time, took place on Monday evening, October 22. This address "brought home" to the nation the gravity of the situation. AEC employees, who had been enjoined by secrecy, were now for the first time able to discuss and develop with their spouses concrete plans for the safety of their families. This raised serious questions among the members of the Initial Cadre as to whether, if ordered to occupy the ERC in the face of impending outbreak of hostilities, they would actually bring their families to take up residence in the underground Emergency Relocation Center in Germantown. Helen and I had serious discussions as to our proper course of action should we be faced with such a fateful decision. Fortunately, we never had to make this decision.

The day following the president's address, I informed the Commissioners that AEC operations had been placed under Phase I Alert, i.e., instructions to check that communications were in order, 24-hour duty for communications personnel, additional security guards, etc. It was a tense day, featured by a meeting at which the Organization of American States (OAS) endorsed President Kennedy's action, a spirited discussion in the UN Security Council, and reactions of various types from around the world. What the USSR reaction would do was not yet clear.

Fortunately, after an historic exchange of messages between Kennedy and Khrushchev, a message came from the Soviet government on Sunday, October 28, agreeing to remove the missiles under UN inspection.

Although it was not publicly announced at the time, it is now known that, in return, Kennedy conveyed private assurances to Khrushchev: (1) that the United States would not attack Cuba, and (2) that we would remove Jupiter missiles we had deployed in Cuba.

This brush with disaster brought President Kennedy and Chairman Khrushchev closer together, a prelude to the successful attainment of the Limited Test Ban Treaty less than a year later.

V. The program of international cooperation; including my visits to 60 countries

In 1954 the Atomic Energy Act was liberalized to permit the AEC to transmit peaceful atomic energy information, research tools, and nuclear materials to other nations under "Agreements for Cooperation" pledging the recipient not to use what was received for any military purpose. The number of such agreements greatly increased during the decade of my chairmanship. By the end of 1971 they were in effect with 30 individual nations and two international organizations (EURATOM and the IAEA).

At first, the "safeguards" to prevent military use were implemented by the United States and the cooperating nation. In accordance with what had always been the U.S. intention, this responsibility began in the mid-1960s to be transferred to the IAEA through trilateral agreements among the agency, the United States, and the recipient nation. The principle of international safeguards administration was further strengthened by the 1968 Nonproliferation Treaty (see Section II), which required non-nuclear weapons signators to negotiate safeguards agreements with the IAEA.

The enthusiasm engendered by the U.S. Atoms for Peace Program led in 1955 to the convening in Geneva of a huge UN Conference on the Peaceful Uses of Atomic Energy. The success of this conference led to a second one being held in 1958, a third in 1964 and a fourth in 1971. At the first two Geneva Conferences I was a member, at the third the Chairman, of the U.S. delegation. I had the honor of being elected president of the fourth (1971) Conference. Another repeated occasion for travel abroad was the IAEA General Conference. During my ten and a half years as AEC chairman, I, along with one or more of my fellow commissioners, attended this annual event eleven times, held in Vienna except in 1965 when it was held in Tokyo.

It became my practice to visit other countries before and after the various conferences I attended. Thus, in 1965, when the IAEA General Conference was held in Tokyo, I visited nine countries in a trip around the world. A presidential plane was placed at my disposal for three of my trips: in January 1967 when I circled the globe in visiting five countries; in January 1970 for a trip to six African countries, Spain, and Germany; and in July 1971, when I visited six South American countries. One highlight of my travels abroad occurred in September 1964. Leaving the third Geneva Conference for a weekend, I served as host to high-ranking officials of 15 national nuclear energy organizations abroad the USNS Savannah, the world's first nuclear-powered cargo-passenger ship. The Savannah, which had started operation in August 1962, was completing a tour of the Scandinavian countries and was at anchor in Halsingborg, Sweden. My guests and I spent the night aboard ship, then cruised the Baltic the next day. (Actually, I made several visits to the Savannah during my tenure as AEC Chairman; even before it was launched, my entire family and I [except Dianne, who was judged to be too young] visited her at Yorktown, Virginia, in February 1962.)

Throughout the 1960s, fruitful cooperation on peaceful uses of the atom was enjoyed with the USSR. This was accomplished pursuant to several bilateral Memoranda on Cooperation in the Field of Utilization of Atomic Energy for Peaceful Purposes negotiated between the USAEC and the Soviet State Committee for the Utilization of Atomic Energy. The first of these was signed in 1959 by AEC Chairman John A. McCone and his Soviet counterpart, Professor Vasil Emelyanov. I and my counterpart Andronik M. Petrosyants signed succeeding memoranda in May 1963, July 1968, and early 1970.

One of the fruits of the Memoranda of Cooperation was exchanges of visits by American and Soviet scientists to laboratories and facilities in each other's country. A notable exchange of visits occurred in 1963. In May I led an American delegation on a tour of Soviet nuclear energy facilities. Everywhere we went we were treated with the warmest hospitality. Our hosts accepted unhesitatingly the itinerary we had proposed and even included some additional sites they thought would interest us. Our journey achieved a number of "firsts." We were the first foreign group to visit the Soviet reactor testing station at Ulyanovsk and the site of the high energy accelerator at Serpukhov, the first Western visitors since World War II to visit the Radium Institute in Leningrad, and the first foreign group to see certain industrial reactors and other scientific equipment. Overall, I believe this visit contributed to the improved relations that made possible the negotiation, some two months later, of the Limited Test Ban Treaty.

A high point of the trip took place on May 29, when I met for over an hour with Leonid Brezhnev, who occupied at that time the largely ceremonial position of "president" of the USSR. While interesting at the time, this talk became even more so in retrospect, since Brezhnev's elevation to the post of general secretary of the Communist party occurred less than a year and a half later. It is symptomatic of the extreme insularity of Soviet leaders at that time that, as I was told later, I was only the second American to meet Brezhnev, the other having been Gus Hall, head of the U.S. Communist Party. A reciprocal visit by Chairman Petrosyants and his colleagues took place during the period from November 16 to December 3, 1963. It was while the Soviet group was visiting the Radiation Laboratory in Berkeley on November 22, that news came of President Kennedy's assassination. I will always be grateful for the sympathetic and sensitive behavior of our visitors during the aftermath of the assassination. They seemed sincerely to share our grief.

The first Soviet-American experiment in the nuclear sciences began in 1970. Pursuant to the fourth Memorandum on Cooperation, six U.S. physicists were assigned for six months to the High Energy Physics Institute at Serpukhov, working with Soviet scientists at the 70 Bev (billion electron volts) accelerator. In return Soviet scientists were to be assigned to the 200 Bev accelerator at Weston, Illinois, when it would be completed.

Another exchange of scientist visits led by Chairman Petrosyants and me took place in 1971. The Soviet group visited nuclear facilities throughout the United States from April 15 to 28. Our return tour took place between August 4 and 20. Following visits to laboratories in the Moscow area, an extensive ten-day tour by our party utilized a specialized Aeroflot plane used by Premier Kosygin on some of his trips. Travelling a distance of 12,110 kilometers, we visited nuclear facilities in and around eight cities: Minsk, Leningrad, Ulyanovsk, Novosibirsk, Tashkent, Erevan, Tbilisi, and Schevchenko—with a stop at Samarkand. I also attended meetings and visited research laboratories in Moscow after our tour.

On entering the Soviet Union at this time, I had newly acquired and rarely bestowed status of Foreign Member of the USSR Academy of Sciences. This honor had been conferred on me during the Academy's General Assembly in March.

These trips involved extended separations from my family, disruptions of normal eating and sleeping habits, exhausting schedules at nearly every stop, intensive in-flight "homework" to prepare for the next visit, a host of minor frustrations and inconveniences, and, on return, a mountain of accumulated work. But the rewards were great. I am convinced that my personal discussions with scientists and statesmen of other nations, and visits to their scientific facilities, contributed significantly to the constructive use of the peaceful atom and nuclear safeguards and to better international relations generally. It was gratifying to know that President Johnson, for one, in repeatedly urging me to take such trips, felt the same way.

During my travels I met a rather large number of heads of state or high government officials—British Prime Minister Harold Macmillan, Soviet chairman Nikita S. Khrushchev, Soviet President Leonid I. Brezhnev, Soviet Foreign Minister Andrei A. Gromyko, and V. M. Molotov of the Soviet Union, Swedish Prime Minister Tage Erlander, Indian Prime Minister Indira Ghandi, Pakistani President Ayub Khan, President Chiang Kai-shek and Premier C. K. Yen of Taiwan, Finnish President Urho Kekkonen, Austrian Chancellors Josef Klaus and Alfors Gorbach, Austrian State Secretary Karl Gruber, Yugoslav Vice President Aleksandar Rankovic, Trygve Lie of Norway, U.N. Secretary General U Thant, Israeli Prime Minister Levi Eshkol, Irish President Eamon De Valera, Prime Minister Kittikachorn Thanan of Thailand, Brazilian Foreign Minister Jose da Magahaes Pinto, President Juan Carlos Ongania of Argentina, Mexican Foreign Minister Antonio Carrillo Flores, President Nicolae Ceausescu of Rumania, Moroccoan Foreign Minister Mohamed Syilnassi, Tunisian Foreign Minister Habib Bourguiba of Tunis, Ethiopia's Emperor Haile Selassie and Crown Price Asfa-Wossen Haile Selassie, Vice President Daniel arap Moi of Kenya, Prime Minister Kofi A. Busia of Ghana, Spanish Foreign Minister Gregorio Lopez Bravo, Prince Juan Carlos and Princess Sofia of Spain, Korean President Park Chung Hee, President Suharto of Indonesia, Prime Minister Amir Abbas Hoveyda of Iran, and Canadian Foreign Minister Mitchell Sharp.

The trips were not without some personal "spin-off"—the Danube at Budapest on a clear September day, Roman paving-stones on the Appian Way, the Bibi Khanym Mosque in Samarkand, Inca ruins in Peru, the Great Buddha at Kamakura, the Temple of Bacchus at Baalbek, the Acropolis in Athens, the ruins of Carthage, the house where Beethoven composed "Fidelio," the mighty Congo 2,000 feet below me winding through green jungle toward a dam construction site, canals in Venice, the charm of exotic animals in Australia, sunset over Scotland's downs—kaleidoscopic contacts with nature and the history of man.

VI. Support of research

Physical sciences research programs

From its inception the AEC has felt a responsibility to support research in both the physical and life sciences. These endeavors have been spearheaded by a succession of scientist-commissioners. Starting with Robert Bacher, these have included Henry Smyth, John von Neumann, Willard Libby, John H. Williams, and, during my tenure, in addition to myself, Leland Haworth and Gerald Tape.

The research supported by the AEC in the physical sciences has covered a wide spectrum of knowledge and applications, including the search for new knowledge about nuclear structure and behavior, the discovery of new elements, and the expansion of nuclear technology, among other subjects. Much of this work requires very large, specialized machines. This is one reason why most of AEC's physical research program is carried out in National Laboratories or other AEC-owned, contractor-operated research and development centers. The remainder—about one fourth in terms of expenditures—of the program involves the support of unsolicited research proposals submitted by private organizations, usually educational institutions. In the off-site research program—mostly university research—the number of contracts remained around 550, while the total annual cost level increased from about $47 million in 1961 to some $73 million in 1970.

Accelerator facilities:

During my tenure there were major construction activities under the physical research program centered around the building of large accelerator facilities for research on elementary particles. At the same time, the need to proceed with plans for more complex and expensive machines, such as the National Accelerator Laboratory and the Los Alamos Meson Physics Facility, coupled with budgetary stringencies, forced the AEC to shut down two older, more obsolescent machines—the Brookhaven cosmotron and the Cal Tech synchrotron—in the 1960's.

The principal accelerator improvement program planned for the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory was the "conversion project." The primary objectives were modification of the AGS for operation at increased intensities and provision for improved experimental facilities. The 50 Mev injector was to be replaced with a new proton linear accelerator injector having an energy of 200 Mev. The conversion was authorized in fiscal 1966. Completion is expected in fiscal 1972. The converted AGS will make available secondary beams of nucleons, pions, muons, neutrinos, and strange particles of higher intensities. The higher intensity will also permit support of more experiments running in parallel and sharing the particles of each machine pulse.

The Cambridge Electron Accelerator (CEA) was constructed at Harvard University at a cost of $10.2 million and by August 1962 had achieved an energy of 6.2 Bev. It is operated under an AEC contract with Harvard and is co-sponsored by MIT.

In August 1963, the Princeton-Pennsylvania Accelerator (PPA) of Princeton University reached its design energy of 3 Bev and, following a brief debugging period, operation was sufficiently reliable to schedule experiments. The first 3 Bev proton beam survey experiments were performed in November 1963. By January 1964, an active research program was under way. The PPA was from the beginning under the joint management of the University of Pennsylvania and Princeton University. In March 1971, fiscal stringencies caused the $11.5 million machine to be shut down. AEC support ended on July 1, 1971. Other sources of operating funds were being sought.

The $50 million, 12.5 Bev proton Zero Gradient Synchrotron (ZGS) at the Argonne National Laboratory (ANL) near Chicago was completed in the summer of 1963. The first scientific experiment there began in June 1964. The operating efficiency (the fraction of scheduled machine time actually delivered) was at first between 60 percent and 80 percent. Between three and five experiments were carried out simultaneously. Some two-thirds of the operating time was being devoted to the research program, the remainder being given to machine studies. Through the several years of ZGS operations, steady improvement in operating efficiency has been achieved.

An early decision faced by President Johnson was whether he should support the construction of the large fixed-field alternating gradient (FFAG) accelerator being developed by the Midwest Universities Research Association (MURA). There was a serious difference of opinion in the high energy physics community about whether such a high intensity, but relatively low energy (10 Bev) proton accelerator should be supported (at a cost of $115 million to $125 million) in competition with other research facilities, such as a high energy (200 Bev) proton accelerator. The president decided to stop this development but, as a sort of compensation to the universities involved, he directed me to explore and implement a plan to involve some of them in the operation of Argonne National Laboratory.

The Argonne Universities Association (AUA), an organization of 26 Midwestern universities, came into existence in July 1965 in response to this request from President Johnson. It was organized to aid in stimulating scientific and technological advancement in the midwest, assisting and supporting ANL staff, and helping make the facilities at ANL broadly available to the scientific community. The high energy physics program at ANL is, of course, only one of many major programs at this multi-purpose laboratory.

In November 1966 a tripartite contract involving the AEC, AUA, and the University of Chicago went into effect. Under this contract, AUA has the primary role for formulating, approving, and reviewing policies and programs of ANL. The contract also states that the University of Chicago is to be the operator of the Laboratory in accordance with policies established by the AUA and that the University shall collaborate with AUA developing long-range objectives, programs, and facility plans, and in evaluating the program accomplishments of the Laboratory.

Congressional hearings on a 1957 Stanford University proposal for the construction of Stanford Linear Accelerator culminated in authorization of $114 million for the project in 1961. The AEC entered into a contract with Stanford for the design and construction of the 20-Bev electron facility on a 480-acre site near Palo Alto, California, which was leased to the government for 50 years. Actual construction of the accelerator was begun in July 1962. It was constructed within the initial cost estimate. In May 1966 electrons were accelerated for the first time through the full length of the accelerator obtaining an energy of about 10 Bev. Soon thereafter an energy of 18.4 Bev was achieved. Research operations with the accelerator began in late fall of 1966, six months ahead of the original schedule, , and in January 1967 the machine exceeded its design objective when a beam of 20.16 Bev was achieved.

Following completion of a major improvement program, the Bevatron at the Radiation Laboratory of the University of California at Berkeley reached, in March of 1964, a beam intensity of 0.8×10^{12} particles per second.

The Berkeley Heavy Ion Linear Accelerator (HILAC), unlike its sister machine at Yale, had its intensity increased several times. The discovery at the Lawrence Radiation Laboratory of unexpected variable energy capabilities in the HILAC was accomplished during 1962. A $1.5 million remodeling and modernization program was largely completed in the spring of 1965. It gave the machine the potential of accelerating particles continuously. The intensity (number of particles accelerated in a given time) was increased by about 800 percent for heavy nuclei such as neon and argon, and about 1,000 percent for lighter nuclei such as carbon and oxygen. Suppression of unwanted radiation, which formerly swamped counters in some experiments, opened up new areas of experimentation with sensitive counters. The modification provided for beam splitting and multiple experimentation for the first time, and it reduced the time required for a typical HILAC experiment. With highly desirable lower, monochromatic energies, ranging from 1 to 10 Mev per nucleon, the HILAC became able to elicit a large amount of detailed information on the structure and properties of complex nuclei.

A transformation of the HILAC was approved in 1970. The $3 million overhaul began in February 1971. When it resumes full operation as a research machine in 1972, it will be known as the SuperHILAC and will feature a 3 million volt Cockcroft-Walton injector, improved electron-stripping capability and a 40 kilogauss quadrupole magnet, twice as powerful as any previous magnet of its size, for focusing the beam. Two new linear accelerator tanks, 60 and 100 feet long, will replace the old 15 and 90 foot tanks.

The SuperHILAC will be capable of accelerating all elements to energies between 2.5 and 8.5 Mev. Beam intensity will range from 100 billion ions per second for such heavy elements as uranium to milliamperes (10 million billion ions per second) for such light elements as carbon. It will be the world's first machine capable of accelerating all ions (including uranium) to energies high enough for nuclear penetration.

The 88-Inch Cyclotron accelerator at the Lawrence Radiation Laboratory, Berkeley, built at a cost of $4.6 million, became operative in early 1962. Key features of the accelerator are its versatility in the medium-energy field (deuterons, helium ions, light heavy ions at 30 Mev per nucleon) and its beam intensity of some million-billion particles per second, about double that of the 60-Inch Cyclotron and 1,000 times greater than that of the 184-Inch Synchrocyclotron. The intense beam on the 88-Inch Cyclotron has allowed the production of research quantities of important isotopes of heavy elements.

In a meeting with President Johnson at the LBJ Ranch in December 1966, I succeeded in persuading him, over the objections of Budget Director Charles Schultze, to support the construction at the Lawrence Radiation Laboratory of a new type of accelerator, known as the Omnitron. This accelerator, the invention of Albert Ghiorso, was estimated to cost $24 million and expected to be capable of accelerating substantial beams of heavy ions, over the entire range of elements up to and including uranium, to energies capable of penetrating into the nucleus of even the heaviest target nuclei. Unfortunately, due to the lack of backing by the director of the Lawrence Radiation Laboratory, support for the Omnitron was later stricken from the AEC budget by the Joint Committee on Atomic Energy and it was never possible to restore it. A little later, Ghiorso came up with the idea of using the HILAC as an injector of heavy ions into the Bevatron, a combination which came to be called the Bevalac. It would be capable of accelerating heavy ions to relativistic energies.

The building for the Isochronous Cyclotron (ORIC) at Oak Ridge National Laboratory was completed early in 1961 and the fabrication and installation of the cyclotron components approached completion by the end of 1961 at a cost of 3.7 million. The first proton beam at full radius was obtained in ORIC on March 19, 1962. In 1969 and 1970 major improvements were made in the ion-source of the ORIC so as to permit the acceleration of argon ions.

New isochronous cyclotrons were established during the 1960's at Texas A&M University, the University of California at Davis, and the University of Maryland. The Maryland machine has accelerated protons to more than 100 Mev, making it the world's highest energy operating isochronous cyclotron. An isochronous cyclotron injecting into a tandem Van de Graaff accelerator (called a cyclo-Graaff facility) was established at Duke University.

In view of the need for electron beams of higher intensity, resolution, and duty factor for higher energy nuclear physics research, a 400 Mev electron linear accelerator was built at MIT. It is scheduled for operation in late 1971. Operation of the Oak Ridge Electron Linear Accelerator (ORELA) began in 1969. New tandem Van de Graaff accelerators were established at ANL, Oak Ridge, Rice University, University of Minnesota, Yale University and BNL. The one at BNL is the world's highest energy Van de Graaff system accelerating hydrogen ions to an energy of more than 30 Mevs.

Research reactors, nuclear chemistry, neutrino detection:

The High Flux Isotope Reactor (HFIR) is discussed in section VIII.

The High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory became operational on October 31, 1965. Built at a cost of $12.5 million, this 40-thermal-megawatt reactor is cooled and moderated by heavy water and contains a heavy water reflector and provides a maximum flux of more than 1.6 x 10^{15} neutrons per square centimeter per second at full power. The HFBR is used for basic research in nuclear physics, nuclear chemistry, solid state physics and metallurgy.

The Ames Laboratory Research Reactor (ALRR) became operational on February 17, 1965. In 1968 researchers at the Ames Laboratory succeeded in growing a large, single crystal of solid helium and scattering neutrons (from the ALRR) off it to study the vibrations of the helium atoms in such a lattice.

Throughout the history of science, as a given area of research has developed, the interrelations between that discipline and others have increased. Never has this phenomenon been more apparent than in the chemistry research programs supported by the AEC's Division of Research. Some of the developments over the past decade have been: a) the synthesis of new elements and new isotopes, b) new insights into nuclear structures and properties, c) new methods for studying the chemistry of radioactive ("hot") atoms, d) new light shed on the chemical effects caused by ionizing radiation, and e) further development of new analytical techniques.

The past ten years were marked by increasing applications of nuclear methods. These included neutron diffraction, Mossbauer effect studies, electron spectroscopy for chemical analyses, and determination of chemical structures. Much of the role of chemistry in nuclear energy related programs, such as the production of fissionable materials, reactor chemistry, and the large-scale production of radioisotopes, is attributable to past research supported by the AEC. Two specific examples are the californium-252 production program and Oak Ridge's molten salt reactor program.

Efforts to extend the Periodic Table of the Chemical Elements have been successful. At the Berkeley Radiation Laboratory element 103 (lawrencium) was discovered in 1961, while elements 104 and 105 (tentatively named rutherfordium and hahnium) were discovered in 1969 and 1970, respectively. New element synthesis, through the heavy ion approach, became increasingly difficult with increasing atomic number. New methods of detecting new heavy isotopes and elements were developed. An important discovery made at the Oak Ridge National Laboratory was the identification of transuranium elements by x-ray spectroscopy.

By 1966, a solar neutrino experiment (production of argon-37 from chlorine-37) was being conducted by the Brookhaven National Laboratory 4,900 feet below the earth's surface in the Homestake Mine at Lead, South Dakota. Data for 1967 and 1968 were collected and the background noise of the counting instruments were reduced. Significant improvements in instrumentation led to the first positive evidence for the detection of neutrinos from the sun. The astrophysical theory of neutrinos would suggest that one should have seen some two to seven events a day. In 1970 the argon-37 production rate was found to be 0.5 ± 2 events per day. The neutrino intensity found is at most one-fifth of that predicted by the best theoretical calculations of the sun's behavior. This result calls into question some fundamental and widely accepted concepts in astrophysics.

Metallurgy, solid state physics and isotope separation:

Greater availability of transuranium isotopes caused an upswing of work in the metallurgy and solid state physics of these elements. A committee was established by the AEC in 1961 to help coordinate the research conducted in these fields by various AEC divisions. Several important scientific achievements occurred in the metallurgy of plutonium during this period. A method for preparing high-purity metallic plutonium by electrorefining from a molten salt bath was developed at Argonne National Laboratory (ANL) in 1960. Single crystals of plutonium were prepared for the first time in 1967 at ANL. Ductile metallic alpha-plutonium was made at Pacific Northwest Laboratory (PNL)in 1970 by inducing grain refinement through extrusion of high-purity metal.

Following the discovery, announced in 1961, of magnetically hard superconductors, applications in many AEC programs were immediately obvious. Basic research projects were reoriented within the metallurgy and materials program to accelerate progress in the physics and metallurgy of superconductivity and applied efforts were initiated in the high-energy physics and controlled thermonuclear research programs.

In the field of extra nuclear properties of matter, research studies were carried out on a variety of topics, including optical spectroscopy, mass spectrometry, behavior of low-energy ions in matter, magnetic resonance techniques, and low-temperature phenomena.

Electromagnetic separations of stable isotopes and isotopes of the heavy elements were performed at Oak Ridge National Laboratory. In 1970, ORNL completed 25 years of separating and distributing enriched isotopes. Starting in 1945 with 4 calutrons, the program has grown to one which has 34 separators available for use in the separation of stable isotopes. In addition, a doubly-contained facility including eight calutrons, together with associated laboratory and process area, was completed and put into operation for the isotopic separation of the isotopes of heavy elements such as thorium, uranium, plutonium, americium, and curium. Samples were made available for all AEC research programs as well as for member countries represented on international data committees, especially for neutron cross-section measurements.

University, materials, radiation research:

AEC research projects with educational institutions are generally supported by means of a Special Research Support Agreement. Under this type of arrangement the AEC pays the institution its cost of performing the research, up to a specified amount (referred to as the "support ceiling") in consideration for its performance of specific research activities described in the agreement and in accordance with the provisions of the agreement.

Larger research projects, generally those with an estimated cost in excess of $250,000 annually, may be financed through a cost-type contract which permits closer AEC surveillance of the work in accordance with appropriate contractual provisions not included in a Special Research Support Agreement.

During the 1960's, the number of scientific man-years supported under the Physical Research Program increased from about 3,200 to some 4,700 per year, while the number of graduate students participating in the program went from around 2,600 to nearly 3,700. Scientific publications resulting from the program increased from some 4,000 annually during the early 1960s to more than 5,400 in 1970.

In 1959 the Federal Council for Science and Technology instituted the Interdisciplinary Materials Research Laboratory (IDL) Program wherein participating agencies provide block research support and assist in the construction of research facilities at selected universities. The AEC, already supporting substantial numbers of research projects on the campuses of the University of Illinois (Champaign-Urbana) and the University of California (Berkeley), agreed to sponsor IDL's at these institutions.

The IDL at Berkeley was formed as part of the Lawrence Radiation Laboratory (LRL). Selected members of the staff of the campus Metallurgy and Ceramics Engineering departments joined with the high temperature chemistry group under Professor Leo Brewer of the campus Chemistry Department and became the Inorganic Materials Research Division of LRL with Brewer as its Director. A research laboratory was completed and occupied at LRL in 1965.

In 1961 Congress authorized the AEC to construct a Materials Research Laboratory on the campus of the University of Illinois. However, Congress declined to appropriate the necessary funds. In 1964, the authorization was rescinded after the Advanced Research Projects Agency of the Department of Defense, as part of its IDL program, provided the University of Illinois with the necessary assurances to go ahead and construct a facility with its own funds on a DOD pay-back basis. A laboratory building was completed in 1966. It is known as the Materials Research Laboratory (MRL). Professor Robert Maurer of the Physics Department has been the Director of the MRL.

For the Notre Dame Radiation Laboratory the decade 1961-1971 represents a period of recognition, consolidation, expansion and trial. A federal appropriation for construction of a Radiation Research Building was made in 1961 and construction formally began on January 15, 1962. The new building was first occupied by the Radiation Laboratory on March 15, 1963. In October 1963, the staff numbered 1000 of whom 62 (i.e., those requiring repeated access to radiation sources and other specialized equipment) were actually housed in the new building. Just as congestion had been divisive, freedom of motion suddenly resulted in a spirit of cohesiveness. Theoretical developments were encouraged and the unity of objective in the experimental groups became more clearly apparent. The major radiation sources were the 10 kCi ^{60}Co source, the kCi ^{60}Co underwater source and the new and very flexible 2 Mev Van de Graaff generator. Shortly thereafter a very elaborate mass spectrometer was acquired. Subsequently, the growth and increasing diversity of interests among the senior personnel of the Laboratory resulted in some fractionation of the efforts of the experimental group into smaller groups. These included one on pressure effects and another on luminescence and associated studies.

Biomedical research programs

Irradiation of ecosystems:

The Brookhaven ecology forest program was initiated in 1961 as a part of the Brookhaven radiation ecology project. Its purpose was to investigate the nature of the changes following exposure of an oak-pine forest in the temperate zone to low levels of ionizing radiation. The project, designed to run for many years, has been yielding classic information on physiological characteristics of organisms growing under their local natural conditions; the sensitivity of this type of forest to gamma irradiation; the long-term genetic modifications in each component of the system; and a variety of associated phenomena such as the direct and indirect effects of irradiation on insect populations in the litter.

Marine sciences:

Investigators from the Woods Hole Oceanographic Institution isolated a nitrifying bacterium, Nitrocystis oceanus, from ocean water collected from radioactive tracer studies. Nitrocystis is able to oxidize ammonia to nitrate. Until this discovery the mechanism whereby organic nitrogen is converted back to an inorganic nitrate was unknown. The bacterium has now been cultured from water at all depths down to several thousand feet in all major oceans.

An unexpected observation by radioecologists at Oregon State University promises to revise present ideas about the size of radiation doses to aquatic organisms. Organisms living at depths below the penetration range of cosmic radiations were thought to be exposed only to the radiations from the naturally radioactive isotopes built into their cytoplasm, chiefly potassium-40, the radiation dose from which would equate to about 30 mrads per year. Analyses of fish for the radioactive isotopes lead-210 and polonium-210 disclosed amounts of these isotopes that would raise their annual radiation dose about tenfold. But, since the radioactivity is restricted almost exclusively to the liver, viscera, and bones, no health hazard for man is anticipated.

Thermal effects studies:

In 1968 the AEC's Division of Biology and Medicine expanded its long-established program on the effects of thermal additions to natural bodies of water. The result is an improved capability for predicting the effects on the local biota of heated waste water from nuclear power plants. Thus, the investigations of the thermal discharges from single nuclear power plants indicate that the effects are confined to a small local area and do not endanger the ecosystems of the recipient bodies of water.

Effects of radiation on man:

The research protocols of the Atomic Bomb Casualty Commission (ABCC) at Hiroshima and Nagasaki, Japan, have become the model for many other large-scale prospective epidemiological studies. With the cooperation of the Japanese people and government, three major lines of investigation are now functioning smoothly to detect and measure long-term effects of exposure to the mixed radiations from nuclear weapons. By careful physical examinations every other year, a selected group of originally about 10,000 exposed and 10,000 matched non-exposed people are being followed to detect abnormalities and diseases in their incipient stages. An additional approximately 45,000 exposed and 45,000 unexposed are being followed for longevity and cause of death. The third program is a study of the pathologic anatomy of persons in control and exposed groups.

As of 1970, 25 years after exposure, only three effects can be identified with assurance. 1) A characteristic cataract developed on the posterior sub-capsular surface of the lens of the eye in fewer than 100 people within five years of exposure. The cataract is similar to those seen in the small number of early cyclotron workers who thoughtlessly looked directly into the beam. The cataracts are amenable to surgery. 2) The annual incidence rates of leukemia five to nine years after exposure rose six to seven times over those in the control population. The leukemias were histologically identical with those which occur spontaneously among the Japanese. The subsequent rate declined until now it is just a little higher than the rate in the control population which, interestingly, has been gradually decreasing. 3) The incidence of thyroid tumors has begun to be statistically higher in the exposed compared to the control population and there seems to be a positive correlation with radiation dose. The tumors are indistinguishable from the thyroid neoplasms occurring spontaneously.

Transuranium Registry:

This special registry was organized in order to maintain close medical contact with workers who have accidentally accumulated an appreciable body burden of the recently man-made transuranium elements, chiefly neptunium, plutonium, americium, and curium, during the course of their employment. Fortunately, contaminating accidents have occurred infrequently and have on the whole been modest to negligible, so that knowledge of the toxicity of these radioelements had to be based on their effects in experimental animals. The resulting experimental data indicate that the toxicity of this group of elements is comparable to that of radium, but it is still necessary to know whether man will react to these radioactive metals like the experimental animals. Since it is unacceptable to use human volunteers for such toxicologic investigations, a registry is the only device available for maintaining the continued contact needed for learning the outcome, if any, of such contamination among humans. The voluntary cooperation of the workers, including releases for autopsy study, has been outstanding.

Beneficial applications of L-Dopa:

The discovery that daily doses of the amino acid, L-3,4-dihydroxyphenlalanine or L-Dopa, are of great value in relieving the symptoms of Parkinson's disease was an outgrowth of studies on manganese toxicity in miners by Brookhaven National Laboratory investigators. L-Dopa therapy represents (in 1971) the best effective medical treatment of Parkinsonism and the side effects of the chemicals are tolerable. In addition to its clinical usefulness, L-Dopa has introduced new concepts in the management of neurological disorders affecting the structures at the base of the brain. Nondestructive, sequential studies of the metabolism of radiolabelled L-Dopa and its analogs raise the possibility of uncovering the neurologic basis of Parkinson's disease which affects approximately 500,000 Americans.

Beneficial applications of hormone assay:

An in vitro clinical diagnostic procedure for assay of circulating hormones has been developed in which appropriate radioisotopes or antibody reagents labelled with radioisotopes are added to small samples of blood or other tissues taken from patients. This chemical or immunochemical type of radioassay is highly sensitive and specific. In many cases it can be used as a rapid, inexpensive office procedure for estimating the blood level of a number of hormones. The technique is of particular importance as it does not expose the patient to radiation, an advantage that is especially desirable in the case of children and pregnant women in whom irradiation is to be avoided.

Beneficial applications of californium-252:

A program for evaluating the effectiveness for cancer therapy of neutrons from naturally fissioning californium-252 was begun about three years ago when californium-252 sources were loaned to two medical institutions. The initial studies focussed on the dosimetry and radiobiology of this man-made radioisotope, first in normal malignant cell cultures and then on the skin of swine. To date (1971) 17 specially selected patients with far-advanced carcinoma have received radiation therapy by means of the X- and gamma-rays and neutrons from californium-252 implants; by far most of the tissue dose results from the neutron flux. The californium-252 is sealed in platinum-iridium tubes like those used to contain radium-226 for radium implant therapy.

Beneficial applications of technetium-99m and the "cow":

In 1960 the "hot atom group" of Brookhaven National Laboratory suggested that technetium-99m ought to be used for diagnostic purposes. However, the six-hour half-life of this radioisotope, a desirable property from the standpoint of low radiation dose to the patient, tended to restrict it to laboratories close to facilities having neutrons to irradiate molybdenum targets. The Brookhaven group solved this transportation impediment by designing the following isotope generator system: the parent radioactive isotope, which is firmly adsorbed onto a resin, decays into the daughter radioisotope not retained on the resin; an appropriate eluant then removes at will the daughter isotope in high degree of purity ready for conversion into a pharmaceutically acceptable form. In the case of technetium-99m the parent radioisotope is the radioisotope molybdenum-99. This kind of generator was given the name "cow" since the eluant percolates down through a vertical tube packed with the resin and the daughter radioisotope is "milked," from the generator. The basic concept is now used to obtain many short-lived radioisotopes.

Beneficial applications of the Anger camera:

The Anger Camera, named for its developer, Hal Anger, a scientist at the Donner Laboratory in Berkeley, can provide a series of scanning pictures of a total area made a few seconds or minutes apart and so record the kinetics of change of concentration of an injected radioactive isotope in a tissue. In addition, by use of focussing collimators and a refined computer program, a depth dimension can be achieved. In this way a series of tomographic pictures can be taken which give a three-dimensional picture of a tumor as well as indicating the depth of a defect from the surface of the body. Today virtually every major nuclear medicine facility routinely uses this camera in its diagnostic clinics. The scanning instrument, however, retains its position as the mainstay diagnostic tool.

Beneficial applications of biomedical engineering:

At the Oak Ridge National Laboratory the molecular anatomy (MAN) program in biomedical instrumentation, jointly sponsored by the National Institutes of Health and the AEC, has led to the development of a number of centrifuge systems that have revolutionized several areas of biomedical research and development. These zonal centrifuges are highly effective in separating cell particles, various large biologic molecules, and animal and human viruses in the purest forms attained to the present time (1971). For example, a large 1.7 liter continuous-flow centrifuge is being employed by a number of pharmaceutical houses to isolate the influenza virus that now is used to manufacture the pure influenza vaccine which the world has chosen for prophylactic immunization. The ability of the zonal centrifuge rapidly to isolate small amounts of undamaged specific biomolecular species from large volumes of fluid has made this instrument a necessity for pharmaceutical houses and laboratories preparing pure enzymes, nucleic acids, proteins, and hydrolysis products.

VII. Los Alamos Meson Physics Facility and 200 Bev Accelerator

The Los Alamos Meson Physics Facility (LAMPF)

In August 1963, the Los Alamos Scientific Laboratory (LASL) submitted to the AEC a proposal for the construction of a "Los Alamos Meson Physics Facility" (LAMPF), at an estimated cost of $47,142,000. It was proposed that architect-engineering work be initiated in the first quarter of fiscal 1965. In the project's description it was stated that it would provide for a meson physics facility consisting of a linear accelerator capable of producing a 1 milliamp beam of protons at 800 Mev, a suitable target and experimental area at the output end of the accelerator for conducting an experimental program using mesons, an accelerator tunnel, support areas and utilities. The AEC responded favorably to this proposal.

In its markup of the AEC's 1967 budget, the Bureau of the Budget eliminated $3 million requested for LAMPF. This was among a number of adverse actions on the AEC budget that I appealed to the President during a visit to his Texas ranch in December 1965. After hearing me and Budget director Charles Schultze debate the issue, the president restored the funds. It was now possible to proceed with the design and construction of LAMPF.

Groundbreaking ceremonies were held at Los Alamos on February 15, 1968, the 25th anniversary of the founding of LASL. I delivered an address at the ceremonies.

The 200 Bev Accelerator

In May 1963, the AEC, acting on a recommendation by a joint panel of the President's Scientific Advisory Committee and its own General Advisory Committee, authorized the Lawrence Radiation Laboratory, Berkeley, to proceed with an advanced engineering study of a proton accelerator in the unprecedented energy range of 200 Bev (billion electron volts).

As this study proceeded, great interest was evinced in the scientific community. The Joint Committee on Atomic Energy also followed it very closely. On January 25, 1965, I forwarded to President Johnson a report that had been requested by JCAE Vice Chairman Holifield. Entitled "Policy for National Action in the Field of High Energy Physics," the report summarized the status of national and international efforts in this field and included among its proposals construction of the 200 Bev accelerator. In transmitting the report to Holifield, the president commended the AEC and its staff "for their efforts in working out a well-considered program.."

Earnest consideration began to be given now to where the accelerator would be located. Bearing in mind its high cost (estimated at $350 million), it was evident that there could be only one such facility in the United States. It was important, therefore, that it be accessible to all qualified experimentalists. On January 17, 1965, the NAS hosted a meeting of 25 university presidents at which this and related matters were considered. This meeting initiated a train of events that culminated in the formation of the Universities Research Association, which was to be under contract to the AEC to construct and operate the accelerator.

It was soon decided that there should be a national competition to select a site. On March 2, 1965, I wrote to Frederick Seitz, president of the NAS, asking that his organization study the problems associated with selecting a site and listing several general criteria. A month later a site evaluation task group was established within the AEC to conduct a preliminary screening of proposed sites. This effort, covering 126 site proposals involving over 200 potential locations in 46 states, was completed by the end of August. On September 15, the AEC publicly identified 85 site proposal packages that it had transmitted to the NAS for further evaluation. To assist the NAS, the AEC organized eight site visit teams to inspect and gain further specific data on all 85 locations.

Meanwhile, design work had been continuing at LRL. Its continuation was placed in jeopardy when Budget Director Charles Schultze struck our request for $4 million from the FY 1967 budget. This was one of the matters I took up with the president at his ranch on December 10, 1965. When he ruled in our favor, it represented a turning point in the fortunes of the 200 Bev accelerator. From this point forward, the funding process in the Executive Branch proceeded on a schedule pretty much in tune with the project's requirements.

The report of NAS's Site Evaluation Committee was received on March 21, 1966. It identified six sites as clearly superior to the others. These were at Ann Arbor, Michigan; Brookhaven National Laboratory, New York; Denver, Colorado; Madison, Wisconsin; the Sierra Foothills near Sacramento, California; and South Barrington and Weston, both near Chicago, Illinois.

Following community opposition, South Barrington was soon withdrawn from the competition. On April 11, the AEC announced that a group of AEC officials -- headed by me -- would inspect each of the six sites. Such visits were indeed made. In addition, the AEC evaluated a number of factors relating to the five proposals. These included construction costs, civil rights and equal opportunity aspects, electric power requirements, air accessibility, proximity to universities, projected growth patterns for these schools, probable university involvement with the facility, and the general effect it might have on the surrounding region.

On December 16, 1966, the AEC announced that it had selected the Weston, Illinois site. Maintaining to the end his stance of leaving this decision entirely to the AEC, despite what must have been some strong political pressures on him to intervene in behalf of one site or another, the president specifically requested that he not be notified in advance of the public announcement.

In April 1967, following the suggestion of Illinois Congressman Frank Annunzio, among others, I announced that the National Accelerator Laboratory would be named in honor of the late Enrico Fermi. On December 1, 1968, a wintry day in Chicago, with approximately 1,000 people in attendance, laboratory director Robert R. Wilson and I broke ground for the project. In my address, I stated: "Symbolically, we could say that the spade that breaks ground on this site today begins our deepest penetration yet into the mysteries of the physical forces that comprise our universe."

In retrospect, it might be said that the success in getting this project launched was due in large part to an early shift of the debate form the question of whether we should build such an accelerator to the question of where we should build it. The cooperation of all concerned in the resulting competition, including the White House, the NAS, many members of Congress, and the AEC, helped to give the process credibility and wide acceptance.

VIII. The National Transplutonium Production Program

The National Transplutonium Production Program may be said to have had its genesis on October 24, 1957, when I wrote to Atomic Energy Commission Chairman Lewis Strauss about the need for a "very high flux reactor" and for a two-fold program to 1) irradiate ^{239}Pu in a high flux production-type reactor to produce ^{244}Cm and 2) irradiate curium in a "very high flux reactor" to produce berkelium, californium, and einsteinium in substantial quantities (milligrams!).

In late 1964 a Transplutonium Program Committee was officially formed as an advisory body to the director of AEC's Division of Research. The same group of scientists had previously served as, first, the "Ad Hoc Committee for Reactor Actinide Production" and, then, as a "Transplutonium Advisory Group" with membership as follows: A. R. Van Dyken (AEC, Chairman), Richard W. Hoff (LRL), Paul R. Fields (ANL), Richard Dodson (BNL), Robert A. Penneman (LASL), T. Raymond Jones (AEC, Vice-Chairman), D. E. Ferguson (ORNL), Albert Ghiorso (LRL), O. Lewin Keller (ORNL), A. Chetham-Strode (ORNL), and Clark H. Ice (SRP). The Committee membership has remained unchanged except that O. Lewin Keller replaced A. Chetham-Strode following the latter's sudden and untimely death on December 23, 1965.

The interest developing in 1963 in the use of ^{244}Cm and ^{242}Cm for isotopic heat sources led to a proposal for production of ^{244}Cm at the Savannah River Plant (SRP) in South Carolina. In May of that year, the AEC approved initiation of a large-scale program to produce ^{244}Cm; subsequently, it was decided that a pilot production program should precede any large-scale effort. Accordingly, a pilot program to make about 3 kg of ^{244}Cm to demonstrate production techniques and provide material for tests was approved by the AEC on September 6, 1963.

Curium production was carried out as a main-line effort at SRP in two stages. The first, designated Curium-I, involved irradiation of ^{239}Pu-Al alloy material to almost complete burn-up of the ^{239}Pu. The targets were then chemically processed and the actinides recovered, refabricated as Al alloy, and reirradiated at a high flux, about 10^{15} n/cm^2/sec, in a second stage designated Curium-II. Curium-I was carried out in 1964 and Curium-II in 1966. The production concept of high flux operation of an SRP reactor for Curium-II was evaluated immediately following Curium-I; chemical processing of the original Curium-I targets took place at SRP in 1965.

Transplutonium Production Program plans originally were that all additional irradiations of ^{242}Pu, ^{243}Am and ^{244}Cm following their recovery from the early SRP irradiations would be carried out in the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL). Advantage was taken, however, of the high flux operation of the SRP reactor in 1965 to accelerate transplutonium production for the research program by continuing the irradiation of a portion of the ^{242}Pu produced for HFIR feed at SRP.

The high flux irradiation was carried out in 1965 at fluxes in excess of $2\text{x}10^{15}$. For these irradiations, ORNL contributed 520 g of ^{242}Pu from the 930 g that had been delivered to ORNL following the two campaigns originally carried out to provide target material for HFIR. The ^{242}Pu was fabricated into three types of slugs.

Finally, eight SRP slugs were fabricated at SRP, each with about 35 g of ^{242}Pu. These were also charged at the beginning of the high flux run in early 1965. The high flux run lasted one year through February 1966, and was followed by another run in 1966.

The HFIR was authorized in FY 1961 for construction at ORNL at an estimated construction cost of $12 million. The actual cost for construction was $14,718,000. HFIR went critical August 25, 1965. By the end of 1965 it had operated at 50 MW, and in May 1966, approval was given for 100 MW operation. Cycle 2 (operation on the second core) was initiated June 30, 1966 and completed July 31, 1966, reaching a power level of 75 MW. Cycle 3, initiated August 9, 1966 and completed September 4, 1966, achieved a power level of 90 MW. Full reactor design power, 100 MW, was reached with Cycle 4 which was initiated September 9, 1966, and ran through September 30, 1966. Many full power cycles followed. From the very beginning, reactor cycles were averaging better than 2200 megawatt days (MWD), as compared to the original design estimate of 1500 MWD.

Construction of the facility for chemical processing of the transplutonium products of these neutron irradiations, the Transuranium Processing Plant (TRU), was authorized in FY 1963 and construction started in July 1963, and completed on schedule in May 1965. Its cost of construction,$8,818,000, was only slightly higher than the original estimate. Equipment for initial operation was installed at the beginning of 1966. TRU's first "hot" processing took place in July 1966. During its first year of operation, ^{244}Cm, ^{243}Am, ^{249}Bk, and ^{252}Cf were isolated.

During the second year of operation of TRU, through May 31, 1968, 17 processed targets processed in 1967 yielded around 5 mg of californium. A major campaign to recover, purify and make available multigram amounts of ^{243}Am and ^{244}Cm from the original SRP raffinate solution was conducted. Products, including 70 g of curium and 25 g of americium, were shipped to about a dozen customers. This was followed by many more such campaigns and shipments.

In early 1968 three special californium targets were fabricated and irradiated in HFIR to produce einsteinium. A secondary purpose for the irradiations was to refine some of the calculated values of the cross sections in the production chain of isotopes from californium. It was discovered that the capture cross section of ^{252}Cf is considerably higher than previously supposed, apparently in the range of 40 to 50 barns instead of 7 to 10. About three milligrams of ^{252}Cf were irradiated in March 1968 and produced approximately 6 micrograms of ^{253}Es. This was followed by a continuing program of irradiations.

As a result of this National Plutonium Production Program, by the end of the decade, about 3 kg of curium (mainly ^{244}Cm, containing also a mixture of the heavier isotopes ^{245}Cm, ^{246}Cm, ^{247}Cm, and ^{248}Cm), about 70 mg of ^{249}Bk (which is a source of an equal amount of daughter ^{249}Cf), about 500 mg of ^{252}Cf, about 1 mg of ^{253}Es, and about a picogram of ^{257}Fm had been produced.

IX. Civilian nuclear power

In March 1962 President Kennedy asked the AEC to take a "new and hard look at the role of nuclear power in our economy." (Actually, my administrative assistant, Howard Brown, and I had planted the notion of such a study in the White House, hoping that this might increase the president's interest in civilian nuclear power and, thus, give it a higher priority.) The president asked that the study identify the objectives, scope and content of a nuclear power development program in light of the nation's prospective energy needs and resources and of advances in alternative means of power generation.

The year 1962 was an appropriate one for a "new and hard look." By this time 25 experimental or prototype nuclear power reactors had been funded by the government, while 12 others had been funded under cooperative programs with industry. From this work had come substantial advances in nuclear technology and considerable operating experience, sufficient to make the goal of economically competitive nuclear power seem attainable, at least in areas of the country with high conventional fuel costs. Not surprisingly, such progress had stimulated increased industry interest in nuclear power and in the private ownership of nuclear fuel. On the other hand, general economic conditions did not seem to warrant the construction of additional experimental facilities without more definitive program guidance. Guidance was needed particularly to help determine what reactor concepts should be emphasized in the coming period. The plants thus far built had been of several different types, each having its virtues and its champions.

Light water-cooled reactors had demonstrated their reliability, having been used extensively, for example, in nuclear submarines and in the Shippingport Atomic Power Station near Pittsburgh. They were not extremely complex either in construction or operation, and could be built and operated with available technology.

The use of nuclear superheating, to obtain higher thermal efficiencies and steam conditions more compatible with conventional turbogenerators, had been explored, for example, with the 50 Mwt Boiling Nuclear Superheat Power Station [BONUS] in Puerto Rico.

Gas-cooled systems were known to permit relatively high thermal efficiency. Potentially the coolant gas could drive a turbine directly, and this concept, known as the HTGR (High Temperature Gas-Cooled Reactor), showed promise of being able to use thorium fuel, which was in abundant supply.

Through operation of experimental reactors, it was known that liquid metal-cooled reactors could achieve high temperatures and thermal efficiency, permitting low net power costs. In addition, the liquid metal-cooled reactors could be breeder reactors. Their further development could therefore be considered essential to achieve the full benefit of nuclear power.

Heavy water-cooled and moderated reactors had been examined, but had limited support in the U.S., because of the availability of enriched uranium fuel material. (Heavy water reactors could use natural uranium fuel and required larger facilities because they could not produce as much energy per cubic foot of reactor as those using enriched fuel.)

In November 1962, the AEC issued the requested report to the president. It was of major significance to the civilian reactor development program. It set forth program objectives and proposed planning for a national energy production effort—for the president, the Congress, the utilities, the nuclear industry and the general public—all those whose support would be needed to carry out the program.

A major contribution of the report was to establish the national and international need for nuclear electric power and to set forth why there should be a civilian nuclear power program in the U.S. to help meet this need. It did so by first analyzing the availability of alternative fuels for energy production. It then indicated that nuclear energy was technically feasible and economically reasonable for electric power and process heat applications, and that it could extend indefinitely the fuel reserves of the United States through the use of breeder reactors which could utilize available uranium and thorium resources. Other advantages of nuclear power cited were that it would: 1) eliminate geographic variations in power costs, 2) place the U.S. in a position of international leadership, 3) improve the defense posture of the U.S., and 4) reduce air pollution.

At the time of preparation of the 1962 report to the president, it was believed desirable for the most efficient use of nuclear fuel reserves to develop converter reactors that were more advanced than already existing or planned light water reactors. These were expected to be in operation during a transition period prior to construction of the so-called high gain breeders, such as the Liquid Metal-cooled Fast Breeder Reactor (LMFBR).

The advanced converters thought most likely to succeed in bridging the gap were the thorium-fueled high temperature gas-cooled reactor (HTGR), the heavy water moderated organic-cooled reactor (HWOCR), the sodium graphite reactor (Hallam Nuclear Power Facility), and a spectral shift control reactor. In addition, the AEC planned to build an advanced Shippingport-type reactor (seed-blanket) which would be able to demonstrate low gain breeding in a light water reactor. Like the HTGR, this light water breeder reactor (LWBR) and was expected to utilize thorium-uranium-233 fuel.

One of the important trends in atomic energy development in the 1960's was the emergence of economic nuclear power. On March 26, 1964, the Jersey Central Light & Power Co. applied to the AEC for a permit to construct a 515 Mwe nuclear power station at Oyster Creek, near Tom's River, New Jersey. The company had chosen a boiling water reactor, a type for which there was a considerable accumulation of operating experience. While the capacity of the plant was large, other plants then being planned were not much smaller. The plant was to be wholly investor-financed. The most significant aspect of the company's application was its statement that nuclear power has been chosen over alternative (fossil-fueled) generating systems on the basis of economics alone. The plant vendor, General Electric Co., took the bold step of submitting a firm bid for the turn-key construction of this unit.

The Oyster Creek decision was but one dramatic event in a trend which the Commission had signalled in its 1962 report to President Kennedy. The report had predicted that nuclear power was on the verge of being competitive in high-cost power areas in the U.S. and that it had prospects for later expansion on a more widespread geographic basis. The 1962 report forecast a nuclear generating capacity in the U.S. of 5,000 Mwe by 1970, and 40,000 Mwe by 1980. In 1964, following the Oyster Creek announcement, the AEC increased these estimates, predicting that U.S. nuclear generative capacity would be 6,000 to 7,000 Mwe by 1970 and between 60,000 and 90,000 Mwe by 1980. Several years later, when utilities had begun to order reactors with spectacular rapidity, the AEC raised its projections to between 130,000 and 170,000 Mwe by 1980.

Although the Oyster Creek decision did not initiate an immediate large-scale shift to nuclear power. It undoubtedly had some relationship to an increase in contracts awarded for nuclear power plants which began to appear in the latter half of 1965. Westinghouse and other nuclear reactor vendors also became very active. In the three-year period 1966-68, U.S. utilities ordered, without direct government assistance, 67 reactors, the units ranging in size from about 450 Mwe to more than 1,100 Mwe. By the end of 1970, three of these reactors were operable and more than 50 were being built. All but one of these orders were for light water reactors (the exception being an HTGR).

There were several reasons for the rapid growth of nuclear power and the initiative taken by industry. Those utilities which had had experience with nuclear power plants were expressing their confidence by planning for more and larger units. Increasing demands for electric power were causing a new emphasis on expanding generating capacity. Further, the trend in the industry was toward larger plant size, a factor that favored nuclear power plants, which were relatively more economic as plant size increased. Possibly, the growing concern over air pollution was another factor. The most significant factor was undoubtedly economics. Projections indicated that nuclear power, previously thought likely to be competitive only in high fuel costs areas of the country might also be so in in areas where fossil fuels were abundant. For example, in 1966, the TVA announced plans to install three large nuclear reactors in the coal-mining area of northern Alabama. Also, in 1970, Louisiana Power and Light Co. ordered a large nuclear plant to be built west of New Orleans, an area of gas production.

By January 1, 1967, there were 13 operative central station nuclear power plants in the U.S. and 36 others under construction or ordered. Development of the various reactor concepts had proceeded more-or-less as planned and proposed; emphasis had begun to be placed on the development of high gain breeder reactors, as recommended in the 1962 report, especially the liquid metal fast breeder reactor.

Later in the year, the AEC prepared a supplement to its 1962 report. Such an updating had been recommended by the Joint Committee on Atomic Energy and by officials in the Executive Branch to take account of developments since 1962, such as the sharply increased rate of addition of nuclear generating capacity, some wide disagreements in estimates of future growth, technical developments in certain advanced reactor fields, and some new estimates of uranium resources.

An important finding of the 1967 supplement was future reactor development would center on the LMFBR. Pursuant to this finding the AEC organized an LMFBR program office at Argonne National Laboratory. Following months of discussions, reviews, and assessments by this office, the AEC, the AEC's national laboratories, the nuclear industry, and the electric utilities, an agreed program emerged.

Important components of this program included the privately-owned SEFOR (Southwest Experimental Fast Oxide Breeder Reactor) at Fayetteville, Arkansas, a 20 Mwt (megawatt thermal) sodium-cooled fast reactor used primarily for safety experiments; the plutonium-fueled Zero Power Plutonium Reactor (ZPPR) at the National Reactor Testing Station (NRTS) in Idaho and its related ZPR reactors at ANL; the Experimental Breeder Reactor No. 2 (EBR-2) at NRTS; and the Fast Flux Test Facility (FTFF) under construction at the AEC's Hanford Works in Washington.

The climax of LMFBR development will be reached when a demonstration plant is constructed and operated on a utility system. In 1969, the AEC, in cooperation with industry, initiated the first of a two-phase approach leading to the construction of the such a plant. This project definition phase (PDP) involved: proposed plant and site definition; project cost estimates; assessment of technical and economic risks; scoping and planning for research and development; quality assurance programs and codes and standards efforts; engineering, procurement, construction training, and operational effects; identification of utility and reactor manufacturer resources; and identification of relationships among architect-engineer, reactor manufacturer, utility and AEC. The three AEC contractors carrying out this first phase were Atomics International, General Electric and Westinghouse.

The second phase, the Definitive Cooperative Arrangement, will arrange for the design, supporting development, tests, construction, and operation of an LFMBR demonstration plant. It will be a cooperative undertaking with participation by the AEC, the electric utility industry, reactor manufacturers, equipment suppliers and others.

During 1971, each of the three PDP contractors indicated its interest in proceeding toward a cooperative arrangement for the construction and operation of a demonstration plant. More than 100 utilities, representing about half of the Nation's electric generating capacity, have expressed their preparedness to participate financially or in other ways. During the year, two utility advisory boards were formed to assist the AEC determining the extent to which the electric utilities might participate and in establishing suitable arrangements. These two boards were the Senior Utility Steering Committee and the Senior Utility Technical Advisory Panel.

A canvass of the Nation's utility industry by the advisory committee members, with the assistance of the Edison Electric Institute, the American Public Power Association, and the National Rural Electric Cooperative Association, indicated that utility support for the first demonstration plant of about $240 million could be expected. The AEC is now concentrating on the identification of utilities willing to undertake the responsibilities and financial obligations of plant ownership, including the provision of suitable alternate sites. At year end, discussions were continuing with several utility groups which had indicated an interest.

On June 4, 1971, at a climatic meeting of President Nixon's cabinet, including some key members of Congress, I made a presentation proposing a vigorous program for the development of the LMFBR. Following the meeting, the president supported the idea, stating:

> "...Our best hope for meeting the Nation's growing demand for economical clean energy lies with the fast breeder reactor. Because of its highly efficient use of nuclear fuel, the breeder reactor could extend the life of our national uranium fuel supply from decades to centuries, with far less impact on the environment than the powerplants which are operating today..."

The president also said that it was important to the Nation that the commercial demonstration of a breeder reactor be completed by 1980.

Initial operation of a demonstration plant is being planned for the late 1970's.

During the 1960's the Power Reactor Development Co. (PRDC) built and operated a fast neutron power plant, the Enrico Fermi Atomic Power Plant (60 Mwt) at Lagoona Beach, near Detroit, Michigan. Detroit Edison Chairman Walker Cisler offered the Fermi reactor to the AEC as a source of fast neutrons for irradiation experiments potentially useful to the fast reactor development program. Due to a long history of antagonism toward Cisler (due to his alleged earlier opposition to governmental development of civilian nuclear power), influential New Mexico Senator Clinton Anderson, a JCAE member, and AEC Commissioner James Ramey opposed the acceptance of this offer. The program was interrupted by a partial fuel meltdown at the plant occurred on October 5, 1966.

AEC's civilian nuclear power efforts have extended into several realms in addition to its main preoccupation with achieving economically competitive production of electricity from nuclear plants. One of these was a program to analyze, develop and demonstrate nuclear reactor systems for desalting sea and other brackish water. The AEC's activities in this field have been closely coordinated with the Office of Saline Water (OSW), Department of the Interior. The Oak Ridge National Laboratory has provided technical support for both OSW and the AEC. Joint studies were completed for many areas both in the U.S. and abroad, and extensive interest has been expressed in this potential use of nuclear power, especially in a large industrial and agro-industrial complex, termed the "Nuplex" by ORNL. However, a large nuclear desalting project, the Bolsa Island Nuclear Power and Desalting Plant, proposed for Southern California, did not materialized.

The AEC has conducted a widespread nuclear reactor safety program. Some of the efforts have had generic application to the siting and safety of all research, test, and power reactors; others have dealt with problems of particular reactor concepts. The results are essential to the design, siting, operation, and licensing of nuclear plants. During the early 1960's, most of the safety work related to water-cooled reactors. Later, some of the the emphasis turned toward the safety of breeder reactors and the effects of operations on the environment.

The disposal of high level radioactive waste remains a problem. In 1970 the AEC announced a significant new policy designed to insure that high-level radioactive waste products are disposed of in a manner that will not damage the environment. Years of research have proven the feasibility of converting liquid radioactive wastes to solid form. This greatly reduces their volume; 100 gallons can be reduced to one cubic foot. However, over the long term, safe storage of the alpha-emitting actinide elements presents a very difficult problem. One possible solution, storage in salt formations, has achieved recent prominence. Between 1965 and 1967 there was a successful demonstration project in a salt mine near Lyons, Kansas. Encouraged by this experience, the AEC, in 1970, tentatively selected a salt formation near Lyons as the site for its first long-term storage of solid high-level and long-lived low-level wastes. This project unfortunately did not materialize. It was opposed vigorously by residents of Kansas. And then, in 1971, measurements showed that there were possible routes for the entry of water into the site.

The decade in civilian power reactor development closed with an outstanding record of accomplishments. There were some disappointments--some of the pioneering demonstration plants had to be closed out earlier than anticipated--but even in these instances knowledge was gained which helped push nuclear progress onward.

At the end of 1971, 130 central station nuclear power plants, representing an aggregate capacity of more than 108,600 net megawatts of electricity (Mwe) were built, under construction or planned in the United States, , as follows: there were 25 operable units (including two licensed for fuel loading and subcritical testing), representing a total capacity of 11,400 Mwe; 52 units (44,500 Mwe) were under construction or being reviewed for operating licenses; 39 units were under AEC review for construction permits, representing 38,400 Mwe of initial capacity; and there were 14 units for which utilities had contracted but not yet filed construction permit applications, representing 14,000 Mwe.

The AEC was involved, in cooperation with the Department of Army, in the development of compact reactor systems suitable for use in remote areas or for unique military purposes. Such reactors actually operated for a time at such places as McMurdo Sound, Fort Greely (Alaska), and Camp Century, Greenland. Later, attempts were made to develop a prototype mobile Military Compact Reactor (MCR) to furnish 3,000 kilowatts of electric power to troops in the field. Technical and funding problems led to the discontinuance of such projects.

In Project Pluto, a joint AEC–Air Force undertaking, a nuclear ramjet engine was to be developed at the Livermore Laboratory for use in strategic missiles, giving them a unique capability for supersonic flight over long distances at low altitudes. Air–cooled high temperature reactors, designated the Tory series, were tested in the early 1960's at the Nevada Test Site. Again, technical and funding difficulties led to the demise of the program.

X. Raw Materials Program

The original objective of the AEC's raw materials program, and a major AEC concern in the 1950s, was to secure the large amounts of uranium urgently needed for the production of nuclear weapons. The major accomplishments in the 1950s were the acquisition of sufficient uranium to meet the requirements of both defense and non-defense programs and the development of a domestic source of supply.

By contrast, the principal task facing the AEC and the uranium industry in the 1960s was adjusting to the developing oversupply of uranium, which reflected the success of the exploration program and the cutbacks in military requirements. A transition was necessary from a crash AEC procurement program, geared to meeting urgent military needs, to a program whose goal was the establishment of a viable domestic uranium industry capable of supplying, on a commercial basis, the energy resources for the developing civilian nuclear power economy. The transition was complicated by a hiatus of some years between the time when the major portion of the military requirements had been met and the development of the civilian market.

In early 1962, it appeared evident that a large-scale non-defense market for uranium probably would not develop for a number of years after 1966, the established termination date of AEC's procurement program. An AEC surplus was also forecast if the procurement program were to be continued through 1966 at the previously projected rate. Thus, it was desirable to find a means of reducing deliveries to AEC which would at the same time also provide for a continuing uranium industry capable of meeting future civilian and military needs.

To meet these needs, the AEC announced on November 7, 1962, a program under which its uranium procurement would be extended at a reduced level through December 31, 1970. A producer participating in this "stretch-out" program would hold back delivery until 1967 and 1968 of a part of the material under contract for delivery to the AEC before 1967, and AEC in return would buy in 1969 and 1970 an additional quantity equal to the amount deferred and delivered. The deferred material would be bought during the 1967-1968 period at the then-existing contract price of $8 per pound of U_30_8. The equal additional quantity would be bought during 1969 and 1970 at fixed prices under each contract, the prices to be determined by application of a formula to allowable costs of production for the 1963-1968 period subject to a ceiling price of $6.70 per pound of U_30_8. Uranium producers were invited to submit proposals covering the quantity of U_30_8 in concentrate under their existing contracts with the AEC which they would be willing to defer.

Contracts were renegotiated with 11 companies to defer delivery under this formula of more than 15,000 tons of U_30_8, reducing AEC's procurement costs in the 1963-1966 period by $246 million.

Although a reasonable balance between uranium purchases and requirements had been projected in 1962, even with the added purchases in 1969 and 1970 under the stretch-out program, decisions in 1964 and 1965 to reduce production of nuclear weapons materials resulted in a substantial surplus of uranium. The stretch-out program originally provided a market for about 8,000 tons of U_30_8 per year during the 1967-1970 period. This was expected to achieve the other stretch-out objective of a continuing industry production base which could be expanded as necessary to supply the long-range commercial market.

The AEC uranium surplus and the earlier-than-anticipated development of the commercial market permitted AEC to reduce its purchases in 1969 and 1970 by negotiation of reductions in, or termination of, deliveries under some of its contracts without endangering the viability of the uranium producing industry. In fact, total industry sales (AEC plus commercial) substantially exceeded the originally anticipated stretch-out level of 8,000 tons of U_3O_8 per year, rising to 9,500 tons in 1967 and to more than 14,000 tons in 1970. Most of the companies who did not stretch out their contracts were also able to make commercial sales to utilities and reactor manufacturers. The renegotiation and termination of contracts reduced AEC's expenditures by $56 million and reduced its excess uranium accumulation by 4,900 tons.

As a result of these additional reductions in procurement commitments and some shortfalls in deliveries, the four-year stretch-out in production was achieved through the purchase of only an additional 9,135 tons of U_3O_8 at a cost of $107 million.

A natural outgrowth of private ownership of nuclear fuel (authorized by Congress in the Private Ownership Act of 1964) was the concept of toll enrichment. This involves the delivery of privately-owned uranium to the AEC in government-owned plants and the subsequent return to the customer of a lesser amount of uranium containing a greater concentration of U-235 upon payment of an enrichment services charge.

The private ownership legislation also gave the AEC the authority to enter into long-term contracts for toll enrichment. This provided the basis for a commercial market for natural uranium and permitted the phasing out of government procurement for non-government needs. It ended the government monopoly over uranium and permitted the emergence of a strong and competitive domestic uranium industry capable of satisfying peaceful nuclear energy requirements for years to come.

As a result, the only industrial activity for which operators of nuclear power reactors are now dependent on the AEC is the enrichment of uranium in the fissionable isotope U-235. This is accomplished in large government-owned gaseous diffusion plants using highly classified technology developed under the AEC's military program. Such enrichment may ultimately be provided by U.S. industry as well.

Abroad, the incentive to use toll enrichment was even stronger than in the U.S. because it had been AEC policy to make enriched uranium available for foreign power projects through sale, rather than lease, to foreign governments. Hence, the prospect of toll enrichment afforded foreign nations greater independence in supply of this vital material and more flexibility in managing balance of trade payments or in using natural uranium stocks already available to them. In addition, they have the same economic incentive as domestic users of the enrichment service; that is, the opportunity to seek uranium in commercial markets at lower prices. The assurance of long-term enrichment services favorably influenced the foreign power industry toward selection of enriched uranium reactors and the use of U.S. capabilities for the long-term supply of fuel for these reactors.

Although the Private Ownership Act deferred the actual availability of toll enrichment services until January 1, 1969, its enactment authorized AEC to enter into contracts for such services earlier. By this means, AEC gave assurance to its customers of the long-term availability of enriching services. Meanwhile, the deferral of actual enriching did, of course, allow for some liquidation of AEC natural uranium stocks.

XI. Gas Centrifuge Program

A constant proliferation danger was that some breakthrough in technology might occur that would bring nuclear weapons more easily within the reach of additional nations. One such possibility was the gas centrifugation process for producing enriched uranium. In this process, the heavier ^{238}U atoms in uranium hexafluoride gas are spun out by centrifugal force and thus separated from the lighter ^{235}U atoms, much as milk is separated from cream. The centrifuge was briefly considered as the enrichment method of choice in the early days of the wartime atomic bomb project, but was rejected in favor of the gaseous diffusion method largely because the latter had fewer development problems remaining to be solved at a time when haste was of the essence. It was always recognized, however, that the centrifuge had significant potential economic advantages, particularly for European countries. As compared to gaseous diffusion it would require only a small fraction of the electricity per unit of output. (Electricity was relatively more costly in Europe than in the United States.) In addition, centrifuge plants could operate efficiently on a much smaller scale than diffusion plants, which are intrinsically huge.

In 1953, the AEC began to study centrifuge technology as a possible economic encouragement to the development of civilian nuclear power. Development work was undertaken also in Britain, West Germany, and the Netherlands. The interest of these countries was in producing enriched uranium for power reactors in a way that would be economically attractive and that would lessen dependence on ^{235}U supply by the United States. In 1959, the AEC concluded that centrifuge technology had advanced to such an extent that units already developed could be used in ^{235}U enrichment plants and that the power and space requirements for such plants were so modest as to be amenable to clandestine operation. The AEC at once came under competing pressures. On the one hand, U.S. industry wanted the technology made freely available in order to lessen the fuel costs of future civilian power endeavors. On the other hand, there were those who wanted the centrifuge placed under wraps as an antiproliferation measure. It was economics versus security—a classic dilemma of the nuclear age.

The AEC tilted toward the latter view and embarked on steps to limit spread of the technology. In July 1960, it prevailed on the U.K., West German, and Netherlands governments to impose security classifications on their gas centrifuge programs. At the same time, tight security restrictions were imposed on the industrial firms participating in the AEC's own program, and gas centrifuges and their component parts were placed on the Commerce Department's Positive List to prevent export.

By 1964 there were indications, both at home and abroad, of desires to break free from these restrictions. At a meeting of U.S., British, Dutch, and West German representatives early in the year, the latter two argued for a relaxation of the restrictions, ostensibly because the centrifuge process was useful in a variety of peaceful applications in addition to the separation of ^{235}U. It was only with difficulty that we persuaded them to continue their classification arrangements. U.S. firms working in the field were similarly restive. Thus, when I met with representative of the General Electric Company and the Allied Chemical Company, who were conducting a joint centrifuge venture, they told me of their frustration in having to explain to their boards of directors that, under existing restrictions, there was no indication they could establish a commercial operation even if their development work was successful. Compounding the AEC's difficulty in determining a policy was the realization that, despite our best efforts to restrict it, the gas centrifuge technology might eventually be acquired by other nations.

In April 1964 I wrote to ACDA Director Foster and Secretary of Defense McNamara, among others, seeking guidance "to assure that the [centrifuge] policy we adopt at this time will best serve our national security interests." Specifically, I asked for their views on "the importance to the United States of maximum delay in the acquisition by an Nth power of a capability to produce fissionable materials for atomic weapons use, even in very limited quantities."

Foster's views were strong and unequivocal. He wrote, "I believe that we should continue to resist all pressures to release controls on the dissemination of gas centrifuge technology."

McNamara replied in similar vein. He recognized that we could only retard, not prevent, the technology's growth and diffusion. "Even so," he wrote, "the goal of retardation is a worthwhile one." He recommended that we continue our restrictive policies and endeavor to persuade others with significant centrifuge programs to do the same. He also recommended that, in order to dampen the incentive of countries to develop their own centrifuge technology, "the U.S. should leave no doubt that enriched uranium will be available from this country on attractive terms. . . ."

On October 11, 1964, I also discussed our dilemma with Chairman Holifield of the Joint Committee on Atomic Energy. At first Holifield said he favored AEC continuing to develop the gas centrifuge technology, but doubted that U.S. industry should be allowed to continue this development work. I told him there was some argument in favor of allowing industry to continue under strong security controls, since this would place it in a strong competitive position in the event foreign countries should develop the process. This could actually aid the non-proliferation concept rather than hinder it; it would discourage other countries because their process would not be economically competitive. After I made these points, Holifield seemed to agree that his was a question that deserved further discussion at an executive session of the JCAE.

Such a session was indeed held, but not until March 9, 1967. Four for the five AEC commissioners were present, signifying the importance we attached to the issue. By this time the proliferation scare had worsened considerably, largely due to the Chinese tests and the reaction to them. As a consequence, the AEC had, albeit reluctantly, come round to the point of view expressed by Holifield more than two years earlier: We believed that private work on the gas centrifuge should be cut off, but that the AEC should continue a strong program. All the JCAE members agreed readily, with the exception of Representative Craig Hosmer. He at first argued vigorously against excluding industry, but in the end he also went along.

Another opinion being expressed on this issue was that of the Soviet Union. The Soviets charged that further work on the centrifuge in Western Europe could lead to West German development of nuclear weapons.

The next task was to break the news to industry. On March 14, 1967, the AEC commissioners (again all but one—Commissioner Samuel M. Nabrit was out of town) met with officers of two of the companies involved, W.R. Grace and Company and Electro Nucleonics, Inc., to tell them that we had decided to terminate centrifuge work in private corporations. Electro Nucleonics took it particularly hard. Their representatives tried to persuade us, as a minimum, to support their work. Later in the day I received a letter from them pointing out hat our action would result in about a $10 million loss of stock equity on the open market and hinting that they would hold the AEC responsible. (Subsequently, the AEC helped Electro Nucleonics move from weapons-related work into the biological field, where their experience with and knowledge about the centrifuge found useful applications.)

The results of the AEC's program for the past ten years are classified. However, on the basis of work done so far, there is still not sufficient experience to determine whether the gas centrifuge process can compete in countries like the United States with the proven gaseous diffusion process for the separation of uranium isotopes. There is, however, the possibility that the gas centrifuge process may offer economic competition in the future. The laboratory results obtained since 1960 must be confirmed and the cost, reliability, and life of many components determined before meaningful evaluations can be made.

XII. Cutback in production of fissionable materials

In his State of the Union Message on January 8, 1964, President Johnson, speaking in reference to a "world without war" and "the control and the eventual abolitional of arms," said:

> "And it is in this spirit that in this fiscal year we are cutting back our production of enriched uranium by 25 percent. We are shutting down four plutonium piles."

At the time of the president's announcement, the AEC had 13 production reactors in operation and another, the New Production Reactor or "N" reactor (which also would produce electricity) at Richland, Washington, then in final stages of construction. There were eight reactors (not counting "N") at Richland and five reactors at the Savannah River site in South Carolina. The Richland site had expanded from the assigned wartime three reactors to nine. The Savannah River site was a new production complex constructed in the early 1950's. The gaseous diffusion facilities at Oak Ridge, Tennessee, were expanded and the new Paducah, Kentucky, and Portsmouth, Ohio, facilities were added at that time for the production of enriched uranium. Additional advances in reactor and gaseous diffusion technology and production processing and control pushed the capability of the AEC production sites far beyond their original design limits.

By March 1, 1961, long-range requirement studies still seemed to indicate the gaseous diffusion plants at a power level of 4,850 Mwe (reduced from a maximum level) and all of the production reactors were needed for maximum production. It was not until two years later that President Kennedy, in a letter to me of February 2, 1963, asked that the Commission, in conjunction with the Department of Defense, "initiate appropriate action as soon as practicable to adjust production of enriched uranium...in accordance with revised objectives." The primary revisions to the previous production requirements that resulted in the president's letter were the result of the widely publicized decisions of the president to cancel both the Sky Bolt missile and 8-inch artillery shell programs.

By May 1963, the AEC had completed its studies based on the revised objectives. On May 17th, I wrote the president indicating the results of the studies and outlining the AEC's plans for production adjustments by reducing power requirements for the uranium enrichment plants and shutting down some plutonium production capacity.

The AEC production complex in total was further examined to achieve the reductions in the most economical manner. These refinements were necessary in order to continue to take advantage of advances in weapons and production technology and to be able to cancel, with the lowest possible penalty, long-range electric power contracts with various suppliers.

As a follow-up to President Johnson's reduction announcement, the AEC issued a public statement detailing the cutbacks in relation to the total AEC program effort at the affected sites. The cumulative effect spread throughout the feed chain. On January 11, 1964, a second AEC public announcement considered the effects of the production site cutbacks on the uranium feed processing plants which provided the fuel for the facilities being shut down.

The uranium concentrate plants at Weldon Spring, Missouri, and Fernald, Ohio, would continue operation but at reduced levels. The feed material plant at Paducah, Kentucky, which supplied products to the gaseous diffusion plants, would be shut down and placed in standby by June 30, 1964, and the Metropolis, Illinois, plant of Allied Chemical Corporation would not be kept under contract to the AEC beyond the existing expiration date of June 30, 1964.

Of the four reactors to be shut down, three were at Richland and one was at Savannah River. The reductions in power were to be made at all uranium enriching sites, Oak Ridge, Paducah, and Portsmouth.

Five reactors at Richland would remain in operation and the new "N" reactor startup, scheduled for later in the year, would not be affected. At Savannah River, the AEC would continue to operate four reactors. It was also explained at that time that the loss of reprocessing load, through the Hanford reactor shutdowns, would eventually lead to the shutdown of one of the two Hanford fuel reprocessing plants then in operation. Later, at the end of 1966, the Redox chemical processing plant was shut down.

Reactors shut down in keeping with the president's announcement were: the Savannah River "R" reactor, on June 19, 1964; the Richland "DR" reactor, on December 30, 1964; the Richland "H" reactor, on April 21, 1965, and the Richland "F" reactor, on June 25, 1965.

The 25 percent megawatt electrical reduction in power at the gaseous diffusion plants, covered by the presidential announcement became effective July 1, 1964, through reduction of 360 Mwe. at Oak Ridge, 375 Mwe. at Paducah, and 600 Mwe. at Portsmouth. In conjunction with the reduction of power at the Oak Ridge gaseous diffusion plant, one of the process buildings (K-25) was shut down on June 30, 1964. This was the original U-shaped structure built during World War II. Operations in the other process buildings at the other sites were continued but at a reduced level.

In the interim, on April 20, 1964, in accordance with a further decision of the president, I announced additional power reductions totalling 945 megawatts (445 at Oak Ridge, and 500 at Portsmouth) beginning in 1966, with completion in 1968, which would reduce the power and hence production by 40 percent from the previous operating level. In February 1965, under direction of the president and as a result of continuing studies, the AEC announced further cutbacks in enriched uranium production which would, by December 31, 1968, reduce the power level to 2000 Mwe.

This long-range shutdown situation was a time of deep personal concern to all in the AEC, particularly as it affected the employees and communities involved. Hardest hit would be the cities of Oak Ridge and Richland which had been established in World War II by the Manhattan Engineer District. These communities were, by design, in isolated areas and had virtually no support beyond that provided by AEC activity. Additionally, homes and commercial facilities in the communities had recently been sold to individuals. Also, local school and hospital services were turned over to the municipality. Concern for the personal problems the shutdowns caused was magnified by the possibility that the recruiting and maintenance of an adequate staff at the AEC facilities might be severely affected if the living areas were not adequate for plant employees.

Most severely hit was Richland where about 2,000 positions or approximately 24 percent of the then existing employment level of 8,300 would be affected. As severe as this would be there were mitigating factors. The first reactor shutdown was a year away and the other two shutdowns were scheduled for subsequent shutdown at three-month intervals; the full impact would not be felt until fiscal 1967 when certain auxiliary facilities (principally the plutonium separations plant) would be shut down as an after effect of the reactor shutdowns. Additionally, in fiscal 1964 the newest AEC production reactor ("N") would be placed in service and ease the employment situation.

At Savannah River the scheduled reactor shutdown would take effect within six months and reduce the plant employment level by about 500 positions or eight percent of the then existing employment level of 6,500 employees.

Employment in Oak Ridge, Paducah, and Portsmouth would be reduced by some 400 (later increased to 450) employees of a total of 5,100 positions, 180 of 2,600 at Oak Ridge; 150 of 1,367 at Portsmouth and 120 of 1,133 at Paducah.

At the feed material sites Fernald would lose 300 of 2,100 employed and Weldon Spring, 50 of 600. The close-down of the Allied Chemical Corporation plant at Metropolis, Illinois, would, of course, drop its entire staff of 150 employees. The grand total affected by these first announcements, but not necessarily reflected in people to be released—primarily because of the time lags involved and the new "N" facility startup—was 3,450. While the total number was not overwhelming it was staggering to the isolated communities and to the individuals who specialized in nuclear activities. Additionally, those persons close to the situation knew this was just the beginning. More plants would have to be retired from service. Only timing and the specific facilities to be affected were unknown.

That the effects of these shutdowns were foreseen well in advance did not lessen the immediate concern as the shutdowns became an accomplished fact. As early as 1962, when it became apparent from long-range studies that future shutdowns were inevitable, the AEC adopted a policy to cooperate with local communities where AEC operations constituted the major economic force in their efforts to encourage diversification of the economic base of these communities. Many studies were undertaken, and other Federal agencies as well as commercial concerns were made aware of the capabilities of the sites for various activities.

Strengthening this effort became a major concern as the shutdown periods approached. Effective May 6, 1964, the AEC established an Office of Economic Impact and Conversion to coordinate analysis and review of management activities designed to cope with the broad economic impact resulting from program cutbacks.

The initial shutdowns announced by President Johnson were only a prologue to what followed; yet the communities of Oak Ridge and Richland have continued to expand in total population and the quality of the municipal services they are able to offer has remained at a high level. At no time has the AEC's ability to recruit or retain personnel been threatened by the inability of these communities to provide the level of services considered adequate by the highly skilled and trained professional AEC work force. By making the shutdown announcements well in advance, and by carefully controlling hiring rates, the majority of employees were able to find new employment elsewhere, take an early retirement, or be reassigned to another AEC facility as normal attrition reduced the work force.

There was another aspect to the production cutback announcement which had far-reaching consequences. This was in the area of the Cold War and increasing world tensions. As President Johnson indicated in his announcement, the reductions in production capability were made in the interest of world peace. It came as no surprise, therefore, that on April 20, 1964, the Soviet Union announced:

> "The moment has come now when it is possible to take steps to reduce the production of fissionable materials for military purposes...and that the Soviet government has decided:
>
> 1. To discontinue now the construction of two new, enormous atomic reactors for the production of plutonium;
>
> 2. To reduce substantially in the next several years the production of uranium-235 for nuclear weapons; and
>
> 3. To allocate more fissionable materials for peaceful uses ...".

While U.S. action to cut back nuclear production was not contingent upon any agreement with the Soviets, part of the intent was to show good faith that vertical nuclear proliferation would not go unchecked, and that perhaps this evidence of good faith would meet with an affirmative response from other nuclear weapons powers.

In contrast to the well-publicized original shutdown announcement, future curtailments in plant operation received little national notice. These shutdowns were conducted in an orderly, spaced manner consistent with maintaining capability to meet long-range military and sharply increasing civilian requirements.

The Commission shut down the uranium concentrate plant at Weldon Spring in October 1966 and eventually returned this facility to the U.S. Army in December 1967.

Other reactor shutdowns followed the first four: the Richland "D" reactor, in June 1967; Richland's "B" reactor, and the Savannah River "L" reactor, in February 1968; the Richland "C" reactor, in April 1969; the Richland "KW" reactor, in February 1970; and the Richland "KE" reactor, in January 1971. This left only the "N" reactor at Richland and three reactors at Savannah River operating.

While some of these reactors are retained in standby condition for production startup in 18 months, it becomes more doubtful with the passing of time that they will be reactivated or that some of them could be satisfactorily operated.

Power reductions at the uranium enrichment plants reduced the total electricity supplied to a 1,900 Mwe. level in July 1969.

In contrast to the continued shutdown of the reactors and their auxiliary facilities, portions of the shutdown diffusion plant began to be restored in March 1970 in connection with preproduction of uranium hexafluoride for use as fuel in civilian nuclear power reactors.

XIII. Regulation

On March 16, 1961, as one of my first acts as Chairman, I announced the Commission's action to separate its regulatory function from the operational and developmental functions administered by the General Manager. A new position of Director of Regulation, reporting directly to the Commission, was established, vested with the authority to discharge licensing and related regulatory functions other than those where the final decision rested with the hearing examiner or the Commission, or which involved the Commission's authority to approve the issuance of regulations. Subsequently, all AEC staff regulatory activities including those associated with licensing and regulation, compliance and enforcement, and the development of radiation protection standards and regulations were consolidated under the Director of Regulation. The Commission named Harold L. Price, former Director of the Division of Licensing and Regulation, to the new position.

On February 8, 1962, the Governor of Kentucky executed with the Commission in Washington the first agreement whereby a state would assume some regulatory authority in the interest of public health and safety, all of which had been exercised exclusively by the Federal Government. In an address the next day before a joint session of the Kentucky Legislature in Frankfort, I stated:

> "There are those who hold, and not without some historical support, that the shifting of power and responsibility from the States to the Federal Government is a never-ending, irreversible process. Here is one significant instance of a noteworthy exception, but I think it would be a mistake to regard this event as a triumph of States' rights. This milestone in Federal-State relations is a triumph of good government in accordance with Jeffersonian principles."

It was in keeping, I noted, with a unique mission of the Atomic Energy Commission—"by an orderly process to fit atomic energy into the traditional, democratic structure of our society."

The transfer of 104 AEC materials licenses to State jurisdiction when the Kentucky agreement became effective on March 26, 1962, signalled the start of an upswing in State radiation control activities that was sustained throughout the decade. Mississippi, California and New York joined Kentucky as Agreement States during 1962, and thereafter two or three agreements were signed each year by Governors with the Commission.

An agreement with Maryland on December 18, 1970, brought to 23 the number of States (Alabama, Arizona, Arkansas, California, Colorado, Florida, Georgia, Idaho, Kansas, Kentucky, Louisiana, Maryland, Mississippi, Nebraska, New Hampshire, New York, North Carolina, North Dakota, Oregon, South Carolina, Tennessee, Texas and Washington) entering into agreements with the AEC for regulating the peaceful uses of the atom. At this date, all but six of the remaining States had enacted enabling legislation and several of these were actively moving toward such agreements. Nearly half of the more than 16,000 atomic materials licenses in the total Federal-State program were being administered by the States.

When the developing regulatory program was separated from the Commission's operational and developmental functions in March 1961, materials licensing and regulation occupied the major portion of the new Director of Regulation's manpower of some 260 personnel. It administered a wide variety of more than 10,000 licenses through the country. But the emergence of the regulatory program as a primary function of the Commission came as the electric utility industry turned increasingly to the nuclear power reactor as a primary source of energy in the mid-1960's.

This turn of events was hardly discernible in 1961. At the beginning of the year, operating licenses and authorizations were in effect for only three power reactors, and 11 others were in various stages of construction. The year saw most of these relatively small nuclear plants under way delayed by problems such as fuel fabrication difficulties, pressure vessel cladding cracks, procurement delays, or construction labor strikes. Utilities as a whole continued to eye the nuclear field with skepticism over the next three years.

As indicated in Section IX, on March 26, 1964, the Jersey Central Power and Light Company jolted the utility industry by applying to the AEC for a permit to construct a 515-Mwe boiling water reactor at its Oyster Creek site in Ocean County, New Jersey, about 35 miles north of Atlantic City. Although it was one of the first two nuclear power plants in the 500-Mwe class to be proposed, the significance of the Oyster Creek plant was that it represented the first decision of a utility to build a nuclear generating station solely on the basis of economics in competition with conventional power facilities.

The Oyster Creek application marked the beginning of a year of intense regulatory activity and continual efforts to maintain pace with a new and remarkably expanding industry. The statistics and predictions at the end of 1964 placed in some perspective the AEC's projected regulatory task of protecting the public health and safety: Installed nuclear electric power from all 12 licensed "central station plants," several of which were small prototypes destined for early retirement, had reached only 1,000 megawatts—a total that would be exceeded by the capacity of many individual units to be undertaken within the decade. Forecasts were projecting up to 20,000 Mwe of installed nuclear power capacity by 1974, and some felt more than half the nation's energy requirements would be furnished by nuclear plants at the end of the century.

Although the stimulus of the Jersey Central action to other utilities was not immediately apparent, the repercussion of a wave of nuclear plant orders hit the regulatory program abruptly during 1966 with the filing of construction permit applications for 16 large power reactors representing a total of 11,500 Mwe. Twin reactor units on single sites were proposed for the first time, and the first reactors in the 1,000-Mwe class were proposed by the Tennessee Valley Authority for its Browns Ferry Station in Alabama. The surge toward nuclear power reached its peak of the decade during 1967 when utilities filed applications with the AEC for the construction of 29 nuclear power units -- nine of which were 1,000 Mwe plants -- representing a total design output of 24,287 electrical megawatts.

A major reorganization of the regulatory staff took place in early 1964, emphasizing the reactor licensing function. At year end the Director of Regulation, in a progress report to the Commission, noted that "projected workload data, particularly in the reactor licensing area are startling when projected through 1970." It appeared inevitable that this expected growth would have a powerful impact on the regulatory program, and that the time involved in the licensing process would affect the planning schedules of utilities. Of predominant importance in staffing up to meet the workload, however, was the need to recruit professional personnel with outstanding talent for the technical safety evaluation of power reactors of new design and increasing size.

As nuclear power plant applications mounted, the Commission and staff undertook numerous studies and actions to improve and streamline the licensing process on virtually a continuous basis for the remainder of the decade. Internal and external reviews were conducted, including an exhaustive examination by the Regulatory Review Panel of 1965, headed by William Mitchell, former AEC General Counsel. The JCAE, concerned over the implications of increasing nuclear power applications, also conducted, in 1967, the most extensive public hearings on reactor licensing and regulation to be held since passage of the 1954 Act.

In its report to the Commission, the Mitchell Panel stated:

> "On the whole, in the few years it has been in existence, the regulatory staff has done a remarkable job in organizing its work and in developing competence in the technology of reactor safety. The Director of Regulation has been successful in recruiting persons of a high level of technical skill and experience and also has been successful in establishing an esprit de corps which is necessary to attract additional competent scientists and engineers. With the increased workload anticipated in the future and the need for an enlarged staff, the matter of quality of the staff is of real importance. The contributions the staff has made to techniques of safety analysis and reactor technology and the opportunity to make further contributions doubtless contribute to developing a climate attractive to professional people. It is necessary that this climate continue into the future. The panel believes that, accordingly, the work of the staff will be the principal component in the discharge of AEC safety responsibilities, and this premise is inherent in and vital to several of the recommendations."

In recommending actions to simplify the regulatory process, the panel noted that, "If the size of the regulatory staff were to grow in direct proportion to the number of reactors, this staff would soon number thousands of individuals."

In a period of rising competition from the expanding nuclear industry for highly qualified technical professional people and continuing austerity in national budgets, the Commission brought total regulatory staff strength to slightly over 500 by the end of 1970.

Some 75 percent of these were professionals in a broad spectrum of disciplines such as physics and various branches of engineering. More than half of these were engaged in the licensing, regulation, and inspection of reactors and other nuclear facilities, and the development of safety standards pertaining to their construction, design and operation. The marked increase in reactor licensing activity also impacted heavily on the workload of the other two review bodies regularly involved in the regulatory process, the Advisory Committee for Reactor Safeguards (ACRS) and atomic safety and licensing boards.

During 1961 the statutory ACRS, a 15-man body of recognized scientists, engineers and other experts in fields important to reactor safety, had found it necessary to conduct only nine full committee meetings and 30 subcommittee meetings on nuclear safety matters. By contrast, the ACRS during 1970 held 12 regular three-day meetings, one special meeting and 109 sessions of subcommittees and ad hoc working groups. It provided reports to the Commission on 25 nuclear facilities and several special subjects, and engaged in a wide range of activities related to safety.

The atomic safety and licensing boards, which were authorized by law in 1962, had handed down initial decisions in only four cases by the end of 1963. During 1970, three-man boards drawn from the Atomic Safety and Licensing Board Panel conducted 17 public hearings on nuclear facility applications in 12 states. The Commission established a permanent chairman and staff to coordinate the Panel's activities in 1967, and in 1970 had increased its membership to 18 qualified technical experts and ten attorneys experienced in administrative procedures.

Milestones in nuclear power plant licensing during 1961-1971 included issuance of operating licenses for the first fast breeder facility (Enrico Fermi plant in Michigan) in 1963, the first high-temperature, gas-cooled reactor plant (Peach Bottom Unit 1 in Pennsylvania) in 1966, the first two facilities with more than 400 Mwe of capacity (San Onofre Unit 1 in California and Connecticut Yankee's Haddam Neck plant in Connecticut) in 1967, and the first plants in the 500-Mwe and 800 Mwe classes (Oyster Creek-1 in New Jersey and Dresden-2 in Illinois, respectively) in 1969.

The licensing of the Oyster Creek facility, originally scheduled for operation in 1967, was delayed for nearly two years when discovery of weld defects in connections to the pressure vessel led to extensive evaluations and repair. The regulatory staff conducted 50 inspections of the plant during this period.

At the end of 1970, the AEC had licensed or authorized the operation of 19 central station nuclear power units with a capacity totaling 6,708 Mwe (includes AEC's nonlicensed Shippingport station in Pennsylvania). In addition, 53 other large reactors representing 44,040 Mwe of capacity were in various stages of construction or awaiting action on operating licenses, and 30 proposed plants aggregating 29,103 Mwe in design capacity were under review for construction permits.

In related actions, the AEC was acting on several hundred operator license applications a year for individuals who manipulate or supervise manipulation of reactor controls. More than 2,000 such licenses were in effect at the end of 1970.

Until 1970, the Commission's regulatory authority under the Atomic Energy Act of 1954, as amended, had been limited essentially to radiological health and safety concerns and common defense and security considerations. The enactment of two Federal laws during 1970 greatly enlarged the AEC's responsibilities concerning environmental matters with increasing impact on licensing activities.

In addition, an amendment to the Atomic Energy Act in December 1970 eliminated the requirement for finding of "practical value" and invoked the "commercial section" (section 103) of the act which made all future license applications for commercial or industrial nuclear facilities subject to antitrust review by the Attorney General and the Commission. The Atomic Energy Act included the requirement for a finding of "practical value" by the AEC before nuclear facilities (such as power reactors and fuel reprocessing plants) could be licensed under the "commercial section" (section 103) of the law. Such licenses had been issued under the research and development section (104b) of the Act. In the past the Commission had considered the matter and concluded each time that the finding could not be made on the basis of cost information limited to the prototype and noncompetitive nuclear power reactors then in operation. From now on licenses are to be issued under section 103.

The wave of public concern over environmental quality that swept the country at the end of the Sixties coincided with the building of nuclear power plants on a large scale, and a spotlight of public attention was focused on atomic energy activities that had not been experienced since the beginning of the program.

A primary focal point was in the health implications of radioactive discharges from nuclear power plants. Among the leaders in the clamor on this issue were two Livermore Laboratory biological scientists, John W. Gofman and W. R. Tamplin. (Gofman did his Ph.D. research with me, 1940–1943, and was co-discoverer with me of the fissionable isotope uranium-233.) They claimed that their analyses indicated that if everybody in the United States were exposed to the allowable amount (170 millirads per year) of radiation this could finally produce 32,000 extra cancer and leukemia deaths plus 150,000 to 1,500,000 extra genetic deaths per year. It was, of course, absurd to assume that everyone in the United States could be exposed to this amount of radiation as the result of operating nuclear power plants. Other analyses, by AEC staff and other biological scientists, have led to the conclusion that these dire predictions are gross exaggerations; some such contrary views suggest that the number of additional cancer cases caused by the operation of nuclear power plants will be so small in number as to be immeasurable.

Another primary focal point was on the potential adverse effects on aquatic life of discharging large quantities of heated condenser cooling water from nuclear plants into the rivers and other bodies of water on which they were located. Such water use is characteristic of all steam-electric generating plants, whether nuclear-fueled or fossil-fueled, but the water-cooled nuclear plants of current design discharged somewhat more waste heat than modern conventional fossil-fueled plants.

The Commission had long been concerned over the potential adverse thermal effects of nuclear power plants and, in fact, was supporting in its development program more extensive research in this field than any other Federal agency. In 1962, the regulatory staff began to routinely obtain comments of the Department of the Interior's Fish and Wildlife Service regarding each application for a construction permit or operating license for a nuclear power plant. These comments, in addition to recommendations concerning radiological matters, recommended actions to minimize the possibility of adverse effects of thermal discharges. The AEC, although having no jurisdiction in the nonradiological area, made it a practice to call the applicant's specific attention to the Fish and Wildlife Service's recommendations on thermal effects and to urge his cooperation with the appropriate agencies.

Although the AEC's position, concurred in by the Department of Justice, was that it had no regulatory authority to consider thermal effects in licensing, this issue was pursued by intervenors in licensing proceedings. Some hearings before atomic safety and licensing boards toward the close of the decade, both at the construction permit and the operating license stages, became arenas of controversy where radiological and other environmental issues were sharply joined. In June 1968, the State of New Hampshire petitioned the Court of Appeals for the First Circuit (Boston, Massachusetts) for review of the Commission's licensing action in the Vermont Yankee Nuclear Power Corporation case with respect to the denial of AEC jurisdiction over thermal effects. In January 1969 the court upheld the Commission's position, and a petition by New Hampshire for review by the U.S. Supreme Court was subsequently denied.

Several bills were introduced in both the 90th and 91st Congresses to give authority to the AEC or other agencies such as the Federal Power Commission to impose conditions regarding thermal effects in nuclear power plant licenses. The Commission, in testimony before Congressional committees in March 1969, supported proposed legislation that would require a certification that the facility to be licensed would not violate appropriate water quality standards, including thermal standards.

The National Environmental Policy Act of 1969 (NEPA), which became law on January 1, 1970, followed by enactment in April of the Water Quality Improvement Act of 1970 (WQIA), thus had a major impact on the AEC regulatory program.

Under NEPA, Federal agencies were required, among other things, to prepare and file with the Council on Environmental Quality a detailed statement on specified environmental considerations regarding each major Federal action "significantly affecting the quality of the human environment." The WQIA amended the Federal Water Pollution Control Act to require certification from the appropriate state, interstate or federal water pollution control agency that there was reasonable assurance that federally licensed activities resulting in discharges to navigable waters of the United States would not violate applicable water quality standards (including thermal standards).

Although NEPA did not specifically refer to licensing activities, the AEC interpreted it to cover the licensing of nuclear facilities – particularly nuclear power plants – as "major Federal actions" affecting the environment. The Commission proceeded promptly to initiate procedures to bring its licensing program into conformity with the new environmental legislation.

The AEC's final policy statement on NEPA, issued on December 4, 1970, also took into account requirements of the WQIA and provided for fuller consideration of the whole range of environmental issues in the licensing of nuclear power plants. In testimony before a House committee regarding progress in implementing NEPA, Russell E. Train, Chairman of the Council on Environmental Quality, characterized the new AEC policy provisions as "very responsive developments" in implementing the Act. (At an annual meeting of the Atomic Industrial Forum and American Nuclear Society in Washington, D.C. in November 1970, Dr. Gordon J. MacDonald of the Council on Environmental Quality, stated: "The AEC has by far the best record of any federal agency in submitting environmental reports under NEPA. The AEC reports are the most complete, the best thought out, and the most sophisticated of any agency.")

As a result of the environmental legislation of 1970, a number of procedural changes were integrated into the AEC licensing process for nuclear power reactors and fuel reprocessing plants, including the provision of conditions in permits and licenses to the effect that licensees will 1) observe all standards and requirements validly imposed under Federal and State law for protection of the environment, and 2) comply with the appropriate water quality certification provisions of the Federal Water Pollution Control Act. Atomic safety and licensing boards also were authorized to consider, under NEPA, nonradiological environmental matters to the extent that a party raises as an issue whether issuance of the permit or license would be likely to result in a significant, adverse effect on the environment.

Similar procedures were provided for other licensing proceedings on proposals significantly affecting the environment, including licenses for: 1) nuclear fuel fabrication plants, scrap recovery facilities, and uranium hexafluoride conversion plants; 2) uranium milling and production of uranium hexafluoride; and 3) commercial radioactive waste disposal by land burial.

On July 23, 1971, the U.S. Court of Appeals for the District of Columbia made an historic ruling directing the AEC to revise, in several respects, its rules on consideration of nonradiological environmental matters in licensing facilities, i.e., directed the AEC to broaden its responsibility. The court held, in the consolidated cases of Calvert Cliffs Coordinating Committee, Inc., et. al., vs. the U.S. Atomic Energy Commission, et. al., that AEC regulations for implementing NEPA in licensing procedures did not comply in several respects with NEPA. The petitioners had also questioned several aspects of the AEC's application of NEPA procedures to Calvert Cliffs Nuclear Power Plant of the Baltimore Gas & Electric Co., a facility near Lusby, Maryland, on the Chesapeake Bay for which a construction permit had been issued six months before enactment of NEPA, and the court agreed. The AEC took several implementing steps immediately following the court's decision.

XIV. Radioisotopes Program

In analysis and controls applications, cobalt-60 and cesium-137 encapsulated sources for industrial radiography were the principal products employed in 1960 in terms of quantity. During the decade, there has been increased use of iridium-192 for radiography, low-energy photon sources for X-ray fluorescence, and tritium and promethium-147 for self-luminescent applications.

In nuclear medicine, iodine-131 was the principal product in use in 1960 and continues to be important. However, technetium-99m, which has been approved for similar diagnostic uses, results in decreased radiation exposure of the patient and increased definition of the body organ functions. The technetium-99m agent was developed at Brookhaven National Laboratory (BNL) and first studied for medical applications at Argonne Cancer Research Hospital. Many other products have been studied as diagnostic agents during this period, including iodine-124, copper-67, zinc-69m, gallium-67 and indium-111.

In the process radiation field, cobalt-60 and cesium-137 have continued to be the principal products of interest. Considerable work was carried out using cobalt-60 produced in AEC reactors to develop an efficient and reliably contained cobalt-60 source. Much of the AEC's process radiation development work was based on the use of cobalt-60. However, recent emphasis has been give to the use of cesium-137 for this purpose.

One of the most significant developments in radioisotope processing during the decade was the recovery of megacurie (a million-curies or more) quantities of fission products in the ORNL Fission Products Development Laboratory. During the early 1960's, the plant demonstrated the ability to recover cesium-137, strontium-90, promethium-147, and cerium-144, and technetium-99 (from processed fuel) in quantities in some cases up to many thousands of curies a year. As the decade passed, the output of cesium-137 and strontium-90 for radiation and heat sources grew to million-curie quantities annually. This production activity has provided the only significant large-scale supply of encapsulated fission products for isotopic power and process radiation applications during the decade.

Strontium-90 is the long-life (28 years) fission product of principal interest for terrestrial isotope power use as well as for process radiation applications. Strontium titanate was developed as the isotopic fuel form for application in terrestrial isotopic power (SNAP-7) systems. With thermoelectric conversion, use of such fuel can furnish power for use at remote places on land or sea to transmit information to receiving stations more conveniently located. Such use includes weather stations both in the Arctic and Antarctic regions, and U.S. Coast Guard flashing light buoys. Another use is for underwater acoustic beams. Other radioisotopic power sources were developed to meet a variety of needs.

Cesium-137, in equilibrium with its 2.6-minute barium-137m daughter, is the other long-lived (30 years) high-yield fission product of principal interest produced during nuclear reactor operation. It is produced along with other stable and radioactive cesium isotopes, including the 2.3-year cesium-134. The yield of cesium-134 is such that the mixed cesium-137/134 product will have significant radiation processing applications. As a radiation source, cesium chloride is preferred, principally for: (a) its high specific activity; (b) its thermal and radiation stability; (c) its reasonable compatibility with encapsulating materials; and (d) its ease of production.

Promethium-147 is an intermediate-lived (2.67 years) fission product in sufficient supply for isotopic power consideration. Its relatively low-energy radiation is readily shielded. The promethium-148 (42 days), which is initially present with the promethium-147, has a very energetic gamma which requires about 2 years storage to allow its decay before use. In addition, there are trace amounts of promethium-146 (1.9 years) present with sufficient gamma radiation to require shielding beyond that which is necessary for plutonium-238. Materials studied have demonstrated the feasibility of using promethium oxide at temperatures up to 2,000°C. (3,632°F.)

The short-lived fission products plant at Oak Ridge continued to be the principal supplier of 13 fission products (with half lives from 3 to 65 days) for research, industrial, and medical uses. Typical isotopes prepared in this plant are: barium-140, iodine-131, molybdenum-99, niobium-95, ruthenium-103, strontium-89, xenon-133, yttrium-90, and zirconium-95. With the exception of niobium-95 and yttrium-90, which are recovered from their parents zirconium-95 and strontium-90, these products are produced from irradiated uranium-235 targets.

Cobalt-60 is the most readily prepared reactor product with a reasonably long half-life (5.26 years) and radioactive decay characteristics of major interest. In selected applications, it competes directly with 28-year strontium-90 and 30-year cesium-137. In the past decade, while withdrawing from production of many forms of cobalt-60, the AEC has also carried out tests that show the production feasibility of hundreds of millions of curies of high specific activity cobalt-60 (400-600 curies per gram) for many applications. At the same time, industry has established its own capabilities in test and power reactors to produce most of these product grades in quantities to satisfy the market.

The transuranium product series results from multiple neutron capture in both the nuclear reactor fuel, uranium-235, and the source material uranium-238. The nuclides of principal interest include plutonium-238, curium-242, americium-241, and californium-252 and their applications require the conversion to forms useful in both thermal and radiation applications. In the thermal area the production of plutonium-238, curium-242, and curium-244 represented significant efforts.

Accelerator products have significantly different decay characteristics from isotopes prepared in a reactor since they are neutron-deficient and generally cannot be readily produced by neutron irradiation. These products find their principal use in medical diagnosis, Mössbauer applications and metallurgical studies, as well as several research applications. For many years, the Oak Ridge 86-inch cyclotron has been the principal source of accelerator products. More recently, a group of accelerators with additional capabilities have become available at Brookhaven and the future program will be expanded to include the use of the Los Alamos Meson Physics Facility.

There are about 15 radioisotopes in some 30 chemical forms approved by the AEC for medical use. In 1966, the U.S. Public Health Service surveyed the frequency of the various medical procedures. The results show that iodine-131 represented 70 to 80 percent of the radioisotopes used in the organ function studies or for radiopharmaceutical therapy procedures, while cobalt-60 was the predominant radioisotope used for teletherapy procedures, and radium and strontium-90 for brachytherapy (source implant) procedures. A survey today (1971) would show that the use of technetium-99m may now exceed the use of iodine-131 for scanning procedures, since the use of technetium-99m was just getting underway when the survey was carried out in 1966.

In 1965, the development of the technetium-99m generator for medical diagnostic application brought this technology to the attention of all potential users of radioisotopes. Today, this generator represents an important part of the radioisotopes products industry; technetium-99m generator sales for 1969 were estimated at $6 million.

During the past decade, much effort has been directed toward establishing neutron activation analysis as an accurate and reliable technique particularly for measuring trace elements in materials. It is now well established technically and is proving to be very valuable in many important applications throughout the world; in medicine, to determine trace metals in tissues; in industry, to analyze products and determine trace compositions; in crime detection, to analyze materials taken as court evidence; and for a variety of tests in geology, oceanography, agriculture, meteorology, public health and other sciences. The technique has recently met several important needs for analyzing foods to determine concentrations of pollutants such as mercury.

Another analytical technique whose range of applicability has been greatly expanded by the advent of radioisotopes is X-ray fluorescence. As a consequence of this AEC initiative, at least six U.S. companies are now marketing radioisotope XRF systems for many analysis and control applications such as ore assaying, metal alloy analysis, and monitoring various solid and liquid chemical processes.

About 1961, work was started at West Virginia University (Morgantown) on the fabrication of wood-plastic composites. The process involves impregnation of wood substrates with a liquid monomer and subsequent irradiation by gamma rays, during which the monomer hardens. The result is a plastic-filled wood with the aesthetic properties of wood and the durable properties of the plastic. The work at West Virginia University, and related work at North Carolina State University (Raleigh) and Research Triangle Institute, provided the technological basis for the production of a new commercial product. In 1964, the American Novawood Corp. (Lynchburg, Va.) was formed for the purpose of commercializing the new wood-plastic material. Since that date, three other companies have begun commercial production of wood-plastic materials. In each case, the principal product is parquet flooring.

An outstanding success has been the adoption of radiation sterilization of medical supplies both by isotopes and by accelerators. Radiation sterilization plants now number more than 20 in countries all around the world, and the trend is accelerating. Both technical and economic advantages are afforded by this process through: (a) elimination of the damaging effect of heat; (b) sterilization in final container; (c) greater reliability; and, (d) elimination of residual sterilization gas.

During the early part of the 1960's, a new application was exploited in the isotopes development program. This was the use of heat resulting from radioisotope decay to produce useful energy. The most promising isotopes with sufficient abundance for research and use were the fission products strontium-90, cerium-144, cesium-137, and promethium-147 and reactor-produced isotopes thulium-170, polonium-210, plutonium-238, curium-242, curium-244, and cobalt-60. Applications of radioisotope heat are directed toward the production of electricity using the Seebeck (thermoelectric) process. This work was most dramatically exemplified by development and demonstration in June 1961 of nuclear power in space and in August 1961 of the world's first radioisotope-powered automatic weather station (see next section, XV).

The Division of Isotopes Development first became interested in the concept of an implantable radioisotopic power source for an artificial heart in May 1964. In the process of considering such a program and through discussions with personnel of the National Heart Institute (now the National Heart and Lung Institute) of the National Institutes of Health, it was apparent that the development of a fully implantable artificial heart was not only extremely complicated undertaking but one in which success could not be projected with any degree of assurance.

XV. Nuclear power in space

The first use of nuclear power in space took place on June 29, 1961 when a U.S. Navy Transit satellite carrying a small nuclear–electric power source achieved earth orbit. Because of the reliability of that nuclear system, today (1971), more than nine years later and after its more than a billion miles of travel, the signals from that navigational satellite can still be monitored.

The climax of nuclear energy in space in the 1960s was the emplacement on the moon's surface of a small power device called SNAP (Systems for Nuclear Auxiliary Power). This radioisotope thermoelectric generator is the sole source of electrical power for all of the data gathering devices left on the moon by the Apollo 12 astronauts. This plutonium–238 fueled atomic battery, designated SNAP–27, was developed by the AEC for NASA's Apollo Program and has been performing extremely well since its deployment on the moon on November 19, 1969.

The AEC has delivered four additional SNAP–27 systems to the NASA for use on Apollo missions to other areas on the moon's surface, and has recently been requested to build another one. One of these systems was placed on the moon by astronauts of the Apollo 14 mission. Another, was flown by the Apollo 13 mission. Both the AEC and NASA were, of course, deeply disappointed that the objectives of the latter mission were not fulfilled. However, the reentry characteristics of the SNAP–27 were demonstrated on that mission. All data indicate that the capsule in its protective cask returned to earth intact as designed and is resting two to five miles deep in the Pacific Ocean.

The SNAP–27 generator and its plutonium–238 are carried to the moon as separate packages. The generator is transported in a compartment and the fuel, contained in a capsule or metallic tube, is carried in a graphite cask attached to the leg of the lunar module. Upon arrival on the moon, the astronaut removes the fuel capsule and inserts it in the generator and electricity begins to flow. For Apollo 12, when Astronaut Alan Bean inserted the fuel capsule in the generator, 73 watts of electricity were produced and have flowed ever since to the various lunar data gathering devices.

On January 16, 1959, a device that turned heat from radioactivity into electricity was demonstrated publicly, for the first time, on the desk of the President of the United States. President Eisenhower introduced this device to the world fueled by polonium–210, as the first atomic battery.

The unit launched in June 1961, an improved version of this nuclear system, was the size of a grapefruit. It weighed four pounds and produced 2.7 watts of electrical power using plutonium–238 as fuel. This first nuclear device used in space was called SNAP–3A. The Navy Transit satellite, with the SNAP–3A aboard, holds the record as the oldest operating U.S. satellite.

By April 1964, a total of five radioisotope electric generators, another SNAP–3A and three SNAP–9A/s, had been launched. The SNAP–9A was a larger and more advanced model of the SNAP–3 and was developed to supply all the power requirements of other navigational satellites. This improved model also used plutonium–238 fuel. It produced 25 watts of electricity—about ten times more than the earlier SNAP–3A. The first SNAP–9A was launched in September 1963, the second in December 1963, and the third in April 1964. Of the five generators launched to that date, three continue to supply power to their respective satellites. Unfortunately, a satellite failure, unrelated to the nuclear system, terminated the operation of the second SNAP–9A after only eight months in space. The satellite carrying the third SNAP–9A failed to achieve orbit.

Research and development began in late 1965 on a generator designated SNAP-19. The SNAP-19, unlike the SNAP-27, provided for the plutonium-238 fuel capsule as an integral part of the generator, and was developed for use on the NASA weather satellite known as Nimbus III. The first Nimbus satellite, with two SNAP-19 devices aboard, was destroyed during launch in May 1968 when the guidance system of the booster vehicle failed. A second SNAP-19 generator system was delivered to NASA for use on a replacement Nimbus in December 1968 and was launched aboard that satellite in April 1969. Both the satellite and SNAP-19 are still operating successfully. The SNAP-19 is augmenting solar cell power sufficiently to sustain continual operation of all weather monitoring equipment. Without the SNAP-19 some of the equipment would have to have been shut down periodically.

In July 1969, NASA requested the AEC to provide Radioisotope Thermoelectric Generators (RTG's) for two more operational space missions--the Pioneer, which is an unmanned Jupiter fly-by probe to be launched in early 1972 and 1973, and the Viking, an unmanned Mars lander to be launched in 1975. At the Navy's request, the AEC is also developing an RTG for an advanced Transit navigational satellite to be launched in the early seventies.

In 1965, the first zirconium hydride reactor, a 500 watt experimental system, was flown. This reactor system, designated SNAP-10A, was launched from the Vandenberg Air Force Base, California, in April of that year. While in orbit, this system operated at full-power for 43 days before a failure in the satellite's voltage regulator system---not the reactor system---caused a shutdown of the entire satellite. Had this failure not occurred, the chances are that the SNAP-10A would have effectively operated throughout its design lifetime. An exact copy of this orbital unit completed over a year of uninterrupted operation on the ground at the Santa Susana, California test site. This is the longest uninterrupted operation of any nuclear reactor in the world to date.

For the past decade and even before that, the AEC, working jointly with NASA, has been developing the technology for a nuclear rocket system which can do the propulsion jobs in space that will be required for the advanced missions of the future.

The nuclear rocket operates on the same principle as the chemical rocket. However, unlike the huge chemical rockets which must burn tons of fuel and liquid oxygen per second to produce their thrust, the nuclear system uses the heat of a reactor to expand liquid hydrogen into the escaping hydrogen gas that produces the rocket's propulsive force. A rocket's efficiency is measured in terms of what engineers call "specific impulse"; that is, the pounds of thrust per pound of propellant flow per second through the rocket's exhaust nozzle. The nuclear rocket undergoing development will have a specific impulse value at least twice that of the best chemical rockets today.

In recognition of the potential benefits of nuclear propulsion in space, AEC and NASA established, in August 1960, a joint agency office and program for the development of nuclear rocket technology, the Rover program. By that time, some nuclear rocket ground tests had already been conducted by the Los Alamos Scientific Laboratory at the Nevada Test Site (NTS). Later, a portion of NTS was designated the Nuclear Rocket Development Station (NRDS). The Kiwi-A reactors (named for the flightless bird of New Zealand) were tested there at power levels under 100 megawatts to check reactor design methods and to test niobium carbide coatings for protection of carbon against attack by hydrogen.

The first Kiwi-B reactor was tested in December 1961 at a power level of 300 megawatts with gaseous hydrogen supplied to the reactor as the coolant-propellant. A regeneratively-cooled jet nozzle was used on a rocket reactor for the first time in this test. Another test was conducted September 1962 at 900 megawatts. Operation in this test with liquid hydrogen caused no unexpected control or stability problems but structural weaknesses in the reactor core were revealed. These problems were resolved in subsequent Kiwi tests before the series ended in 1964.

With the phase-out of the Kiwi tests, LASL had moved forward with the development of the Phoebus reactors, including the high-powered 4,000 megawatt plant. This program culminated in the power testing of the Phoebus-2A reactor in June and July 1968 at power levels up to 4,200 megawatts, the highest power ever attained by a rocket reactor. Total operating time in two test runs at various power levels was more than one hour. The power density in the reactor actually exceeded that necessary for the NERVA nuclear rocket, which, by 1968, had been redirected to a power plant with a thrust level of 75,000 pounds rather than the 200,000 pounds earlier contemplated.

The primary objective is to build a flyable reactor, a little larger than an office desk, that will produce the 1,500 megawatt power level of the Hoover Dam hydroelectric power plant and achieve this power in a matter of minutes from a cold start. During every minute of its operation, high-speed pumps must force nearly three tons of hydrogen, which has been stored in liquid form at minus 420°F. (below zero), past the reactor's white-hot fuel elements which reach a temperature of 4,000°F.

XVI. Nuclear weapons tests

The U.S. atmospheric test series, designated Operation DOMINIC, began April 25, 1962, with an air drop in the intermediate-yield range (20 kilotons to 1 megaton) off Christmas Island. (In reporting its own and Soviet tests, the Atomic Energy Commission frequently adopted the practice of reporting yields in size categories rather than as precise numbers. Prior to 1964, the categories and the yield ranges they represented were: low yield, less than 20 kilotons; intermediate, 20 kilotons to 1 megaton; low megaton, 1 to several megatons.)

In all, the series comprised 40 tests, conducted between April 25 and November 4, 1962. It included the firing of 29 nuclear devices dropped from aircraft in the vicinity of Christmas and Johnston islands and five detonations of nuclear devices carried to high altitudes by missiles launched from Johnston Island. Two nuclear weapons system tests were also involved—one in the Christmas Island area and one in the eastern Pacific. These 36 Pacific tests were conducted by a joint AEC-Defense Department task force that, at the peak of its activity, numbered over 19,000 men. In addition to the Pacific tests four small tests were conducted near the surface at the Nevada Test Site.

I witnessed my only nuclear weapons test on a visit to the Pacific test site near the end of June, along with McGeorge Bundy, Arnold Fritsch (my technical assistant) and Dwight Ink (AEC Assistant General Manager). On June 30, on Christmas Island, we went to Observation Point where at 6:20 a.m. we saw an explosion 30 miles south at 5,000 feet, the low megaton yield BLUESTONE event. It was dropped from an airplane. It was necessary to use dark glasses for the first eight seconds. Upon removing them, I found the area brighter than full daylight, an awesome sight.

In accordance with the restrictions imposed by the president, the total yield of the DOMINIC series was held to approximately 20 megatons. The Soviet series in the fall of 1961 had yielded almost ten times as much, including a 50 megaton explosion.

By and large, DOMINIC went well. There were, however, certain difficulties. After we had alerted the scientific community of the world, it was with acute embarrassment that we learned that BLUEGILL had to be destroyed after launching from Johnston Island on June 5 due to a failure of radar tracking. Then on June 20 STARFISH suffered an abort on its Johnston Island launching pad. However, STARFISH went successfully on July 9, lighting the sky all the way from Hawaii to Australia. To our great surprise and dismay, it developed that STARFISH added significantly to the electrons in the Van Allen belts. This result contravened all predictions.

As the series neared its end, I presented a summary evaluation in a letter to the president. A salient portion read:

> "The current tests have produced many important successes. They have also yielded some surprises and some failures which confirm that we are indeed experimenting at the frontier of weapons technology. The test successes vindicate, in a large measure, the elaborate computational and certification procedures which were developed during the moratorium [1958-61]. The surprises and failures serve to remind us that our theories and procedures are, at best, only approximate...
>
> Although not a stated objective of our test program, I believe that one of the most significant results is the fact that our laboratories have become revitalized to a major degree. The importance of this reawakening of our defense posture cannot be overstressed."

The United States resumed nuclear weapons testing, initiating the underground NOUGAT series on September 15, 1961 after the Soviets had broken the voluntary U.S.–Soviet moratorium on the testing of nuclear weapons with an atmospheric test on September 1. From that date through December 31, 1970, the AEC has publicly announced a total of 359 United States nuclear tests which have been conducted in the various environments (in the atmosphere, in space, underwater, and underground). Of that total, 25 were Plowshare experiments and six were tests to improve our capability to detect nuclear weapons tests (the Vela program). The rest were weapons-related tests. In addition there were four joint United States – United Kingdom tests.

Since 1963, the AEC has conducted underground nuclear tests at the Nevada Test Site, which is approximately 65 miles northwest of Las Vegas; the Central Nevada area, which is approximately 175 miles north of Las Vegas, Nevada; Amchitka Island in the Aleutian Islands, which is approximately 1,400 miles southeast of Anchorage, Alaska; Farmington, New Mexico; Fallon, Nevada; and Hattiesburg, Mississippi.

The AEC conducts almost all of its underground nuclear tests at the Nevada Test Site. Since the Limited Test Ban Treaty the AEC has conducted these underground detonations at depths that provide reasonable assurance of containing radioactive debris. However, there were occasions when such underground tests, nevertheless, vented radioactivity to the atmosphere. Perhaps the most famous of these is the PIKE event of March 13, 1964. Apparently, a crack had developed as the result of a local weakness in the geological structure. There was much concern from the standpoint of possible violation of the Limited Test Ban Treaty. Airborne radiation monitors and automatic recording instruments were used to measure radioactive levels along the fallout trajectory. The increase of radioactivity in Las Vegas, Boulder City, Yuma, and elsewhere in Arizona, while measurable, was slight and considered not to be hazardous. It was concluded that air masses that might have contained suspect material entered Mexico and then returned to the United States.

The Soviet Union did not make a big issue of the PIKE incident, although a Tass news dispatch and a formal diplomatic note made it clear that they had taken note of it. In all likelihood the Soviets tempered their response because they understood full well that such mishaps might happen in their own program also and they did not want to establish too high a standard of accountability. The Soviet Union also had its problems in this respect. On January 15, 1965, they conducted an underground test of intermediate yield (20 kilotons to a megaton) of which about 10 percent vented, as measured by acoustic signals. It was the largest Soviet underground test yet. High flying U.S. planes picked up small quantities of radioactive material over the northern Pacific Ocean.

As a result of the active U.S. underground nuclear weapons test program, the Nevada Test Site was expanded in 1963 and 1964 by more than 153,000 acres to its present size of about 860,000 acres. However, in 1966 it became apparent to the AEC that additional areas would be needed for the underground testing of devices with yields greater than those which could be safely accommodated at the Nevada Test Site. The higher yield tests were needed to satisfy certain military requirements. After a number of studies, the sparsely populated Central Nevada area and the unpopulated Amchitka Island in the Aleutian chain were chosen. The choices were based on relative development costs, relative absence of logistical and environmental problems, and the low chance of possible off-site damage. These two supplemental test areas, as they are known, have been developed and the Amchitka site is currently in use, while the Central Nevada site has been put in a caretaker status.

Because of technological limitations other than yield, additional localities, such as those near Farmington, New Mexico; Fallon, Nevada; and Hattiesburg, Mississippi, have been used. These possess unique qualities, such as geological formations, hydrologic factors and terrain features, which are necessary for a specific type test. These localities have been used in the peaceful uses of nuclear explosives and the Vela detection program and were intended for one time use. The facilities are small and generally temporary in nature.

In addition to the test areas mentioned above, the AEC and DOD maintain Johnston Atoll in the Pacific Ocean. It has been improved and maintained in the event the Limited Test Ban Treaty is abrogated and testing in presently prohibited environments is necessary.

There have been a number of underground high yield tests. These were publicly announced in advance and this gave rise to a good deal of public concern that the tests would contaminate the water, change water levels, trigger earthquakes and cause structural damage to buildings. A special concern was the question of damage to buildings in Las Vegas. In the case of the BOXCAR event, the largest underground nuclear weapons test to date with an estimated yield of about one megaton, billionaire Howard Hughes, because of concern about the effect on his property in Las Vegas, tried to exert pressure on me and then on President Johnson to cancel or postpone this test. Normal administrative procedures had been followed in securing Presidential approval for this test, but the President wanted to review the matter in view of this protest and other protests. A telephonic justification of the test was made to the White House just an hour before the scheduled execution time. Only when the President was convinced of the necessity of the test and of the adequacy of the safety studies was final approval given. The BOXCAR event was conducted at Pahute Mesa, Nevada, approximately 100 miles north of Las Vegas, on April 26, 1968, with minimal environmental effects.

Although public concern continued to be expressed the subsequent high yield tests proceeded under less dramatic circumstances.

The BENHAM test, with a yield of about one megaton, was conducted at the Nevada Test Site on December 19, 1968. The test was necessary in the development of more advanced nuclear weapons. The device which was buried 4,600 feet deep produced ground motions which were felt at various locations in Las Vegas and Tonopah, Nevada and Salt Lake City. At Hoover Dam, southwest of Las Vegas, the maximum acceleration from the test was less than one percent of those accelerations caused by the largest natural earthquake recorded at the dam in 1963.

The JORUM test was conducted in Nevada on September 16, 1969. This test was a weapons-related event. The device, with a yield of about a megaton, was buried 3,800 feet deep and produced lower seismic activity than BOXCAR and JORUM.

The MILROW test, with a yield of about one megaton, was conducted at Amchitka Island off the coast of Alaska, on October 2, 1969. The specific purpose of the Milrow test was to obtain the required information on both physical and bioenvironmental effects from which a realistic evaluation could be made of the similar effects to be anticipated from a follow-on weapons-related test. The device was detonated at a point 4,000 feet below the surface. Milrow had no major impact on the environment.

The HANDLEY test was conducted at the Nevada Test Site on March 26, 1970. This test, with a yield of more than one megaton, was a weapons-related event. The device was buried 4,000 feet deep and produced no damage to off-site structures.

The Soviets conducted another atmospheric nuclear weapons test series in the summer of 1962, which included a 30 megaton explosion.

XVII. Plowshare

The first Plowshare (Peacefuul Uses of Nuclear Explosions) experiment, to investigate the feasibility of the use of nuclear explosives for excavation purposes, was SEDAN, a 100-kiloton device which was detonated in Nevada on July 6, 1962. It involved excavation of a crater 1,280 feet in diameter and 320 feet deep. (I flew over the crater with President John Kennedy in a visit to the Nevada Test Site on December 8, 1962.) However, further excavation experiments became fraught with difficulty due to the provision of the Limited Test Ban Treaty prohibiting any nuclear explosion that "causes radioactive debris to be present outside the territorial limits of the State under whose jurisdiction or control such explosion is conducted."

The next excavation experiment, SULKY, of estimated yield only 0.1 kiloton took place on December 18, 1964, at the Nevada Test Site. In order to be sure of not violating the test ban treaty, the AEC buried the device at an overly conservative depth. As a consequence we ended up with a mound instead of a crater. Even so, some radioactivity was detected off-site. The amount was small and quickly dissipated, long before it could reach a national border.

SULKY was not a total loss. We obtained useful information from it. What we had chiefly lost was time. To still the clamor of its opponents and ease the impatience of its friends, Plowshare needed a relatively quick success. We had hoped through the series of experiments of which SULKY was a part to demonstrate nuclear excavation technology convincingly to skeptics in the United States and elsewhere. As 1964 ended we were a long way from having done that.

On April 14, 1965, we conducted a Plowshare experiment called PALANQUIN at the Nevada Test Site. It involved detonation of a 4-kiloton thermonuclear device buried at a depth of 180 feet in an emplacement hole drilled to 615 feet. The purposes were to explore cratering mechanisms in hard dry rock such as might be encountered in Panama, and to investigate emplacement techniques that would reduce the amount of radioactivity released in the atmosphere.

It was our expectation, based on earlier experiments, that a large fraction of the radioactive debris would go down the hole and that very little would reach the atmosphere. Also, following the experience of SULKY, we expected PALANQUIN to create a fully contained mound rather than a crater. (The purposes of PALANQUIN, unlike SULKY, were such that we would have been satisfied with a mound.) Our expectations proved wrong in both respects. The dust cloud from the explosion rose to a height of 8,000 feet, and contained higher-than-expected levels of radioactivity. This air mass moved northward rather slowly, dispersing laterally as it travelled. As I reported to the president, the radioactivity was much less than that following the errant Soviet test of January 15, 1965, and well below any possible health hazard level, even close to the test site. Worrisomely, however, the radioactivity was sufficient to be readily detectable by properly equipped aircraft should the cloud drift into Canada. On the afternoon of April 15, the radioactive air mass was located east of Spokane, the next morning over Butte, Montana. To our relief, it appeared then to drift to the southeast. However, the Soviets wrote to us in protest.

After many, many postponements due to concerns over LTBT violations, CABRIOLET, using a 2.7-kiloton explosive, was detonated at a depth of 170 feet in hard, dry rock at the Nevada Test Site on January 26, 1968. It created a crater about 400 feet across and 125 feet deep. The wind was right, blowing away from Mexico, and a snowstorm in northern Nevada apparently brought down much of the debris. The snowstorm was a stroke of good luck! No radioactivity attributable to CABRIOLET was detected by the Canadians.

The successful detonation of CABRIOLET on January 26, 1968, set the stage for the execution of two other cratering experiments during that year. In neither case was there major opposition from within the government. BUGGY went off on March 12. It involved the simultaneous detonation of five low-yield (about 1 kiloton) nuclear explosives in a row. It created a ditch-like crater 860 feet long, 280 feet wide, and 68 feet deep. As with CABRIOLET, the explosion was set off in hard rock, the medium most likely to be encountered in a trans-Isthmian canal. Again there were no problems of radiation crossing the border. (After seeing a film of BUGGY, I commented somewhat testily in my diary: "This and CABRIOLET should have been approved for execution long ago.")

On December 8, 1968, SCHOONER was successfully detonated at the Nevada Test Site, creating a crater 850 feet in diameter and over 240 feet deep. Its purpose was to extend cratering technology in hard rock to encompass higher yields, approaching those that would be required for actual construction of a canal. (SCHOONER's yield was 300 kilotons, as compared to CABRIOLET's 2.7.) It released in the atmosphere the highest levels of radioactivity recorded in the United States since the test ban treaty. The radioactive debris seemed to stay well within U.S. borders, however; there appeared to be no treaty violation. What was our astonishment, then, when on January 21, 1969, the first full day of the Nixon administration, the Soviet chargé d'affaires in Washington delivered an aide-mémoire stating that SCHOONER had caused a "two to fivefold increase in fallout in the regions along the Baltic, Volga, Northern Caucasus, and Crimea." The following day I explained to Nixon's assistant Robert F. Ellsworth that this corresponded to an absurdly small amount of radioactivity. As it developed, we were unable, despite President Nixon's favorable prejudice, to obtain administration approval for even one further cratering experiment.

The demise of nuclear excavation was a heavy blow to the Plowshare program, whose hopes for the future rested so heavily on the foreseen opportunities to perform excavation projects as a service for other nations. I would not wish to leave the impression that the delays or denials of CABRIOLET and other experiments bore sole responsibility for this unhappy denouement. Without doubt, they hastened the outcome, but there were serious objections to nuclear excavation that might well have prevailed in any case.

In 1965, the El Paso Natural Gas Company proposed a cooperative project with the AEC and the Interior Department to examine the phenomena involved in the use of nuclear explosions to recover gas. An experimental explosion, called GASBUGGY, took place on December 12, 1967, on one of the company's leases in New Mexico. It involved a 29-kiloton explosive buried at a depth of 4,240 feet. There had been little difficulty gaining approval for this experiment since the explosion would be fully contained--there was virtually no possibility that escaped radioactivity would cause accusations of a treaty violation.

GASBUGGY seemed highly successful. A rate of production several times greater than that of neighboring wells was achieved, although, because the gas was slightly radioactive, none of it was sold commercially.

A second experiment, equally successful, followed in September 1969. Its purpose was to extend GASBUGGY experience to greater depths and different types of rocks. Named RULISON, this second experiment involved explosion of a nuclear device more than 8,000 feet deep near Grand Valley, Colorado. The industrial sponsor in this case was the Austral Oil Company. Resulting natural gas production was copious. Amounts of radioactivity in the gas were very small but there was some and, again, none of the gas was sold commercially.

The Plowshare program made substantial contributions to basic research, including experiments in the production of transplutonium elements. The high flux of neutrons in nuclear explosions can be utilized for the synthesis of heavy isotopes and many were identified for the first time or further investigated by the use of this technique. (Those identified for the first time, however, came from a nuclear weapons test, not a Plowshare experiment.)

The most dramatic of these experiments was the unexpected discovery of einsteinium (atomic number 99) and fermium (no. 100) in the airborne debris from the first thermonuclear explosion, the "Mike" shot staged in the Pacific on Elugelab Island, Eniwetok Atoll, in November 1952. A large group of scientists from the Berkeley Radiation Laboratory, the Argonne National Laboratory and the Los Alamos Scientific Laboratory participated in these discoveries. In addition to ^{253}Es and ^{255}Fm, the first known isotopes of einsteinium and fermium, the isotopes ^{244}Pu, ^{246}Pu, ^{246}Am, ^{246}Cm, ^{247}Cm, ^{248}Cm, ^{250}Cm, ^{249}Bk, ^{249}Cf, ^{252}Cf, ^{253}Cf and ^{254}Cf were discovered. They were produced by the capture of fission neutrons in the ^{238}U in the Mike device, followed by a series of successive beta decay processes.

The success of such fast neutron capture reactions for the synthesis and identification of new heavy isotopes led, in the 1960's, to the fabrication of specially tailored nuclear explosive devices, by the Los Alamos Scientific Laboratory, and the Lawrence Livermore Laboratory, for the further production and study of such isotopes. In these underground experiments, performed at the Nevada Test Site, the greatest success was obtained with ^{238}U targets. The neutron capture products are distributed in the vaporized rock and must be recovered from 300-600 meters below the surface. Only a small fraction of the total production is recovered, although much greater than in the atmospheric Mike explosion, and it usually takes several days after the explosion for the first samples to become available for chemical identification and counting.

Some of the more notable experiments were named Par (conducted by Livermore in October, 1964), Barbel (Los Alamos, October, 1964), Tweed (Livermore, May, 1965), Cyclamen (Los Alamos, May, 1966), Kankakee (Livermore, June, 1966), Vulcan (Livermore, June, 1966), and Hutch (Livermore, July, 1969). Of these, the 13 kiloton (kt) Cyclamen and especially the 20-200 kt Hutch events were by far the most productive. The Cyclamen device produced a flux of 15 moles neutrons/cm^2 and Hutch 40 moles neutrons/cm^2.

A greater quantity of nuclides with mass number greater than 250 was produced in the Hutch event than in the Mike explosion, in spite of the much larger explosive yield of Mike (10,000 kt). For Cyclamen the production of heavy nuclides was also very impressive--the yields of products with mass number greater than 250 was only one order of magnitude less than for Mike, while the total explosive yield was nearly three orders of magnitude less. The fraction of the total products produced in the device that was recovered was about 10^{-8} for Hutch compared to about 10^{-12} for Mike.

Although no new nuclides or new elements were detected in these underground explosions, significant amounts of some rare and heavy nuclides were produced. More ^{250}Cm was recovered from Hutch debris than has been produced by neutron irradiations in reactors. The Hutch detonation produced 6×10^{17} atoms of ^{257}Fm, of which 6×10^{9} atoms (2.5 picograms) were recovered, which is more than has been produced and recovered by neutron irradiations in reactors. The 80-day ^{257}Fm, the heaviest and longest-lived isotope of fermium, was discovered in 1964 as the result of a four-year neutron irradiation in the Materials Testing Reactor (MTR) in Idaho.

In total the United States conducted 41 Plowshare explosions. Most were conducted in the years 1962 to 1968. During each of these years there were four or more tests. Thereafter, the program dwindled rapidly. There were only two explosions in 1969, one in 1970, and no more while I was Chairman of the Atomic Energy Commission.

XVIII. Controlled thermonuclear research (CTR)

At the beginning of 1961 the many devices for research on controlled fusion reactions were divided into five different categories: stellarators, mirrors, pinches, Astron, and rotational plasma research. The Model C Stellarator (doughnut-shaped magnetic container with a twisted container carrying current outside the plasma) at the Princeton Plasma Physics Laboratory (Princeton, New Jersey) was then two-thirds completed. The Scylla (a high beta stellarator), forerunner of the Scyllac device, was operating at the Los Alamos Scientific Laboratory (LASL), while at the AEC's Livermore Laboratory, in collaboration with and part of Lawrence Radiation Laboratory in Berkeley, "a rather old mirror machine" (a linear machine) called Table Top was producing plasmas with 25 kev electron plasmas. The Astron facility (plasma confined by a circulatory electron beam), also at Livermore, was nearing the stage where hopefully a step-by-step test of the Astron principle would be possible. At Oak Ridge National Laboratory (ORNL), the DCX-2 facility was being designed to replace DCX-1 (a mirror machine injected with molecular deuterium ions).

However, in the research with these devices, between 1961 and 1965, a veritable host of plasma instabilities was discovered, some experimentally, some theoretically. Each in its turn had to be understood and either eliminated or minimized. Critical experiments and better theory had to be developed. Together they would have to provide a depth of understanding of plasma phenomena that went far beyond anything that anyone had formerly conceived of as necessary. Altogether a good deal of progress in such understanding was made. An important advance was made in the early 1960's by the Soviet physicist M. Joffe, referred to as Joffe bars effect, which made possible increased plasma stability. Gradually the belief emerged that, though troublesome, plasma instabilities did not present an insuperable obstacle to the attainment of adequate plasma confinement.

Another ray of hope came from other places. In October 1963 Professor Donald Kerst at the University of Wisconsin reported encouraging results in a small device called a toroidal octupole (a doughnut-shaped container with circular conductor carrying current outside the plasma). Tihiro Ohkawa at General Atomic reported, in November, preliminary results on a linear octupole. The studies of Kerst and Ohkawa paved the way for an entire new genus of devices, the multipoles; and Dr. Ohkawa's work culminated in 1970, with a demonstration of classical plasma confinement in a large toroidal octupole.

During 1964 and 1965, program emphasis on Controlled Thermonuclear Research (CTR) began to shift from basic plasma research to a more applied form in which the considerable body of knowledge about instabilities was applied to the design of a new generation of confinement systems.

At the request of the JCAE a review panel composed of scientists not connected with the CTR programs at the four (national) laboratories was appointed. The full committee met for the first time on May 25 and 26, 1965. Subsequent to this organizational meeting the panel met at each of the four laboratories during the period late June to mid-July 1965. By late July the first tentative conclusions had been reached and these were forwarded to Dr. Paul McDaniel, Director of Research, on August 4, 1965. The panel met on October 9-10 to consider their final recommendations.

On December 30, 1965, the final report of the Controlled Thermonuclear Research Review Panel was forwarded to the Commission. In its final form the panel report addressed itself directly to the then existing status of research in CTR as well as to future program requirements. On the latter subject the panel was distressed to find that the U.S. contribution to world research in fusion was declining rapidly. It recommended "a doubling of scientists and engineers engaged in CTR under AEC auspices in a period of approximately five years." Furthermore, it recommended that "the AEC take immediate steps toward establishing a national center for plasma studies and nuclear fusion research."

The panel concluded that fusion research in the four major laboratories was in a healthy state and the "CTR (was) rapidly moving from an experimental art into a quantitative science." These recommendations included specific references to various experimental programs and how these could be augmented and improved.

At year end, 1965, a major administrative change took place in the Controlled Thermonuclear Research Program. Amasa Bishop, who had headed the program from 1954 to 1958, returned to take charge again. On February 10, 1966, I sent a revised version of the panel report to Charles Schultze, the director of the Bureau of the Budget. I noted that "the views of the Commission were guided in great measure by the report of the Review Panel on Controlled Thermonuclear Research."

During the months that followed, the proposed policy and action paper was subjected to extensive review both within and without the Commission. Early in March, a subcommittee, headed by Sydney Drell, was commissioned to review the report on behalf of the President's Science Advisory Committee. On March 22, the entire Committee was briefed and by mid-June, when the document was put in final form, the Commission's General Advisory Committee had reviewed it also.

On June 16 and 17, 1966, two staff papers were sent to the Commission. One was a request "to consider the adoption of an AEC policy and action paper on controlled thermonuclear research." The other was to consider the establishment of a CTR advisory committee as proposed in the policy and action paper. This advisory committee was envisioned to consist of approximately eight members: the four directors of the primary CTR programs; the assistant research division director (for controlled thermonuclear research), who would act as chairman; and an additional three or four members of the committee to be selected from among the ranks of the U.S. scientific community.

On June 21, 1966, the Commission adopted the policy and action paper including approval of the CTR advisory committee. In response to the recommendations made in the policy and action paper, an orderly expansion of the CTR program began. An internal program review committee was established in 1966. Officially titled the "CTR Advisory Committee," it became known within the program as the Standing Committee. Within a year, four ad hoc panels were convened to study the LASL Scyllac proposal, Low-Beta Open, and Low-Beta Closed, Systems and the Livermore Astron project. The reports they made provided the necessary sound scientific support for the programmatic decisions that followed.

In the scientific-technical area, the document urged that "a number of large new experimental devices (be built) in order to test recent concepts for improved plasma confinement."

The list of fiscal recommendations included one that urged "a net increase of about 15 percent a year in normal operating funds over the next five years," and another recognized the need for major fabrication funds of from $3 million to $4 million annually.

At its third meeting on September 7 and 8, 1966, the Standing Committee approved its panel recommendation on the LASL Scyllac. The motion concluded with the unanimous recommendation that the project "be pursued vigorously, through its incorporation in the FY 68 budget." This led to the inclusion of $8.5 million in the FY 1968 budget for this facility.

During 1967 the other three ad hoc panels of the Standing Committee were appointed in the following subject areas (and chronologically in the order shown): Low-Beta Toroidal Plasma Research, Low-Beta Open System Research, and the Astron program.

After accepting the Low-Beta Toroidal panel's report, the Standing Committee, on September 7 and 8, 1967, went on to authorize fabrication of a superconducting multipole (FY-1) at Princeton.

The Standing Committee reviewed the Low-Beta Open System panel's report on October 30, 1967, and approved a statement which included the following points:

> "We find that the present mirror program is well balanced and that the fusion motivation for mirror research continues strong.
>
> We see a clear need for proceeding with the construction of the Baseball II facility as recommended unanimously by the panel...
>
> We support in principle the target plasma program at ORNL ...
>
> We note with gratification the excellent plasma regime achieved semi-empirically in the 2X experiment. We urge the Lawrence Radiation Laboratory (at Livermore) to exploit this encouraging achievement by increasing the effort devoted to it."

Based on the recommendations of the Astron panel, the report of the Standing Committee in March 1968, was not favorable to the Astron project.

In 1967 the crucial objective of the Low-Beta Toroidal research program was a clear demonstration of substantially improved plasma confinement over that predicted by the Bohm formula. So stated the Panel on Low Beta Toroidal Research; and so did the scientific community believe. In the January 19, 1970 issue of Physical Review Letters, such confinement was unequivocably demonstrated. Not even the journal's sterile prose can disguise the magnitude of the breakthrough by Tihiro Ohkawa and his General Atomic co-workers:

> "The confinement of 300 Bohm times is observed...In high-density regimes the loss process is found to be due to classical diffusion."

Not only had there been a demonstration of substantially improved confinement, but in fact classical diffusion of a magnetically confined plasma had been obtained for the first time. (The Bohm formula is an empirically observed scaling law that tells how the diffusion time is increased as the dimensions and the field are increased.)

Another significant development program occurred which would have a marked effect on the U.S. Low-Beta Toroidal Program. At the third IAEA Conference on Plasma Physics and Controlled Thermonuclear Research held in Novosibirsk, USSR, in the summer of 1968, new results on toroidal confinement had been presented. In particular, the Soviets disclosed that in the T-3 and TM-3 Tokamak devices (doughnut-shaped magnetic container with current circulating within the plasma) they had confined hot plasmas (electron temperatures of kilovolts and ion temperatures a fraction thereof) for times on the order of 10 milliseconds, which represented a factor of 50 over that predicted by the Bohm formula. The Tokamak program director, L. Artsimovich, was no newcomer to CTR. he had been developing and refining the Tokamak principle for over a decade. Immediately after Novosibirsk, the CTR office began a searching re-evaluation of the U.S. Low-Beta Toroidal Program.

At the September Standing Committee meeting at Los Alamos, Bishop requested that each laboratory analyze the impact of the Novosibirsk Conference on its program. By April 1969 there seemed to be general agreement that the Soviets had forged significantly ahead in low beta toroidal confinement research. As a result, an Information Paper on CTR was forwarded to the Commission on May 15. In it were detailed the Soviet results as they were then appreciated.

> "Hot plasma is now reported to have been confined in the T-3 Tokamak for times of more than 1/50 of a second which corresponds to at least 80 times the Bohm value. In these experiments the ion temperatures are reported to be about 500 eV, the initial plasma density being about $5 \times 10^{13}/cm^3$. If these figures are valid, this combination of factors is by far the best achieved anywhere in the world."

Following the May Information Paper, the Standing Committee met at Albuquerque from June 26 to 28, 1969. The major item on the agenda was what the proper response to the Soviet challenge of tokamaks should be. It was unanimously agreed that at least one tokamak experiment had to be started in fiscal 1970 and a second would be highly desirable. On the basis of the speed with which the experiment could be put on line and on its ready ability to check out Soviet interpretations, the PPPL conversion of Model C to a Symmetrical Tokamak (ST) device and the ORNL ORMAK (Oak Ridge Tokamak) program were approved. Inasmuch as the Committee also had to consider excellent proposals from General Atomic for Doublet-II (toroidal multipole with current circulating within the plasma), from MIT for Alcator (a tokamak), and from the University of Texas for its turbulently heated system, the decision to approve only two devices represented a concession to the fiscal pressures then operative.

Of the three proposals not acted upon at the time, the first deserves special mention. Doublet-II was the extension of an already existing Tokamak-like device called Doublet-I, whose genesis can be traced back to an idea of Ohkawa's in late 1967 to combine the best features of the Tokamak with the best features of the multipole. Ohkawa was clearly the first of the U.S. scientists to appreciate the importance of the tokamak geometry. In his proposal to the AEC dated May 22, 1968, he related his entire design of Doublet-I, then called a plasma current multipole, specifically to the Tokamak and outlined its properties in terms of that concept. By the time of the Albuquerque Standing Committee meeting, Doublet-I had already shown the feasibility of obtaining a geometrically stable Magnetic Hydro Dynamic (MHD) equilibrium in the Doublet geometry and had indicated the possibility of obtaining stable confinement of an intermediate beta plasma. Late in fiscal 1970, the Standing Committee finally agreed that the project should be funded and recommended it to Bishop. Funding began in February 1970. Completion was scheduled for the summer of 1971.

The other two tokamak proposals not originally approved by the Standing Committee fared equally well. As a result of the British verification of the T-3 results in August 1969, there was no longer any doubt that the Soviets had indeed made a major contribution to the CTR program. Virtually overnight, attention focused on how to take advantage of the breakthrough. The MIT and Texas programs were tailor-made for that purpose. The MIT group had fashioned a program that depended on the special high field capability of the Francis Bitter National Magnet Laboratory. They were prepared to investigate the scaling of tokamak behavior to reactor-like magnetic fields, i.e., fields in the 120-150 kG range; while the Texas program had addressed itself to the problem of increasing ion-heating through the use of induced plasma turbulence. Both proposals were reviewed extensively and favorably during the fall of 1969 and the winter of 1970. By late December 1969, the Division of Research had completed its review of Alcator (the MIT device) and on June 6, 1970 the AEC's General Manager was notified of "plans to initiate in fiscal 1970 the fabrication of a high magnetic field toroidal experiment at the Massachusetts Institute of Technology."

The Model C Stellarator was shut down in December 1969 and conversion to a symmetric tokamak (ST) was completed by May 1970. The first series of experiments confirmed the Soviet results on T-3 and provided the confidence needed to push forward with the other systems.

While the Low-Beta Toroidal Program was undergoing redirection, the embodiment of the High-Beta Toroidal effort, Scyllac, was proceeding along well-defined lines. Scyllac had been authorized in fiscal year 1968. However, building construction did not start until late November 1968. Thereafter, with the exception of a one month delay due to labor difficulties, the Scyllac project stayed right on schedule. Initial operation began on March 8, 1971.

Like the High-Beta Toroidal Program, the Mirror Program followed quite closely the Low Beta Open System panel's recommendations. At the Novosibirsk Conference in 1968, the Livermore (Berkeley) group reported near-classical plasma confinement in the 2X device. Additional data, taken during the year that followed, demonstrated the need for larger plasma volume, and deeper well depth.

As a result, the 2X (mirror) device was shut down early in 1970 and conversion to 2X-II was begun. In 2X-II the mirror ratio was to be increased by 50 percent, the plasma volume by a factor of 2, and the classical confinement time by a factor of 10. If the device is found to exhibit only classical losses, the case for stable confinement in mirror reactors will be greatly strengthened. Concurrently, the Baseball I (mirror) device, in which Landau damping was shown to be the controlling element in the plasma buildup process, was being converted to a larger neutral injection system in which several high energy beams can be injected simultaneously. Baseball II, although delayed somewhat by funding stringencies, was expected to be operational in summer 1971.

Thus by 1971 the following devices were operating or near operating: the Scyllac at Los Alamos, the Symmetric Tokamak and FM-1 (Multipole) at Princeton, Baseball II and 2X-II at Livermore (Berkeley), Doublet-II at General Atomic, ORMAK at Oak Ridge, and Alcator at MIT.

XIX. Nuclear education and training

To illuminate the orders of magnitude of the number of persons assisted, the FY 1969 program has produced the following education and training accomplishments: supported advanced study through 466 fellowships and 155 traineeships, enabled the training of 804 faculty members through summer and academic-year institutes, trained 672 individuals through nuclear courses and provided training opportunities at AEC laboratories ranging from participation in research to short instruction in use of scientific instruments for 1,182 faculty, 2,742 students and 609 others from government and industry. Additionally, close to 200 Puerto Ricans and Latin Americans were trained at the Puerto Rico Nuclear Center.

The program that experienced the greatest expansion in the ten-year period was the University-AEC Laboratory Cooperative Program. In July 1965 the Division of Nuclear Education and Training (DNET) organized a Laboratory Relations Branch to accelerate the Commission's programs of encouraging colleges and universities to make greater use of the unique talents and sophisticated facilities of AEC laboratories for educational purposes. The establishment of this branch enabled the Division to provide several full-time professionals with the opportunity to 1) motivate both AEC laboratories and educational institutions to expand interactions among themselves, 2) improve coordination of laboratory cooperative activities with other agencies and industrial nuclear laboratories, and 3) work with college and university consortia to develop new programs of cooperation with AEC laboratories. This program is administered for the Commission by a number of university consortia throughout the United States. These include Oak Ridge Associated Universities, Argonne Universities Association, Associated Western Universities, the Northwest College and University Association for Science and several others. These cooperative educational programs are developed by committees of the associations, representing a number of nuclear disciplines. The support of faculty and students at AEC laboratories is administered principally by the consortia but may also be administered in some instances through the laboratory providing the research facilities. The laboratory cooperative endeavors comprise principally: faculty and student research participation, faculty-student conferences, laboratory graduate fellowships, honors programs, and engineering practice schools. There are 15 AEC laboratories that participate in some or all of these activities.

Another important educational activity under the Assistance to Schools category is the program of training teachers through summer and academic-year institutes. Most of the training in this category is in the field of radiation science and technology. However, its level has been cut in two over the ten years ending in FY 1971. The major reduction has been in phasing out training of high school science teachers, due to budget stringencies. In the early years of this program the related funding was provided by both the National Science Foundation and the AEC. NSF provided the support for the college and high school teachers attending the institutes and the AEC provided operating support to the host universities conducting the institutes. In recent years the AEC has been providing the total funding required for these institutes, but confined to teachers.

Since 1954 the Commission has provided financial support to colleges and universities for nuclear materials and services related to their instructional programs in the nuclear sciences and engineering. The support for this category has more than doubled over the FY 1960– FY 1970 period. In the last few years, nevertheless, it has been possible to accommodate less than one-half of the requests received. Most of this activity, about 80% of its funds, has been for fabrication and reprocessing of fuel for university reactors, known as fuel cycle assistance. Two dozen reactors on campuses spread widely through the United States are assisted in this way and 15 of them are rated above 1 megawatt. Many of these are increasing in power and usage, thereby resulting in increased fuel and operating costs. A most serious problem facing universities with large research reactors is how to meet the increasing cost of operating these facilities. The universities bear three-quarters of this cost but they depend on the AEC for some financial support for their reactors. For this, fuel cycle assistance is augmented by waiver of use charges for fuel and waiver of reprocessing costs for spent fuel elements. The institutions possessing these larger reactors produce more than 90% of the M.S. level and 97% of the Ph.D. level nuclear engineers. These advanced degree graduates contribute greatly to fulfilling the manpower requirements for the nuclear industry and AEC contractors. These reactors also help to diffuse nuclear phenomena into many scientific disciplines other than nuclear engineering. It is estimated that a typical university research reactor is utilized over 50% by disciplines other than nuclear engineering.

In recognition of the versatility of these reactors, the AEC in 1969 instituted a program of reactor-sharing, whereby institutions with reactors are compensated for costs added by sharing the reactors with nearby colleges and universities. To date there are five such reactor-sharing centers located in California, Texas, Kansas, Georgia and New York. It is the intent of DNET to expand this program in the future to establish at least 20 such centers within the United States.

As part of the Atoms for Peace program of the Eisenhower Administration, the Commission established the Puerto Rico Nuclear Center for the training of Latin American scientists and engineers in nuclear technology. The initial budget for the establishment of the Center was in FY 1958 and that the budget has expanded from $510,000 in FY 1960 to $1,340,000 in FY 1970. During this growth a shift took place from emphasis on instruction in radioisotope techniques to graduate degree programs in the physical and life sciences and engineering, all with a nuclear emphasis. The shift was made concurrently with a Commission determination that it was necessary to have a research capability at the Center as a base for graduate education and training, and for an instructional center whose staff would be up to date in techniques. Thus, in addition to DNET's financial support for educational activities at PRNC, the Division of Biology and Medicine instituted in 1962 a life science research program approximating $600,000 per year, and the Division of Research initiated a physical sciences program running about $200,000 per year.

It must be apparent that during the period FY 1960– FY 1970 and continuing to date the Commission has made substantial changes in its education and training program. Because of stringent budgets in recent times DNET has terminated its program of training high school science teachers and is concentrating on the training of college faculty, including faculty from junior colleges and technical institutes who will be trained to instruct the technicians urgently needed by the expanding nuclear industry. Increased emphasis is being placed on the traineeship mode of support for graduate study as distinguished from fellowships. Traineeships provide the Commission with a greater voice in choice of graduate curricula and degree level than do fellowships. Likewise, more emphasis is being placed on M.S. level programs than the Ph.D. degree in Nuclear Engineering and Radiation Science and Protection. Some of these changes in emphasis reflect not only the changing picture of government contractor and industrial employment but also concerns of the Office of Management and Budget and the Joint Committee on Atomic Energy resulting from their review of the Commission's education and training budgets.

The 1970 workshop for black institutions at Oak Ridge was broadened from the 1969 format to include faculty from all university disciplines instead of engineering alone. Reports during August 1970 indicated that this workshop also has been quite successful.

The story of nuclear education and training would not be complete without mention of the excellent assistance that has been rendered to educational institutions and the AEC by the American Nuclear Society (ANS), the American Society for Engineering Education (ASEE), and the American Institute of Biological Sciences (AIBS). The Commission has worked hand-in-glove with these organizations almost from the inception of the program for nuclear education and training. The ASEE and the AIBS were particularly helpful in the early part of the 1960's, whereas the contributions made by the ANS have been exercised during the latter five years of the decade. These three organizations' invaluable professional assistance has been principally in the areas of faculty institutes, training aids, manpower surveys, conferences, seminars, and symposia.

In summary, the 1960's may be characterized as the period when the joint venture of AEC and educational institutions to develop instructional capabilities on campus in the nuclear sciences and engineering paid off to the benefit of the government, industry, education and the public. The Commission has invested over $125 million plus $20 million worth of loans of nuclear materials and substantial indirect aid through use of its laboratory facilities on behalf of this venture. Similarly, the institutions have more than matched this sum in estimates as high as an additional $160 million.

XX. Technical information

As of 1961, the Commission was publishing four quarterly Technical Progress Reviews, journals which covered developments in particular areas of the nuclear energy field of interest to technical and management people. The four were Nuclear Safety, Power Reactor Technology, Reactor Core Materials (renamed Reactor Materials in 1962), and Reactor Fuel Processing, and were prepared by staffs of major laboratories. A fifth journal, Isotopes and Radiation Technology, was added in 1963; and in 1967, the publication schedule for Nuclear Safety was increased from four to six times per year.

In 1966, when it became apparent that chemical reprocessing of nuclear fuel had become routine, Reactor Fuel Processing was merged into Power Reactor Technology. In 1969, Reactor Materials was merged with Power Reactor Technology.

Another means of furnishing scientists with needed information covering the state of knowledge in their fields of interest was provided in 1968, when AEC began publication of its Critical Review Series. (A critical review has been defined as "an article on a specialized field of study in which the scientific objectives within the field are defined, concepts or hypotheses are examined, existing knowledge is evaluated, and new concepts are synthesized.") Five volumes were issued in this series: Sources of Tritium and Its Behavior Upon Release to the Environment; Plume Rise; Atmospheric Transport Processes, Part I; Reactor-Noise Analysis in the Time Domain; and The Analysis of Elemental Boron.

Since its inception, the AEC has received a steady flow of inquiries from the general public, particularly secondary school students and their teachers, regarding various aspects of nuclear science and its applications. By 1963, the volume of such requests had become so heavy that the AEC decided to prepare topical booklets to provide answers to the questions asked most frequently. These could serve as tools for the strengthening of science education. Accordingly, a series of educational booklets was initiated under the title of "Understanding the Atom." Prepared by established science writers, the booklets are made available in limited quantities without charge.

The series proved to be enormously popular from the outset, resulting in repeated reprints and the addition of more titles. Many of the booklets have been translated into foreign languages, and seven which have been produced in Braille are being distributed to blind high school students through the American Printing House for the Blind. The growth of the series may be seen in the following table.

Understanding the Atom Booklets

Year	Number of titles in Print	Number of Copies Distributed (Cumulative)
1962	3	
1963	8	
1964	19	
1965	28	
1966	39	3,328,200
1967	45	4,779,000
1968	51	6,524,000
1969	54	8,047,600
1970	56	9,456,400

The booklet "The Elusive Neutrino," by Jeremy Bernstein, received the 1970 Science Writing Award in Physics and Astronomy sponsored by the American Institute of Physics and the U.S. Steel Foundation.

By 1970 it was felt that there was a need for educational materials on a somewhat less technical level than "Understanding the Atom." Accordingly, under the title of "World of the Atom," a new series of booklets was begun, designed for use by students in upper elementary grades and for basic adult education courses. Five titles were published in this series during its first year.

Among the accomplishments of which I am most proud were the publication of the two histories of the Atomic Energy Commission: Volume I, The New World, 1939/1946 by Richard G. Hewlett and Oscar E. Anderson, Jr. (The Pennsylvania State University Press, 1962), and Volume II, Atomic Shield, 1947/1952 by Richard G. Hewlett and Francis Duncan (The Pennsylvania State University Press, 1969).

During the ten years (1961–70), the AEC organized U.S. participation in 120 IAEA conferences held throughout the world. The U.S. sponsored approximately 3,000 participants who presented 1,500 papers covering a broad spectrum of subject matter. The IAEA conferences which drew the largest U.S. attendance abroad and the greatest number of papers were those on Plasma Physics and Controlled Thermonuclear Research. There were three such conferences held: at Salzburg, Austria, in 1961; Abingdon, U.K., in 1965; and Novosibirsk, USSR, in 1968. Several of the IAEA conferences were held in the United States. Most highly attended was the conference on "Environmental Aspects of Nuclear Power Stations," held at United Nations Headquarters in New York in August 1970 (which I attended).

In addition to the IAEA meetings, there were 152 other conferences supported by the AEC during the ten-year period. Especially noteworthy among these were:

> Radiation Research Congresses held in England (1962), Italy (1966), and France (1970).
>
> International Congress on Nuclear Physics, Gatlinburg, Tenn. (1966).
>
> Conference on Constructive Uses of Atomic Energy, Washington, D.C. (1968).

To facilitate access by the scientific community to the world's nuclear literature, the AEC established in 1948 its semimonthly journal Nuclear Science Abstracts (NSA). Trends in nuclear science and technology have been mirrored by the yearly changes in NSA contents. During the 10 years (1961 through 1970), the number of literature items abstracted annually increased from 33,064 to 53,080. A very significant trend reflected in the contents of NSA is the increased tempo of nuclear research and development in foreign countries. Whereas in the early years a heavy preponderance of the literature abstracted in NSA originated in the United States, a crossover occurred during the 1960's, and the U.S. shared of the total dropped below 50 percent.

A notable change, initiated during the decade and still in process, is the computerization of the actual production of Nuclear Science Abstracts.

In 1967, an automatic data processing system with input prepared via paper tape was instituted to increase the speed of input and to facilitate storage of the information for index cumulation and other retrieval purposes. In 1970, an even faster and more efficient system was initiated through which the contents of NSA are inputted through keyboards attached to video display cathode ray tube terminals. These permit the information to be edited and corrected prior to entering the data base. A key feature of the new procedures is that the single keyboarding step used for automatic entry of bibliographic citations also provides information for the titling of microfiche, reproduction copy for catalog cards and weekly accession lists, data for the production of NSA indexes, and a bibliographic data base for further computer manipulation.

In addition, there has been under development since 1966 an International Nuclear Information System (INIS), operated under the aegis of the International Atomic Energy Agency for all its member states. The basic plan of INIS is that each country surveys its own national scientific literature, identifies items on the peaceful uses of nuclear energy which fall within the subject scope of the system, and supplies English-language bibliographic descriptions, abstracts, and subject indexing terms for those items. The IAEA then merges the data received and makes available on magnetic computer tape copies of a complete bibliographic file which each member state can use to supply nuclear information services within its borders. The IAEA also furnishes periodic categorized listings of the items reported to the system and, on request, copies of scientific and technical reports. Following approval by the IAEA's Board of Governors, the INIS became operational in May 1970 with a subject scope limited to reactor technology for the initial "debugging" period. In 1970, submissions were received from about 30 countries, including the U.S. (about 2,400 items) and the USSR.

"This Atomic World," the AEC's nationwide mobile lecture-demonstration program, aims to stimulate high school students' interest in science and increase their understanding of the basic principles and peaceful applications of nuclear energy. During the academic year, the teacher-demonstrator, traveling in a specially-equipped van, visits a different school each day. In a 40-minute assembly program for the entire student body, the teacher covers basic aspects of nuclear science including radioactivity, chain reactions, reactors and their uses, and applications of radioisotopes. Subsequently, s/he conducts more specialized sessions for the school's science classes.

By the end of 1970, more than 19 million students in all 50 states had seen the program. A long-standing goal of the program is to be able to reach every U.S. student at least once during his/her high school career. To reach more students without substantially increasing Federal expenditures for the program, a cooperative method of support was introduced in 1966-67. Under this procedure, AEC supplies the van and its equipment and trains the demonstrator, while a State or local organization employs the demonstrator and handles scheduling. In 1970, 18 of the 21 units were operated in this manner.

AEC has found museums, especially those with active science programs, to be excellent locations for presentations of exhibits and demonstrations on nuclear energy. One of the first of these exhibits was "Radiation and Man" which opened at the Museum of Science and Industry in Chicago, Illinois, in 1963. It utilizes audience participation devices to explore highlights of nuclear science, with particular attention to the effects of radiation on living matter. It also features lecture-demonstrations which explain uses of radiation in research, medicine, and agriculture. In 1964 and 1965, "Radiation and Man" and Atomsville, U.S.A.," a nuclear museum for children ages 7 through 14, were displayed at the New York World's Fair Hall of Science.

Another museum exhibit, "Life Science Radiation Laboratory," features a biology laboratory where actual experiments are carried out with plants, animals, and fish which have been "tagged" with radioisotope tracers. This exhibit has been shown at many U.S. museums.

An important addition to the Commission's traveling museum program is the "Energy" exhibit originally designed under the Office of Education auspices for the Cincinnati Science Center. When that Center was closed in 1970, the exhibit was transferred to AEC. Its three major components, "Electrical Energy", "Radiant Energy", and "Mechanical Energy" have been loaned to the New York Hall of Science, Franklin Institute in Philadelphia, and the Oregon Museum of Science and Industry in Portland, respectively.

The AEC agreed to support the installation of a research reactor and a gamma irradiation facility in a new atomic energy wing being added to the New York Hall of Science.

From 1959 through 1969, the AEC presented a series of month-long nuclear science demonstration expositions in major cities of the world. The program has been terminated because of lack of funds.

A major exhibit demonstrating U.S. achievements in nuclear technology was held in conjunction with the Third Geneva Conference in 1964. It was visited by more than 22,000 persons.

The AEC and the Department of Interior cooperated in a nuclear desalting exhibit at the Levant Fair in Bari, Italy in 1966. Other presentations on desalting were made in 1967 in Milan, Italy, and Sao Paulo, Brazil, and during 1968 in several major cities of Pakistan.

The AEC displayed information on desalting, peaceful nuclear explosives, and other subjects at NUCLEX-66, a nuclear industry exposition at Basel, Switzerland. Other AEC exhibits abroad were presented in connection with the Mexico City Olympic Games in 1968 and at the Paris Air Show in 1969.

XXI. Civil Defense

As a result of the persistent efforts of Alvin Weinberg and Eugene Wigner, a civil defense research program, supported jointly by AEC and the Office of Civil Defense, was established at the Oak Ridge National Laboratory in 1964. A general national lack of support for civil defense led to the demise of this program.

AUXILIARY AND PERSONAL ACTIVITIES

My journal includes descriptions of various auxiliary and personal activities.

During this decade I gave some 500 major speeches, including the annual historic "Prelude to Independence" Address at Williamsburg, Virginia, in May 1962; addresses at each of the 11 annual General Conferences of the International Atomic Energy Agency, 1961–71; 18 commencement addresses at universities and colleges; 20 addresses at dedications of university or college laboratories; talks each year at the annual joint meetings of the Atomic Industrial Forum and the American Nuclear Society (1961–71); six talks at the annual International Science and Engineering Fairs; seven talks at the annual Science Talent Search in Washington; three talks at the California Commonwealth Club in San Francisco; and two talks at the National Press Club.

During this period I received a number of awards, including being named "Swedish American of the Year" by the Vasa Order of America (1962), election as a "Kentucky Colonel" by the State of Kentucky (1962), receiving the Franklin Medal of the Franklin Institute (1963), the Charles Lathrop Parsons Award of the American Chemical Society (1964), the First Spirit of St. Louis Award from St. Louis University (1964), the Leif Erikson Award from the Leif Erikson Foundation (1964), the Washington Award from the Western Society of Engineers (1965), the Willard Gibbs Medal of the Chicago Section of the American Chemical Society (1966), the Arches of Science Award of the Pacific Science Center Foundation (1968), the Chemical Pioneer Award of the American Institute of Chemists (1968), the Prometheus Award of the National Electrical Manufacturers Association (1969), the Nuclear Pioneer Award of the Society of Nuclear Medicine (1971), the Oliver Townsend Award of the Atomic Industrial Forum (1971), and the Distinguished Honor Award of the U.S. Department of State (1971). In addition, I was awarded about 40 honorary degrees (including D.Sc., Sc.D., LL.D., D.P.S., D.P.A., D.Eng., and L.H.D. degrees).

I was also elected to membership in the following foreign academies: Argentine National Academy of Sciences (Honorary Member, 1967), Bavarian Academy of Sciences (Corresponding Member, Mathematics–Natural Science, 1968), Royal Academy of Exact, Physical and Natural Sciences, Spain (Academic Foreign Correspondent, 1969), and the USSR Academy of Sciences (Foreign Member, 1971).

Soon after my arrival in Washington I moved into the University Club, which served as my residence until the arrival of my family in late June of 1961. Before they arrived I purchased a house (with four bedrooms, an attic dormitory room and a study which could serve as a guest room) in the Old Chevy Chase or Reno Park area of northwest Washington (3825 Harrison Avenue). A major criterion for the location of the house was proximity, i.e., easy walking distance, to Ben Murch Grammar School (grades kindergarten through six), Alice Deal Junior High School (grades seven through nine), and Woodrow Wilson High School (grades ten through 12). Peter (age 15) was scheduled to start the 10th grade in the fall; Lynne (soon to be 14), the ninth grade; David (12), the seventh grade; Stephen (soon to be 10), the fifth grade; and Eric (to be seven in November), the second grade. Dianne (to be two in November) started kindergarten three years later (after having to pass an entrance examination because she was too young, by a matter of days, to qualify in the regular manner).

Upon graduation from Woodrow Wilson High School in 1964, Peter entered Harvard University to major in history, and graduated in 1968. Lynne followed him, to Radcliffe College in 1965, where, as an anthropology major, she graduated in 1969. David went to the University of California, Davis, as a zoology major in 1967, and Stephen followed him there in 1969 as a psychology major. Thus, my journal includes copies of the letters that I wrote to them after they went off to college. Lynne married William B. Cobb, a Harvard social relations major and classmate of Peter in June 1968 (at the end of her junior year) in a ceremony at the Swedish Embassy in Washington, presided over by Judge Luther Youngdahl. Peter married Jane Rubenstein at the United Nations Chapel in New York in June 1971.

My mother visited us from her home in South Gate, California, one or more times each year until ill health overtook her in 1967, followed by her death in 1968. Much of my correspondence with her is attached to the pages of my journal.

Before any of the kids left home, the eight of us enjoyed our family vacations together--in 1961, short visits in our Pontiac station wagon to Ocean City, Maryland, and the Shenandoah Mountains; in 1962, a visit via air travel to my hometown of Ishpeming, Michigan, the newly opened Century 21 Exposition (World's Fair) in Seattle, Washington (as guests, in recognition of my service on the National Science Planning Board), and our home area of Lafayette, California; in 1963, an automobile trip to New England and eastern Canada, including Quebec; in 1964, an automobile trip to Gatlinburg, Tennessee, and the Smoky Mountains via the Blue Ridge Parkway in the Shenandoah Mountains; and in 1965, an automobile visit to the Pocono Mountains in Pennsylvania and Atlantic City, New Jersey. A favorite spot for short vacation interludes was Skyland Lodge in the Shenandoah Mountains. We also enjoyed a rented cottage on the beach at Virginia Beach, where I visited the family on weekends during their more extended stays. We were a pretty sight, the eight of us packed into our red station wagon with a luggage rack on the top often packed full of equipment and food.

After 1965, Peter and Lynne had their own agendas at summer vacation time and no longer accompanied us. However, the four younger kids continued to do so. In 1966, we flew to Chicago, rented a car to drive to and visit my hometown of Ishpeming; in 1967, we drove to Montreal, Canada, to visit Expo '67 (Peter and Lynne flew up for short visits with us); in 1968, we drove to Florida and toured the state, and visited the Savannah River Laboratory on the way back; in 1969, we flew to Los Angeles to do the sights (Disneyland, Knott's Berry Farm, movie studios, etc.) and Helen and I attended a banquet that President Nixon gave for our astronauts who had landed on the moon the month before; and in 1970, we made an automobile tour of historic and scenic regions in Pennsylvania.

Although I played some golf at the Chevy Chase Country Club (of which we were members), on the whole I neglected my exercise during the first half of our stay in Washington due to the pressures of my work and travel schedule, with the result that I began to feel tired. I then began to hike with some regularity, taking, when the weather permitted, almost daily hikes on the marvelous trails of Rock Creek Park,and sometimes longer hikes on weekends. A favorite hike was to Old Rag Mountain in the Shenandoahs, which became an annual event in which we were joined by members of the AEC staff--on one occasion by as many as 50. Also, at my request, a hiking trail was fashioned at our Germantown headquarters, which later became known as the "Seaborg Trail," and on which I and some of my staff often hiked after lunch, on those days when we were at Germantown.

In 1965, I joined the Board of Trustees of Science Service, and in 1966, upon the retirement of Leonard Carmichael, I became President. Watson Davis also retired as Director at that time and was succeeded by Ted Sherburne. Science Service is devoted to the public understanding of science, sponsors the annual Westinghouse Science Talent Search, the annual International Science and Engineering Fair and is the publisher of Science News. Thus, I began to interview the 40 finalists each year at the annual Science Talent Search in order to help select, as one of a panel of judges, the winners of the scholarships.

I served on the Board of Directors of the National Educational Television and Radio Center (1958–1964 and 1967–1970), the Board of Trustees of the Pacific Science Center Foundation (1962–1971), the Board of Trustees of the American Scandinavian Foundation (1968–1971); became a member in 1969 of the Board of Directors of the newly formed, Washington-based, World Future Society; continued my membership on the Scientific Advisory Board (SAB) of the Welch Foundation and attended their semi-annual meetings in Houston, Texas; and served on the editorial boards of the Journal of Inorganic and Nuclear Chemistry (1954–71) and the Panel of User Consultants of the American Heritage Dictionary (1964–1971).

After having declined to do so on several previous occasions, on the basis of my heavy schedule, I consented in the fall of 1970 to run for president of the American Association for the Advancement of Science (AAAS), this time on the basis that I knew that I would finish my service as AEC Chairman in the summer of 1971. I was elected, am serving as President-Elect now (in 1971), will serve as President in 1972, and as Chairman, in 1973. In this capacity, I began to attend the meetings of the Board of Directors in 1971, when my old friend Athelstan Spilhaus is Chairman and Mina Rees is President.

During this decade I participated in countless press conferences in this country and in almost all of the 60 countries that I visited. Major press conferences occurred at each of the 11 General Conferences of the International Atomic Energy Agency, and the two Geneva Conferences on the Peaceful Uses of Nuclear Energy. I appeared on the NBC news program "Meet the Press" twice (in 1961 and 1971), the ABC news program "Issues and Answers" several times, the NBC "Today" show and many other TV and radio news programs. I was featured in news magazines, including cover stories in both Newsweek (October 1961) and Time (November 1961), a cover story in Business Week (December 1964), and interviews in U.S. News & World Report.

With all of this, I managed to read the scientific journals in my specialty, enabling me to stay abreast of my research field of transuranium elements and nuclear chemistry. I published about two dozen scientific articles, the most notable being a 100-page review article in the 1968 issue of the Annual Review of Nuclear Science entitled "Elements Beyond 100, Present Status and Future Prospects". Thus, I feel, I am returning to the University of California in a position to resume research in my specialty.

APPENDIX A

Commissioners

Bunting, Mary I. Biologist and former president of Radcliffe College	1964–1965
Costagliola, Francesco Former staff member of the Joint Committee on Atomic Energy	1968–1969
Haworth, Leland J. Physicist and former director of the Brookhaven National Laboratory	1961–1963
Johnson, Wilfrid E. Engineer and former general manager of the Hanford Atomic Works	1966–1971
Larson, Clarence E. Chemist and former general manager of Oak Ridge Operations	1969–1971
Nabrit, Samuel M. Biologist and former president of Texas Southern University	1966–1967
Olson, Loren K. Washington attorney and former general counsel of the Atomic Energy Commission	1961–1962
Palfrey, John G. Former professor, Columbia School of Law	1962–1966
Ramey, James T. Former executive director of the Joint Committee on Atomic Energy	1962–1971
Tape, Gerald F. Physicist and former president of Associated Universities, Inc.	1963–1969
Thompson, Theos J. Nuclear engineer and former professor, Massachusetts Institute of Technology	1969–1970
Wilson, Robert E. Former chairman of Standard Oil of Indiana and member of the General Advisory Committee	1961–1964

APPENDIX B

Members of the General Advisory Committee

Abelson, Philip H. (Director, Geophysical Laboratory, Carnegie Institution, Washington, D.C.)	1961-1962
Benedict, Manson (Professor of Nuclear Engineering, MIT, Cambridge, MA)	1961-1967
Bugher, John C. (Director, Puerto Rico Nuclear Center, San Juan, PR)	1964-1969
Eliassen, Rolf (Environmental Engineer, Stanford University, Palo Alto, CA)	1970-1971
Friedman, Herbert (Superintendent, Space Science Division, U.S. Naval Research Laboratory, Washington, D.C.)	1968-1971
Froman, Darol (Retired, Espanola, NM)	1964-1965
Goldwasser, Edwin L. (Professor of Physics, University of Illinois, Urbana,IL)	1966-1971
Hafstad, L. R. (Vice President, Research Laboratories, General Motors Corporation, Warren, MI)	1962-1967
Hall, Jane H. (Assistant Director, Los Alamos Scientific Laboratory, Los Alamos, NM)	1966-1971
Lawroski, Stephen (Associate Laboratory Director, Argonne National Laboratory, Argonne, IL)	1964-1969
Libby, Willard F. (Professor of Chemistry, University of California, Los Angeles, CA)	1961
Murphree, Eger V. (President, Esso Research & Engineering Co., Linden, NM)	1961
Pitzer, Kenneth (Professor of Chemistry, University of California, Berkeley, CA)	1961-1964
Ramsey, Norman F. (Professor of Physics, Harvard University, Cambridge, MA)	1961-1971
Squires, Lombard (Manager, Atomic Energy Division, E. I. Du Pont de Nemours & Co., Wilmington, DE)	1968-1971
Sterner, James H. (Professor of Environmental Health, University of Texas School of Public Health, Houston, TX)	1971
Vesper, Howard G. (Vice President, Standard Oil Company of California, San Francisco, CA)	1965-1971

Warner, J. C. (President, Carnegie Institute of Technology, Pittsburgh, PA)	1961-1963
Webster, William (President, New England Electric System, Boston, MA)	1963-1971
Wigner, Eugene P. (Palmer Physical Laboratory, Princeton University, Princeton, NJ)	1961-1963
Williams, John H. (School of Physics, University of Minnesota, Minneapolis, MN)	1961-1965

Scientific Officers

Charpie, Robert A. (Oak Ridge National Laboratory, Oak Ridge, TN)	1961-1962
Harrison, Melvin A. (Lawrence Radiation Laboratory, Livermore, CA)	1968-1971
Sewell, Duane C. (Lawrence Radiation Laboratory, Livermore, CA)	1963-1967

Secretary

Anthony A. Tomei	1961-1971

APPENDIX C

GLENN T. SEABORG is currently University Professor of Chemistry (the most distinguished title bestowed by the Regents), Professor in the Graduate School of Education, Associate Director of the Lawrence Berkeley Laboratory and Chairman of the Lawrence Hall of Science at the University of California, Berkeley.

He received his A.B. in Chemistry from UCLA in 1934 and his Ph.D. in Chemistry from Berkeley in 1937. He has served on the faculty of the Berkeley campus since 1939 and was Chancellor of that campus 1958–1961. In 1961 Dr. Seaborg was appointed Chairman of the Atomic Energy Commission by President John F. Kennedy. He was subsequently reappointed by both Presidents Johnson and Nixon, serving in that position until 1971.

Winner of the 1951 Nobel Prize in Chemistry (with E. M. McMillan) for his work on the chemistry of the transuranium elements, Glenn Seaborg is one of the discoverers of plutonium (element 94). During World War II he headed the group at the University of Chicago's Metallurgical Laboratory which devised the chemical extraction processes used in the production of plutonium for the Manhattan Project. He and his coworkers have since discovered nine more transuranium elements: americium (element 95), curium (96), berkelium (97), californium (98), einsteinium (99), fermium (100) mendelevium (101), nobelium (102), and element 106. He holds over 40 patents, including those on elements americium and curium (making him the only person ever to hold a patent on a chemical element).

In 1944 Dr. Seaborg formulated the actinide concept of heavy element electronic structure which accurately predicted that the heaviest naturally occurring elements together with synthetic transuranium elements would form a transition series of actinide elements in a manner analogous to the rare earth series of lanthanide elements. This concept, one of the most significant changes in the periodic table since Mendeleev's 19th century design, shows how the transuranium elements fit into the periodic table and thus demonstrates their relationships to other elements.

His co-discoveries include many isotopes which have practical applications in research, medicine and industry (such as iodine-131, technetium-99m, cobalt-57, cobalt-60, iron-55, iron-59, zinc-65, cesium-137, manganese-54, antimony-124, californium-252, americium-241, plutonium-238), as well as the fissile isotopes plutonium-239 and uranium-233.

Dr. Seaborg continues to work as an active research scientist, with a research group in the search for new isotopes and new elements at the upper end of the periodic table, including a search for the "superheavy" elements. The group is also investigating the mechanism of the reactions of heavy ions with heavy element target nuclei. Another aspect of the research program is concerned with the determination of the chemical properties of the heaviest chemical elements.

Seaborg is the author of numerous books—his most recent, Kennedy, Khrushchev and the Test Ban (1981) and Stemming the Tide: Arms Control in the Johnson Years (1987) describe, respectively, the negotiations for the Limited Test Ban Treaty of 1963 and the Nonproliferation Treaty of 1969. He has also authored over 400 scientific articles and guided the graduate studies of more than 60 successful Ph.D. candidates. In addition to the Nobel Prize and a great many other awards for his work in chemistry, science education and community service, Dr. Seaborg has been awarded 50 honorary doctoral degrees.

Among his many interests are international cooperation in science (as President of the International Organization for Chemical Sciences in Development), history of science (documenting the early history of nuclear science), nuclear arms control (advocating a comprehensive test ban treaty), conservation of natural resources and hiking. A member of the National Commission on Excellence in Education which published the much-publicized report A Nation At Risk in 1983 and Chairman of the Lawrence Hall of Science, Dr. Seaborg is recognized as a national spokesman on education, addressing in particular the crisis in mathematics and science education.

December 1988