CHAPTER 4

Marriage: 1955–1965

Shocked by Sputnik, *the United States created the National Aeronautics and Space Administration*

The 1950s were marked by the cold war, a period of tenuous nonaggression between the world's superpowers: the USA and the USSR. At its core was the mutual fear that either side could use its growing arsenal of atomic weaponry to destroy much of civilization. Early in that period, in 1950, the tension in Korea grew into a localized "hot war" that pitted the United States and the Republic of Korea against Soviet-armed North Korea and the Peoples Republic of China. The Korean War was a conventional war; no atomic or thermonuclear devices were deployed. However, many American lives were lost, mostly because of the precipitous demobilization of the U.S. forces after WWII, which left the United States largely unprepared to mount even a limited war in Asia.

The war ended in a stalemate in 1952, the same year that Eisenhower succeeded Truman in the White House. Both sides were back where they had started: the United States and Republic of Korea on the southern side of the thirty-eighth parallel and the North Koreans and Chinese on the northern side. The United States was satisfied that it had thwarted the North Korean attempt to overrun and conquer South Korea and avoided an atomic weapon confrontation with the USSR. The Korean War showed how acute the cold war had become. But U.S. military might, combined with simultaneous U.S. development of the hydrogen bomb, could hedge against the continuing threat presented by the USSR.

The science establishment that was created under the Truman administration had not been called on for special contributions during the Korean War and, apart from budget cuts and the manpower draft that were required in all areas of U.S. society, was left mostly untouched. Three years after the war's end, however, scientific research and development were flourishing. Americans realized that they had an affinity for science, for the excitement and drama as well as the practical benefits. A long history of colorful inventors—Samuel Colt, Eli Whitney, Thomas Edison, and Alexander Bell, to name only a few—had conditioned Americans to view science, both applied and basic, as another manifestation of the pioneer spirit. Absorbing novels and nonfiction accounts of scientists and their work, such as those by Sinclair Lewis, Paul de Kruif, and Hans Zinsser, also influenced several generations of young Americans. The achievements of science and technology in WWII were alive in the minds of the public and Congress.

The uneasy respite over Korea came to a jarring halt with the launch of *Sputnik*, the Soviet Union's successful entrance into space in October 1957. The impact of that event can hardly be imagined now. The U.S. public and Congress, as well as the military, had visions of heavily armed satellites, perhaps with nuclear warheads, with the ability to destroy military bases at home and abroad, leaving cities defenseless against an unassailable enemy. It was likely to be a time enormously more dangerous than the brief era of the flying bombs in WWII. But possibly most shocking to everyone—even those less alarmed by the military potential of *Sputnik*—was the notion that something was wrong with the American system, that it had been outthought and outproduced in an absolutely vital matter. It now appeared that the United States had been unaware that it was being outstripped in the technology of space. How, the country asked, could we have fallen so far behind when our strength should have made us dominant?

An immediate reaction was needed to remedy the situation. But this was easier said than done. *Sputnik 1*, the first man-made satellite in orbit, weighed 183 pounds; the American plan had been to start with the navy's *Vanguard* satellite, at 3 pounds, and work up to 22 pounds in later flights.

That alone was bad news, and more was still to come. The USSR launched *Sputnik 2* less than a month after *Sputnik 1*, and *Sputnik 2* carried a dog as a passenger in addition to its own weight of 1,100 pounds. Then, on December 6, 1957, the much-advertised 3-pound *Vanguard* test vehicle collapsed in flames a few feet above its launch platform.

In the tradition of not putting all its eggs in one basket, the United States was ready at the end of January 1958 with another small satellite from a different (army) program. *Explorer 1* was successfully put into orbit, and the scientific apparatus it carried—all two pounds of it—reported the existence of an intense belt of radiation around the earth at an altitude of 594 miles, named the Van Allen belt after its discoverer. This was an important basic science discovery because it showed the existence of a region surrounding the earth that contained electrically charged particles trapped in the external magnetic field of the planet. These particles had saturated the radiation counters in *Explorer 1* and were recorded by the scientific ground crew that monitored the launch. By mid-March 1958, *Vanguard 1* joined *Explorer 1* in orbit, and U.S. confidence in its fledgling space program was beginning to rebound. However, the intense competition among the armed services and the National Advisory Committee on Aeronautics, each determined to assume responsibility for a viable space program, did not recommend a group effort for the U.S. space program of the future. Nevertheless, there was widespread public and federal consensus that a single, augmented space program was essential; the only question was: who would run it? By March 1958 President Eisenhower and his newly appointed science adviser, James R. Killian, formed the administration's position, which was in general agreement with the finding of Lyndon Johnson's Senate subcommittee on space, namely that the U.S. space agency should be a civilian agency, with the National Advisory Committee on Aeronautics (NACA) as its nucleus. This committee had existed since 1915 and had a large, experienced staff, well-equipped laboratories, and a well-earned record of research performance in aircraft flight. It would provide the core of a strong space program, and at the same time the peaceful, research-oriented nature of the program would mostly avoid projecting the tension of the cold war into outer space, an important consideration to the administration and Congress at the time.

In April 1958 a bill to establish the National Aeronautics and Space Administration (NASA) was submitted to Congress. Both houses had already formed select space committees, and on July 29 President Eisenhower signed into law the National Aeronautics and Space Act. In August T. Keith Glennan, president of the Case Institute of Technology and former commissioner of the AEC, was nominated and confirmed as NASA's first administrator.

By October 1 Glennan was able to announce that the NACA assets—eight thousand people, three laboratories, and two experimental flight stations, with facilities valued at $300 million and an annual budget of $100 million—had been transferred to NASA. The forty-three-year old NACA had come to an end. At that time, the president also transferred to NASA Project *Vanguard*, its 150-person staff, and the lunar probe and rocket engine programs from the army and air force.

The first two years of NASA were a period of organization, innovation, and activity. Design and operations groups had to be formed. For example, Project *Mercury*, the United States' first manned spaceflight program, began in 1958 and needed a worldwide satellite tracking and data acquisition network. And powerful new launch capabilities were urgently required to supplement the existing *Redstone*, *Thor*, and *Atlas* launch vehicles. Planning began for *Scout*, a low-budget booster that would put small payloads into orbit; *Centaur*, a liquid-hydrogen upper-stage booster that promised higher thrust for bigger payloads; *Saturn*, which, with proper upper stages, would put more than 46,000 pounds in Earth orbit and be ready by 1963; and *Nova*, several times the size of *Saturn*, for manned lunar flights in the 1970s. *Centaur* and *Saturn* were already in progress in the Department of Defense space program.

Other major space research programs and the facilities and staff that went with them also moved to NASA. The government owned the Caltech Jet Propulsion Laboratory (JPL) then under contract to the army and an integral part of the army's rocket program. An installation at Huntsville, Alabama, was the center of the army's military rocket program and housed the powerful *Saturn* booster project and a four-thousand-person Development Operations Division headed by the controversial Wernher von Braun, a dynamic German rocket expert from the flying bomb (V-1, V-2) era of WWII. Von Braun was a gifted engineer whose personable qualities also enabled him to make the transition successfully from Nazi Germany to the United States deep in the cold war. Over the strenuous objections of the army, both JPL and Huntsville were transferred to NASA.

The early launch record with existing boosters, however, was not satisfactory. By the end of 1959 more than two-thirds of the thirty-seven

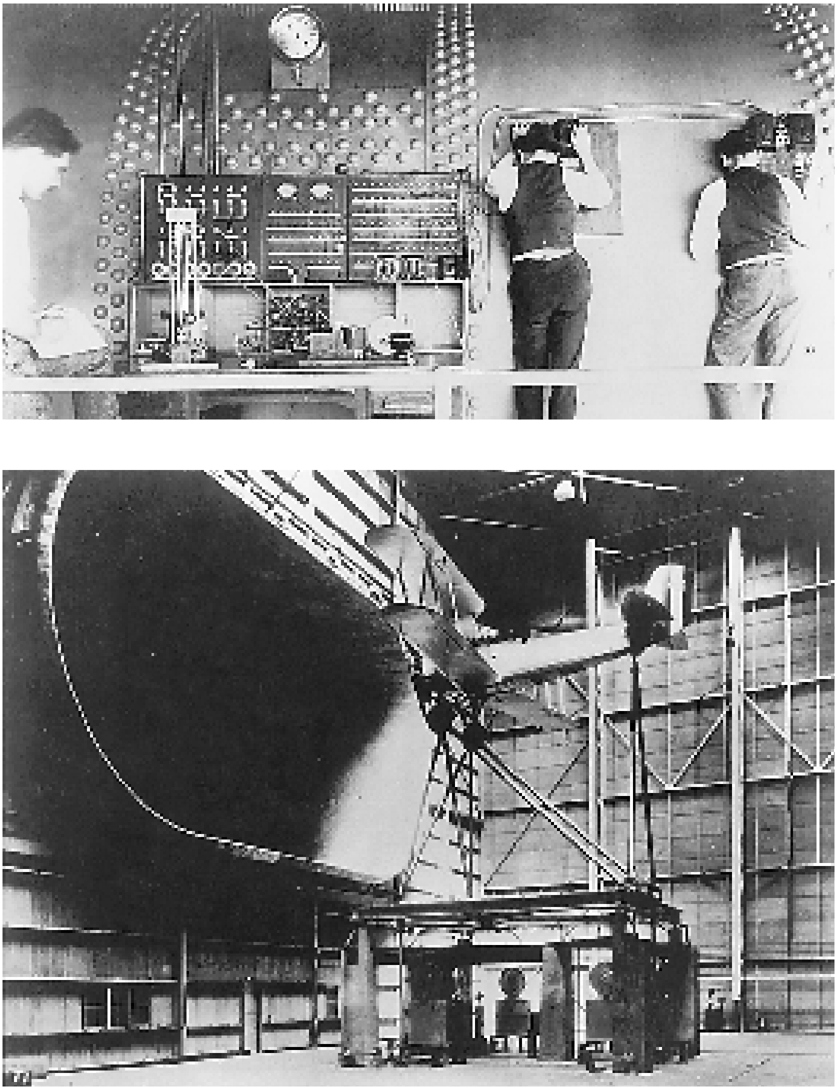


FIGURE 4.1. *Top*: A NACA TEAM CONDUCTS RESEARCH USING THE VARIABLE DENSITY TUNNEL IN 1929.

Source: R. E. Bilstein, *Orders of Magnitude: A History of the NACA and NASA, 1915–1990*, NASA SP-4406 (Washington, D.C.: NASA, 1990), p. 8.

Bottom: A Vought 030 set up for tests using the full-scale wind tunnel at Langley Field, completed in 1931.

Source: R. E. Bilstein, *Orders of Magnitude: A History of the NACA and NASA, 1915–1990*, NASA SP-4406 (Washington, D.C.: NASA, 1990), p. 17.

launches failed to attain orbit. The space program appeared to be a questionable venture, especially in view of its extremely large cost. This concern remained as the Eisenhower administration drew to a close. After the 1960 election, the new Kennedy administration criticized the program's lack of progress and scrutinized its ballooning budget. A committee chaired by the new science adviser to the president, Jerome Wiesner, professed skepticism about NASA's future.

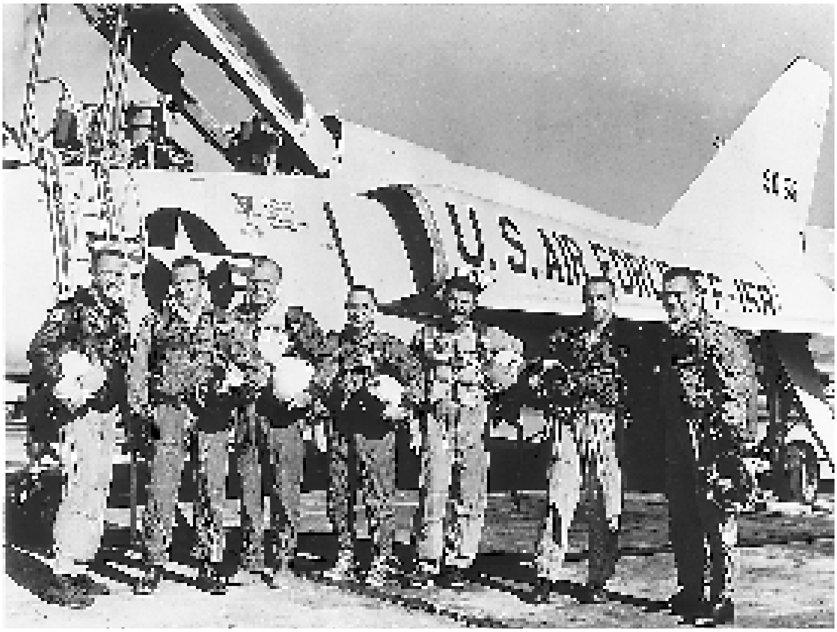
Once again, the USSR resolved U.S. doubts. In April 1961 Soviet Cosmonaut Yuri Gagarin rode *Vostok 1* into orbit, 24,800 miles around the earth, reentered the atmosphere, and landed safely. The question of money and priority for NASA was answered: Congress and the new president pushed ahead with a previously formed ten-year plan for NASA. But to what end? To formulate an answer, Kennedy chose a new administrator of NASA, James E. Webb, owing in part to his reputation for managing large projects in industry and for directing the Bureau of the Budget in the Truman administration. Webb named Hugh L. Dryden, who had been director of NACA and deputy to Glennan, as his technical deputy; the associate administrator and general manager of NASA was Robert C. Seamans Jr., another experienced NASA veteran.

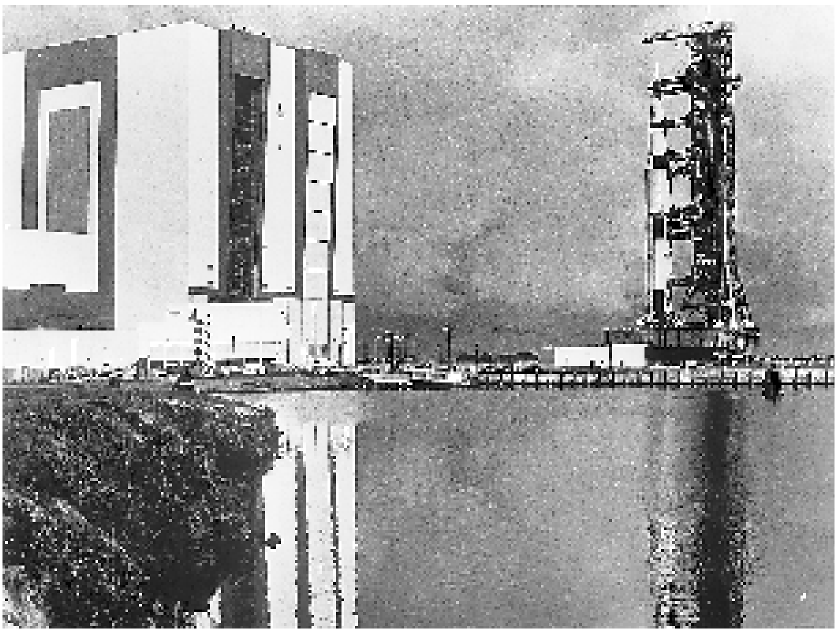
The space program needed a goal that would require more of it than the ability to launch satellites efficiently and catch up with the Russians by putting a man in Earth orbit. President Kennedy was equally in need of a goal to divert the American public from its preoccupation with the cold war. The new NASA administration proposed putting a man on the moon and returning him safely to Earth as the goal of the U.S. space program. It was a risky but ambitious response to the Soviets, and it appealed to Kennedy as a new initiative for the nation. He proposed it to Congress on May 25, 1961, saying:

> Now it is time to take longer strides—time for a great new American enterprise—time for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on earth.
>
> . . . I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish.[1]

Project *Apollo* changed NASA irrevocably. Previously, NASA had been a multifaceted agency, cautious and expensive, aiming to satisfy several important but loosely connected goals. After Kennedy pledged to put a man on the moon in the 1960s, however, NASA's planning grew more single-minded and more risk and expense tolerant. No new scientific or technological breakthroughs were necessary, but the size and power of the lunar launch vehicles and spacecraft presented problems that were an order of magnitude greater than any NASA had ever encountered. The 1.5-million-pound-thrust boosters needed to launch *Apollo* spacecraft demanded a new logistics system that would take components from the design stage to the launch site with new efficiency and speed. Huge new test stands and launch complexes intended to handle the multistory boosters and spacecraft were too large to be moved by rail or truck. The only option was to employ ship transportation. This required that new NASA centers be located near navigable bodies of water. The Michaud Ordnance Plant outside New Orleans, where the ten-meter diameter *Saturn V* first stage would be fabricated, was on the Mississippi River; the Mississippi Test Facility, with its giant stands for static firing tests of booster stages, was just off the Gulf of Mexico. And the major Launch Operations Center at Cape Canaveral, Florida, which required the purchase of 110,000 acres of Merritt Island, had both water access and sufficient isolation for safety. The resources of the Army Corps of Engineers were called on to undertake construction and provide facilities, just as it had done for the Manhattan Project.

At the heart of this planning was the issue of precisely how to put men on the moon and how to get them off. Initially, it was thought that a big enough booster would allow a direct flight to the moon and the landing of a large vehicle, some part of which—containing moderate-power boosters and a modest-size spacecraft—would return directly to Earth. Technical problems caused this idea to be discarded early in the planning stage, however. Instead, a complex but feasible plan was adopted, one that would require for the first time a lunar-orbit rendezvous of spaceships. In this plan, the launch of a massive mother spacecraft into Earth orbit would be followed by the dispatch from the mother craft of a set of nested spacecraft into a moon orbit. That set in turn would send a smaller craft to land on the lunar surface, let the astronauts explore, and then rejoin the lunar-orbiting spacecraft for the return trip to Earth. This required putting payloads of 300,000 pounds in Earth orbit and 100,000 pounds in lunar orbit. These payloads were demanding enough, but could a rendezvous of spacecraft be made routinely, and, if so, could they dock without a calamity? Project


U.S. AIR



Gemini was initiated in January 1962 to answer these and similar questions and bridge the conceptual and hardware gap between Project *Mercury* and Project *Apollo*.

Both *Mercury* and *Gemini* carried out a long series of spaceflights of increasing technical proficiency that provided the data on which to base *Apollo*. Doubts and reservations about the ultimate success of the *Apollo* mission remained but decreased as the accomplishments of *Mercury* and *Gemini* increased. The speech that President Kennedy was on his way to deliver in Dallas on the terrible day of his assassination was to begin thus: "This [Apollo] effort is expensive—but it pays its own way for freedom and for America. There is no longer any doubt about the strength and skill of American science, American industry, American education, and the American free enterprise system." Indeed, it was an expensive effort. Originally anticipated to be a ten-year program costing an average of $1.5 billion per year, the NASA budget went from $967 million in 1961, to $1.33 billion in 1962, $3.67 billion in 1963, and $5.1 billion in 1964 and several years thereafter. By that time, NASA directly employed thirty-six thousand people and its contractor and university forces increased that number to four hundred thousand.

As the magnitude of the *Apollo* project was realized, a charge was leveled against NASA that it was solely directed to reaching the moon and ignored the more immediate problems on Earth. This charge was not completely justified. Given the priority of *Apollo*, NASA nevertheless launched the first active communication satellite for the American Telephone and Telegraph Company (AT&T) in 1962. Within a decade, communication and weather

FIGURE 4.2. *Opposite page top*: NASA's seven original astronauts were all experienced test pilots. Posed in front of a Convair F-106, they are (*left to right*) Scott Carpenter, Gordon Cooper, John Glenn, Virgil Grissom, Walter Schirra, Alan Shepard, and Donald Slayton.

Source: R. E. Bilstein, *Orders of Magnitude: A History of the NACA and NASA, 1915–1990*, NASA SP-4406 (Washington, D.C.: NASA, 1990), p. 58.

Opposite page bottom: Kennedy Space Center as it appeared in the mid-1960s. The 350-foot-tall *Saturn V* launch vehicle emerged from the cavernous Vehicle Assembly Building aboard its crawler and began its stately processional to the launch complex three miles away.

Source: R. E. Bilstein, *Orders of Magnitude: A History of the NACA and NASA, 1915–1990*, NASA SP-4406 (Washington, D.C.: NASA, 1990), p. 70.

satellites would be essential in daily life on Earth. Moreover, NASA's development of microelectronics for monitoring the health of astronauts soon gave rise to the everyday use of advanced techniques for patients in hospitals throughout the nation.

Apollo needed more than powerful boosters and giant launch sites, however. It also needed scientifically trained people and a lot of them. As the magnitude of the brain drain grew, NASA was accused of monopolizing valuable resources, chief among them scientific manpower. This was a valid accusation, and NASA felt compelled to meet it with a program of support for science and scientists in universities that followed the precedents set earlier within the science establishment. Beginning in 1962 NASA paid for the graduate education of five thousand scientists at a cost of $100 million and spent another $82 million on university campuses. This program ended in 1970, but contracts and grants for university research rose from $21 million in 1962 to $101 million in 1968 as NASA broadened its effort to include universities as junior partners in the space enterprise.

In short, the infant civilian space agency, NASA, despite the urgent demands of its lunar mission, managed to avoid public contention with the armed services as it competed for resources and planned for its future work in space. It accomplished this by supporting university science and engineering departments, as had U.S. science agencies before it. By 1965 the successes of Projects *Mercury* and *Gemini* provided good reasons to believe that the rapidly maturing Project *Apollo* would be successful also.

The Atomic Energy Commission addressed new challenges of "Atoms for Peace"

The three major problems that the AEC faced when it began business in 1947 were the deterioration of the science capabilities of its laboratories, particularly Los Alamos; whether or not to proceed to develop the hydrogen bomb; and at what rate to move toward use of the atom for peaceful purposes, as in the generation of electric power on a commercial scale. The commission had successfully solved the first two problems by 1955, but the issue of control of commercial power generation, which had been a subject of intense debate during deliberation of the Atomic Energy Act in 1946, remained to be addressed.

As early as mid-1953 the commission formulated a plan to bring nuclear reactor technology into the marketplace. The plan involved acquiring significantly more technical information than was available at the time and modification of the secrecy provisions of the Atomic Energy Act. Qualified information would then be made public. The power utilities would be able to evaluate the magnitude of the technical problems and the investment required of them. To obtain the additional information, the commission recognized that basic research on materials and power reactor types would have to be conducted separately in its own laboratories. It seemed likely that the commission would also be forced to build a nuclear power reactor to provide data on the performance and cost of a full-scale system. With that experience in hand, the reasoning went, it would be possible to assist industry in designing and constructing economically viable full-scale power reactors.

This plan was realistic and would have been possible given the new relaxed classification and security rules in the Atomic Energy Act of 1954. But the role of the AEC and its laboratories in transferring nuclear technology from laboratory to power plant was seen as unacceptable federal interference in the private sector and too slow and cumbersome compared to previous technology transfers. Critics referred to radio broadcasting and commercial air travel, neither of which had depended for growth on government participation and promotion to the extent that nuclear technology promised under the commission's plan. The Joint Committee on Atomic Energy pointed out that radio broadcasting and air travel had been accomplished piecemeal with modest investments by many entrepreneurs moving quickly and with minimal government impedance. But those freewheeling procedures, the commission argued, were not possible for the development of nuclear power, as it would require huge investments in research before a full-scale plant could be designed, much less constructed and operated. Moreover, the AEC cautioned, there were extremely dangerous aspects to nuclear power that demanded government participation and supervision. How then, was the transfer of nuclear technology to be done safely and fairly and within the constraints of the free enterprise system?

This difficulty did not come as a surprise to the commission or the joint committee. It had arisen during the hearings on the Atomic Energy Act of 1946, when the observation was made that Congress was about to establish an administrative agency vested with unprecedented sweeping authority and entrusted with portentous responsibilities. The act would create a government monopoly of the sources of atomic energy and make that field an island of socialism in the midst of a free enterprise economy. Nevertheless, the situation in 1954 contained no acceptable solution to the problem. In the opinion of the AEC's director of reactor development, Lawrence R. Hafstad, reactor technology was not then well enough developed to allow the construction of full-scale power reactors for commercial use, and there was a limit to what could be learned from paper studies. A veteran scientist and science administrator, Hafstad had directed the Johns Hopkins Applied Physics Laboratory, which had produced the proximity fuze, and had later served with Vannevar Bush on the research and development board of the Department of Defense before taking leadership of the commission's reactor division in 1949. This experience gave weight to his opinion in both the commission and the joint committee.

Hafstad was likewise in the difficult position of steering a course between those who advocated a government-dominated reactor program—concentrating on military projects such as ship propulsion for immediate results—and those who urged an accelerated civilian power program, relying heavily on private industry for development, which would have been unrealistic and dangerous. But neither the AEC nor Hafstad was entirely free to pursue the course of their choice. The commission's reactor development program was heavily committed to reactors for propulsion of ships and planes that preempted available funds and manpower. The chief of the naval reactor program was Captain Hyman G. Rickover, who previously had established himself, with remarkable single-minded determination, as head of the navy's reactor program and was the top official in charge of commission reactor laboratories before Hafstad joined the AEC. With the concurrence of the commission and the joint committee, Rickover gained control of three reactor research facilities: the Argonne National Laboratory, near Chicago; Westinghouse's Bettis Laboratory, outside of Pittsburgh, Pennsylvania; and General Electric's Knolls Atomic Power Laboratory, near Schenectady, New York. All were dedicated to producing a seaworthy nuclear submarine by January 1955. With that control, he was able to supervise the decisions of his contractors and focus on technical obstacles that threatened his timetable. He bypassed small reactor experiments and set out simultaneously to build prototypes of two propulsion systems, one at Bettis and one at Knolls. By mid-1953 he had a prototype operating at the commission's Idaho Test Site, generating enough power to carry a submarine across the Atlantic. With added hard work, a nuclear power plant was made ready for the submarine *Nautilus* by late 1954. This achievement, more than any other single event, convinced the inexperienced, overly optimistic joint committee that nuclear power was a reality and ready to be taken over by private industry.

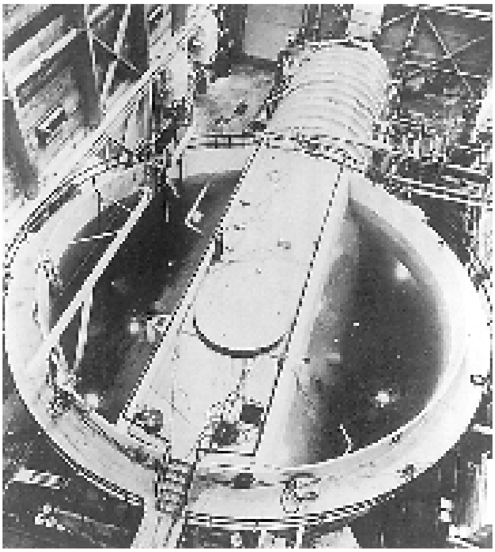


FIGURE 4.3. *Top*: Planning the development of nuclear-powered ships. Captain Rickover with General Electric and government officials in Schenectady, summer 1946. *Left to right*: C. Guy Suits, John J. Rigley, Hyman G. Rickover, Leonard E. Johnson, and Harry A. Winne.

Source: R. G. Hewlett and Francis Duncan, *Atomic Shield: A History of the U.S. Atomic Energy Commission*, vol. 2, *1947/1952* (Washington, D.C.: U.S. Atomic Energy Commission, 1972), p. 142.

Bottom: Submarine thermal reactor, mark I, Idaho. The land-based prototype as it appeared in 1954. The reactor is located within the portion of submarine hull surrounded by water.

Source: R. G. Hewlett and Francis Duncan, *Atomic Shield: A History of the U.S. Atomic Energy Commission*, vol. 2, *1947/1952* (Washington, D.C.: U.S. Atomic Energy Commission, 1972), facing p. 142.

Power reactors for industry presented different problems, however. Experience with smaller, limited power reactors did not provide enough information to allow extrapolation to a pilot plant and certainly not to proven full-scale reactor technology. There were many examples of this. A plutonium breeder reactor, developed at Argonne as a test of principle, was built at the Idaho Test Site, using liquid metal coolant, and although it showed technical progress, its methods were difficult to use. It was not likely to be a model for a commercial power reactor and was not funded further. A homogeneous reactor also showed initial promise because it had the advantage of eliminating expensive component fabrication. By placing a single fluid mixture of fissionable material, moderator, and coolant in a properly configured tank, a critical mass was produced, and consequently a chain reaction. The experiment produced a few watts of electric power and illustrated that a homogeneous reactor was possible, but it did not indicate how to overcome the serious problems of handling the highly radioactive and corrosive fluid continuously on a large scale. The most promising reactor types were those using water as moderator and coolant. For his submarines, Rickover went to a reactor using water under pressure, which prevented boiling and local power surges thought to be dangerous. Later, boiling water reactors were shown to have higher thermal efficiency than pressured water types, and it was further discovered that local boiling-induced power surges did not give rise to uncontrolled instabilities but would shut down a system if boiling became too severe. Still, the bottom line was that none of these designs was then a practical or economical model for a full-scale power source. Rickover's power plant for the *Nautilus* was the model the joint committee pointed to, but its capacity was limited by the needs of its task, and it was not economical or intended to be economical; it was not the immediate answer to the quest for a peacetime, commercial nuclear power reactor.

The nuclear powered submarine would, however, completely change undersea warfare and influence U.S. military strategy for containment of cold war Soviet expansionism. That strategy focused on hydrogen weapons as a deterrent of unprovoked Soviet military action. The idea was to put the USSR on notice that such action, even if not overtly directed at the United States, would draw U.S retaliation by hydrogen bombs aimed at the USSR. To make the warning credible, the United States developed a multipronged system to deliver bombs throughout the USSR, from the air by the Strategic Air Command, from the land by intercontinental ballistic missiles located in the United States, and from the sea by the nuclear-propelled submarine fleet.

It turned out that the commission had no solution to the problem of devising a commercial nuclear power reactor. Despite seminars and meetings intended to encourage participation and investment by large utility groups, a stalemate with industry persisted. The high cost of developing nuclear power and its difficult technical problems frightened utility executives away from risk taking. This attitude was intensified—not eased—by the successful operation of a commission-financed pressurized-water reactor at Shippingport, Pennsylvania, in December 1957. That first trouble-free, complete full-scale nuclear power plant in the nation reached its full net power rating of sixty megawatts of electricity in the same month that it was commissioned. It had been designed and constructed by Rickover and the staff at Bettis following the engineering practices developed for the Nautilus project, but it was not simply a scaled-up version of that plant. The planned performance of its components had demanded new levels of design engineering and fabrication. The reactor core, for instance, consisted of almost one hundred thousand fuel elements, each encased in a little-known element, zirconium. The decision to use uranium oxide in the fuel elements in slightly enriched rather than fully enriched form had been made after many months of research and testing that produced fundamental engineering data for the future. Shippingport showed the intensive nature and extended scope of the research required for the development of nuclear power reactors at the time.

The total cost of the Shippingport reactor was estimated at sixty-four mills (6.4 cents) per kilowatt of capacity, compared to six mills per kilowatt for existing conventional power plants. Utility executives found this unacceptable, even discounting that Shippingport had broken completely new ground and incurred heavy expenditures to complete the plant by a set deadline. Furthermore, the criticism went, the plant proved nothing because it had not been built by private industry to commercial specifications. The significance of Shippingport went largely unappreciated, as did its public training courses in reactor safety and operation organized during the next six years by the Duquesne Light and Power Company. These courses taught more than one hundred engineers and technicians from the United States and ten other countries the rudiments of reactor technology.

Despite strong pressure from the joint committee and a Democratic Congress, the AEC was restrained by its chairman, Lewis Strauss, and the Eisenhower administration from going beyond the Shippingport reactor. Higher-capacity power reactors were seen as a government-financed program that

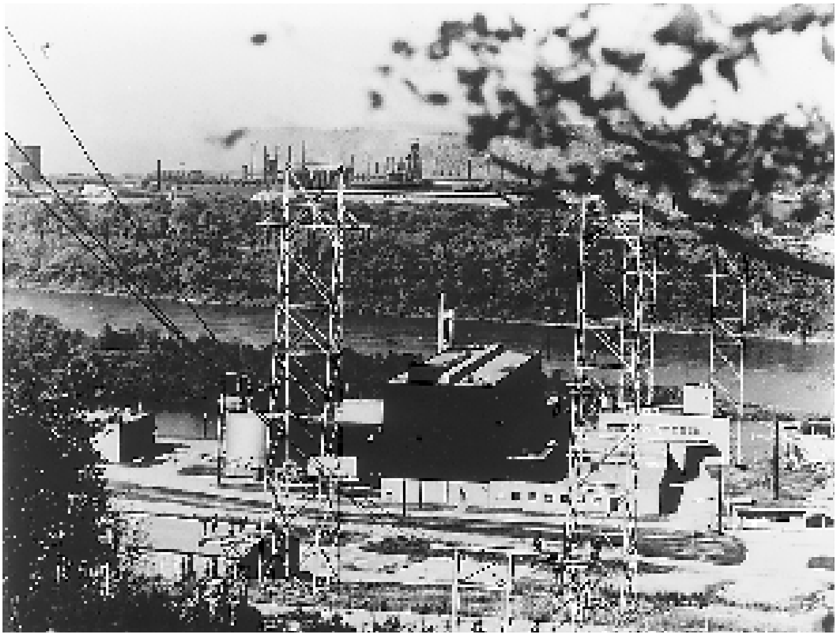


FIGURE 4.4. The Shippingport Atomic Power Station in Shippingport, Pennsylvania, was constructed during the mid-1950s to develop and demonstrate pressurized water reactor technology and to generate electricity. The reactor was fueled with three different types of cores, the last being a light water breeder core. The station was shut down in 1982, after completion of the breeder demonstration program. Plant disassembly demonstrated the safe and economical decommissioning of a commercial power reactor.

Source: T. R. Fehner and Jack M. Holl, *Department of Energy, 1977–1994: A Summary History* (Oak Ridge, Tenn.: Office of Scientific and Technical Information, 1995), p. 14.

would build nuclear power plants and establish a government monopoly in nuclear power, similar to the Tennessee Valley Authority's monopoly in conventional power. That prospect was anathema to the Republican Party. As a result, when Strauss retired as chairman in June 30, 1958, the commission had not been able either to formulate nuclear power policy or to promote the development of nuclear power. That was the situation that greeted the new chairman of the AEC, John A. McCone, during his exploratory tour of Shippingport, Bettis, Knolls, and the Idaho Test Station. McCone was a construction engineer who had become president and director of the Bechtel-McCone Corporation when it was organized in 1937. During WWII, he had been executive vice-president of the Consolidated Steel Corporation and president of the California Shipbuilding Corporation. In addition to his business activities, McCone served as special deputy to Secretary of Defense James Forrestal and as undersecretary of the air force in charge of procurement. Eisenhower had previously shown confidence in him.

The director of reactor development, W. Kenneth Davis, who succeeded Hafstad, resigned when Strauss did, and McCone turned to Rickover to give him his first glimpse of the commission's reactor program. McCone was impressed by Shippingport and understood fully that it was not a power plant but a laboratory tool. He did not dismiss it, as some industry leaders had previously. He was also troubled that company engineers at Bettis and Knolls were proceeding to install in commercial reactors fuel assemblies with cheaper and possibly less dependable materials than Rickover had specified in the navy projects. In his personal notes after the trip, McCone wrote: "As a result of these discussions, I am convinced that our reactor division must make the most penetrating study of how the commercial people intend to answer their core design and construction problems. It seems to me that it will be the center of our problem both from the standpoint of economics and ultimate success and safety." McCone intended, he said, to take a constructive approach to nuclear power but not to proceed with "anything which is unsound."[2]

As the fourth chairman of the AEC assumed office, the commission launched into another intensive research and development program, this one to provide critical oversight of the transition from conventional to nuclear power plants. It would not be solely a matter of regulation and equitable treatment of utilities and consumers alike but also involve acquiring and disseminating technical information about radioactivity and the dangers of the enormous energy residing in nuclear power reactors. Much of the work would be done in its own laboratories, but much—the actual construction of power plants—by private industry. And the commission needed to establish a harmonious working relationship with that sector.

The development of nuclear power in the United States was not, however, the only R&D program required of the AEC at the time. Two years after taking office, President Eisenhower had given a stirring speech to the United Nations General Assembly in which he announced the Atoms for Peace program and pledged that the United States would "devote its entire heart and mind to find a way by which the miraculous inventiveness of man shall not be dedicated to his death, but consecrated to his life."[3] Specifically, he proposed establishing an international atomic energy agency and expressed the willingness to share peaceful U.S. atomic energy technology with an international body. Implicit in his promise was renewed vigor in the search for international control and inspection of atomic weapons. There was enthusiasm for the general features and spirit of the program, but the question of control and inspection of fissionable materials and weapons raised by the president's speech caused grave concern in the commission and the joint committee. Soon after Eisenhower's speech, for example, people realized that the abundance of uranium then available in the world made it very difficult, if not impossible, to assure that all fissionable material was declared and accounted for, short of a system of continuous and unimpeded inspection in all countries.

More touchy and immediate were the technical problems created by the worldwide demand to ban atomic weapons testing and to promote disarmament. These involved complex issues that caused nations to align themselves differently from what might have been expected. Predictably, the Soviets emphasized the need for political agreement on a test ban, leaving the method of verification for a later time. They did not take seriously the details of inspection and control necessary to a disarmament agreement since they had no thought of allowing foreign oversight or inspectors into their country. The British objected to a test ban unless the United States was willing to share the nuclear information that had been acquired previously in many tests, but the USA was unable to do this without amending certain restrictive provisions of the Atomic Energy Act of 1954. Nevertheless, Eisenhower succeeded in convening a conference of experts in Geneva, Switzerland, in July 1958. The stated purpose of the conference was "To Study the Methods of Detecting Violations of a Possible Agreement on the Suspension of Nuclear Tests."[4] The U.S. representatives were James B. Fisk, vice president of Bell Laboratories and a member of the president's science advisory committee, Ernest O. Lawrence of Manhattan Project fame and Robert F. Bacher, former AEC commissioner and member of the science advisory committee. Hans Bethe, professor of physics at Cornell University, and Harold Brown, associate director of the AEC's Livermore laboratory, were assigned to advise the U.S. representatives.

Although the Geneva Conference purported to be a meeting of experts on technical issues, it was really an attempt by the president to begin an international dialogue on nuclear weapons and by the State Department, led by Secretary John Dulles, to press for relief from the acute tension in the world at the time. Moreover, there were strong differences of opinion within the government and among scientists on the benefits and disadvantages to the United States of a test ban. Strauss, by then special assistant on science to Dulles, joined with the commission and the joint committee in opposition to an unlimited test ban. Edward Teller and Willard F. Libby, an AEC commissioner, were also opposed because they wished to perfect small, defensive nuclear weapons to counter the huge Soviet standing army. Others took intermediate positions. Whatever their views, all were agreed that verification, as complete as possible, was an absolute necessity for any long-term ban on testing. And they were equally agreed that it was not then available. There was some likelihood that an agreement to ban tests in the atmosphere could be obtained, because violations of the ban might be detected by aircraft sampling the air currents over the earth. This was the method used by the United States, at Strauss's urging, to detect the explosion of the first USSR nuclear weapon in 1949. But tests conducted underground were another matter. In principle, they could be detected with the same seismic apparatus used to study and monitor earthquakes and similar disturbances. Seismic detection depended on the coupling of the underground explosion to the surrounding Earth that served to transport the shock waves to the seismographs. There was, however, the possibility of decoupling the explosion from its surroundings by first firing a relatively small weapon in a very large underground chamber, thus muffling the seismic waves and confusing the detection systems. This possibility, if it were real, needed to be explored in depth because the only alternative was on-site inspection of areas where test ban violations were suspected, and that was unacceptable to the Russians.

In the meantime, it was argued, various compromises were possible that would involve a test ban of limited duration but under strictly specified supervision. The ultimate decision on how much damage to the U.S. nuclear armament should be tolerated and how much risk of Russian violation of any test ban agreement was acceptable would be made in the White House and not by the commission or its scientists. And that was the way the Geneva Conference turned out. The day after it adjourned, Eisenhower announced that the United States would suspend nuclear weapon testing indefinitely, provided the nuclear powers could establish an effective inspection system and make substantial progress on arms control.

The announcement of a U.S. moratorium on testing caused a flurry of activity among those nations with nuclear capabilities. American, British, and Russian scientists rushed to carry out tests both underground and in the atmosphere before October 31, 1958, the start date of Eisenhower's moratorium. Furthermore, several of the U.S. underground tests raised questions about the data originally used at the Geneva Conference. These and other arguments for and against a test ban sapped the strength of the U.S. movement toward a comprehensive test ban, and the Russian unwillingness to consider on-site inspections without a right to veto any or all of them left the entire question dead in the water.

The breakdown of the test ban negotiations was the result of the mutual mistrust and hostility that continued throughout the cold war. Russian intransigence stemmed from American insistence on monitoring Russian activity, not only with respect to nuclear weapons but in everything concerning its armed forces. And the U.S. spy plane flights over Soviet territory exacerbated Russian paranoia in this regard. American suspicion of Russian belligerence and secrecy had been reinforced by spaceship *Sputnik*. This confirmed the U.S. belief that the Russians were capable of secretly preparing major new military threats and springing them on an unwary world. Determined not to be caught unprepared again, the Eisenhower administration gave scientists and engineers renewed responsibility and influence in the higher councils of government. It also expanded its earlier heavy reliance on the AEC and its laboratories for technical advice on the scientific matters that dominated national security issues. Events obliged the Kennedy administration to maintain that posture. Once again, the AEC remained a research and development agency throughout its second decade, heavily influenced in its practices and outlook by academic and industrial scientists and engineers.

Despite all this, the commission managed to sustain research in a variety of applied and basic problems even while confronting pressing new tasks affecting national prosperity and security. Some of the work was done in its own laboratories and some in industrial and university laboratories, and not all of it was successful. Encouraged by the joint committee and the air force, the commission attempted to develop reactors for military aircraft propulsion, hoping to achieve the same success it had shared with the navy. But the work lacked a promising technical base as well as a convincing purpose. Neither Eisenhower nor his advisers, George B. Kistiakowsky, who succeeded Killian as presidential science adviser, and Herbert F. York, the director of the new office of research and engineering in the Department of Defense, was willing to continue recommending the project to Congress after expenditures of more than $600 million and fifteen years of effort had produced little progress. One of President Kennedy's first decisions in 1961 was to kill the project completely. Greater success along a related line was attained when, stimulated by *Sputnik*, auxiliary power generators that employed small reactors were developed to produce more than ten kilowatts of electricity to be used in space by NASA. This $13 million project was the most successful of all the commission's air and space endeavors.

An especially ambitious and exciting idea for power generation emerged at the time that studies of the hydrogen bomb began. The idea was to develop a power reactor utilizing hydrogen fusion rather than uranium fission. A fusion reactor containing an ionized gas of hydrogen isotopes would rely on an inexhaustible, readily available supply of fuel, and radioactive waste would not be a significant byproduct as it was in a uranium reactor. The drawback was that fusing the hydrogen isotopes and releasing the enormous energy associated with thermonuclear reactions would require the temperature of the gas to be raised to one hundred million degrees, many orders of magnitude higher than any temperature ever achieved in a laboratory. Nevertheless, a fusion reactor promised to be the outstanding accomplishment of the peaceful uses of nuclear energy and the hallmark of the Atoms for Peace program. It received enthusiastic support from the commission and the joint committee.

A laboratory system to confine the enormously hot ionized hydrogen gas in a restricted space by means of strong magnetic fields was designed by Lyman Spitzer Jr., a professor of astronomy and astrophysics at Princeton University, while theoretical studies of a hydrogen bomb were in progress. Confined in that way, the gas could continue to be heated, and fusion reactions would ultimately take place when a high enough temperature was reached. The commission funded Spitzer's studies at the same time that the Los Alamos and Livermore laboratories began theoretical work on other containment systems for the same purpose. But this pioneering work made slow progress until the subject of fusion was declassified and opened to wider participation by other laboratories. Scientists interested in doing long-term basic research to understand the physics principles underlying the behavior of gaseous plasmas began to make progress, and articles on fusion research appeared in open technical journals, including the new specialized journal *Physics of Fluids*. By 1965 perhaps $300 million had been expended by the AEC with no fusion reactor yet in sight. But the goal remained as attractive as ever, and research support was not threatened.

With its strong scientific tradition, the AEC envisioned U.S. preeminence in the basic nuclear sciences as a vital part of the Atoms for Peace program. After WWII, nuclear science had moved along several different paths: nuclear chemistry and nuclear medicine blossomed into full-fledged scientific disciplines, and exploration of the nuclear physics of the entire table of elements enlarged understanding of the nuclear force. But discoveries of unanticipated properties of very high energy cosmic ray particles and experiments carried out at higher energy particle accelerators—the synchrocyclotrons sponsored by the ONR and AEC—opened entirely new areas involving new principles in physics. It was these discoveries that had prompted General Groves's science advisers to recommend the construction of new laboratories and new high-energy accelerators in the waning days of the Manhattan Project. The AEC's General Advisory Committee echoed that sentiment.

As scientists used those accelerators to probe more deeply into the phenomena of the new field of physics—high energy physics, as it was called—new constituents of matter, at least as fundamental as the neutron and proton constituents of atomic nuclei, were exposed for the first time, and the need for still more powerful probes became acute. Once again the General Advisory Committee pressed the case with the AEC and the Joint Committee for more energetic accelerators at new and existing laboratories. The commission chairman, John McCone, was not easily convinced that support of expensive research in a field so new and so removed from the mission of the AEC was justified. It required all the authority the high energy physics community could muster, authority derived from its members' contributions to the national defense during WWII, and the strong support of the president's science adviser to change McCone's mind. But it was done, and the AEC became the godparent of another new branch of science: high energy physics.

In all respects the National Institutes of Health grew at an astonishing rate in the period 1955–65.

The legacy of *Sputnik* provided a bonanza for all U.S. science agencies. Within four years after *Sputnik*, the total NIH budget exploded from $98.5 million to $400 million, and appropriations earmarked for extramural research grew from $55.6 million to $322.6 million in 1960. Universities, medical schools, and hospitals generated a burst of requests for the recently established institutional grants, while the volume of individual research proposals that required separate review increased from 2,750, averaging $12,600 annually, to almost 8,000 requesting an average of $19,500. That programmatic growth had to be matched by administrative growth in the DRG. The formerly compact Division of Research Grants ballooned to a complex hierarchy with five operational branches and a staff of 360 full-time positions, and the number of study (review) sections began a steady growth.

The sudden affluence opened doors of opportunity that had been tightly shut before. Over a three-year period, the DRG was able to dispense $90 million in matching grants for university and hospital construction projects. Moreover, the division was in a position to stimulate the development of new basic science areas necessary for advances in medicine. For example,

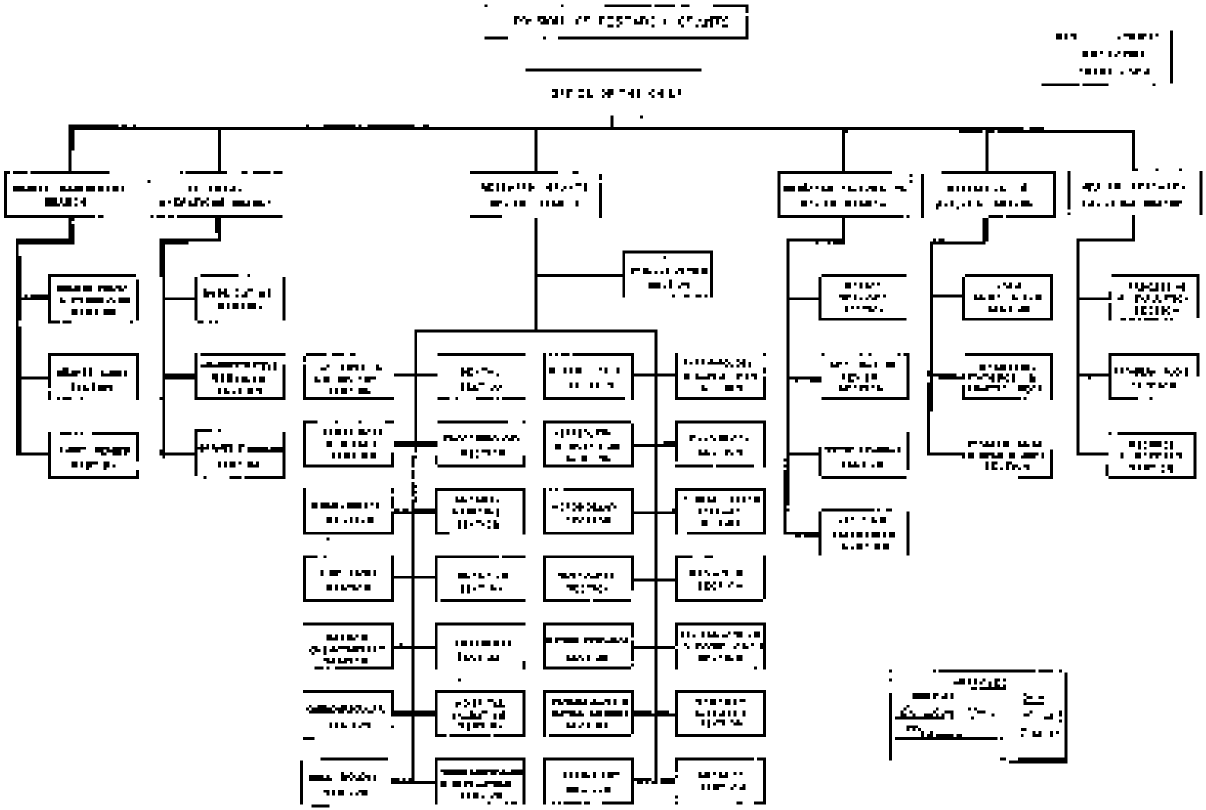


FIGURE 4.5. Table of organization of the Division of Research Grants of the NIH in May 1958.

Source: Richard Mandel, *A Half Century of Peer Review (1946–1996)* (Alexandria, Va.: Division of Research Grants, National Institutes of Health, Logistic Applications, 1996), p. 71.

electron microscopy and X-ray crystallography, both relatively new to medicine at the time, were throwing light on fundamental molecular structure. The Biophysical and Biophysical Chemistry Study Section was able to use a four-year, $600,000 grant to support conferences and lectures in those fields as part of college curricula. Similarly, the Morphology and Genetics Study Section, another area of nontraditional medicine, was enabled to catalyze the field of cell biology by conferring grants on university centers, founding a national journal and a national society, and promoting the idea of a separate institute within the NIH. In 1958 the Cell Biology Study Section became independent, and a dozen working groups of university-based scientists were organized. The Radiation Study Section advanced radioisotope use in diagnostics by awarding grants and organizing conferences on current projects related to radiation effects on health, this at a time when atom bomb testing in the atmosphere was still being conducted and a matter of deep concern throughout the world.

The new ventures were a mixed blessing, however, because they added to the already huge DRG administrative workload. The elaborate review and follow-up procedures carried out for each grant application were overwhelming the study sections and the DRG staff. An ad hoc high-level advisory committee formed to address the situation recommended that an increasing proportion of the NIH research budget go to program and institutional grants as opposed to grants to individual investigators. The committee hoped that this change in emphasis would relieve some of the pressure on the DRG. An early step involved the formation of a new division in the NIH, the General Medical Sciences Division, to focus on extramural basic research. A new branch in the DRG, the Statistics and Analysis Branch, was also created to develop a central source of grant application information by means of automated data processing.

This reorientation established the DRG as a monitor of the NIH research and training programs throughout the nation but did not alleviate the administrative workload. Rapid growth soon caused some units of the DRG to disperse to Silver Spring, Maryland, and soon thereafter the entire extramural organization moved to a site away from the Bethesda, Maryland, center of the NIH. Another effect of the growth was that for the first time the General Accounting Office found that supervision of the granting process was inadequate. Proper control of NIH research funds could no longer be guaranteed. This perception arose despite the fact that the study sections were spending 2.6 days per meeting and processing thirty-one applications per working day and that staff assistance to the study sections was strengthened. As a result, the DRG began to tighten its criteria for grant approval based on excellence rather than growth, both for the science's sake and for its own survival. By 1960 the study sections reported a 43 percent approval rate, down from 65 percent in 1956.

At the end of 1960 Ernest Allen, who had been assistant chief under Van Slyke and then chief of the DRG, moved to the office of the NIH director. He left behind a leadership style devoted to facilitating cooperation and understanding between the government agency and the private sector of the medical community. His tenure at DRG spanned the epochal transition from the period in which grants were awarded largely to individual investigators to the period in which grants were awarded to programs and institutions. By the time Allen left the DRG, nontraditional applications of basic science to medical research and medical practice required evaluation by study sections. Allen was confident that the extramural system with its emphasis on peer review could triple in size in the coming decade, but not if it were driven primarily by individual grants. The budget of $351 million that he shaped for 1960 was divided equally among research grants and training, control, and construction of facilities. The research allocation of $182 million was thought to be sufficient to pay for roughly one-half of the new grant applications that were likely to be recommended favorably.

Allen was succeeded as chief of DRG by his deputy, Dale R. Lindsay, a PHS entomologist from the Malaria Control Program. Lindsay was aware that raising the standards for awards would ease but not solve the problems brought on by the growth rate the division was experiencing. He noted that the extramural grants program had thrived under informal and flexible management dedicated to scientific freedom but that the size and diversity of the program required by emerging biomedical technology demanded more in the way of administrative management. New branches in program review and career development were organized, and new study sections, among them sections in accident prevention research and primate research, were created, indicating the strong trend toward the development of research interests outside clinical medicine. Nevertheless, the division remained seriously understaffed as new divisions with the authority to grant awards were formed in the NIH and the PHS. The chronic understaffing was due to a lack not of money but of experienced administrators and the speed with which medicine was changing among all its disciplines.

The NIH and DRG struggled for a decade to stay abreast of the rush of demands made on them, with only minor hands-on, critical oversight by Congress. That situation changed in early 1962, when a subcommittee of the House Committee on Government Operations, chaired by L. C. Fountain, criticized the NIH for failing to implement adequate fiscal control over grantees as promised. The charges were not without merit. The NIH had been slow to carry out changes in audit analysis and control, largely because the new administrative structures in biomedicine left a shortage of time and people to supervise grantees as carefully as before. The Fountain committee gave a foretaste of the increasing criticism that the NIH and DRG would meet as the size of their budgets increased. Furthermore, the NIH and DRG would clash with the Congress about what determined adequate oversight. There were fourteen thousand research projects to be audited in 1962, and Richard R. Willey, deputy chief of the DRG, made clear its position in a comment after a site visit to the Harvard laboratories of noted cancer researcher Sidney Farber: "Any impression that NIH staff are going to maintain effective day-to-day surveillance over the plans and expenditures of such a grant, I feel, would be illusory. . . . Spending $12 million over seven years on that grant was scientifically justified, . . . but to certify that these funds have not been used for patient care or in 101 other technically inappropriate ways," as the Fountain committee required, was clearly beyond DRG capabilities.[5] Willey contended that the NIH needed to take a new look at the problem of grant management and assign that responsibility to an outside organization. The DRG would then focus on grant review and the formulation and coordination of grant policies and procedures.

The Fountain committee hearings did, however, speed up the evolution of a strengthened partnership between the DRG and the universities. The director of the NIH, James A. Shannon, recognized that a grant recipient institution was in the best position to develop the necessary administrative controls that Congress wanted, and consequently the task of policing grants should be left largely to the institutions themselves. Removal of this burden from the DRG was slow in coming. Meanwhile, the Office of the NIH Director extended its control of programmatic functions, nominally to lighten the load on the DRG. In June 1963 DRG chief Lindsay opted for early retirement. He was succeeded by Eugene A. Confrey, a health administrator with a background in statistics and the humanities. Shannon hoped Confrey would develop a new NIH scientific evaluation capability in the DRG and, with it, a central data system to expedite systematic analysis of scientific accomplishment. These would enable the Office of the NIH Director to evaluate better the progress of NIH extramural investigators and, especially important, to convey that progress to Congress and the administration.

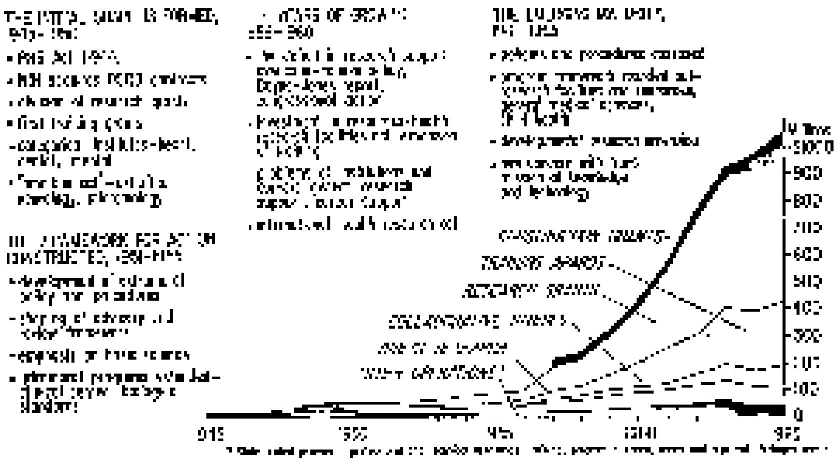
In 1964, in part as a result of the Fountain committee's criticism and in part because the NIH directorate also perceived a lack of control by the DRG, the NIH began to reinvent the DRG, which by then had a staff of 514 to service thirty-two thousand applications for research and training grants and fellowship awards amounting to a budget of $773 million annually. To bring about changes in the DRG, Chief Confrey established new operations offices to handle staff functions, in addition to those in the basic five-branch organization under which the DRG had been doing its business. He also directed some of the management and award duties of the DRG to other institutes and concentrated division activities on initial review of grant applications, based as before on scientific excellence. An external committee appointed by President Kennedy to assess the status of the NIH recommended a strong, centralized NIH administration in which the DRG system would continue as the home ground of the individual investigator. The workload stemming from peer review of those applications would be alleviated by an increasing number of programs managed by the individual institutes, with each program supporting many researchers. That advice was largely negated, however, by President Johnson's campaign in 1964 to turn the NIH away from basic research and toward programs that would concentrate on finding cures for cancer, heart disease, and stroke, by then the leading causes of death by disease in the United States.

The quandary in which the NIH found itself was the product of a cycle that began with the remarkable progress of U.S. biomedical sciences during the period since WWII, progress fueled by NIH encouragement and support. Medical and Ph.D. researchers, in most instances educated and trained at NIH expense, were attracted by NIH success and naturally turned back to the NIH for support in their own research careers. And this cycle, feeding back on itself, renewed itself again and again until after two decades the NIH arrived at an annual budget of $1 billion, which made it the largest federal science agency that provided direct support to faculties in U.S. universities.

The National Science Foundation emerged as a valuable national asset.

The NSF was the only federal science agency that was not part of a larger multifunction agency. It was a study in survival of the idea that there was

POSTWAR DEVELOPMENT OF NIH PROGRAMS



value to be gained from the federal funding of science and science education with no strings attached. It tested the dedication of the government to sustaining a federal agency with so narrow and, according to its critics, so impractical a mission.

The director of the NSF, Alan Waterman, had presided at its birth and helped it grow into a vigorous science agency during its first few years. He was beset, however, by the Bureau of the Budget, the watchdog of the executive office, to fulfill two other mandated directives specified by Congress as part of the NSF's mission: he was required to evaluate science research programs undertaken by other federal agencies and to formulate a national policy for the promotion of science research and science education. But recognizing that those were minefields which, once entered by the NSF, might well destroy it, he steadfastly resisted the pressure to take up those no-win challenges. He saw the function of the NSF to be the encouragement and funding of high-quality science research and science education and kept the NSF on that path with as little deviation into national science policy as he could manage. It was soon clear that Waterman's instinct in these matters was correct. National science policy and evaluation of the federal science establishment could only come from the White House, not from the director of a newly established, small agency that could ill afford to make enemies within the government. President Eisenhower's appointment of a science adviser and science advisory committee at the time of *Sputnik* demonstrated that supervision of the government's science agencies belonged in the executive office. The attempt by Congress to assign that function to the NSF was the first of several unsuccessful efforts to place that responsibility within a science agency under congressional control.

The agency held fast to the principle of peer review of research propos-

FIGURE 4.6. *Opposite page top*: Presidential visit to the NIH Clinical Center, July 21, 1967. *From left*: Surgeon General William Stewart, President Lyndon B. Johnson, NIH director James Shannon, Assistant Secretary of Health Phillip Lee, and Clinical Center director Jack Masur.

Source: Richard Mandel, *A Half Century of Peer Review (1946–1996)* (Alexandria, Va.: Division of Research Grants, National Institutes of Health, Logistic Applications, 1996), p. 113.

Opposite page bottom: Chart showing the postwar development of NIH programs.

Source: Richard Mandel, *A Half Century of Peer Review (1946–1996)* (Alexandria, Va.: Division of Research Grants, National Institutes of Health, Logistic Applications, 1996), p. 87.

als and study awards and championed award recipients' freedom of choice. Accusations of elitism and failure to distribute funds fairly were bound to occur because the principal business of the NSF was to distribute funds and because the director and policy-setting advisory board of the NSF were politically appointed. To keep contention with Congress to a minimum required courage and wisdom on the part of the NSF's director: the courage to recognize and resist undue interference, different from legitimate oversight, and the wisdom to know when and how to do it. Long after he retired, the second director of the NSF, Leland J. Haworth, told of an incident that illustrated the kind of situation that occasionally arose. This involved a quiet dinner at the home of a senator soon after Haworth assumed the directorship. As the main course was served, the senator remarked to Haworth that the NSF disbursed substantial sums of money each year to individuals and institutions in several states of the union, but his (the senator's) state was not among the most favored. The senator thought Haworth might remedy that situation, which he implied would ensure his future cooperation in matters affecting the NSF when they came before the Senate. According to Haworth, this was all stated gently and tactfully, but Haworth knew that he was being challenged directly and that he had to make a stand, equally gently and tactfully. The response he chose was slowly to push away the plate of untouched food in front of him with the quiet comment that he was unhappily afraid that it was too rich for him. Smiling, the senator pushed the plate equally slowly back to its position before Haworth, with the comment that it was plain and simple fare that would not lead to discomfort. No more was said on the subject, and Haworth—who played no favorites—noted that the senator became his friend and a staunch supporter of the NSF during his directorship. But he often wondered how he and the NSF would have fared if he had failed the test.

The pre-*Sputnik* years of the NSF were marked by modest but adequate budgets that were used in part to introduce new programs and activities that were the seeds of later rapid growth. In the period from 1952 through 1956, science and science education (SSE) amounted to 27.7 percent of the total NSF budget, the remainder going to research and research-related activities (RRA). Most of the RRA expenditures were in the form of awards to individual investigators, but a small fraction went for surveys, travel grants, conferences, and support for data collection and data bases, all of them contributing to the flow of information within the science establishment. During the five-year interval immediately after *Sputnik*, from 1957 to

1961, SSE rose to 39.7 percent of the total budget, and individual investigators continued to dominate research activities.

But a small fraction of research funds began to flow to the support of groups of four or more scientists working in collaboration, for example, on preparation for the International Geophysical Year (IGY). A larger fraction, averaging 19 percent of research funds, went to the support of facilities like the national astronomy observatories and the centers for atmospheric research. The NSF was designated the funding agency and coordinator of U.S. participation in the IGY of 1957–1958, which served as an incentive to support new global atmospheric and oceanographic research and ecological studies. One of the United States' primary interests in the IGY was to bring about an international treaty to preserve the Antarctic for peaceful scientific research. The NSF was made responsible for promoting U.S. interests and instructed to encourage and fund research projects that were best located on that continent.

The visibility of group research left the NSF open to praise for the accomplishments of those efforts and, correspondingly, open to criticism when an ill-conceived project was funded. One such was Project Mohole, said disparagingly by critics to have been planned by a committee. The aim was to dig deep into the earth's crust to explore for the first time the interior of the earth's mantle. Project Mohole never succeeded but was supported at between 5 and 10 percent of the research budget from 1963 to 1969, when it was terminated. It caused the NSF only a moderate headache because Congress was beginning to understand that not all research projects turned out well.

One year after *Sputnik*, the appropriation for the NSF had more than tripled, from $40 million to $134 million, in recognition that the foundation was a vital component of the U.S. response to the questions raised by Soviet advances in nuclear weapons and space technology. Even in the short period between its founding in 1950 and the spaceflight of *Sputnik* in 1957, the NSF became an important supporter of basic research in a variety of scientific fields and a significant partner in science education in schools at all levels.

By 1965 the NSF had survived fifteen years of growth and external pressures, still embracing the values that constituted the reasons for its creation in the first place. It was respected for its manifest determination to hold to those values. More than any other federal science agency, the NSF represented the spirit of science to Congress.

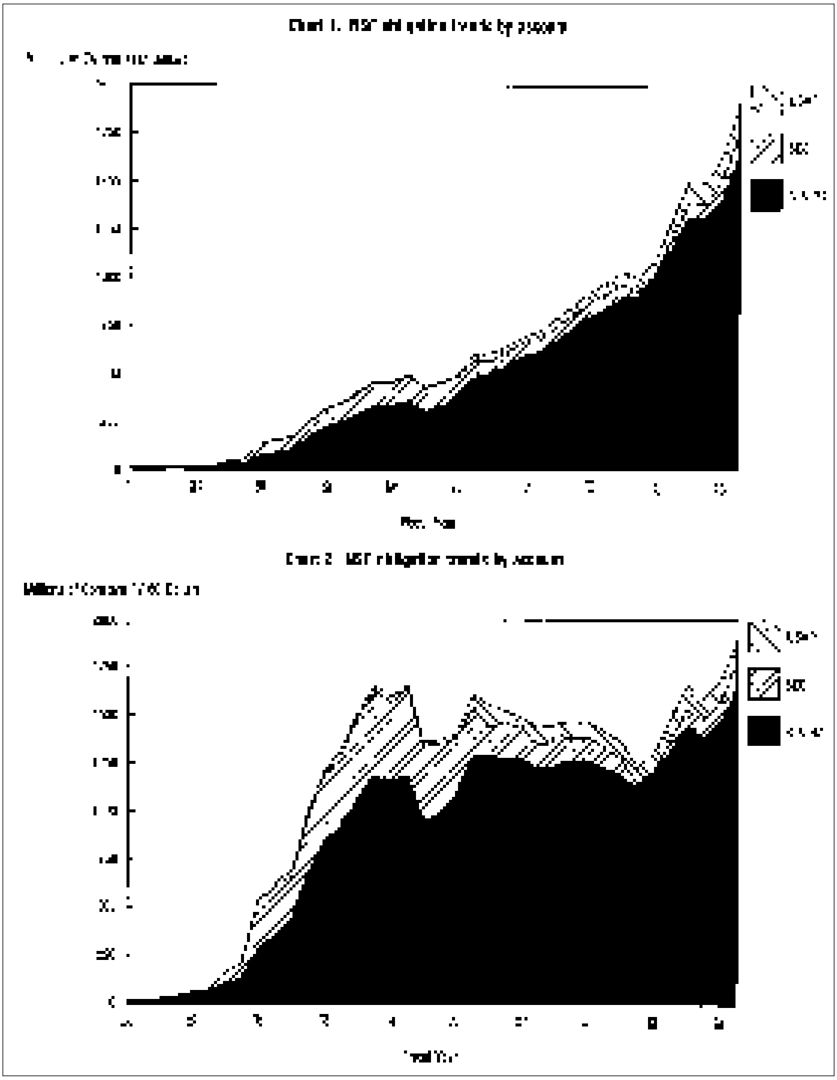


FIGURE 4.7. Charts showing the NSF total budget by account during the years 1951–1987. USAP, U.S. Antarctic Program; SEE, Science and Engineering Education; R & RA, Research and Related Activities. *Top*: current year dollars; *bottom*: constant 1988 dollars.

Source: T. N. Cooley and Deh-I Hsiung, *Funding Trends and Balance of Activities: National Science Foundation, 1951–1988*, NSF 88-3 (Washington, D.C.: National Science Foundation, 1988), p. 4.