Chapter I
Introduction

Technological change has accelerated tremendously in recent decades. Today's new breakthroughs are disseminated almost immediately to the lay public via television and soon become tomorrow's routine occurrences. No technological developments of this accelerated age have captured more attention than those in space and those relating to nuclear energy. The technology which provided nuclear power for space missions cuts across these two broad fields of technical and scientific development.

In spite of their many spectacular triumphs, both the space age and the nuclear age have very recent beginnings. They date from the period following World War II when America assumed worldwide responsibilities. Throughout the 1950s, the two technological revolutions gained momentum, and in the decades which followed they brought amazing technological feats to the senses of many people throughout the world. They also influenced, and were influenced by, other events in the world.

The first man-made satellites, launched in 1957 by the Russians, led to a searching reassessment of American science and education. Eventually they triggered the race to the Moon of the 1960s and astronaut Neil Armstrong's "giant leap for mankind." Subsequently, unmanned Mars landings, missions to fly by Saturn and Jupiter, and other space probes punctured old beliefs and led to revised theories among space science specialists, while providing a view of the universe never seen by previous generations.

Dramatic developments in nuclear energy also unfolded during those years, although their appearance frequently was accompanied by public concern after the earlier cheers had subsided. From the beginnings at Stagg Field and Alamogordo, awe was mixed with foreboding, and efforts to generate peaceful uses of nuclear energy have been burdened by fears of the uncontrollable. Growing concerns about ever more destructive bombs and fears of fallout contamination led to concerted efforts to control testing and find peaceful uses for nuclear energy. As a consequence, the Atomic Energy Commission (AEC), successor to the greatest weapon development project of all time, began to devote more of its developmental efforts to civilian applications of nuclear energy. According to a history of the AEC, in 1966 "the AEC budget for the first time was divided about equally between weapons and peaceful uses."[1] Yet even the peaceful applications of nuclear energy were to face some barriers.

The radioisotopic program, a part of the overall effort to develop systems for nuclear auxiliary power for space missions, was a participant in these events. It benefitted from the plutonium produced and made available in sizable amounts by the many years of nuclear weapon development under the AEC. The space uses of isotopic power received their greatest boost from the highly-publicized missions conducted by the National Aeronautics and Space Administration (NASA), in America's participation in the space race.

The space isotopic power program, however, has been a quiet program, somewhat shielded from evolving public concerns about nuclear power and rarely the star of the space spectaculars. Space isotopic power has developed quietly because it is indeed a quiet technology. For example, it does not involve explosive power; nor does it require human interventions in nuclear processes to induce nuclear fission or fusion. It is a battery-like thermal power emanating from the natural decay of radioactive elements; when used in and applied to space missions, the technology operates far from the terrestrial environment.

The history of the radioisotope power program is basically a success story, although it is certainly not one of linear success. The program was initiated by the AEC under impetus from the Department of Defense but first went public late in that decade as part of the "atoms for peace" movement, with President Eisenhower showing an atomic battery to the world and extolling its peaceful potential uses. Subsequently, while the Defense Department supported mostly test applications of the radioisotopic power devices in space, the program reached its pinnacle of success through uses by the civilian space agency NASA.

The program never became truly big but was a vital part of larger programs while outliving its "big brothers" in the space-nuclear field. In the spring of 1961, as the first radioisotopic thermoelectric generator (RTG) space missions were about to be launched, proponents of the use of nuclear energy in space were projecting the future technologies that would enable Americans to achieve the goal set by President Kennedy—a man on the Moon by the end of the decade. They proclaimed: "Nuclear Rockets will get him there... Nuclear

Power will sustain him there."[2]

The story told here will show how the second part of that prophecy came to fruition through the use of radioisotopic power.* It will describe how the RTG program matured in the 1970s to deliver RTGs that were vital components of missions to distant planets and beyond. It will look at the human, organizational, political, and social factors contributing to the survival and continuing achievements of the space isotopic power effort throughout its history.

The history of the space isotopic power program is essentially one of opportunities, perseverance, and attentiveness to detail—especially regarding safety measures and public communications about them. In its ultimate measure, space isotopic power is a program sustained throughout its history by a team of people who, in spite of changes in the larger organizations surrounding them, were ready at the launch pads when opportunities arose to demonstrate the technology in which they believed.

The story begins with the first glimmerings of opportunities for this space and atomic age technology.

---

*The faltering of the nuclear propulsion and space nuclear reactor power efforts is a secondary theme in this history.

Chapter II
The Beginnings

An Auspicious Debut

The radioisotopic power program made an auspicious public debut. A banner headline in the Washington, D.C. *Evening Star* of 16 January 1959 announced:

PRESIDENT SHOWS ATOM GENERATOR[1]

An accompanying photograph showed President Eisenhower examining the "world's first atomic battery" as it sat on his desk in the Oval Office of the White House. The president had personally ordered the display of the device shortly after seeing it himself for the first time.

The small, lightweight device on the president's desk was a radioisotope-fueled thermoelectric generator (RTG)—a companion effort to nuclear reactor developments in the Systems for Nuclear Auxiliary Power (SNAP) program. Ready for space missions, the RTG could provide the necessary auxiliary power to operate the instruments of a space satellite. The RTG displayed for the public in that historic moment had been designated SNAP-3 by the AEC. In later years, especially on missions to the Moon and beyond, the RTG role as a bit player in space spectaculars, kept it out of the headlines, but on that day it was the star of the show.

Although the isotopic power device was not made public until January 1959, the AEC had briefly discussed its development a year earlier before the Joint Committee on Atomic Energy (JCAE). The hearings before the JCAE had focused on "Outer Space Propulsion by Nuclear Energy," but Colonel Jack Armstrong, chief of the AEC Aircraft Reactors Branch, also introduced Committee members to the small isotope power program. The program had been spurred, he said, by indications that the Russian Sputnik, with its long-lasting signals, used something other than conventional battery power for its transmitter. Efforts to develop space-nuclear power for the electrical equipment in the Air Force reconnaissance satellite 117L had led to research and development in both reactors and isotopes for space-power uses. Funds were found in the nuclear propulsion appropriation for 1958 to finance a low-key, low-cost effort in isotopic power development "to provide an extremely light, an extremely small source of power...."[2]

Only four months before the televised display on Eisenhower's desk, the Martin Company of Baltimore, Maryland received a contract for producing an isotopic generator. The Minnesota Mining and Manufacturing Company developed the conversion system by which heat from radioisotopic decay of polonium 210 was transformed into electricity. The five-pound experimental unit which developed five watts of power had been developed soon after the Martin contract was signed. Armstrong was reported as saying that "the cost of the model was $15,000 exclusive of atomic material." He estimated the cost of fueling with 3,000 curies of polonium at $30,000.[3]

The men from the AEC meeting with President Eisenhower hailed their small generator, which had no moving parts, as a "significant breakthrough" for its efficiency in producing electric energy from the heat of decaying radioactive isotopes through a method called "thermocoupling." According to Armstrong, until the breakthrough in conversion methods, American scientists exploring isotope technology used rotating machinery driven by radioactive power sources to produce electricity. The new generator achieved its efficiency, stated to be 8 to 10 percent of electrical energy output from heat energy input,* through a radiating system of metal spokes, with each spoke in contact with a container that shielded the radioactive polonium and heat from the decaying polonium radiating up the outside ends of the spokes as electrical energy. The new RTG technology was not intended as propulsion for nuclear powered airplanes; Armstrong said that immediate uses were for NASA to decide, adding, "We can tailor the product to fit the customer."[4]

Although NASA soon became the major user of RTGs in space, it was the Department of Defense that first capitalized on isotopic power technology for space—in satellites. Defense uses dominated nuclear energy developments throughout the 1940s and 1950s, with developments in the "big" nuclear technologies coming to public attention with the "world-shaking events at Hiroshima and Nagasaki. While opportunities for uses of isotopic power in the 1950s were linked to the "big" nuclear technologies and the new atomic age, the

*Later accounts reduced estimates of this efficiency to about 5 percent.

development of isotopic power itself has a history that goes back many decades.

The Quiet Nuclear Technology

Glenn Seaborg, Nobel laureate in chemistry and pioneer in the discovery of radioactive elements, has noted that while nuclear power plants generate headlines and engender debates about potential dangers, "the atom works away quietly, as it has for half a century, in medicine, industry, agriculture, and science."[5] Radioisotopes and atomic radiation, used in medicine since the early 1900s, marked the first phase of the atomic revolution, a phase which Seaborg believed was already over. He described the quiet technology:

> The 'silent' atomic tools are varied; most depend not upon fission and fusion but upon more subtle properties of the atom, such as its precise clockwork, the high-speed projectiles it emits, and the vivid, distinctive label it provides.[6]

Behind these quiet tools was the discovery, in 1896, of radioactivity by Henri Becquerel. Investigating the phosphorescence of certain minerals after their exposure to light, the French physicist accidentally discovered that phosphorescent uranium salts affected a photographic plate. Most startling was his observation that uranium's phosphorescent property did not depend on prior exposure to light, but was an inherent characteristic of the element. He had detected the disintegrating nucleus of the atom of an unstable element and had shattered the assumptions of classical physics, which viewed the atom as the irreducible building block of matter.[7]

Pierre and Marie Curie later used electrical methods to pursue the phenomena of radioactivity, building on the discovery that uranium and its compounds rendered the air near them a conductor of electricity. Their research into the radioactive properties of elements led them to the discovery of radium and polonium in 1898. They also detected, in their experiments with radium, the buildup of a voltage difference that was used in 1913 by English physicist H.G.J. Moseley in constructing the first nuclear battery. Moseley's battery consisted of a glass globe silvered on the inside with a speck of radium mounted on a wire at the center. The charged particles from the radium created a flow of electricity as they moved quickly from the radium to the inside surface of the sphere.[8]

As late as 1945 the Moseley model guided other efforts to build experimental batteries generating electricity from the emissions of radioactive elements.[9] These devices converted the motion energy of the charged particles from a radioisotope directly into electricity, without first converting the motion energies to heat, and thus generated very low powers (thousandths of a watt). At that time neither converters for transforming heat to electricity nor materials exhibiting sufficient efficiency in thermoelectric properties were available. The route that finally led to the RTG—obtaining heat from radioisotopic emissions and converting this heat to electricity—was not followed for some time.[10] Before describing how that route was finally taken, it would be useful to describe the basic nuclear radiation process that is the essence of the quiet atomic tools.

An isotope is "any of two or more varieties of the atoms of a chemical element."[11] Isotopes of the same element have different numbers of neutrons in their nuclei, although they otherwise display the same characteristics of the element. The isotopes of elements that exhibit radioactive decay properties are called radioisotopes. Radioisotopes are unstable elements that produce usable energy in the natural process in which one chemical element is transformed into another. Thus, within a family of radioelements such as uranium, change through decay to another element of the same family is constant and spontaneous.[12]

A radioactive isotope, then, possesses unique and valuable properties that are the basis of the quiet atomic technologies: "It spontaneously emits...nuclear particles.... It decays exponentially in time at a rate which cannot be altered by known physical forces."[13] It is a potential source of usable electricity; its lifetime in generating energy for that purpose can be calculated exactly in terms of the half-life of the particular radioisotope as it decays.

International Confrontations and Vistas for New Applications

Before the Manhattan Project developed the atomic bomb, only very small quantities of radioisotopes were available. The AEC-sponsored reactors that continued to turn out large quantities of fission products brought about a great increase between 1940 and 1950 in radioiostopes and in the decay heat available to engineers. Moreover, in 1950 the need for small and reliable electrical power supplies was becoming manifest in the infant space program.[14]

As the 1950s opened, the wedding of the quiet technology to early space efforts was spurred by cold war confrontations that dictated developments in both atomic and space science.

The United States' monopoly of nuclear weapons ended in 1949 when the Soviet Union exploded a nuclear device of its own. The decision by President Truman to proceed with the development of a hydrogen bomb (H-bomb) followed within five months. Great power tensions reached a new high in June 1950 with the beginning of the Korean War. New military demands and the development of the H-bomb led to a tremendous expansion of AEC production facilities in the fall of 1950. New plants for producing plutonium were a major part of this expansion. Nuclear weapon testing increased also, and America's first experimental thermonuclear device was detonated at Eniwetok in the fall of 1952. In the years 1950 to 1953 the AEC created a vast complex dedicated almost totally to military purposes.[15]

During the cold war years, when the weapons race among the super powers intensified, the adversaries also pursued ever more sophisticated methods for learning about each other's technological advances. Surveillance satellites became major elements in the early space race, and radioisotopes had the potential for providing power for these military satellites. An early study by the North American Aviation Corporation had considered radioisotopes for space power.[16] Then a RAND Corporation report in 1949 discussed options for space power in "Project Feedback," strategic satellite reconnaissance the corporation was studying, and concluded that a radioactive cell-mercury vapor system was feasible for supplying 500 watts of electric power for up to one year.[17] These assessments and the growing recognition of power requirements in Project Feedback led the AEC in 1951 to commission studies of a 1-kilowatt electrical space power plant using reactors or radioisotopes. Several companies who performed these studies recommended the use of isotopes for space power. In 1952, the RAND Corporation issued a Project Feedback summary report with an extensive discussion on radioisotopic power for space.[18] The interest in isotopic power for space satellites increased.

A significant achievement for the quiet technology occurred in early 1954 at Mound Laboratory in Miamisburg, Ohio. It was at this laboratory, which in future years prepared the fuel packages for succeeding generations of isotopic devices, that scientists pioneered the design of a thermocouple to convert isotopic energy to usable electrical energy Mound scientists Kenneth Jordan and John Birden had been frustrated in efforts to use decaying radioactive materials as heat sources to boil water to drive a steam turbine and generate electricity They hit upon the idea of applying the thermocouple principle, using metals that differ markedly in electrical conductivity, to create a thermopile that would conserve and harness the heat from radioactive material and generate electricity * Within a few days of working out the calculations, the Mound scientists constructed a working model of the technology The principle of using the thermocouples was patented by Jordan and Birden, and today remains the basis for all radioisotopic-power thermolectric generators [20]

A Program Takes Form in an Atmosphere of Challenge

With the need for space reconnaissance being given high priority and nuclear power now viewed as feasible for uses in surveillance satellite systems the Department of Defense requested in August 1955 that the AEC perform studies and limited experimental work toward developing a nuclear reactor auxiliary power unit for the Air Force satellite system under study [21] In agreeing to undertake the development of such auxiliary nuclear power systems, the AEC stated that it intended "to explore the possibilities of using both radioisotopes and reactors as heat sources "[22] This was the birth of what became the SNAP program of the AEC

The title "SNAP" replaced an earlier title of the program In the 1958 hearings before the JCAE, Senator Clinton Anderson asked, "Is SNAP by any chance kin to the Pied Piper?" Armstrong's reply was "It is Pied Piper renamed, sir "[23]

That exchange occurred after momentous events had shocked American defense planners, space scientists, and the public at large In October 1957 the Soviet Union launched its first Sputnik into orbit That same month, the editor of *Aviation Week* stated

> The Soviet satellite now orbiting around the earth approximately 16

---

*The thermoelectric conversion was discovered in the early 19th century by the German physicist Seebeck The Seebeck principle of thermocouples indicates that an electrical current is produced when two dissimilar metals are joined in a closed circuit and the two junctions are kept at different temperatures [19]

> times every 24 hours. . .offers incontrovertible proof of another Russian scientific achievement. . . .
>
> We believe the people of this country have a right to know the facts about the relative position of the U.S. and the Soviet Union in this technological race which is perhaps the most significant single event of our times. They have the right to find out why a nation with our vastly superior scientific, economic and military potential is being at the very least equalled and perhaps being surpassed by a country that less than two decades ago couldn't even play in the same scientific ball park.[24]

In the same issue of *Aviation Week* an article surmised that success of the Soviet Sputnik would give new impetus to a Lockheed project for a satellite reconnaissance project called "Pied Piper" being developed for the U.S. Air Force. The project referred to was the one for which the AEC took the responsibility of developing nuclear energy as a possible source of auxiliary power. Repercussions at the AEC came quickly.[25]

"Pied Piper" was the code name for the advanced reconnaissance system for which the AEC was preparing a nuclear auxiliary power unit. Since the publicity in *Aviation Week* compromised the term, the AEC issued instructions on 27 October 1957 to all field offices and contractors involved in the AEC part of the program to discontinue using the code name. The unclassified title "Systems for Nuclear Auxiliary Power," or "SNAP," became the authorized reference for AEC's work on nuclear auxiliary power units.[26]

Technical work on SNAP devices went on, perhaps in an atmosphere of greater urgency—not so much due to immediate mission needs, but because of the challenge to American technological capabilities that Sputnik represented. The nation was caught up in self-doubt and questioning such as it had never known in the modern age. New institutions were being created to revitalize American science, especially space science. President Eisenhower, after presiding over a confident if turbulent era in the 1950s, was besieged for answers about the apparent decline in America's preeminence in modern technology.

In response to this concern, Eisenhower created a President's Science Advisory Committee in November 1957, with James R. Killian becoming the first Science Advisor in the Executive Office of the President. Killian described the atmosphere of that time as America strove to recapture lost prestige:

> On December 6, the first test of the US *Vanguard* space vehicle, carrying a three-and-one half pound satellite, seemed to the world an ignominious flop This spectacular failure, coming as it did after the successful *Sputnik II,* increased the hysteria and embarrassment in the United States and the ridicule abroad In England, the press revelled in caricaturing *Vanguard,* calling it, among other things, *Puffnik, Flopnik, Kaputnik,* or *Stayputnik* [27]

Later that month, however, Killian prepared a memorandum for the President containing the judgment of a Science Advisory Committee panel chaired by George Kistiakowsky Taking on the implications of competitive space (and therefore missile) capabilities in light of the Russian Sputnik, the panel expressed the judgment that "technically our missile development is proceeding in a satisfactory manner," and although the United States was behind the Soviets in the space race, having started much later, the nation's technological progress in the missile field was, in fact, "impressive "[28]

Another panel of the Committee recommended outlines of an American space program and the organization to manage it As a result, NASA was established in July 1958 to conduct civilian aeronautical and space research The first administrator of NASA, Keith Glennan, recalled the subdued tone of the president as he asked Glennan to take on the task of furthering America's advances in space science and technology

> The meeting with President Eisenhower was brief and very much to the point He stated clearly his concern over the development of a program which would be sensibly paced and prosecuted vigorously As I recalled it, he made no mention of any great concern over the accomplishments of the Soviet Union although it was clear that he was concerned about the nature and quality of scientific and technological progress in this country [29]

To calm the public concerns and deflect Department of Defense strategies to mobilize U S space efforts primarily on a military basis, the president and his advisors set a course for civilian leadership in space The president sought to further calm matters in the international nuclear contest by announcing, in August 1958, a moratorium on nuclear weapons testing to begin October 31 of that year

Soon after it accepted the space nuclear assignment requested by the Defense Department, the AEC began parallel power plant efforts with two private corporations: odd-numbered SNAP programs using radioisotopes were spearheaded by contractual work at the Martin Company; even-numbered SNAP reactor power systems were developed through contractual work with the Atomics International Division of North American Aviation, Inc. The work by the Nuclear Division of Martin-Baltimore progressed through an early SNAP-1 effort to use the decay heat of cerium 144 to boil liquid mercury and drive a small turbine. In the course of following this development path, the Martin Company also let subcontracts to develop generators that would not require rotating equipment and the introduction of gyroscopic action to space vehicles. In 1958 work began on two thermoelectric demonstration devices at different companies, Westinghouse Electric and Minnesota Mining and Manufacturing (3M), while AEC contracts with other companies explored the development of demonstration thermionic units.*

The program to develop advanced energy conversion techniques that did not require rotating equipment (as in SNAP-1) was given the designation SNAP-3. It yielded results quickly; the 3M Company delivered a workable thermoelectric generator to Martin in December 1958. Using polonium 210 (capsuled by Mound Laboratory), the generator, quickly assembled and tested by Martin, was delivered to the AEC as a proof-of-principle device, producing 2.5 watts with a half charge of polonium 210 fuel. The AEC thus had at hand a capability for producing units that would generate 120 watts of electricity continuously for a year.[30]

Echoes of "Atoms for Peace"

President Eisenhower, shown this breakthrough in the quiet technology in January 1959, was eager to share the success story with the American public and the world at large. There was a sense of calm and composure about the debut of the proof-in-principle RTG. The event around President Eisenhower's desk emphasized "peaceful uses" for this technology. The president's eagerness to display the device openly testified to such purposes and provided an

*Thermionic conversion is the transformation of heat to electricity by the process of boiling electrons off a hot surface and collecting them on a cooler surface.

opportunity to issue a challenge to NASA, then a fledgling civilian space agency, to develop missions appropriate to the potential of the device. The small package that was the RTG appeared and was represented as harmless and non-threatening.

Perhaps the president saw an opportunity to use this example of American technical capabilities to publicize calming themes for space research much as he attempted to tone down the nuclear contests throughout the decade. Eisenhower attempted early in his first Administration to turn world attention away from nuclear confrontations and toward peaceful uses of atomic energy. His "Atoms for Peace" address to the United Nations came in his first year in office. The Atomic Energy Act which soon followed made possible private development of nuclear power in the United States, and at the close of Eisenhower's first term the AEC made large amounts of U-235 available for use in power reactors in the United States and abroad.* President Eisenhower showed great determination throughout his Presidency to turn nuclear science and technology away from international confrontations and races for technological superiority. On the threshhold of a new international race—the quiet nuclear technology was not a powerful booster for such a race but a tool for sustaining people and their machines in the space ventures, whatever the purposes of those ventures. The momentum of a race eventually would open the greatest opportunities for applications of the quiet technology.

*Sales of radioisotopes at Oak Ridge National Laboratory increased from 5,389 curies at the beginning of Eisenhower's Presidency to nearly 150,000 in the first year of his second term in office.[31]

Chapter III
Recognition of Potential

A Time of Transition: 1960-1961

Throughout his eight years in office, President Eisenhower strove to project attitudes of calm and of confidence in the future, but events worked against him. Early in his first term, the nation's sense of innate superiority was weakened by the realization that the Korean conflict was ended by a negotiated settlement rather than a clear cut military victory. Nine months into his second term, that sense was severely shaken by Russia's orbiting of Sputnik I. At that point, Eisenhower had already initiated programs to revive scientific, technological and organizational energies. In 1955, for example, he had approved plans for launching an American satellite as part of U.S. participation in the International Geophysical Year. After Sputnik's launch there was a greater appreciation of the political significance of such accomplishments.[1] Existing programs were accelerated and new ones undertaken. Eisenhower saw the need to match and surpass these achievements. He saw also a need to prevent the U.S. response to this challenge in space from being equated by other nations as being limited solely to military needs and objectives.[2] It was to avoid this interpretation that from the outset, in planning for NASA, the emphasis was on scientific objectives, and on the peaceful, civilian pursuit of scientific goals.

Homer Newell, a NASA administrator, and later an historian of the agency, wrote of the circumstances that helped shape its mission:

> A majority of those who would finally make the decision soon became convinced that the most effective way of proving U.S. leadership in space would be to demonstrate it openly. Moreover, a space program conducted under wraps of military secrecy would very likely be viewed by other nations as a sinister thing, a potential threat to the peace of the world.... It seemed important, therefore, that the U.S. space program be open, unclassified, visibly peaceful, and conducted so as to benefit, not harm, the peoples of the world.[3]

NASA's philosophy was thus in accord with the President's reservations about the power of the nation's military industrial complex He "was not disposed to foster further growth by adding still another very large, very costly enterprise to the Pentagon's responsibilities "[4]

The content of the space program of the new civilian space agency was not specifically prescribed by Congress in the NASA Act passed in 1958 The charter provided only the framework for coordination and cooperation between NASA and other agencies Under its first administrator, the new agency moved vigorously in the direction of a civilian space science program, setting "a strong but measured pace," according to Newell The pace on serious commitments to a lunar science program was slow at first, and "Glennan for a while showed a reluctance to discuss planetary missions except as plans for later, for the more distant future "[5]

On the nuclear side of the nation's space efforts, two important aspects were forcefully addressed in that transition year of 1960 safety problems and organizational needs

A few months earlier, the AEC had established an Aerospace Nuclear Safety Board "to analyze and project the possible effects of nuclear space devices upon the health of the peoples of the world and recommend standards of safe practice for the employment of nuclear powered space devices proposed by the U S "[6] In May 1960, Glennan and AEC Chairman John McCone assessed the problems of safety along with the potential benefits in the use of nuclear components in space programs In that early speculative period, Glennan wrote

> In respect to the use of nuclear sources for power generation in spacecraft, it is our belief that for certain missions the use of nuclear components may be the only way in which the mission requirements can be fulfilled Here again, however, there is considerable question as to the acceptability of the hazards involved The hazards to personnel and equipment on the surface of the earth, the radiation problem incident to manned space flight the interference with experimental measurements in spacecraft, and the radiological contamination of extra terrestrial bodies, are all moderating influences on the use of nuclear systems [7]

Glennan suggested that the AEC begin to define the conditions for safe use of nuclear auxiliary power systems in space missions and propose the safeguards which would have to be provided. He assured McCone of NASA's willingness to work closely with the atomic agency on these matters.[8]

In August 1960, the two agencies formalized arrangements for working together more effectively on all aspects of space nuclear efforts. A "Memorandum of Understanding between Atomic Energy Commission and National Aeronautics and Space Administration" affirmed "that Mr. Harold Finger will serve as the manager of the joint AEC-NASA project office and Mr. Milton Klein will serve as the deputy manager."[9] The new joint AEC-NASA Nuclear Propulsion Office reported to the Director of the Division of Reactor Development in the AEC and to the Director of Launch Vehicle Programs in NASA. As joint office manager, Finger wore two hats: he headed the joint office of nuclear propulsion and retained direction of the NASA office for space power. Finger thus exercised responsibilities for integrating AEC-developed RTGs into any NASA missions.

Both the early safety concerns and the organizational effort to bring the AEC and NASA together for joint efforts in the space nuclear field had enduring effects on the future of nuclear auxiliary power and the progress of the quiet space-nuclear technology. Safety concerns led to new organizational mechanisms for handling and anticipating safety problems as opportunities were sought to prove the usefulness and value of isotopic technology in space. At the same time, the new joint AEC-NASA Office, while it dealt with nuclear *propulsion,* prepared the way for merging the SNAP program with NASA projects. NASA's missions eventually came to lead in using RTGs for power in space.

The nuclear propulsion effort, designated Project Rover, now came under the single management of the new joint AEC-NASA office. The SNAP program continued as an AEC effort in the agency's Division of Reactor Development. When the AEC-DOD Aircraft Nuclear Propulsion Office (ANPO) was disbanded, its director, Armstrong, became Assistant to the Director of the Division of Reactor Development at AEC. Lieutenant Colonel G.M. Anderson, formerly SNAP project officer in ANPO, became chief of the SNAP Branch in the new division.

Before the momentum of the race into space increased, the SNAP program, particularly its quiet technology, was developing momentum of its own. At the end of the Eisenhower Administration, radioisotopic power stood on the threshhold of its first mission applications. The RTG technology was ready. Its proponents were looking for opportunities to put it to use. On Capitol Hill, in JCAE hearings, the pressure was on Project Rover. Committee members pressed for a flight schedule that would test nuclear propulsion in space.

The JCAE was also manifesting an interest in the SNAP program and its potential for providing long-lasting power to expensive satellite systems. In early 1961 hearings on "Development, Growth and State of the Atomic Energy Industry," JCAE Chairman Holifield told AEC officials that some committee members felt the SNAP program promised a payoff in continuing performance, perhaps for a year or two, from satellites costing hundreds of millions of dollars. Asked by Holifield if he was satisfied with the way the SNAP program was going, the Director of the Division of Reactor Development, Frank R. Pittman, replied: "As far as the technical aspects of the SNAP program are concerned, I am satisfied that it is. . .progressing quite well." Pressed, however, for information on whether progress had reached the establishment of requirements by user agencies, Pittman replied that such requirements had been established at that point only for certain even-numbered (reactor) SNAP systems. "We have requirements on the SNAP 2, the SNAP 10, and SNAP 8, with time requirements for testing."[10]

Potentials and Precautions

The SNAP-3, which was demonstrated to President Eisenhower in 1959, later came to be known as "the salesman of our working SNAP devices."[11] The first proof-of-principle SNAP was shown at several foreign capitals as part of the American "Atoms for Peace" exhibits. Reactions from academicians and students attending seminars held in conjunction with the exhibits were highly positive, although sometimes questions regarding safety were raised.[12]

In the U.S., one of the first public expressions of concern followed the demonstration in Eisenhower's Oval Office. According to George Dix, then responsible for safety at the Martin Company's isotope power project, and later head of the total space nuclear safety program under Finger at the AEC, nuclear critic Ralph Lapp complained that a highly lethal item had been placed on the President's desk. RTG engineers were attuned to reactions regarding safety and in a matter of days they developed a safety evaluation which apparently satisfied Lapp. The report, which covered handling procedures and all other matters regarding the safety of RTGs, thereafter accompanied SNAP-3 when on display in foreign capitals.[13]

Dix also pointed out that it was President Eisenhower who pressed for the use of the new technology in space satellites as soon as possible. According to Dix: "This successful demonstration came along about the time we had lost a Vanguard on the pad. Ike said, 'Let's fly this thing. [The Russians are] beating us on other things. Let's beat them on power.'"[14]

During 1960, technical journals continued to make a case for nuclear auxiliary power in space, but they also expressed reservations over the safety factor.[15] Despite the president's enthusiasm, the first RTG flight came two and a half years after the White House demonstration. The prevailing attitude was summed up by *Nucleonics:* "Isotopic Power Ready for Space But Caution Delays Use." Describing the comprehensive safety program of the Martin Company for SNAP-3, the journal noted that the "devices are being designed so they will remain sealed in any abort prior to leaving the earth's atmosphere but...will disintegrate to molecular-size particles on re-entry." These particles were described as so small they "will reside in space until long after the contained radioactivity has decayed to meaningless levels."[16]

Despite the conscientious safety programs at AEC and NASA, the Defense Department continued its preference for solar devices over isotopic power because the former presented no radiation problem. A series of solar device failures, attributed to leakage of storage batteries, forced a reconsideration of this policy. A need was seen to rely on isotopic power while industry worked at perfecting solar cell batteries. One unmanned source at DOD's Advanced Research Project Agency was quoted as saying RTGs could be "here to stay, particularly for missions where there is no sunlight."[17]

The AEC approach was to face the safety issue head on and to take steps to systemize safety reviews and safety procedures shaped to criteria that left no apparent margin for error. These criteria were developed in June 1960 at a three-day meeting of the AEC's Aerospace Nuclear Safety Board,[18] and spelled out in a September 1960 report to McCone. The criteria for the safe use of radioisotopic units, according to the report, provided that:

> The isotope material should be contained and the capsule present no hazard in the event of a launch abort.

> The above conditions should obtain in the event of failure to reach orbit, and in addition the capsule should fall in broad ocean areas
>
> In the event of failure to obtain a stable orbit, or in re-entry from a successful orbit for any planned time, the capsule and contents should be burned and dispersed in the upper atmosphere [19]

Citing results of tests already conducted, the Board indicated that a definitive program of further tests was being planned An initial step in this program would involve placing pods on Atlas test vehicles launched from Cape Canav eral [20]

At the end of 1960, the Chairman of the Aerospace Nuclear Safety Board, Lieutenant Colonel Joseph A Connor, Jr , of the United States Air Force announced an AEC position on safety in the nuclear space program Addressing the Atomic Industrial Forum, he stated that SNAP isotope and reactor devices had been thoroughly tested and found capable of burn-up on re entry into the atmosphere at speeds above 24,000 feet per second, for a burn up time of 300 seconds or more Connor concluded "the use of nuclear powered devices sufficient to meet all space requirements expected to be developed by 1980 would release but a small fraction of the radioactivity considered by the Federal Radiation Council to be tolerable for the general population "[21]

Firming a Base for Accelerated Space-Nuclear Achievements

President Kennedy had defined sharp views on new approaches to atomic energy and its control in the international arena at the outset of his Administration Glenn Seaborg, then Chancellor of the University of California at Berkeley, recalled being in the university's Radiation Laboratory on 9 January 1961 when President elect Kennedy called to ask him to accept the post of Chairman of the AEC Upon his acceptance, Seaborg found himself "plunged into a new kind of chemistry, that of national and international events "[22]

Seaborg was to find out that President Kennedy wanted a scientist as the AEC Chairman, and although he wanted a Democrat for that job, he was not interested in the party affiliation of those named to fill the other senior level positions within the agency "I felt my job as chairman was nonpartisan," said Seaborg, and he added that it became clear to him that in the nuclear field the new president wanted most to mobilize the scientific community and involve its members in the pending crucial decision on atomic energy [23]

Seaborg's heading the AEC proved a boon to the isotopic power program In the course of his career prior to entering government he had been involved in the discovery of plutonium and many of the transuranium elements He was co discoverer of certain isotopes, including Pu-239 and U-233 As the AEC Chairman, he kept abreast of developments in isotopic power, arranging to be briefed on RTG programs soon after his arrival at the agency [24]

Together with Seaborg, another man crucial to a growing space-nuclear partnership was James Webb, who was called on by the Kennedy Administration to head NASA as it stood on the threshhold of the space age Webb had held several key administrative positions in Washington He had been Executive Assistant to the Secretary of the Treasury in the early Truman years, and the Director of the Bureau of the Budget when the AEC was formed In 1952 he had served as Undersecretary of State Noted for his expertise in administration, Webb saw the New Frontier being faced by NASA as a venture in both space science research and development and administrative research and development [25]

When it was behind him, Webb saw the experience at NASA as a lesson in the role of political factors in essentially scientific programs He observed that

> If NASA program managers, scientists, engineers and top officials had not thought of their work in political terms if they had not arranged their activities to gain support from other NASA divisions, Congress, the Bureau of the Budget, the scientific community, etc —Apollo would not have met its goals
>
> political relationships are not something added on to the work of line managers or program officials as less important than other duties, these relationships are an integral part of their work, inasmuch as personal relationships and a sensitivity to the total environment are essential parts of leadership responsibilities if the system is to work at all [26]

A second basic lesson was the importance of being able to adapt to continuous change This, Webb found, was permitted by a feedback mechanism in the form of an executive secretariat established at NASA* to provide senior

*The secretariat at NASA consisted of Administrator Webb his Deputy Administrator Hugh Dryden and Associate Administrator Robert Seamans Jr management with reliable information, as well as the systematic exchange of officials between headquarters and decentralized offices. In addition to keeping senior management on top of things, the executive secretariat worked to insure a flow of information to other levels so that all NASA employees could grasp with greater clarity their specific roles in the accomplishment of established missions.[27]

Webb and Seaborg had not been close associates before they accepted their assignments in the Kennedy Administration. Seaborg met with Webb on his first Sunday after arriving in Washington and recalled that the two "hit it off from the start."[28] Their working relationship strengthened as they ushered their agencies' joint programs through many congressional hearings on Capitol Hill and through budget sessions within the Executive Branch.

Webb recalled that soon after his assignment at NASA there were pressing problems with the military which required immediate resolution. The Pentagon had not given up completely on its desire to be the lead agency in the space program. It saw the inauguration of a new president as a possible opportunity to swing the space effort from NASA to the Air Force. Defense Secretary McNamara, however, felt NASA should keep the space program, and key scientists around the country backed this support for civilian control.[29] McNamara's position was consistent with NASA's mandate by the Space Act to develop extensive relationships with universities and corporations and undertake a major cooperative effort to develop the scientific, technical, and administrative capabilities of the nation and its institutions. NASA was also mandated to share this effort with other nations, and therefore wanted the space program to be as open and non-secretive as possible. Webb later explained that he wanted to be able to "say to the press and the scientists and engineers of the eighty nations cooperating, 'Come and bring your camera.'"[30]

The "open" approach of NASA would lead to some problems in AEC-NASA relationships, since the mandates and the traditions of the two agencies differed in significant ways. A firm basis for cooperation was set by the two men who headed these agencies. The need for cooperation increased greatly once President Kennedy announced his challenging goal for space.

It was four months after Kennedy assumed the presidency before he stirred the nation with his startling and exciting goal of landing a man on the Moon by

1970. Seaborg recalled that he was present by special invitation[31] when the president, in a special message to Congress on 25 May 1961, announced:

> 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, ...I believe 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.[32]

Webb understood the significance of a "race" to put a man on the moon and he welcomed Kennedy's introduction of this concept. "It meant we had a target. I kept reminding Congress that we were committed to putting a *man* on the Moon and to demonstrating our technical capabilities in that achievement. Getting to the Moon would be proof positive that we had developed our capabilities in a full range of disciplines. If we could get man to the Moon and back with our technology, we could do anything." There were times, however, as NASA's program and budget quickly grew, when President Kennedy would question whether the full range of NASA's activities was necessary to carry out the landing on the Moon. "I told him we have to bring along the universities and the other institutions and push the total concept of development,'"[33] Webb recalled. One NASA task was to orchestrate the combined efforts of many universities and other institutions whose common goal was to make the fantasies of centuries become a reality within a few short years.

It was in the first year of the race to the Moon that the quiet technology got its chance to take its steps into space. Its proponents were impatient, but they too were learning about the importance of the chemistry of national and international events combining with technology in a total environment.

First Success in Space

The first successful use of RTGs in space occurred in a Navy satellite program. The Navy's Transit program had been underway for some time. It was a system for orbiting a navigation satellite that would provide accurate sightings for ships and planes in all weather conditions. The effort began at the Applied Physics Laboratory (APL) of Johns Hopkins University in 1957. The first link between the Transit developers and the isotope people at the AEC (and their Martin Company contractors) came about almost fortuitously, as John Dassoulas of APL recalled.

"I had been looking into the possibilities of isotopic power since we first began the Transit program. We had a five-year goal for the life of the operational Transit, and we weren't confident that the hermetic seals on batteries would hold up for five years. But I wasn't aware of the SNAP program at all."[34]

In 1958 the Department of Defense sponsored a big meeting in Pasadena, California about space (satellite) power. Dassoulas attended the conference but did not meet with any of the nuclear power people until, on his return flight, he found himself sitting next to Anderson, who headed the isotope SNAP work at the joint AEC-DOD office. Anderson responded to Dassoulas' expression of interest in isotopic power for the Transit program with an invitation for him to visit the Martin Company's Baltimore facility and to become acquainted with the work there on SNAP.[35]

Following the visit, Dassoulas returned to APL and asked for and received permission to use an isotopic SNAP device on Transit. Plutonium, however, was then unavailable because of AEC restrictions, and APL refused to permit the use of strontium-90 because of the excessive weight of the necessary shielding. The AEC eventually relaxed its policy and agreed to provide the plutonium fuel and SNAP-3A, as a result, was converted from polonium-210 to plutonium-238, permitting a power life of five years.[36]

At the request of DOD a development program was initiated by AEC in February 1961 "to provide two plutonium-238 isotope-fueled generators for TRANSIT satellites to be launched in June and July." The AEC, looking beyond the Transit mission itself, held that "a primary purpose of the flight test is to demonstrate the performance of a SNAP...generator under actual space conditions."[37]

Tests for the safe use of SNAP devices on Transit had been conducted the previous fall. The next spring "safety" remained a critical issue, although both the Transit people at APL and the RTG people at the AEC and Martin looked forward hopefully to a chance to fly the isotopic generator. The planned trajectory of the launch vehicle from Cape Canaveral was to take the Transit over Cuba and South America. This added further qualms to those advising caution because of anxiety about possible Cuban reactions to a fly-over after the Bay of Pigs incident.

In March, the Martin Company completed a comprehensive safety analysis of the Transit generator, focusing on potential hazards that might result if launch or re-entry failures were to occur. Martin concluded "that if the radioisotope generator considered is launched in the trajectory proposed for Transit vehicles, it will not produce a significant radiation hazard."[38]

In April, there were impact tests against granite at the Aberdeen Proving Ground to assess whether isotope containment would be maintained in the event the core experienced a crash landing.[39] That same month a hazards analysis report was prepared by the Division of Licensing and Regulation.[40] Later in the month this report and the Martin final safety report were shared at a joint meeting, attended by Navy, Air Force, DOD, and AEC personnel, where agreement was reached on the responsibilities of the various agencies.[41] In May, Seaborg and his fellow commissioners undertook extensive efforts to ensure the SNAP-3A's launch would be approved. Commissioner John Graham, Acting Chairman of the AEC, wrote to McNamara seeking his support and urging him to intercede at the State Department with Chester Bowles, who had expressed concern about the Transit trajectory over Cuba and South America.[42]

Seaborg's May 6 bi-weekly report to the president announced the AEC's approval of the SNAP-3 devices on pending Transit launches. His report urged Space Council and presidential approval of the missions, citing the findings of the hazards study that "any danger to the public is extremely unlikely." Seaborg told the president: "I call this to your attention since this first application of a nuclear auxiliary power source in space is likely to have a wide public impact." He then outlined the suggested procedures for a joint submission of the proposed plan by AEC and DOD to the Space Council for review. Were that not feasible, he said, a meeting could be arranged with Secretary McNamara, Secretary Rusk, and himself. Seaborg concluded: "It may be necessary to present the matter to you directly for your approval."[43]

In spite of Seaborg's efforts, the plan for a SNAP-3 demonstration on the forthcoming Transit launch was rejected by the National Aeronautics and Space Council, primarily because of objections from the Department of State. The Department of Defense, however, reassured Seaborg that it expected "provision will be made for a SNAP unit to be included in the next TRANSIT shot after the one scheduled in June."[44]

Reporters were quick to pick up on high-level government concern over radioactive material in space. On 16 May 1961, the *New York Times* pointed out that "cautious officials" had split with scientists on use of nuclear devices and that the "problem confronting the Administration...is not so much a technical decision as one of diplomatic, political and psychological considerations."[45] On May 19 the *Times* was more specific about the misgivings in certain U.S. government agencies—one article indicated that concern was evident at high levels. While officials believed the vehicle to be safe, concern had arisen, particularly in the State Department, "that in event of an unsuccessful launching, the satellite, with its radioactive parcel, could fall on Cuba or some other Latin-American country" provoking an international incident. Even a successful launch could lead Latin-American countries to "take offense about having radioactive materials flown over their territory."[46]

In early June hopes of the RTG proponents were high again; and throughout the month, right up to the June launch of Transit-4-A, hopes rose and fell. On June 8, Seaborg reported that he hoped for a reversal of the Space Council's decision but that he was not optimistic that a reversal could be achieved.[47] By June 23, however, hopes were high as Gilpatric of DOD told the AEC that the Defense Department was making a last attempt to get the State Department to go along with using the SNAP-3 device on Transit-4-A, scheduled for launch on June 27. Finally on the 23d, word came from Gilpatric that approval had been received.[48]

At the working level, perceptions of how it all came about varied. Robert T. Carpenter of the AEC thought that Seaborg asked the JCAE to intercede with the Space Council. Dassoulas believed that the go-ahead came about because Seaborg had dinner with President Kennedy one evening in June and persuaded him to approve the mission. All agreed that lead time was short and the situation hectic as the small RTG team found ways to get their device on the vehicle at Canaveral on time for the scheduled launch.[49]

According to Dassoulas, a fueled SNAP-3A device had already been shipped to the Cape sometime in June when, because of fears it might be launched without approval, an order came: "Return that thing to Washington and store it at the Martin Company." When the last-second go-ahead was received, the little team scurried to meet the deadline. "One of our people was a Marine Corps pilot, and he checked out a small plane so that he and Carpenter could fly that

RTG out of Andrews to the Cape,"* recalled Dassoulas. The device was kept overnight at the APL in Laurel, Maryland, after Carpenter obtained it from Martin. "We decided he should just bring it over here to APL in his car. I met him in the lobby and we put it in one of the labs, with the rooms on each side vacated." The guards were all instructed what to do and how to handle safety and security. The generator was in Florida the following evening, flown down by Carpenter and the pilot.[50] Finally, on 29 June 1961, after a 24-hour launch delay, a Thor-Able rocket launched three satellites simultaneously—including the first orbiting of an RTG in space.

Thus, two-and-a-half years after its debut on President Eisenhower's desk, the quiet technology made the front page headlines again. The *New York Journal American* of Thursday, 29 June 1961 announced:

U.S. ORBITS ATOMIC BATTERY

According to the newspaper "The successful orbiting of the nuclear device... gives American scientists a significant lead over Russia in the race to harness atomic power for space exploration."[51]

The AEC made efforts to capitalize on that first space-nuclear success by announcing in September that the "World's First 'Atomic Battery' In Space Continues to Operate Successfully" after ten weeks in orbit.[52] In October, Seaborg promoted the atom in space and advocated future applications of nuclear power in space before an international symposium of space scientists and engineers looking back on the success of SNAP-3A on Transit:

> The presence of the 'atomic battery' in the satellite is a symbol of a 'marriage' that was bound to occur—between Space and the Atom. We have known for some time that the two were made for each other. No one would be tempted, at the present time, to abandon other sources of energy for space. However, the atom has made greater strides toward coming of age for space application in the past few years than many of us could have hoped. The day is not far off when atomic energy will be available in many different packages for practical use in space vehicles.[53]

---

*Both Carpenter and Dassoulas recalled that the device was flown to Florida on Saturday for an expected Sunday night launch which was delayed until Monday night Official records show, however, that the launch occurred on Thursday 29 June 1961

As plans went forward for a second SNAP launching on another Transit in November, the political and environmental lessons learned were being applied. Seaborg addressed a letter to Vice President Johnson, who also served as chairman of the Space Council, lauding the Council's role in the June launch. He provided information about the new launch mission, and he said that he was anticipating that the Space Council would again play a critical role.[54] The Vice President replied that he was appreciative of this reference to the assistance of the Space Council in the June 29 launch and that the Executive Secretary would be asked to perform the coordination necessary for inclusion of a nuclear power source in the Transit-4-B launch.[55]

A second successful launching of a SNAP-3A, aboard a Transit-4-B navigational satellite, took place on 15 November 1961. The RTG team, this time with plenty of lead time and operating without the uncertainties of the pioneering launch, was ready at the launch pad. In the wake of this success would come a period of search by this small team for opportunities for the RTGs, which now had demonstrated their capabilities as power sources for space missions.