Nuclear Power: The Litmus Test for Space Exploration

Marsha Freeman reviews James A. Dewar's book on the history of the U.S. nuclear rocket program.[1] Without nuclear propulsion, a visionary manned space program is simply impossible.

Since the dawn of the space age, nearly 50 years ago, it has been well understood that using nuclear energy was the prerequisite to accomplish the goal of exploring the Solar System. Therefore, the fight over the nuclear rocket program, as James Dewar states in the Preface to *To the End of the Solar System: The Story of the Nuclear Rocket,* was not just a fight over a specific technology, but "a proxy: [the fight] was really over the future of the space program."

Those who for decades have opposed the nuclear rocket's development were not arguing against nuclear energy as such, but were trying to halt the only capability that would enable mankind to explore all the way "to the end of the Solar System"—as President Kennedy had put it in 1961.

On Jan. 14, 2004, President Bush placed a multi-decade space exploration program on the agenda, to develop the Moon, and then send human travellers to Mars. There are many drawbacks to the President's plan. The most serious is that it would cut back on space science programs and jettison use of the Space Shuttle and International Space Station—part of the infrastructure that was created to make manned trips around the Solar System more efficient.

One litmus test of the seriousness of the current space vision, will be whether the space nuclear programs are restarted. More than three decades ago, a nuclear reactor to produce electricity was successfully tested in Earth orbit by the United States. Advanced systems for using nuclear power for space propulsion were well along in their development and testing, and few technical issues remained to be resolved.

The nuclear rocket program was killed in 1972. Twenty years ago, under the umbrella of President Reagan's Strategic Defense Initiative, some further progress was made in space nuclear systems.

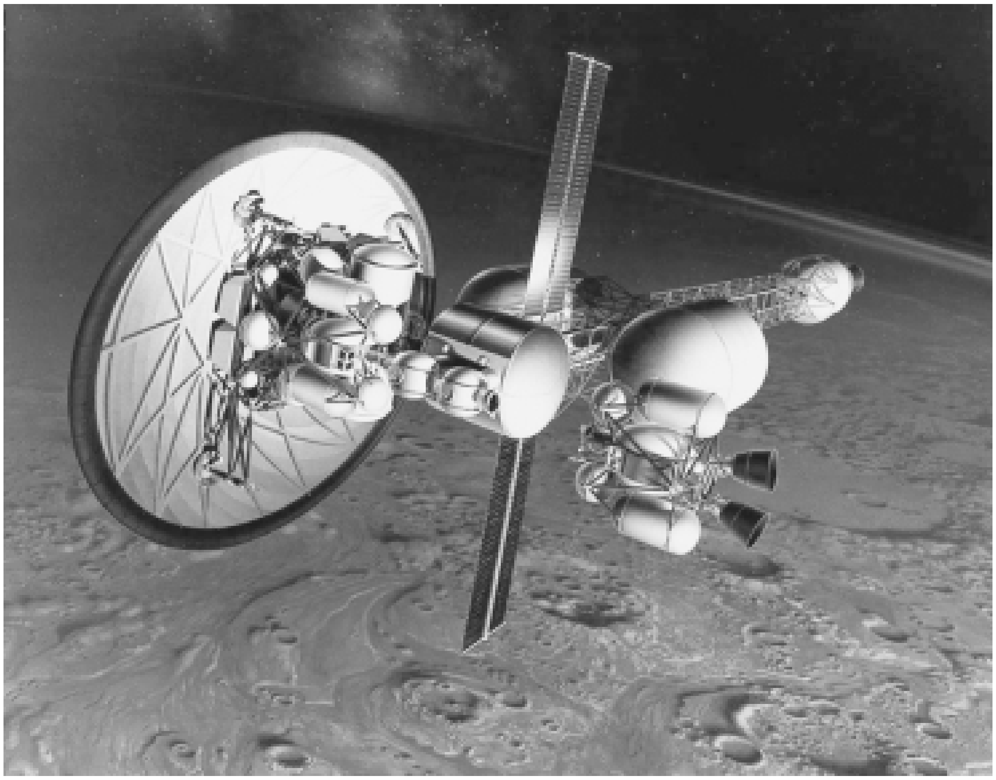
The fight over the nuclear rocket program never centered around issues of science or technology, but was philosophical and political. As Dewar documents, the stakes were the future of the space program.

From Defense to Space

It is not surprising that the first designs for the practical application of nuclear power to rockets came from the nuclear weapons laboratories, Los Alamos and Lawrence Livermore. At the end of the Second World War there was no civilian space program, so the first efforts to promote the development of nuclear rocket technology were to propose to the defense establishment that nuclear power replace chemical propulsion for intercontinental ballistic missiles. But, Dewar reports, the young physicists believed they were taking "the first steps to Mars. That was their agenda, but they had to take the military route, using Mars, the god of war, as V-2 scientists did in Germany."

But as the fission bomb was replaced by the smaller, lighter, and more powerful hydrogen bomb, the rationale for the nuclear-propelled ICBM disappeared, because standard chemical rockets were able to do the job. As the space age

1. *To the End of the Solar System: The Story of the Nuclear Rocket,* by James A. Dewar (Lexington: The University Press of Kentucky, 2004), $65, hardcover, 438 pages.



As early as 1960, NASA was investigating the use of nuclear propulsion. This artist's concept, from that time, envisions a nuclear thermal rocket-propelled spacecraft in orbit around Mars.

was about to dawn, the military nuclear rocket program was re-oriented from powering missiles toward lifting heavy payloads, such as satellites for military applications. In 1956 Los Alamos Laboratory was selected to develop Project Rover for nuclear propulsion.

Despite the enthusiasm of the scientists, the vocal opponents of nuclear power in space insisted it was too expensive, too dangerous, and unnecessary. But the nuclear rocket program had the aggressive support of a key group of Congressmen, led by Democratic Sen. Clinton P. Anderson of New Mexico. Echoing the writings and vision of early space pioneers, in 1956, Anderson discussed using space technology for weather modification and climate control, as well as "sending men to the Moon and colonizing the planets, which he felt should be international, to avoid wars for empires," Dewar reports. The following year, construction began at the Nevada Test Site near Las Vegas on facilities to test nuclear rockets, in an area picked by Los Alamos, called Jackass Flats.

Dewar reports that, confident that work on the nuclear rocket was progressing, Senator Anderson temporarily turned his attention elsewhere, concentrating on civil rights issues, and originating the key compromise that led to passage of the 1957 Civil Rights Act.

The Soviet Union's launch of Sputnik, in October 1957, led to a deluge of Congressional hearings and attacks on the Eisenhower Administration's lackluster civilian space program. It also created the opportunity to place before the nation's lawmakers the boldest, most visionary plans for space. Edward Teller, the physicist who worked in the Manhattan Project and developed the hydrogen bomb, stated at a hearing in November 1957, before the United States had launched anything into space, that nuclear rockets were necessary for interplanetary travel.

Under Anderson's guidance, the Joint Committee on Atomic Energy recommended to the White House that, in addition to upgrading nuclear weapons programs, the U.S. build the nuclear Navy, expand science education, increase support for Eisenhower's civilian nuclear program called Atoms for Peace, and give the nuclear rocket project the highest priority.

In remarks on the floor of the Senate during the debate on the creation of a civilian space agency, Anderson stated: "We don't know what space means now, but as we move into it, it will change us, give us different tools, technologies, and ways of looking at our own planet. And only with nuclear rockets can we have manned interplanetary flights, to Mars, and later interstellar travel. As we deliberate, let us be careful, as our decisions will influence those yet unborn, and perhaps someday may lead to peace on Earth, where men's minds are lifted from their Earth-bound hatreds into the universe." The space program was not seen only as a science and economic driver, but as a multi-generational social and cultural intervention into American society.

The Rover nuclear propulsion program was transferred from the Defense Department to NASA on Oct. 1, 1958, the day the space agency was created. In August 1960, under the urging of Congressional promoters, the Atomic Energy Commission and NASA created the joint Space Nuclear Pro-

Why Use Nuclear Energy?

James Dewar's history of the nuclear rocket focusses on nuclear thermal rockets, the most capable technology for space propulsion. The heat produced by the fission reaction is used to heat a propellant (generally, hydrogen), which is propelled at great speed out the back of the rocket engine, pushing the vehicle forward by producing a reactive, propulsive force.

The key to the increased efficiency and performance of nuclear engines over those burning chemical fuels, is the energy density of the reaction. Nuclear fission can create temperatures significantly higher than chemical burning, in a much smaller volume. The speed at which the rocket propellant is expelled, which is a function of temperature, is a crucial parameter in measuring the performance of any engine. The hotter it runs, the faster the propellant, the more efficient the engine.

Engine efficiency is measured as specific impulse, which is at most 450 seconds for chemical engines, up to about 850 for technology demonstrated by the Nuclear Engine for Rocket Vehicle Application (NERVA), and in the thousands of seconds for more advanced, gas-core nuclear reactor systems. Because it needs to carry both liquid hydrogen and liquid oxygen, only 6-8% of the Space Shuttle's gross weight is useful payload. For an advanced nuclear-driven system, the payload fraction could be more than double that.

What could you do with this vastly increased capability? One concept to make use of a nuclear engine's cargo capacity was put forward in the 1960s by space visionary Krafft Ehricke, which he called Helios. A chemical stage would boost a 15,000 MW nuclear engine to 100,000 feet, where the nuclear engine would be fired. Ehricke calculated that Helios could place a quarter of a million pounds in Earth orbit, or land 80,000 pounds on the Moon.

The high performance gained from nuclear propulsion could also be optimized to shorten trip times, trading off payload capability for speed. People could go to Mars in weeks, not months. Pluto could be reached by an unmanned spacecraft in less than 2,000 days, rather than a decade.

What would be the impact of using nuclear propulsion? Dewar states: "Instead of tiptoeing through the Solar System, these advanced propulsion ideas would allow humans to blast through gravitational fields and conquer the vast distances, to arrive in months or weeks, and then return."

—*Marsha Freeman*

pulsion Office to carry out the nuclear rocket project.

At the end of the Eisenhower Administration, there was some reluctance to embrace nuclear technology, with concerns voiced about safety, radiation, and "what other nations will say." Dewar likens this fear to that on the part of the "oil admirals" that Adm. Hyman Rickover faced when he started developing the nuclear Navy, "who feared sending men deep beneath the waves next to a radioactive reactor. It was probably the same as what the oil and coal officers faced a century earlier from the wind admirals, who feared putting men in the dark hold of a ship next to exploding boilers and steam lines, to be scalded to death."

Kennedy's New Ocean of Space

To pave the way for what they hoped would be a change in policy in the White House under an incoming Kennedy Administration, the Congressional promoters of the space nuclear program inserted a plan calling for the development of the nuclear rocket, as part of an accelerated space program, into the Democratic Party's Platform for the November 1960 Presidential election.

During this time, as Los Alamos was conducting tests on small-scale, high-density reactors that could fly in space, the manager of the Atomic Energy Commission/NASA Space Nuclear Propulsion Office, Harry Finger, called for bids from industry to develop the Nuclear Engine for Rocket Vehicle Application (NERVA). Not surprisingly, opposition from the Bureau of the Budget (BOB) was swift, and persisted throughout the duration of the program. Although Congressional enthusiasts may have exaggerated how quickly nuclear rockets could be propelling spacecraft, the BOB dishonestly objected that the AEC "grossly underestimated" Rover's cost.

In October 1960, an article published under Presidential candidate John F. Kennedy's name, urged a manned lunar landing, a space station, a space shuttle, and a nuclear rocket. But when the Kennedy Administration came to Washington, the President's science advisor opposed the Rover project, as did the budget director. To try to garner support for its hostile position, the BOB put out an estimate that a manned lunar landing would cost $45 billion—purposely a gross exaggeration, more than double what NASA estimated, and what Apollo ultimately cost.

The fight between the Congressional, scientific, and NASA promoters of space nuclear technology, and the anti-technology lobby and the budget balancers, finally came down to the issue of test flying a reactor; this would be an expensive phase of the project, and Congressional supporters knew that anything less would indicate that the program was just for research and development. Opponents were willing to continue a low-level R&D program, but had no intention of flying anything. The fight raged in Washington, with each side vying for President Kennedy's support.

The infighting temporarily abated after May 25, 1961, when President Kennedy made a speech on "Urgent National Needs," before a joint session of the Congress. In addition to proposing that the nation "land a man on the Moon and return him safely to the Earth," within the decade of the 1960s, the President approved a test flight for the Rover nuclear rocket, declaring that this technology "gives promise of some day providing a means for even more exciting and ambitious exploration of space, perhaps beyond the Moon, perhaps to the very end of the Solar System itself."

The importance of including the nuclear rocket project in the President's speech cannot be overstated. What he was proposing was not simply to land a man on the Moon, but a manned space effort based on long-term pre-eminence in space, specifically over the Soviet Union, which was our only competitor. This was not a program that would have an end point, but a commitment to keep the United States in the forefront of science and technology, and leadership in space for decades.

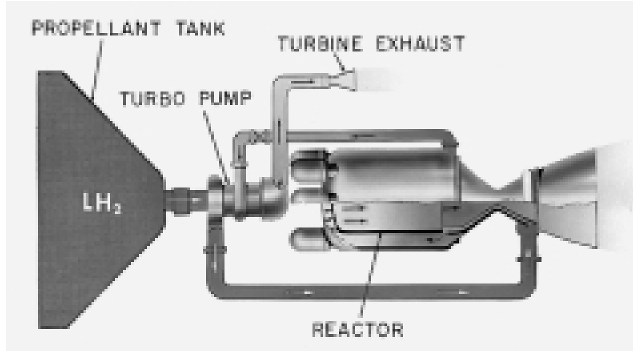
It was not long after the President's speech that the fight within the Kennedy White House resumed. Although the President had made his stand on the lunar landing virtually non-negotiable, by designating a deadline, there was room for the opposition to maneuver. They knew that they could not kill Apollo, but if they could kill the nuclear rocket program, they could cripple the manned exploration programs that would follow it. This would eliminate Kennedy's policy of "pre-eminence."

The opposition to the nuclear rocket program could not credibly be based upon any lack of technical progress, or fears of the effects of radiation or nuclear technology. So it was the fear of what the effort would *cost* that was mobilized as the principal argument.

Congressional supporters mounted eloquent counters to the false arguments put forward by the budgeteers. In a memorandum to Sen. John Stennis (D-Miss.) on July 19, 1961, less than two months after the President's Apollo speech, Senate Space Committee staffer Glen Wilson sought to counter the Budget Office's highly exaggerated estimate of $45 billion for the lunar landing, with his own more realistic estimate of $20 billion.

But regardless of the specific cost, Wilson wrote to the Senator: "Advanced technology gained by this effort will invariably produce 'by-products' of tremendous value to our country and its economy. New materials, new fuels, new manufacturing techniques, and new products will all find their way into every American home. Expanded communications systems and superior weather prediction through satellites will have tremendous impacts on society. New advancements in the life sciences will provide basic information about the human body which could lead to better health and longevity.

"The money spent on this effort will not be spent on the Moon—it will be spent in this country, right here on Earth. It will be spent in factories, laboratories, and universities, for wages, new materials, and supplies. There are very few who will not be benefited, directly or indirectly, in one way or another."



The Nuclear Energy for Rocket Vehicle Applications (NERVA) program involved the development of an advanced, compact nuclear reactor at Los Alamos Laboratory, and the rest of the rocket engine by NASA.

The tactic of gross overestimates of what the lunar mission would cost was applied to projections for a manned mission to Mars—the major mission which would require the nuclear rocket. In an interview with Voice of America in 1963, Kennedy science advisor Jerome Wiesner, who opposed all manned spaceflight, did not attack the idea head on, but used the tactic of "damning it with faint praise," as Dewar describes it. Wiesner proposed that the United States could indeed land a man on Mars by the year 2000, but it would cost $100 billion! As Dewar states: "It was a scare number," which the science advisor "pulled out of the same air as the Bureau of Budget's irresponsible numbers." NASA's own estimates at that time, were in the $32 billion range for the manned Mars mission.

The President—seeing dissent from his science advisor, opposition from Congress, pressure from the ever-present budget-watchers, and also the possibility of improving relations with the Soviet leadership—made the stunning proposal in September 1963 that the Soviet Union join the United States in sending men to the Moon. NASA's leadership worried that with a joint lunar mission, but without the follow-on nuclear rocket and Mars programs, pre-eminence would, by default, be jettisoned.

But the Soviet leadership never took President Kennedy up on his offer, and other events intervened. The President's assassination in November 1963, as he was about to deliver a speech in Texas on the importance of the space effort, brought Lyndon Johnson into the Oval Office.

President Johnson agreed to continue a research and development effort in the nuclear rocket program, but decided to kill the plan to flight-test a nuclear engine. NERVA was reoriented to a technology demonstration effort, consonant with the refusal of the new President to allow the space agency to formulate post-Apollo goals for the manned space program.

Years of Indecision

After the death of President Kennedy, the nuclear rocket program limped along. Impressive technical achievements were made, but the scientists and engineers could only wait for a White House decision to begin a post-Apollo program that would one day take men to Mars.

This dilemma, it seemed, was only made *worse* by the progress in the program, Dewar explains. Ground-based experimental nuclear reactor runs conducted by Aerojet and Westinghouse in the Fall of 1964 demonstrated that "in less than a year, the program was moving much, much faster than the five or so years originally expected, and this, in turn, implied Washington faced those postponed issues of flight tests and missions much earlier than anticipated or desired."

As progress continued in the ground tests, nuclear rocket supporters in Congress, in the Atomic Energy Commission and its laboratories, and in NASA, continued to develop mission scenarios and timetables for milestones, none of which had been approved by the White House.

In the Summer of 1965, nuclear rocket program head Harry Finger summarized the stalemate: "We agree NERVA II's missions include direct Moon flights, extensive lunar exploration, unmanned deep space shots, and manned planetary ventures. The question is, when do we do them?"

He proposed two possible approaches: If such missions were to start after Apollo, flight testing would have to be done around 1973—the more aggressive approach. Were the missions to be postponed to 1980, each year's funding would be less, but the total program "costs more and risks morale problems with people working fifteen years before anything flies. . . . The aggressive approach allows unmanned deep space shots since there are minimal technology requirements for it."

The more conservative option gives NASA time to develop the technologies required for "extensive manned operations," but unnecessarily delays the use of the nuclear technology, which, before it is man-rated, could be used for unmanned science missions. The unexpected progress in the program was increasing the pressure for policymakers to make decisions on the future not just of nuclear rockets, but of the space program overall.

In the Johnson Administration, the political tide was turning. Pre-eminence in space was replaced by the social programs of the "Great Society." NASA Administrator James Webb made a valiant effort to frame the necessary spending on space exploration within those terms, telling the President that the space program is "in its totality . . . truly representative of a Great Society. . . . It stimulates millions with new knowledge while its technologies upgrade our industries and universities. . . . This has almost explosive potential and in reality, the space program should be the cornerstone of your Great Society, and it can be if you increase its budget."

It was, at best, a rearguard action. The London Tavistock Institute and co-thinking social control institutions had, in fact, made the takedown of the space program one of the goals of the "Great Society" hoax.

By 1966, with no post-Apollo plan approved by the President, 80,000 layoffs in the space program were already under way. Soon, the real pressure on the budget became not Johnson's Great Society, but the war in Southeast Asia, which was costing $2 billion per month before he left office.

With the 1969 ascension of Richard Nixon to the White House, the future of NASA and the nuclear rocket only worsened. The Federal budget crisis, due in large part to the spending for the war in Vietnam, and also to the international financial crisis, led to government-wide reductions. Despite the recommendation of the Space Task Group which Nixon had appointed, that Apollo be followed by the development of a shuttle to Earth orbit, an Earth-orbital space station, nuclear-powered spacecraft to take men to Mars, as well as a cargo ferry to the Moon, this was not deemed possible.

The space plan that President Nixon approved was developed solely in order to fit into a constantly shrinking NASA budget. Saturn V rocket production was halted, and the last three planned manned missions to the Moon were cancelled. The space station, needed as a staging base for explorations beyond the Moon, was eliminated. And no one was going to go to Mars.

Senate supporters tried every possible tactic to keep the nuclear rocket program from being shut down. They defeated Nixon's project for a Super Sonic Transport plane, in retaliation for the cuts in the NASA budget. The legislators tried to hold hostage the funding for the Space Shuttle, which Nixon had approved, to the nuclear rocket funding. But finally NASA gave up the fight, when its budget could in no way support the planetary and manned missions that were the purpose of developing NERVA. While NASA Administrator James Fletcher proposed keeping alive a smaller nuclear engine program, George Shultz's Office of Management and Budget zeroed the funding. Finally, on Jan. 5, 1973, NASA stunned the Atomic Energy Commission and its own scientists and engineers, by announcing that all nuclear propulsion activities had been cancelled.

Ironically, Dewar reports, the Soviet Union, which had also been developing nuclear power for space applications, "simply did not believe the United States ended [the nuclear rocket program] after so much progress. They searched for it relentlessly: to end a program with so much potential was so illogicial that it must be a capitalist trick. . . ."

The Impact of the Nuclear Program

About $1.4 billion was spent between 1955 and 1972 on the nuclear rocket propulsion programs Rover and NERVA, and about 8,000 specialists worked on them. The technologies developed through those programs had wide-ranging applications throughout the economy, as supporters had predicted they would.

To place in context the contributions of the space nuclear program, Dewar points out that it was "neither pent-up consumer demand, the automobile and housing industries, nor public works spending [that] drove the economic boom in the decades following World War II. They certainly played a major role," but "it was the development of increasingly more sophisticated nuclear weapons by the weapons and laboratory complex, and then the application of that complex to civilian purposes," plus the military and civilian space program, that "pushed the economy to greater prosperity."

Although the Rover and NERVA programs remained classified throughout their 18-year life, over 100,000 unclassified reports were produced, exchanges took place between industry and laboratory personnel, other technology transfer arrangements were made, and vendor qualification programs forced companies to learn how to do precision work they would never have otherwise attempted.

The materials developed to withstand high temperatures and corrosive nuclear environments, over a long life, revolutionized technology in medical instruments, machine tools, and industrial applications.

Dewar relates how the methodology and analytical techniques developed to manage the nuclear rocket program achieved such a high reliability and safety at Westinghouse, that the company assigned executives from other divisions to the NERVA program for several years, and then rotated them back to their former positions, to apply these new skills throughout the company.

How could a program with such a record of success, that was so vital to the future of space exploration, and had already pushed forward nuclear and industrial technologies, just simply be ended?

Dewar points to the cultural and political change in the nation, reflected by the cultural change of policymakers in Washington. Optimism, economic progress, and innovation were replaced through the 1970s by anti-technology "environmentalism," and fear. Along with this went the dismantling of the institutions that had represented traditional American values, replacing the "producer society" with a "consumer society." In 1976, the Senate abolished its Space Committee, as did the House. The Atomic Energy Commission was abolished during the Nixon Administration, to be replaced with an agency focussed on conservation, so-called "renewable" energy, and fear of anything nuclear. Tearing up these institutions ensured there would be no cohesive lobby for space or nuclear programs.

A generational difference also led to the demise of these programs, Dewar points out: "One could contrast different generations in Congress, for example, those who served [in Congress] after World War II versus those who served after

Dr. Glenn Seaborg on 'The Nuclear Space Age'

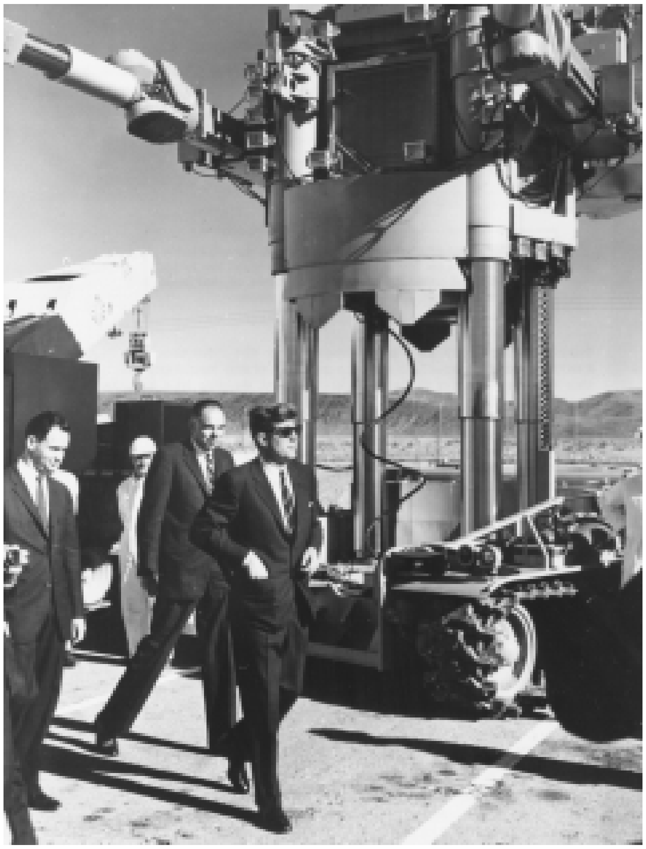
"It is indeed of epochal significance that man has recently become spaceborne after his previously long earthbound existence," wrote Nobel Laureate Glenn Seaborg in an undated pamphlet with the above title, in the late 1960s. The Apollo 11 spacecraft had not yet landed the first men on the Moon, but Dr. Seaborg, the chairman of the Atomic Energy Commission, was looking into the future. "I believe it is providential that our advancing development of the atom and our entrance into space are currently taking place side by side, in what might be called the Nuclear Space Age," he wrote. Dr. Seaborg explained that the major advantage of nuclear energy in space is its compactness, a result of its higher energy density, as compared to the burning of chemical fuels.

Electricity produced in a space nuclear reactor is crucial, where solar energy is not readily available—such as during the two-week lunar night, or at the outer planets. Nuclear reactors will also be the enabling technology for extended manned missions to the Moon and planets, where sophisticated scientific instruments, the processing of raw materials, life support systems, and industrial activity will require multi-megawatts of power.

Even close to Earth, he explains, high-powered nuclear systems producing power will enable a variety of activities at manned space stations, and perhaps in the future, Dr. Seaborg proposed in the 1960s, as author Arthur Clarke had suggested, a system of satellites to enable "communications marvels," such as an "orbital post office providing delivery of copies of letters anywhere in the world only minutes after original letters are posted."

Apart from the practical applications of space technology, however, Dr. Seaborg considers more important the "intangible reasons" for exploring space. "The Age of Space is perhaps the most exciting time in human history since the Age of Discovery that followed Columbus' voyage. . . . When it was possible to explore the atom, we did not hesitate. It has now become feasible to explore space. We dare not shrink from the adventure. We cannot draw a curtain over a New World that is within our grasp. We cannot sit at home, so to speak, and hear second hand of new wonders that men have pondered through the ages. Our enthusiastic participation on the frontier, wherever the frontier exists, is necessary for our continuation as a dynamic and creative people. If there were no other reason for space exploration—and there are a great many more—this one would be good enough for me."

—Marsha Freeman



In his "Apollo" speech, President Kennedy called for accelerating the nuclear rocket program. Here, the President visits the Nuclear Rocket Development Station in Nevada, in 1962. Behind the President is Dr. Glenn Seaborg, chairman of the Atomic Energy Commission, and on the left is Harry Finger, director of the nuclear rocket program office.

Vietnam. The older generation appeared more proactive, promoting the economy and creation of jobs, overseeing the administration, making it acountable and punishing its questionable deed . . . and finally, taking a personal interest in programs."

"Post-Vietnam Congresses, however," he stated, "appeared more concerned with perceived excesses of science and technology. . . . [T]hey set up two often conflicting mantras: saving the environment and enhancing education." The intense and long-term support for space nuclear programs by Congressional figures, such as Senator Anderson, Dewar concludes, who "spoke of colonizing the Solar System a year and a half before Sputnik, . . . had a vision and acted out of principle." What got lost starting in the 1970s, he states, was "the state's traditional role of providing for the common defense and promoting the general welfare and using technology to do so."

During the mid-1980s, President Reagan's Strategic Defense Initiative once again put the need for nuclear power in space on the agenda. The Department of Defense carried out classified projects to re-look at space nuclear power. Nuclear pioneer James Powell, then at Brookhaven National Laboratory, who has developed many creative designs for space nuclear systems, developed a very small nuclear reactor for space propulsion under the SDI. He reports that advanced fuel particles, that could operate at 3,000° Kelvin for several hours, were tested. In a roundtable discussion on space nuclear power, sponsored in August 2004 by the American Institute of Aeronautics and Astronautics, Dr. Powell described some of the advantages of a nuclear reactor propulsion system. Such a system would allow a spacecraft to explore Jupiter's moon Europa, after only a two-year travel time. The high-density power would allow a small craft to land on and take off from planetary surfaces, and could even be re-fueled by electrolyzing water or ice from icy bodies, to obtain the hydrogen needed for propellant.

All of the nuclear "old hands" agreed with Dewar's advice in his book, that no new program should "reinvent the wheel," but rather start with the rich heritage from Rover and NERVA.

Mission-Oriented Exploration

Through the 1960s, when the nuclear rocket program was under constant attack, a courageous fight was made by the program's supporters, such as AEC Commissioner James Ramey. He argued for developing enabling technologies even if they do not have a "mission." The demand that there be requirements for a new technology before spending Federal dollars, he explained, came from the military, which was buying "off-the-shelf things such as guns or tanks. . . . Then the budgeters applied it to research and development, saying nothing should move beyond the prototype stage until a requirement existed."

On the contrary, he stated, "development programs should be carried out that have potential for a broad range of missions, not just a specific one." Using that approach keeps "open the real possibility that once something reaches the prototype stage, many applications will be found for it that were never considered originally."

Dewar agrees with this approach, stating that "insistence on having firm missions before permitting development, if it had existed earlier, would have prevented development of nuclear weapons, [nuclear] submarines, and [nuclear] power plants."

But Admiral Rickover surely had the goal of placing Navy nuclear reactors in submarines when he started his R&D program. And little nuclear engineering would have been funded, but for the promise of providing a new, more advanced technology for producing electric power. The potential applications existed before the technologies were ready.

Although under rational policymaking, research and development would be carried out on a broad scale, from the standpoint that the investment the nation makes in such endeavors, regardless of their specific applications, will provide economic returns in multiples of their cost.

Throughout the history of the space program, innovative future missions were constantly being planned, but real leaps in technology were made only when there was an urgent need to meet a mission goal. When new techologies are developed, they will be applied anyway in myriad ways no one ever thought of, no matter what mission they were ostensibly designed for.

That techologies are developed to accomplish a mission, was understood by the opposition. In remarks made to President Johnson in 1964, before he left his post as President Kennedy's science advisor, Jerome Wiesner stated: "I've long argued Rover should be a laboratory effort because it lacks missions. Now, I've analyzed NASA's programs and find they are sneaking piecemeal into manned Mars [missions]. . . . They may be stealthily doing manned Mars without your knowledge or approval." From Wiesner's standpoint, that was the real "danger."

By 1966, Harry Finger was able to report at the International Astronautical Congress (IAC) in Madrid, that an operating time of 30 minutes had been achieved at a full design nuclear power reactor for 1,100 megawatts, equivalent to 55,000 pounds of thrust. The following year, a full-power test reactor had operated for about an hour—longer than would be required for most operational space missions, he explained, at an IAC meeting in October 2002. The ability to throttle the nuclear engine, or change the power levels while maintaining a high efficiency, was also demonstrated.

By the late 1960s, "the technology of the nuclear rocket propulsion was fully demonstrated as being ready for flight mission applications, but neither commitments nor even plans were made in the U.S. space program" to make use of this technology, Finger stated.

President Bush has put forward a program to go back to the Moon and then to Mars. This certainly sounds like a mission. But the idea that this can be done without making the necessary investments, by scrapping the infrastructure that NASA has spent decades and tens of billions of dollars creating, and by using "off-the-shelf" commercial technology, makes it worse than a hollow promise.

The President has proposed that to replace the Space Shuttle, crew members be taken into space in a Crew Exploration Vehicle. But this vehicle will not make use of nuclear propulsion; in fact, it will not even be launched on a new, more efficient chemical rocket, or more advanced hypersonic vehicle. Instead, NASA has been told to find commercial products—rockets used today to launch satellites—that can be man-rated for space exploration.

NASA has initiated a low-level effort to re-evaluate nuclear propulsion technology. Finger and Dewar warn, that the most foolish thing that could be done, would be to "reinvent the wheel." The nuclear propulsion program NASA is presently designing should start from the dramatic successes of the Rover/NERVA effort. This includes bringing in the veterans. "I know that all those who had that previous nuclear experience and are still here will be eager to join the effort," Finger said, "including me!"