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Reacting to nuclear power systems in space: American public protests over outer planetary probes since the 1980s

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ABSTRACT

The United States has pioneered the use of nuclear power systems for outer planetary space probes since the 1970s. These systems have enabled the Viking landings to reach the surface of Mars and both Pioneers 10 and 11 and Voyagers 1 and 2 to travel to the limits of the solar system. Although the American public has long been concerned about safety of these systems, in the 1980s a reaction to nuclear accidents – especially the Soviet Cosmos 954 spacecraft destruction and the Three Mile Island nuclear power plant accidents – heightened awareness about the hazards of nuclear power and every spacecraft launch since that time has been contested by opponents of nuclear energy. This has led to a debate over the appropriateness of the use of nuclear power systems for spacecraft. It has also refocused attention on the need for strict systems of control and rigorous checks and balances to assure safety. This essay describes the history of space radioisotope power systems, the struggles to ensure safe operations, and the political confrontation over whether or not to allow the launch the Galileo and Cassini space probes to the outer planets. Effectively, these efforts have led to the successful flights of 12 deep space planetary probes, two-thirds of them operated since the accidents of Cosmos 954, Three Mile Island, and Chernobyl.

1. Introduction

Since the dawn of the space age more than fifty years ago, nuclear power systems have been used for many long duration missions. While these technological systems made possible a myriad of accomplishments in space, especially the successful flights to the outer planets, controversies surrounding the propriety of using space nuclear power sources have periodically arisen and enraged the public. This essay will analyze the use of this technology to power spacecraft and the public debate over the propriety of its employment in the Galileo and Cassini space probes, with some discussion of the New Horizons and Curiosity launches in the last decade.

For the first decade and a half of space nuclear power the American public, even though it had an interest in the risk nuclear systems portended, did not register serious misgivings about the use of this technology in space. This changed rather dramatically in the latter 1970s in response to two incidents, the 1978 the Soviet Cosmos 954 accident which spread radioactive debris over more than 100,000 square km in Canada and the 1979 Three Mile Island nuclear power plant accident. Accordingly, support for the use of nuclear power in any setting quickly eroded. As one anti-nuclear group commented: “As we launch more and more radioactive materials on spacecraft there will be even more opportunities for accidents: Three Mile Island, Apollo 13, Chernobyl, etc., demonstrated that low probability events do in fact occur” [1].

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Since that time every American deep space mission – of which there have been six – that used some type of nuclear system elicited important protest efforts[1]. The first example came with the deployment of the Galileo probe to Jupiter in 1989. Because of Galileo's deployment from the Space Shuttle, it would only be able to reach Jupiter using a gravity assist trajectory that required it to pass close to Venus and have two swings past Earth before sling-shotting on to Jupiter. The possibility for Galileo's uncontrolled reentry into the Earth's atmosphere on one of its flybys added to other concerns. Protesters had a point, Carl Sagan, agreed: "there is nothing absurd about either side of this argument" [2].

Such has remained the case to the present. The launch of the New Horizons spacecraft to Pluto and the Kuiper Belt in 2006 and the Mars Science Laboratory (Curiosity) on November 26, 2011, is only the most recent example of this longstanding debate.

1.1. Origins of nuclear power systems for spaceflight

In the latter part of the 1940s several engineers began to consider the possibility of using nuclear power sources for space exploration. The seminal document in this consideration appeared in 1946 from the newly-established RAND Corporation on a *Preliminary Design of an Experimental World-Circling Spaceship*, exploring the viability of orbital satellites and outlining the technologies necessary for their success [3]. It did not take long for scientists and engineers to incorporate nuclear power sources into their considerations and 1947 brought the first publications concerning the subject [4]. By 1949 a full-scale analysis by RAND had sketched out the large-scale use of nuclear power sources for satellites in Earth Orbit [5]. Beginning in 1951, at the Department of Defense's (DoD) request, the Atomic Energy Commission (AEC) sponsored research into nuclear power for spacecraft to support the United States Air Force's (USAF) Project Feedback study, leading to the development of a reconnaissance satellite. By June 1952, as reported in an early classified study of the effort, "preliminary results of the reactor analyses were available; all were favorable to the feasibility of the proposal". This extensive and positive discussion of radioisotope power systems for space application led to an exponential growth in interest in nuclear power for space satellites. A year later, in May 1953, USAF Headquarters took the next step by authorizing development work on a nuclear power source for satellites. This research effort led directly to the nuclear power systems used on spacecraft in the early 1960s [6].

The AEC oversaw this effort, pursuing two related avenues. The first led to a small nuclear reactor and the second to the RTG, or radioisotope thermoelectric generator. Codenamed SNAP for "Systems for Nuclear Auxiliary Power," these power sources were numbered with the odd numbers designating RTGs and even numbers for the small nuclear reactors. For the RTGs, SNAP-1 was built at the Mound Laboratory under Atomic Energy Commission's (AEC) supervision in 1954. It used a thermocouple heated by polonium (Po)-210 for fuel. Exceeding all expectations, SNAP-3, used advanced thermoelectric conversion devices with the first Po-210 fuel compressed into pellets; these pellets would soon become a standard in future RTGs regardless of the type of fuel used. Power generation with an RTG was simplicity itself. The nuclear material generated heat through the decay of the radioactive source. The heat was conducted through thermocouples to create electrical power for the spacecraft. It's capabilities were modest to be sure, and power management was always a consideration in these systems, but they lasted for years and could power a spacecraft on extended missions. In the reactor arena, the SNAP-2 system used a 50-kW(t) reactor system weighing about 600 pounds employing liquid NaK – a sodium (Na) and potassium (K) alloy – as a coolant to transfer heat through a mercury loop. This reaction, basic chemistry really, produced 3 kW of electricity. This led to the research on two additional space power units, SNAP-8 and SNAP-10, emphasizing a metal hydride reactor technology first used in SNAP-2 [7].

These efforts led to a longstanding record of success in meeting the electrical needs of deep space vehicles while offering both reliable and safe operations. As historian Richard Engler concluded:

> The history of the radioisotope power program is basically a success sto[r]y, 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.

This technology proved exceptionally quiet for most of its history, until the latter 1970s when concerns about all things nuclear erupted in the public consciousness. This was in part because it involved neither explosive power nor a human built reactor to operate [8]. Even so, it had been discussed at the highest levels of national discourse. President John F. Kennedy in 1961 believed that nuclear power would be used to send Americans in space, while "Nuclear Power will sustain him [humanity] there" [9].

The possibilities of space nuclear power first entered the public sphere in January 1959 when President Dwight D. Eisenhower posed for a photo op with an RTG in the Oval Office of the White house. It was SNAP-3, the AEC-developed power source on which so many involved in the space program pinned their hopes for exploration of the solar system. AEC officials hailed this RTG as a "significant breakthrough," one that was reliable, simple, flexible, safe,

[1] While Radioisotope Thermoelectric Generations (RTGs) had been Used Extensively for Lunar Exploration, I have Chosen in this Essay to Focus on Outer Planetary Exploration, which Requires such Power Sources to have any Hope of Success – Not Something Absolutely Necessary for Lunar and Terrestrial Planetary Exploration – and to Deal with the Controversies Since the 1980s Concern this Technology's Use.