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MARSHALL SPACE FLIGHT CENTER AND THE REACTOR-IN-FLIGHT STAGE: A LOOK BACK AT USING NUCLEAR PROPULSION TO POWER SPACE VEHICLES IN THE 1960'S

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ABSTRACT

This paper examines the Marshall Space Flight Center's role in the Reactor-In-Flight (RIFT) project that NASA was involved with in the early 1960's. The paper outlines the project's relation to the joint NASA-Atomic Energy Commission nuclear initiative known as Project Rover. It describes the justification for the RIFT project, its scope, and the difficulties that were encountered during the project. It also provides as assessment of NASA's overall capabilities related to nuclear propulsion in the early 1960's.

INTRODUCTION

Ideas about harnessing nuclear energy to propel everything from cars to locomotives to rockets have been around for more than 50 yr. In May 1940, *The Boston Globe* ran the headline: "Just add cold water, fly to the stratosphere. One pill of U-235, miracle substance just announced, would drive an automobile for a year..." Six years later, *The Associated Press* reported that the "The Buffalo Machinery Co. eventually expected to power locomotives from coast to coast at a cost of less then $1."

After World War II, engineers began serious studies regarding how to propel rockets using nuclear propulsion. In June 1946, the Division of Reactor Development for the Atomic Energy Commission (AEC) asked the Applied Physics Laboratory (APL) of The Johns Hopkins University to study the feasibility of nuclear propulsion. Six months later the APL concluded that a nuclear rocket was feasible, but expressed concern over the associated technology problems and expense.

In the early 1950's, Wernher von Braun and co-author Willy Ley wrote, "it is entirely possible... that within a decade or so successful tests with some sort of nuclear rocket propulsion system might be accomplished." About the same time, W. Bussard of the Atomic Energy Commission's Oak Ridge National Laboratory authored *Nuclear Energy for Rocket Propulsion.* Historian Tom Heppenheimer says Bussard work "stirred interest, and led to the initiation of an experimental effort called Project Rover at Los Alamos, New Mexico. Initial work aimed at building a succession of rocket reactors, named "Kiwi" after the flightless bird of New Zealand.

Project Rover included the Kiwi nuclear reactor, the nuclear engine for rocket applications (NERVA), and the RIFT stage. Project Rover was intended to develop test reactors and solve problems involved in achieving high-power density. Engineers also wanted to develop reactor materials capable of withstanding high temperatures and to investigate concepts for converting nuclear energy into useful propulsion forms. Reactor development in Project Rover was under the technical direction of the Los Alamos Scientific Laboratory.

POTENTIAL REACTOR-IN-FLIGHT CAPABILITIES

This paper summarizes Marshall Space Flight Center's (MSFC's) responsibilities in Project Rover. MSFC managed Project RIFT. RIFT… "will furnish the vehicles for the first flight tests of nuclear-rocket engines and will demonstrate the practicality of nuclear-rocket propulsion for space-vehicle applications," wrote Colonel W. Scott Fellows in 1962. Fellows, under assignment to NASA from the U.S. Air Force, was chief of MSFC's Nuclear Vehicle Projects Office.

In the early days of planning for the Apollo program, NASA considered the possibility of direct flights to the moon using a tremendously large Nova chemical rocket. In July 1961, von Braun extolled the Nova's capabilities. "With Nova, we could land a locomotive on the Moon, if anyone wanted one there," he declared, pointing out that Nova vehicles would "give us the most direct approach to manned lunar and planetary exploration." In addition, Apollo planners also studied direct flight to the moon using a nuclear Saturn. This meant using the Saturn V lower stages, but replacing the S-IVB stage with a RIFT nuclear stage. The plan was to take the flight version of the NERVA under Project Rover and test it on a Saturn named RIFT. "Possible applications of a nuclear Saturn would include carrying large payloads into Earth orbit, to the moon or beyond," Marshall officials stated in 1961. "With chemical rockets, only about five percent of the total weight is payload. With a nuclear system, 16 percent can be payload," engineers said. They also studied nuclear propulsion for post-Apollo manned interplanetary and solar system escape missions. Nuclear propulsion systems, they calculated, could provide between 890,000 to 1,100,000 N of thrust.

REACTOR-IN-FLIGHT ORGANIZATION AND MANAGEMENT

The executive order that created NASA on October 1, 1958, transferred responsibility for the nonnuclear aspects of Project Rover from the Air Force to the new civilian agency. Two years later, NASA and the AEC formed the joint Space Nuclear Propulsion Office (SNPO) to serve as an interface between the two agencies.

During the 10-yr period prior to its transfer to NASA in 1960, Dr. Wernher von Braun and his rocket specialists working for the U.S Army in Huntsville had focused on chemical rockets. When the von Braun team transferred to the new NASA Marshall Space Flight Center in Huntsville in the summer of 1960, chemical rockets were still Marshall and the Nation's top priority. However, nuclear propulsion appeared promising for long-range programs and for ≈2 yr, the Marshall Center managed RIFT, a key part of Project Rover. Responsibility for Kiwi was assigned to the SNPO. NASA funded Aerojet and AEC funded Westinghouse to work on NERVA.

In June 1961, MSFC established a Nuclear Vehicle Projects Office to supervise and coordinate the development of high-thrust nuclear propulsion rocket stages for future Saturn and subsequent vehicle systems. Fellows became chief of the new office. William A. Brooksbank, Jr., became his deputy. The new element assigned to MSFC's Structures and Mechanics Division was directed by William A. Mrazek. Plans called for a staff of eight engineers. The new office would manage the development of the RIFT vehicle, proposed to be flight tested as the second stage of a future Saturn C-3 booster within the 1966–1967 timeframe.

Studies conducted by General Dynamics-Astronautics, Douglas Aircraft Company, Lockheed Aircraft Company, and the Martin Company indicated that a nuclear-powered rocket flight test could be launched as an upper stage of a chemical rocket in the Saturn class.

PROJECT PLAN

The RIFT vehicle consisted of an S-IC stage, an S-II stage, and a Saturn-Nuclear (S-N) stage. The RIFT stage itself would be slightly longer than 80 ft. The RIFT stage mounted on the S-IC and S-II stages of the C-5 would provide a vehicle of ≈350 ft in height. Five Rocketdyne F-1 engines on the S-IC stage would provide 7.5 M lb of thrust. Five Rocketdyne J-2 engines would provide 1 M lb of thrust for the S-II. A NERVA using liquid hydrogen propellant would power the S-N stage. Ten RIFT vehicles were to be produced and tested—six for ground tests and four for flight tests—as the third stage of the Saturn C-5 space vehicle. "While RIFT is an experimental test bed for nuclear propulsion, the stage is being designated as a potential stage for an operational nuclear rocket. A C-5 vehicle would be able to carry two to three times as much weight into Earth orbit as an all-chemical Saturn C-5 rocket. For deep space missions, the advantage is even greater," Fellows said. Five of the six ground test vehicles would undergo various types of testing at the Nuclear Rocket Development Station in Nevada. The other test vehicle would be brought to MSFC for dynamic testing.

The four flight units would be fired from Launch Complex 39, Cape Canaveral. In the first flight, the NERVA powering the stage would be inert, i.e., one that cannot go "critical." The other three flight units would be powered by "live " nuclear engines that would be operated only outside the atmosphere.

In 1962, Lockheed was selected to build the vehicle that would accept the Westinghouse/Aerojet NERVA. Lockheed began tank and insulation design. A photo and caption published in the Marshall Star in July 1963 pictured a Lockheed engineer demonstrating the "lightness of a foam material which is being tested by Lockheed as possible insulation for the fuel tank of the giant RIFT nuclear-powered space vehicle. The material is known as 'Freon blown rigid polyurethane' and a cubic foot weight only a pound and a half." Fellows also reported that the project would include a RIFT radiation testing program that would be conducted by Georgia Nuclear Laboratories, located on an 11,500-acre reservation near Dawsonville, Georgia. The program would determine the amount of radiation-induced deterioration in vehicle components and its subsystems. The RIFT was to be built in the dirigible hanger at Sunnyvale, California. Marshall also announced plans to develop a huge RIFT stage transporter 25 ft wide, 75 ft long, and able to carry up to 80 t. Tractor and transporter would roll on 50 tires at a maximum speed of 15 mph.

GAINS AND LOSSES

RIFT was ill fated since its own progress depended on the progress that NASA and the AEC made on the Kiwi Reactor and on the NERVA. It also validated von Braun's belief that nuclear propulsion was still an infant technology in the early 1960's and needed much more work before it would ever become viable.

In the late 1950's, engineers focused on reactor development in Project Rover. The first facilities at the Nevada Test Site were completed. On July 1, 1959, Kiwi A, the first test reactor, passed its first hot-fire test successfully (5 min at 78 MW) after which it was disassembled and inspected. Kiwi A was the first step in AEC's reactor test program. It was designed to demonstrate that a high-power reactor could heat a propellant quickly and stably to high temperatures. In addition, it was intended to establish basic testing procedures. It was also designed to determine the basics of graphite hydrogen interaction. Kiwi-A was a heat exchanger device in which propellant, heated in a reactor core, was expended to the atmosphere through a nozzle. When Kiwi A passed its first test, many were convinced that a nuclear rocket was possible.

During 1961 and 1962, however, engineers continued to experience Kiwi reactor failures. For example, in November 1961, a hydrogen gas leak caused an explosion. The next month, a hydrogen leak caused a large fire. In March 1962, after a Kiwi reactor failed a preassembly test, it was redesigned and AEC personnel began assembling another Kiwi, but they encountered problems with that configuration too. More trouble came in November 1962 during a test that resulted in extensive core damage.

In December 1962, officials briefed President Kennedy on the nuclear propulsion program at Los Alamos. He agreed to continue funding a test program, but it would be an abbreviated program. By January 1963, officials decided to reorient Project Rover with more emphasis on component evaluation and cold tests. Work then slowed because of the delayed progress on the NERVA itself. After that, the program for specific construction of the RIFT failed to materialize, although some design studies were implemented during the late 1960's.

Von Braun's public statements about nuclear propulsion in the early 1960s showed that he believed nuclear propulsion held potential but not for the near term. For Apollo, chemical propulsion, the von Braun team's mainstay since World War II, was more expedient than nuclear propulsion. Von Braun knew this and, in fact, stated as much in April 1961. He had already addressed nuclear propulsion in his famous April 29, 1961, letter to Lyndon Johnson who had been asked by Kennedy to study what chances the United States had to win the moon race. In the letter, von Braun told Johnson that the "basic technology of nuclear rockets is still in its infancy. "Further, he called nuclear propulsion a "promising means to extend and expand the scope of our space operations in the years beyond 1967 or 1968." However, he warned Johnson, that nuclear propulsion "should not be considered as a serious contender in the big booster problem of 1961."

In 1962, Scott Fellows prepared testimony for von Braun regarding the RIFT and the progress made in Project Rover. The progress report was for the Subcommittee on Research, Development, and Radiation Joint Committee on Atomic Energy. Apparently, in defense of MSFC's own progress regarding the RIFT, Von Braun pointed out that the RIFT was "keyed to the development made in the NERVA project and the NERVA engines for RIFT systems testing." In addition, his comments about the likelihood of developing a nuclear-powered vehicle and solving the associated technical problems in the near-term were cautious. "I believe that we now have enough knowledge to logically pursue an orderly program. However, intensive effort and hard work are required to successfully accomplish the program objectives."

Von Braun was more optimistic about the long-term future for nuclear propulsion. He addressed the subject in Tulsa, Oklahoma, on May 26, 1961, at the First National Conference on Peaceful Uses of Outer Space." With a nuclear third stage, a Nova vehicle could be placed into orbit around Mars and returned to Earth later on. " On November 20, 1963, he participated in panel discussion on the future of nuclear energy in space. Planning for the Project Rover program, von Braun said, called "for a nuclear rocket to be available in time to support the follow-on phases of the present Apollo manned lunar landing program, and for follow-on programs of unmanned and manned exploration of the nearby planets as well as unmanned probes of the more distant planets."

Kennedy's speech before a joint session of Congress on May 25, 1961, is often identified as the kickoff date for the Apollo Lunar Landing program. Its eloquence references to landing a man on the moon "before this decade is out " kindled the Nation's interest in the space program. To a lesser extent, it also generated optimism among space program insiders regarding nuclear propulsion. According to historian David Portree, "NASA and AEC together were authorized to spend $77.8 million in FY1962. Funding in the preceding 15 years had totaled about $155 million." Unfortunately, some may have become overly optimistic. For example, Portree points out that William House, Aerojet-General's Vice President for nuclear rocket engine operations, felt sufficiently optimistic to publicly predict in October 1963 that a Saturn V would launch a 33-ft-diameter RIFT vehicle to orbit in 1967. House also predicted that one NERVA stage would eventually be able to inject 15 t on direct course to Mars, or 3 t on a 3-yr flight to distant Pluto.

Unfortunately, Congress and President Lyndon Johnson lacked House's optimism regarding nuclear propulsion. They eliminated all funding for the NERVA in NASA's FY 1968 budget. Funding for nuclear propulsion research had to compete with funding for the Vietnam War and funding for a multitude of new social programs. In addition, the initial interest that von Braun and other space planners had shown in nuclear propulsion shifted to a single goal—meet Kennedy's lunar landing mandate. Kennedy's 1961 decision to accelerate plans for the manned lunar landing had meant that von Braun and others had to rely on what they knew best—chemical propulsion. RIFT never got beyond the paper and preliminary component test phase. Nuclear propulsion, like other nontraditional propulsion technologies, would have to wait.

BIBLIOGRAPHY

Ezell, L.N.: "NASA Historical Data Book, Volume II: Programs and Projects, 1958–1968," *NASA SP–4012*, pp. 481–487, 1988.

Fellows, W.S.: "Rift," *Astronautics*, Vol. ?, pp. 38–47, 1962.

Hechler, K.: *Toward the Endless Frontier: History of the Committee on Science and Technology, 1959–1979*, U.S. House of Representatives, Washington, DC, pp. 255–257, 1980.

Heppenheimer, T.A.: "The Space Shuttle Decision: NASA's Search for a Reusable Space Vehicle," *NASA SP–4221*, 1999.

House of Representatives, Committee on Science and Technology, Subcommittee on Space Science and Applications, United States Civilian Space Programs, 1958–1978, Report, 97th Cong., 1st Session, Washington, DC, pp. 225, 228, 229, 1981.

Logsdon, J.M.: Lear, L.J.; Warren-Findley, J.; Williamson, R.A.; and Day, D.A., Editors: "Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program, Volume I, Organizing for Exploration," *NASA SP–4407*, pp. 429–431, 1995.

Marshall Star, June 21, 1961; July 5, 1961; January 3, 1962; August 29, 1962; May 31, 1963; July 17, 1963.

Portree, D.S.F.: "Humans to Mars: Fifty Years of Mission Planning, 1950–2000, Monographs in Aerospace History No. 21," *NASA SP—2001–4521*, pp. 33–35, 2001.

U.S. Aeronautics and Space Activities, January 1 to December 31, 1959, Report to Congress From the President of the United States.

Von Braun, W.: Opening Statement for Panel Discussion on "The Future of Nuclear Energy in Space," American Nuclear Society Aerospace Division, Hilton Hotel, New York, New York, November 20, 1963.

Von Braun, W.: Statement Before Subcommittee on Research, Development, and Radiation Joint Committee on Atomic Energy, September 13, 1962.

Von Braun, W.; and Ley, W.: *The Exportation of Mars* (1956), Viking edition, Sidgwick & Jackson, London, 1956.