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Nuclear Propulsion

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In his address to the nation committing the United States to a program leading to a manned lunar landing within this decade, President Kennedy recognized the nuclear-rocket program as one of the four most important space projects. National support of the nuclear-rocket program made possible the Nerva follow-on contract which provides for the development of a nuclear-rocket engine for flight testing. This contract, executed in January with Aerojet-General and Westinghouse Electric, represents the most significant development in the nuclear-propulsion field during the past year. Besides inaugurating a major engine-development program, the signing of this contract signals the transfer of the major nuclear-rocket development role into the hands of industry. The vast background of experience necessary to solve the persistent developmental problems involved in producing reliable flight-rated powerplants is now available to the nuclear-rocket program.

After the successful series of tests held in 1961, the nuclear-ramjet program has continued to make progress during this year and has received additional support in the form of an increased budget and test-facility expansion. Currently, preparations are being made for the Tory II-C tests to be run sometime in the future.

The impact of the expanded nuclear-propulsion program was felt at the Nuclear Propulsion Conference held at Monterey last August. Over 85 papers in the many fields associated with nuclear rockets, nuclear ramjets, and the Orion project were presented to about 800 engineers and scientists representing all corners of the nation's industrial, government, and university organizations. The meeting provided, for the first time, a mass dissemination of detailed technical data to all those engaged or interested in nuclear-propulsion activities.

The nuclear-rocket program, the largest nuclear-propulsion effort underway at present, has progressed in some areas and suffered delays in others. The reactor test program schedule slipped due to a combination of factors. Primary among the causes for the delays were the problems of providing for liquid-hydrogen operation in the reactor test cell. There was, however, substantial progress in establishing the basis for the over-all development program. An extensive program of engineering analysis, component and system development and testing, and simulator studies was begun. The pace of construction of the facilities for engine and stage testing picked up considerably. In addition, the management organization needed to bring all the pieces together was firmly established.

Preparation for the first Kiwi-B test was interrupted shortly before the reactor was due to be tested when a hydrogen explosion occurred in the shed housing the reactor on Nov. 7, 1961. The explosion was caused by a leak in a hydrogen valve. Fortunately no one was seriously injured. There was, however, a one-month delay in the Kiwi-B1 test, which was run on Dec. 7, 1961. This test achieved only part of its objectives, as it became necessary to terminate the test after 30 sec at power because of a hydrogen leak. However, it did provide important materials, design, and control data.

The first cold-flow reactor test using liquid hydrogen was successfully run this past July. It provided much liquid-hydrogen information for the first part of the startup cycle of the reactor. The first hot reactor test with liquid hydrogen was run on September 1. It provided detailed information on the automatic startup of the reactor using liquid hydrogen, on the controlled increase in power to the desired value, and on the shutdown of the reactor.

During the startup, flow oscillations were encountered in the system. The preliminary data indicate that these oscillations were the cause of the facility's flow-system arrangement, and the method in which the facility was

operated. They do not appear to be an inherent reactor-flow system problem, and the data indicate that this problem will be eliminated.

As the run progressed to increased power, damage to the reactor occurred. This reactor is not one of the preferred designs, and the possibility of some damage was not altogether unexpected. Important data were also obtained during the shutdown, which took place in a controlled way.

In terms of the extensive data obtained during this test to determine information on operating and controlling future reactors, this was considered a successful test.

The primary technical objectives of the remaining Kiwi-B experiments are the selection of an acceptable core design for use in the Nerva engine development project, the determination of control requirements for safe, reliable startup and shutdown, and the demonstration of a restart capability for the Kiwi core. Upon completion of the Kiwi-B series of experiments, the Nerva engine project will include a series of reactor experiments to test flight modifications to the selected Kiwi design.

In February, the Jackass Flats area of the AEC's Nevada Test Site was designated as the Nuclear Rocket Development Station (NRDS). The NRDS includes those facilities which have been used since 1959 for ground tests of Kiwi reactors in the joint AEC-NASA program. The NRDS is under the management of the Space Nuclear Propulsion Office.

At NRDS, the modifications to Test Cell A were completed to enable the use of liquid hydrogen as a propellant for reactor tests. A new reactor test cell equipped for liquid-hyrogen operation, Test Cell C, has progressed into the preliminary checkout phase. The construction continued of the first downfiring test stand, Engine Test Stand No. 1, and the construction of the engine maintenance, assembly, and disassembly building (E-MAD) has been initiated.

Additional facilities now programmed as part of the NRDS include a second engine test stand (ETS-2), a combined engine and vehicle test stand (E/VTS-3), a stage assembly and maintenance building (SAM), a components test area, and necessary support facilities, such as shops and service buildings.

Aerojet-General and its subcontractors—Westinghouse, Bendix, AMF and EG&G—completed their work on Phase I of the Nerva development contract in January of this year. Phase I called for design analyses, preliminary development, initiation of work on long-lead items, planning of the development program for the Nerva nuclear-rocket engine, and important research tasks. The follow-on contract for the development of the nuclear-rocket engine was executed on Jan. 11, 1962. This contract covers the entire engine development effort through Sept. 30, 1966.

An active program has been initiated on research and development in major component and system areas for the Nerva engine. High component reliability will be developed through non-nuclear environmental tests prior to the initiation of full engine tests. Components and systems will be developed and qualified, wherever possible, in test-reactor radiation fields before using them in a nuclear engine test. Studies and analyses of the engine have strengthened our ability to choose between candidate designs, materials, components, instrumentation, and basic turbopump cycles. In addition, Aerojet and Westinghouse have supplied personnel to assist LASL in the ground-test operations, thus beginning to form a nucleus of experienced personnel in testing nuclear rocket systems, necessary when engine tests begin.

The Nerva fuel-element fabrication facility was completed during the year by Westinghouse. This facility will furnish early development cores, establish product specifications, and assist in the training of candidate industrial suppliers who will provide cores when specifications can be defined accurately. An industry-wide briefing was held in April to discuss the fuel-element technology and anticipated arrangements and requirements for fuel-element procurement for the Nerva development program. Proposals were received from candidate suppliers, and evaluation of these is underway.

Several significant steps were taken during the year on the important question of the safety of the nuclear rocket. Extensive analytical and experimental programs were initiated to define the precise nature of the hazards involved from ground operations through flight and to develop methods of preventing and counteracting these hazards.

Another important step in the development of the nuclear rocket was taken on June 28, 1962, with the execution of a contract with the Lockheed Missiles and Space Co. for the development and initial flight tests of the Rift stage, the first nuclear vehicle. The Rift project is directed for NASA by the Nuclear Vehicles Project Office at the Marshall Space Flight Center.

The initial phase of the contract runs through May 3, 1963. During this 10-month period, Lockheed will begin preliminary designs, planning for manufacturing operations, and detailed planning of the over-all development program. Assuming success in the Kiwi reactor test program, Lockheed will begin actual development of stage hardware in Phase II. The first Rift flight is planned in the 1966-67 time period as a ballistic lob, using the Saturn C-5 launch vehicle, to a predetermined ocean-deep impact point. The Rift stage will be designed so that it can be developed into an operational upper stage on the Saturn C-5. Such a vehicle would be potentially capable of landing large payloads on the moon for lunar-base supply and other missions.

Even though the development of first-generation nuclear-rocket engines is still in the early stages, serious consideration is being given to future engines in an advanced-technology program. Last year, work began on the design and development of advanced reactors, pumps, nozzles, and other components for ground-test reactors. The major effort—reactor development—continues to be centered at the Los Alamos Scientific Laboratory. Advanced research and technology on engine system components, such as advanced flow systems, is centered at the NASA Lewis Research Center, with supporting effort by various industrial contractors. Argonne National Laboratory began an evaluation last year of solid-core concepts to determine their development potential, performance levels, and feasibility.

In summary, the nuclear-rocket program now has work underway that will lead to flight tests to determine the characteristics of nuclear-rocket systems in the flight environment and that will provide the technology for future generations of nuclear-rocket engines. The purpose of these broad technological activities is to provide a range of nuclear-propulsion systems that will meet the requirements of extensive manned space exploration. ♦♦