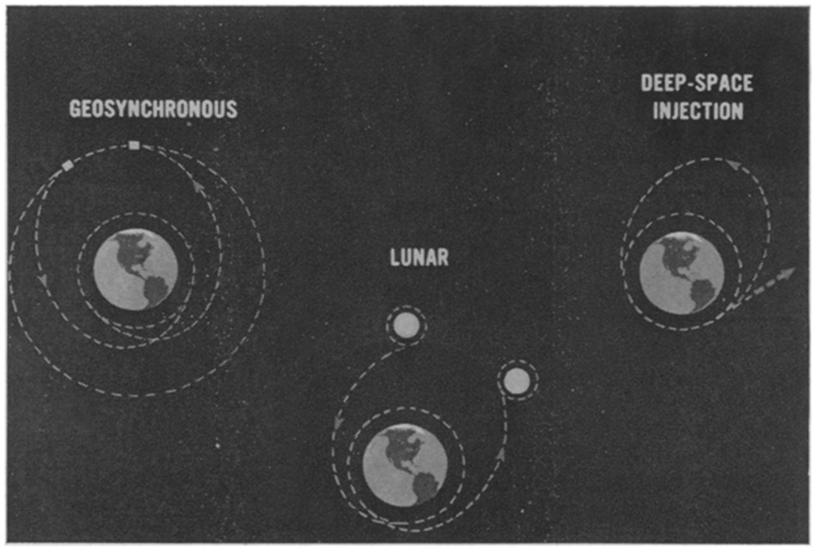
Problems of nuclear rockets

Financial and design difficulties are holding up the testing and completion of a reusable nuclear rocket

by Edward Gross



Photos: AEC/NASA

Injected into space, NERVA will perform various tasks.

In man's effort to conquer space, he has relied on the same type of propulsion that powers cars, lawn mowers, jet planes, Piper Cubs, battleships and motor boats: chemical propulsion. For a long time to come, burning a fuel and controlling its combustion energy will be the way to boost a rocket into space.

This may do for manned missions to the moon. But scientists and engineers at the National Aeronautics and Space Administration and the Atomic Energy Commission regard this method already as antiquated and uneconomical when it comes to missions deep in space.

Over the last decade, AEC and NASA have spent $1.2 billion in developing the basic technology of the nuclear rocket; another $1 billion is needed to complete the project.

"It looks like it's around the corner," says Sen. John D. Pastore (D-R.I.) of the Joint Congressional Committee on Atomic Energy. "We've been working on it for years, but where is it?"

The nuclear rocket, called NERVA (Nuclear Engine for Rocket Vehicle Application), has gone through all its preliminary design and testing stages, and the time from now until 1978—the current project completion date—will be taken up with getting it ready for flight.

The rocket is expected to be ready in time to power a shuttle for ferrying men and cargo from low earth orbit to the space stations in high earth (geosynchronous) or lunar orbit, or to send payloads deeper into space on such missions as a trip to Mars for either a manned landing, an unmanned fly-by or an instrumented sampling mission. Because of the trip time and the heavy payloads involved, NERVA is not only ideally suited for such a job but is considered critical to its success (SN: 9/20, p. 233).

In all of these missions, a chemically powered shuttle rocket (SN: 1/3, p. 22) would first place the NERVA and its companion vehicle in low earth orbit. Then the rocket would blast off for its mission. When done it would return to low earth orbit, waiting for another payload to be launched and docked to it.

The nuclear engine, like other future space systems, is being designed with reusability as a guiding principle. Simply stated, the aim of reusability is to make a nuclear rocket engine that can be used a number of times. The idea is motivated by economics. Just as it would be uneconomical to build a car that could only make one round trip—which is in essence what the present Apollo rockets do—NASA and the AEC want a nuclear engine that can be flown on several round trips.

In no case in the foreseeable future is it envisioned for earth liftoff. The main reason is that chemically propelled rockets are adequate for that job, and present nuclear rocket capability would not provide significant advantages. Another reason is radioactivity, which could escape in small amounts to the launch area or in large amounts if an accident occurred.

A nuclear rocket can carry heavier payloads on less fuel than a chemical rocket because of the nuclear engine's greater propulsion efficiency, or specific impulse. This is the time period in which one pound of thrust is produced by one pound of fuel.

For the best chemical rocket using liquid hydrogen and oxygen, the specific impulse is about 450 seconds; NERVA's specific impulse is nearly double that, 825 seconds, which means that one pound of propellant producing the same thrust as one pound of chemical fuel will last almost twice as long. The saving in fuel can go into carrying extra payload.

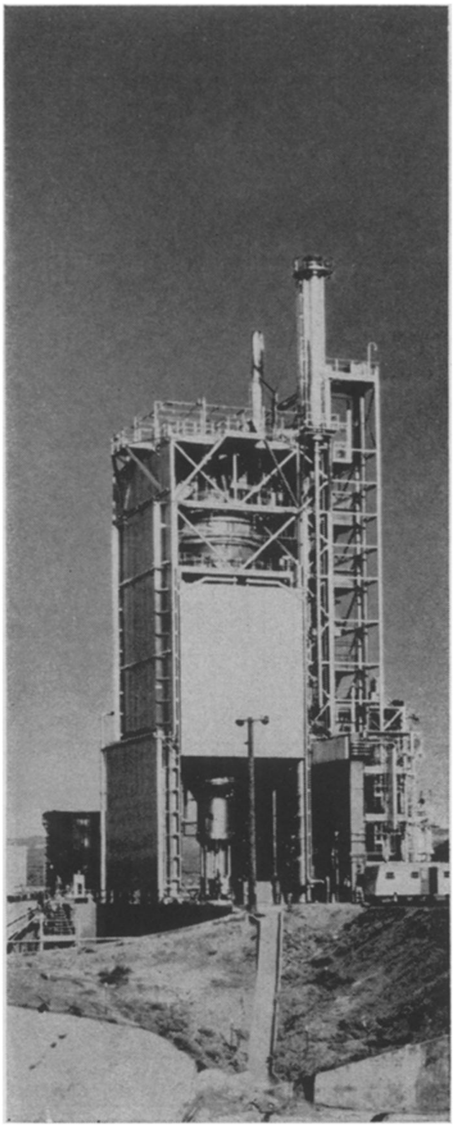
As it now stands, NERVA is composed of two systems: the engine, which is being built by Aerojet-General Corp., and the reactor—the heart of the engine—which is being built by Westinghouse. Twelve reactors and engines have been successfully tested in the past six years. The latest engine is the NERVA-XE, which was successfully tested last year (SN: 3/22/69, p. 283).

Klein: It's still a breadboard engine.

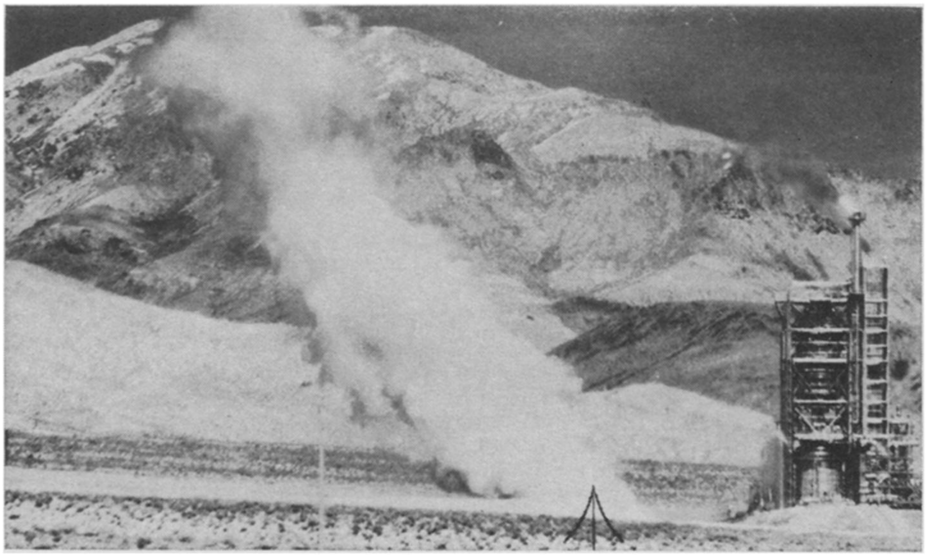
A total of 28 tests was run on the NERVA-XE from March to August, during which time the engine ran for a total of 3.5 hours.

"With these tests," notes Milton Klein, director of space nuclear systems of the NASA-AEC Space Nuclear Propulsion Office, "there has been established a solid foundation of data and experience on which to base the development of a flight-qualified engine. What has been tested is not a finished NERVA engine that can go up. It is a breadboard design, and many components and changes must still go into it."

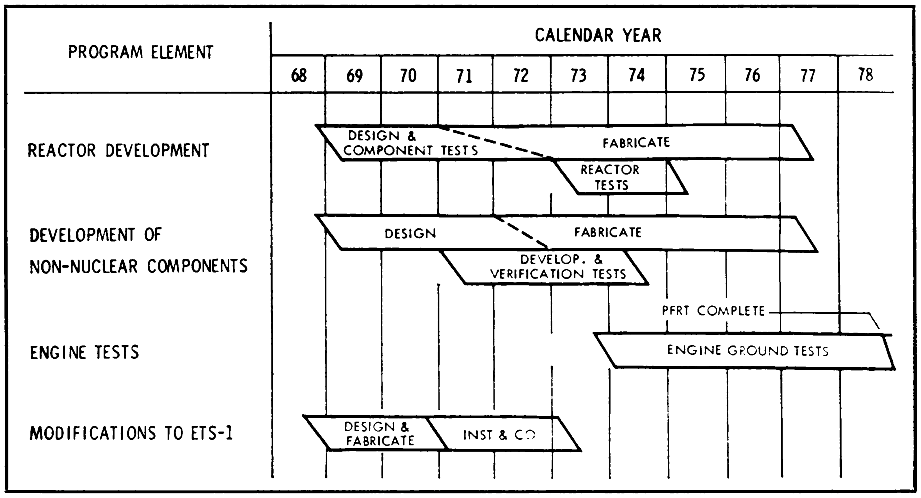
The major obstacle to this goal has been corrosion of the nuclear reactor's



Jackass Flats site: A 10-hour goal.



Power test for NERVA-XE: 25-second blasts produce 5,500 pounds of thrust.



Until 1978 NERVA's time will be taken up with getting ready for flight.

fuel element, which is the nuclear fuel and the metal cladding around it.

NERVA works by heat from the nuclear fission of uranium converting liquid hydrogen to a gas and heating it to about 4,000 degrees F. When ejected through a nozzle in the rear, the gas propels the rocket.

However, the hydrogen gas can eat through the protective cladding and attack the rest of the fuel element. Specifically, it damages the graphite. The graphite, which contains uranium fuel in the form of beads of uranium dicarbide, slows down the neutrons, which split the uranium atoms to release their energy. Damage to the graphite moderator would result in neutrons escaping, instead of being absorbed, and the engine shutting down.

To overcome this, niobium carbide and zirconium carbide coatings have been developed to protect the graphite in recent modifications. As a result, the fuel element's ground-test lifetime has been upped from 10 minutes to 3 to 4 hours, and there are good prospects for an even longer life.

"The rest of the engine is designed for 10 hours," points out Carl Schwenk, assistant manager for vehicle and technology at the Space Nuclear Propulsion Office. "If fuel materials can get to 10 hours, then we'll be ready to use them. But there's still a lot of work to do."

The road to this goal is through improved fabrication and design of the coatings. One possibility is to make a composite matrix of graphite and zirconium carbide in which uranium fuel is dissolved, as an alternate to the beaded uranium dicarbide fuel. This new matrix should be more resistant to corrosion, says Schwenk.

In addition to corrosion, NERVA faces financial problems, tied to the financial picture for all future space projects. There have been recent, severe cutbacks in those projects (SN: 2/17, p. 148). Further cutbacks could push NERVA into the 1980's.

Beyond the 1980's, a decade or more at least, lies the gaseous core nuclear rocket, which uses gaseous uranium instead of solid uranium.

"It has the potential for higher specific impulse than the solid core system," comments Klein. "We don't know if such a system is feasible. We're doing fundamental research work."

Another advantage of the gaseous core rocket is that NERVA is limited by the temperature at which the solid uranium can retain its structural strength. With a gaseous fuel, this is no problem. The trick, though, would be to feed the propellant through the gaseous core without having it sweep out the uranium.

And still farther out is the nuclear fusion rocket, which relies on a controlled nuclear fusion reaction. "The last stop is the fusion rocket," says Klein. "This is the farthest-out source of energy we know of. We're doing nothing except watching what work is being done in the controlled thermonuclear area." □