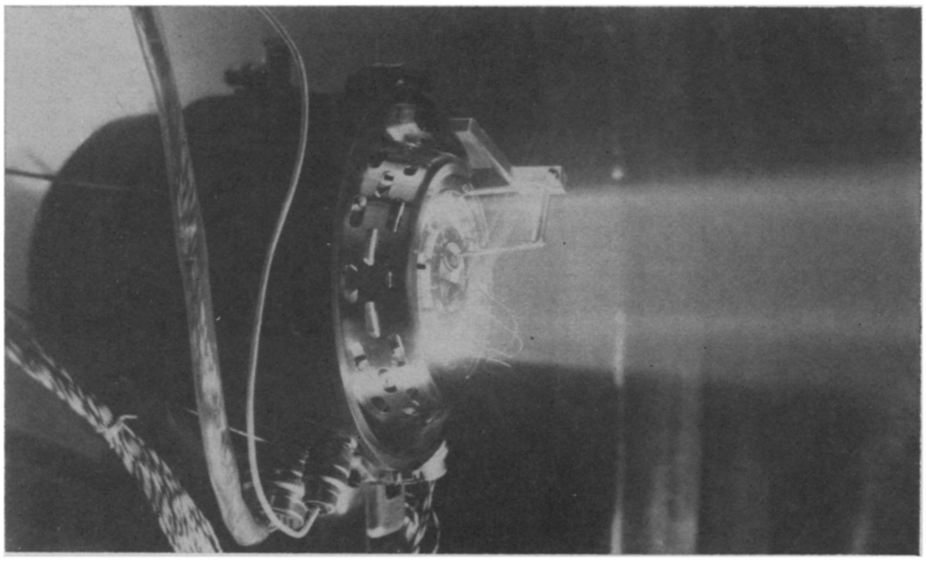

NASA

Electrostatic engine—from thousands of volts, thousandths of pounds.

The Gentle Rockets

Today's chemical rockets are slow, cantankerous fuel hogs compared to the electric and nuclear ones to come.

by Jonathan Eberhart

The gigantic chemical rockets that provide all the push in space today and will soon be carrying men to the moon may someday be playing second fiddle to flying nuclear powerplants full of gases so hot that they're not even gases anymore.

The thermonuclear rocket engine is so far in the future, however, that there are hardly even any sketches of ways to build one, let alone working models. Not the least of its problems is that its superconductive coils must be kept cooled down to almost absolute zero, while only inches away is a raging inferno of almost a billion degrees F.

Other nonchemical engines for space are not so distant, nor are their goals. While fission and fusion rockets are being proposed to cut down trip times to the outer planets in 15 or 20 years, there will soon be a pressing need for an engine that can provide only a tiny amount of thrust, but do it for years on relatively little fuel.

The more practical the things that are done in space—communications, weather-watching, geodetics, even prospecting—the more concern there will be for satellites that can stay in orbit for years, given only an occasional slight nudge to prolong their stay or point them in a different direction.

The number of practical satellites is growing rapidly. "Space has to become more a part of the country and the world, and not just the business of the scientist," North American Aviation rocket scientist Krafft Ehricke warns, "if we don't want to tremble every time the State of the Union comes around—since everything," he adds wryly, "is more important than the space program."

Space was barely mentioned in this year's State of the Union address by President Johnson, but research on nonchemical engines for space is going on in both government and industry laboratories.

A leading candidate for the small but steady "station-keeping" jobs is the electrostatic thruster, whose miniscule push is often measured only in micropounds. The National Aeronautics and Space Administration is considering them both for satellite use and for attitude correction on long interplanetary flights. One engine at NASA's Lewis Research Center has been purring away for over 8,000 hours, more than enough for missions lasting several years.

Powered by solar cells, these engines could be as much as seven times as efficient as present leading chemical boosters. The efficiency rating, called specific impulse, of electrostatic engines could be as high as 3,000 seconds, compared to 460 for a rocket like Centaur, one of today's most efficient.

There are two types of electrostatic engines, one of which could not have been built, even if scientists had known how, when NASA awarded its first contract in the field nine years ago. Called a contact ionization engine, it requires its cesium fuel to be passed through a kind of porous tungsten that simply could not be made with 1958 technology. The heated tungsten strips an electron from each cesium atom, leaving a high-pressure stream of ions which is then accelerated through electrically charged screens and ejected through a nozzle to produce thrust.

The other variety works on a principle called electron bombardment. The fuel, mercury vapor this time, is shot full of electrons from an anode right in the plasma chamber. The incoming electrons knock loose other electrons attached to the mercury atoms, leaving an ionized stream to be accelerated out the nozzle.

One problem presently giving engineers nightmares, however, is the power supply. There are so many different voltages and currents needed to run the engine that Hughes Aircraft, its principal investigator, has not been able to make a power supply smaller than about 20 by 25 inches.

A different approach to steady, low-thrust engines is the electrothermal thruster, which despite its name is the simplest rocket device this side of a Roman candle. It simply heats its fuel past the gas stage into a plasma, and the resulting high pressure does the rest.

The Applications Technology Satellite now in orbit carries an experimental electrothermal engine called a resistojet, in which the fuel is ionized by passing it back and forth through tubes over a heating element. The efficiency of the tiny rocket is to be measured by minute changes in the satellite's orbit.

An equally direct technique is the arcjet, which does not even use the resistojet's internal plumbing. Instead, an electric arc is exposed directly to the fuel. The arcjet may prove to offer somewhat longer life, since its cathode runs right down the middle, keeping the intensely hot ion stream from damaging the chamber walls.

A modification of the electrothermal engine is the electromagnetic engine, in which the outgoing ions are given an extra kick by a magnetic field. The problem here is that the engine designer must either put up with a heavy magnet to obtain a strong enough external field, or else use atomic power to sustain the internal field of the arcjet itself.

Talk of atomic power turns rocket scientists into visionaries. Regularly-

(See p. 97)

. . . Gentle rockets

scheduled earth-moon shuttles, orbiting tourist hotels and seven-man hops to Mars have all been suggested as being within the realm of cheap, reliable nuclear rockets. Kiwi, NERVA and SNAP are all NASA programs covering the design and application of atomic engines in space.

The specific impulse of a typical solid-core fission engine might have a rating of 850; a liquid-core engine 1,500; and a gas-core 2,500, compared to Centaur's 460.

The solid-core engine is the only one that shows real promise at its present stage of development.

Though the other two types have higher specific impulse and thrust ratings, research on them is lagging and they both suffer from a problem that has scientists at least temporarily stymied: they "leak." By their very design, as much as one-tenth of their exhaust stream is the radioactive uranium 235 that provides heat. Their higher efficiencies, however, are possible because they can operate at temperatures that would melt the graphite core of a solid-core engine.

"You could throw away 10 percent by weight of uranium and still wind up better than a chemical rocket," says NASA's Frank Rom. "What worries me is conservation of natural resources—and air pollution."

A possible remedy may be the "nuclear light bulb," a gas-core engine in which fuel and propellant are kept separate by an internally-cooled wall. United Aircraft Corp. thinks this may be the key to stopping leaks.

Though free from this difficulty, solid-core rockets are still a long way from production. "The only way we'll ever use a solid-core nuclear rocket is for large-scale exploration of the planets," says Rom.

The ultimate step is the fusion engine. Prodigious temperatures, pressures of 1,000 atmospheres and a virtually nonexistent technology may relegate the first workable fusion rocket to a spot near the turn of the century, but possible efficiencies as high as 5,000 seconds make the goal worth pursuing. Scientists, in fact, have come up with ideas such as a 40-day stay on Mars using a fusion engine developing 130 million watts, enough to light a small city. Thrust would still be small, but since, unlike chemical rockets, the engine would fire continuously and thus be accelerating throughout its journey, it could more than make up for the powerful but brief blasts of today's upper-stage boosters, some of which can push 200,000 pounds.