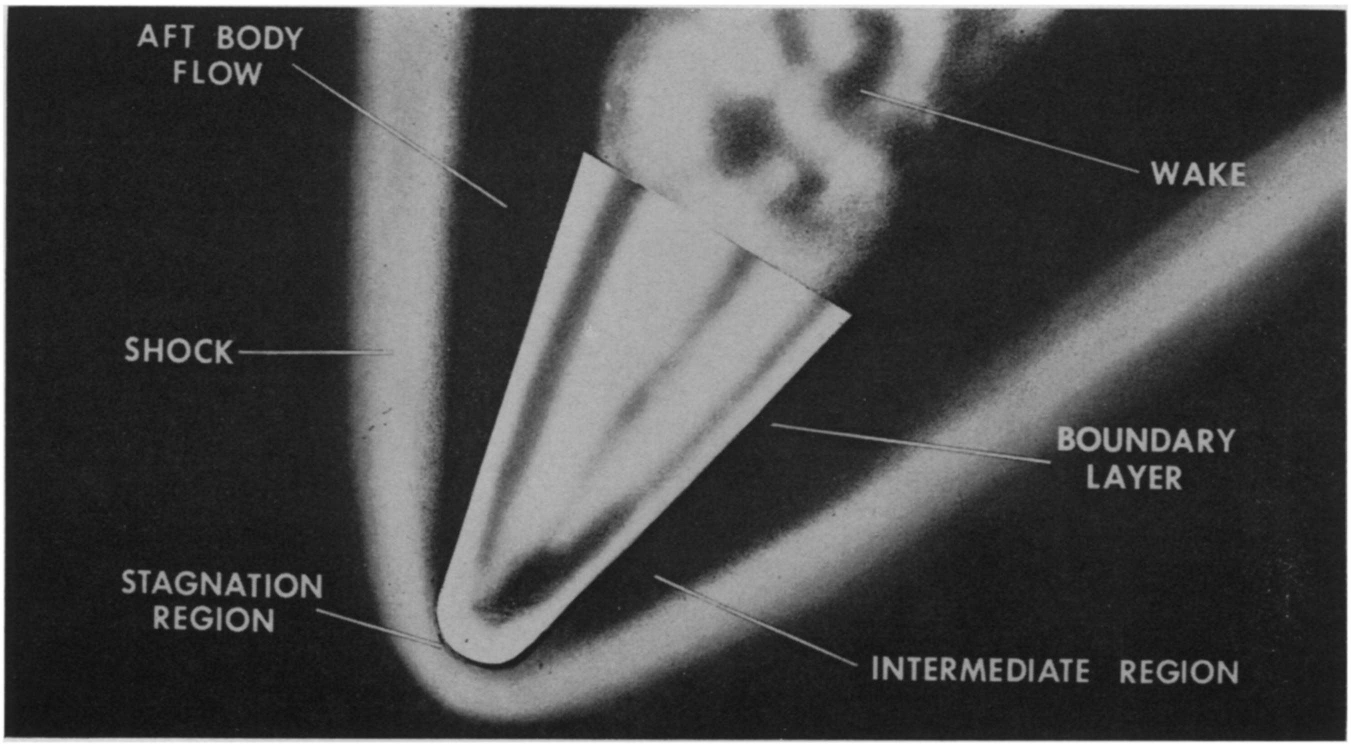


Air Force

Measuring the exact shape of the radio-blocking plasma sheath aids in designing and locating spacecraft antennas.

SPACE COMMUNICATIONS

Piercing the silent curtain

The communications blackout that plagues reentering spacecraft is under attack

by Jonathan Eberhart

Scientists predicted it, missile designers were plagued by it, astronauts have had to live with it, and it is likely to continue making trouble for years to come. But space researchers are fighting back, looking for a way to puncture the wall of silence that temporarily cuts off communications to and from spacecraft and missiles reentering earth's atmosphere at high speed.

The blackout was anticipated as long ago as the early 1950's in research that was to lead to the intercontinental ballistic missile program.

When an object plunges through earth's atmosphere at speeds greater than about 10 times the speed of sound, the investigators theorized, the heat of friction should produce a layer of ionized gas or plasma surrounding the forward parts of the object's skin. This curtain could completely block off radio transmissions in both directions, leaving the object cut off from the ground for a possibly critical few moments.

Early ICBM tests and sounding rocket flights proved the theory right—and turned up another problem.

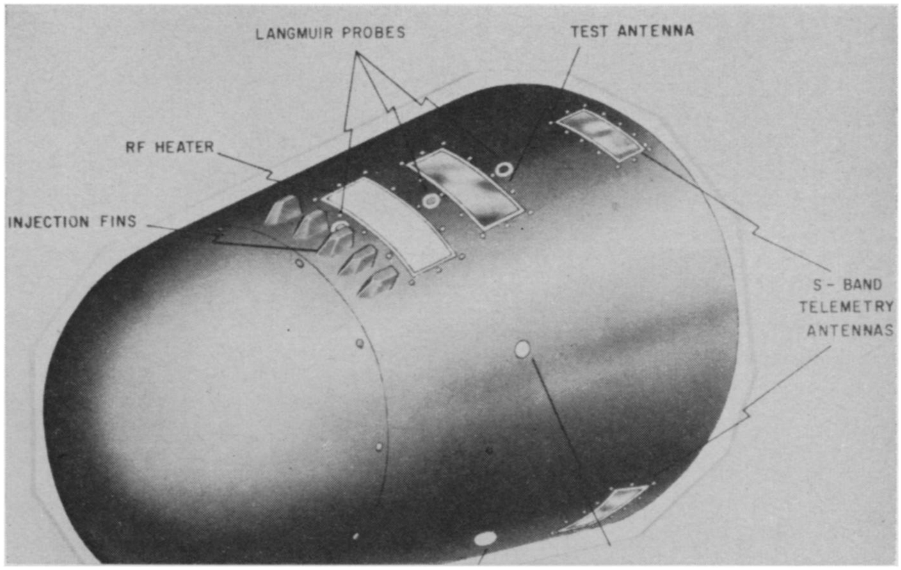
When a rocket has been launched, as the surrounding atmospheric pressure decreases with altitude, the hot plume of the rocket's exhaust expands to many times its original size. As with the reentry sheath, the ionized exhaust gases can block off signals to and from the ground below.

The rocket exhaust blackout problem has since been circumvented by such methods as relaying ground communications up from a point well away from the launch site, to enable transmissions to reach around the plume. But it was during just such a blackout that a phenomenon occurred which has since become the basis for much of the research into remedying the more troublesome reentry blackout.

On July 1, 1960, the National Aeronautics and Space Administration launched the first of its Scout rockets, which have since become the agency's most popular workhorse boosters. As usual, the exhaust plume soon began to blank out the telemetry signals from the vehicle. Then several observers noticed that whenever the rocket's hydrogen peroxide control jets fired into the plume, the strength of the signal was partially restored.

"Some of them thought their equipment was wrong," says Theo E. Sims, who was one of the original observers

. . . reentry blackout



Air Force

Probes check effectiveness of chemical, injected through fins, and RF heating.

and is now in charge of reentry blackout research at the NASA Langley Research Center in Hampton, Va. Others recognized a valuable clue: As the hydrogen peroxide decomposed into water vapor and oxygen, the strength of the blackout was somehow being reduced.

One theory was that the water droplets were attracting the free electrons that had been torn loose in the exhaust gases. The droplets thus became negatively charged, attracting the positive ions, encouraging them to recombine with their missing electrons and thereby reducing the amount of ionization.

The idea of deliberately injecting an electrophilic, or electron-catching, fluid into the plasma was soon incorporated, along with other lines of research, into a full-time Radio Attenuation Measurement program, known as project RAM. Scout boosters have carried instrumented RAM nosecones to altitudes of more than 130 miles, then fired them back down through the atmosphere at reentry speeds of up to 17,000 miles per hour.

The first RAM flight, in August 1961, was simply a check on an almost self-evident idea which had already been demonstrated at less than reentry temperatures in the laboratory: that streamlining, in the form of a relatively sharp nosecone, would minimize the thickness of the plasma layer. The resulting plasma turned out to be less than an inch thick at the stagnation point (the leading point of contact with the air, where the molecules are temporarily stopped short), compared to two or three feet for the blunt Mercury and Gemini spacecraft, and possibly more than that for Apollo.

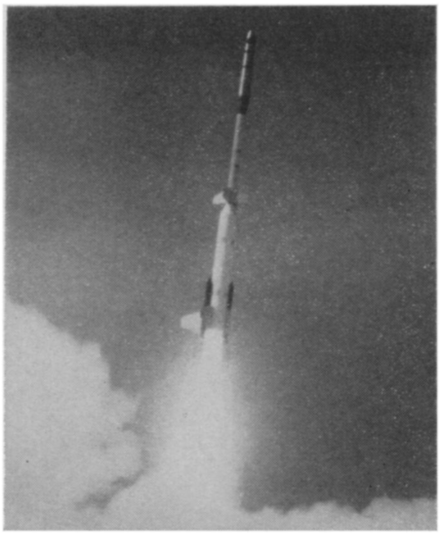
Making future manned spacecraft more aerodynamically smooth, says Sims, would go a long way toward reducing the amount and duration of the blackout.

Another anti-blackout technique being investigated by industry and universities, as well as government agencies, is the use of a strong magnetic field. "The field," says Dr. Ali Bulent Cambel of Northwestern University's Technological Institute, "could rearrange the plasmas which confront the vehicle to produce an electrically neutral hole, permitting normal earth-space communications."

This method has been demonstrated on the ground, but in the only attempt to try it in space, NASA researchers used such a sharp nosecone that they couldn't tell whether credit for the improved radio signal went to magnetism or aerodynamics. Magnetic fields are unlikely to be adopted in the foreseeable future, however, since magnets strong enough to serve manned spacecraft would probably be prohibitively heavy, even when lightened by use of superconductivity.

Using a somewhat more blunt cone, tipped by a six-inch hemisphere, project RAM helped determine that sending messages on higher frequencies was another way to improve their chances of getting through the sheath. Millimeter waves, in fact, which have the highest frequencies in the communications spectrum (about 10,000 to 100,000 megacycles per second), could completely penetrate the plasma unaided; unfortunately, they are also the most susceptible to atmospheric interference.

Low frequency waves, below about a megacycle, could also get through, but their long wavelengths would be al-



Air Force

Air Force rocket lofts reentry test.

most unusable with the narrow bandwidths allowed by the small antennas possible on spacecraft. One solution, suggests Walter Rotman of the Air Force Cambridge Research Laboratories in Massachusetts, might be to use millimeter waves anyway, then avoid the atmospheric attenuation problem by use of airborne rather than ground-based receiving sites, by selection of fair-weather sites such as Edwards Air Force Base (in California), or by use of satellite relay stations.

Changing frequencies is difficult, however, when it means having to convert an entire global tracking network such as Apollo's. Both the VHF (259.7-296.8 megacycles) and S-band (2100-2300 megacycles) used during reentry are within the blackout band.

The first Apollo astronauts, last month, were isolated by the plasma for some five minutes, as were the Mercury and Gemini astronauts before them. On return flights from the moon, which could begin as early as December, there will be two separate blackouts of about 3.25 and 1.5 minutes, as the spacecraft skips in and out of the atmosphere to slow down.

Only one antiblackout experiment has flown on a manned U.S. spacecraft, a water injection test which partially reduced the fading of some telemetry signals during the reentry of Gemini 3 on March 23, 1965. "I anticipate that this will be a successful method someday," said copilot John Young after the flight. "This is pretty important to us."

A variety of fluids are being studied by the Air Force and NASA, and researchers at both agencies agree that water is not the best choice. Sulfur hexafluoride and other additives with high molecular weights help by attracting the electrons in the sheath to form negative ions whose large mass does not interfere with the signal passing through. Some chemicals, such as certain forms of Freon, have an additional advantage in that they react quickly with the plasma—important at the high speeds of reentry. (In a classified program for the Naval Air Systems Command, Lockheed Propulsion Co. of Redlands, Calif., is trying to cut down rocket exhaust interference by adding chemicals directly to solid propellants.)

Another possibility being investigated by the Air Force is the injection of a high-pressure stream of helium gas at the spacecraft's stagnation point, not to affect the recombining electrons and ions, but simply to divert the plasma flow along a smoother path. The device is referred to, in fact, as an aerodynamic gas spike.

Still another kind of injection essentially blows a hole through the sheath with a stream of electrons from a gun like that used in a television picture tube. Modulation of the beam can be used to carry the signal through the plasma. The Air Force plans to fly both the electron beam and the gas spike late this year.

A different approach being tried on model spacecraft at the Cambridge laboratory is one which subjects the plasma to radio frequency energy. This excites the electrons to greater activity, thus stepping up their attachment rate, without actually heating the gas itself.

As manned space flight progresses, the need to puncture the plasma curtain will increase. So far, Sims points out, manned spacecraft still reenter on basically ballistic trajectories. The problem will become critical, however, with the advent of lifting bodies and other vehicles that are piloted all the way to the ground, so that a computer will not be able to predict where they will emerge from blackout.

Like other researchers today, the NASA and Air Force scientists are wondering whether their efforts will be allowed the funds to continue. At the space agency, Sims and his comrades are afflicted by budget worries as they analyze the data from their most recent effort, a diagnostic shot whose goal was to try to map the intensity of the sheath at different points on the spacecraft, with an eye toward picking the best possible antenna locations. The Air Force's counterparts of NASA have not had a shot since last fall, but they are ready with two more.

One way or another, though, but probably not by the time the first U.S. astronauts return from the moon, the curtain of silence will be raised.