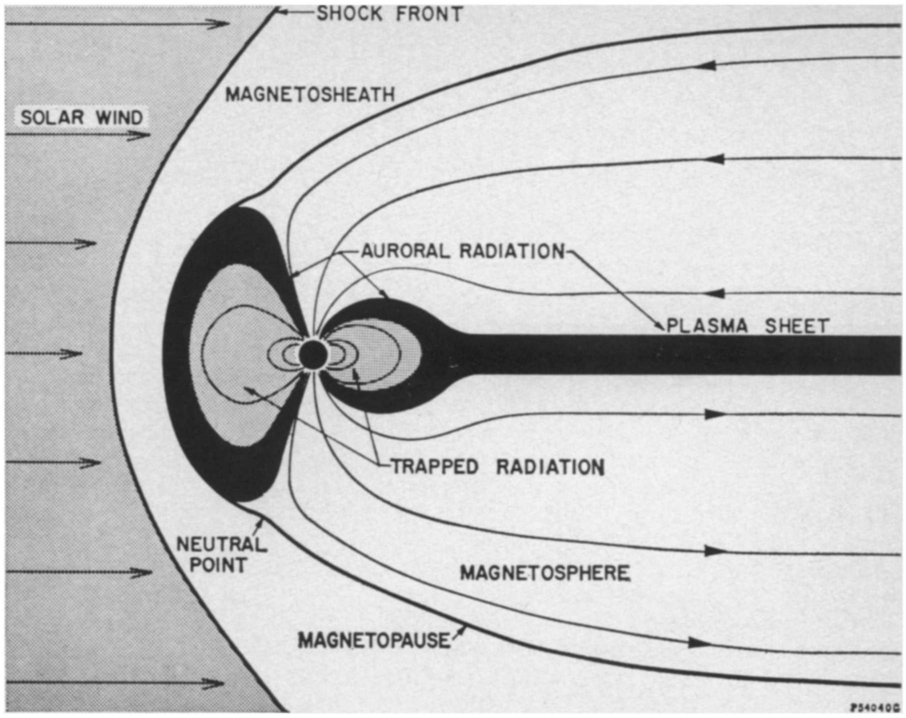


The earth, with magnetic field lines, magnetosphere and boundary zones.

GEOPHYSICS

On the edge of space

Space and ground stations are studying hydromagnetic waves in the farthest out of the earthbound plasmas

by Dietrick E. Thomsen

With the welter of fields, belts and other outside-the-atmosphere phenomena that surround earth, the magnetosphere—a collection of electrons and ions trapped in the earth's magnetic field—is coming under increasing study by astronomers.

One impelling reason is the effort to fulfill President Kennedy's pledge that the United States would land a man on the moon "before this decade is out," which puts the launch at a period of the greatest solar radiation activity.

In addition to sounder knowledge of conditions the astronauts will face when they leave the magnetic field's protection, current research may not only map the field, but provide an explanation of how it was formed.

The research stations involved range from a ground station in the Canadian Northwest Territory town of Tungsten to the synchronous orbit satellite ATS-I, 23,000 miles above Christmas Island in the central Pacific, where it has been since December 1966.

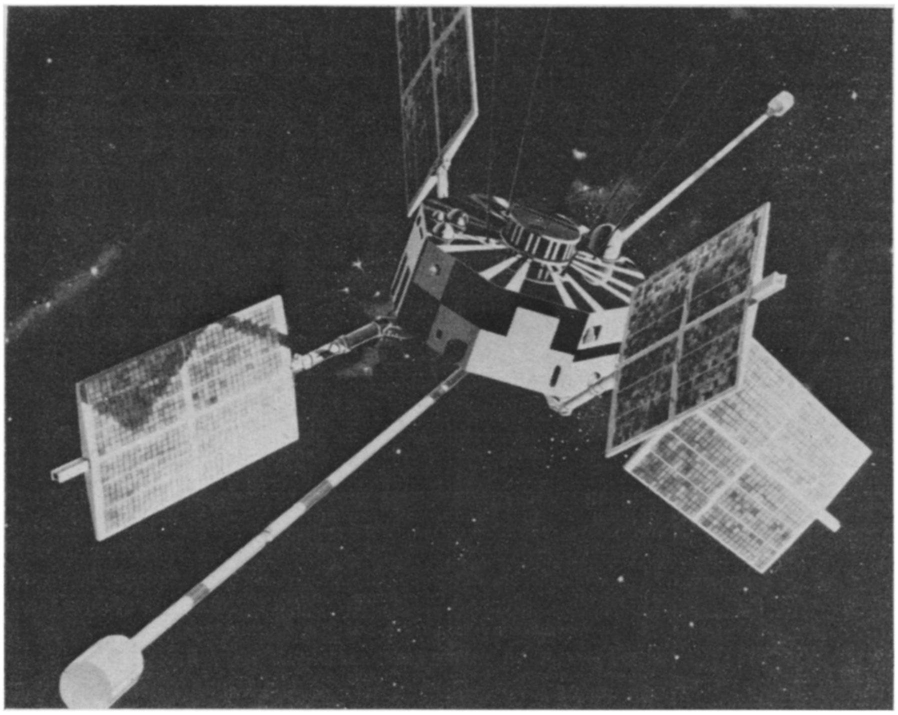
The satellite and the ground station are connected by the lines of force of the earth's magnetic field. The activity in which they collaborate is the recording and measurement of hydromagnetic waves that run along the lines.

Beyond the upper atmosphere is the magnetosphere: a mass of charged electrons and ions bound to the earth's magnetic field. The coupling between the electron and ion plasma and the field is so tight that the field is said to be frozen in the plasma. If the plasma moves, so does the field.

This kind of medium is the home of hydromagnetic waves: complicated disturbances that involve motions of the plasma particles, fluctuations of the magnetic field and sometimes electric field fluctuations as well.

"The magnetosphere is like a taut string. Pluck it, and it vibrates," says Robert Snare, project engineer for the Space Science Center at the University of California at Los Angeles, which is running one of the Tungsten-ATS-I experiments.

The plucking is done at the magneto-



NASA

An IMP satellite in flight as it might appear to an observer nearby.

pause, the boundary between the earth-bound plasma of the magnetosphere and the sun driven plasma of the solar wind. This boundary is always unstable, fluctuating back and forth. Although it usually is found about 35,000 miles out on the sunlit side, at least once in the lifetime of ATS-I the magnetopause was pushed inside the satellite's 23,000-mile orbit, according to the National Aeronautics and Space Administration's Dr. Norman F. Ness.

The cause of the fluctuations appears to be solar wind pressure, the flow of particles continually emitted from the sun and ultimately related to flares or other disturbances.

According to Dr. Ness, the plasma can support vibrations at frequencies up to millions of cycles a second, but many of the waves that are actively being studied are at the lowest end of the frequency scale—with periods as long as several seconds, minutes or even hours.

That there is a plasma region that will support such waves was first discovered through research on a related sort of waves, the whistlers. Whistlers are higher frequency waves, though still very low by radio standards—10 to 20 kilocycles. The energy source for whistlers is in the atmosphere—lightning strokes and similar disturbances.

Whistlers combine with the plasma in the ionosphere, and they travel along magnetic field lines. They were discovered by wire tappers during World War I; the wires of the German field telephones were picking them up.

Since then whistlers have been extensively studied. One favorite method is to set up observatories at conjugate points, the places in Northern and Southern Hemispheres where a given magnetic field line comes to ground, and observe the whistlers that travel along the line.

From such studies much has been learned about the composition of the ionosphere. It was deduced from them that beyond the ionosphere should be a region of much more tenuous plasma. Rockets and satellites have since given direct evidence that it is there.

The same conjugate point stations that study whistlers are often used for research on the hydromagnetic waves, which are also studied in their natural habitat by probes and satellites.

Study of the magnetosphere and adjacent regions is a target of two NASA programs, the Orbiting Geophysical Observatories and the Interplanetary Monitoring Platforms.

"We've sent up six IMP's," says NASA's Frank W. Gaetano, "and they've all carried magnetometers. Three are still performing." The next IMP is scheduled for 1969 for a highly elliptical orbit going out to 20 earth radii, about 70,000 miles. Future IMP's are planned for high circular orbits, 20 or 30 earth radii, about a third of the way to the moon.

"The waves have been observed by just about every satellite that goes up," says Dr. Lawrence Kavanagh of NASA's Goddard Space Flight Center. Gradually a picture of conditions in the magnetosphere and the solutions of some old geophysical mysteries are being developed.

The hydromagnetic waves are closely linked with magnetic storms. The storms consist of sudden sharp rises in magnetic field strength over a few minutes followed by a sustained increase over half an hour or an hour and then a slow dip going far below normal and lasting into the next week.

A problem had been to explain how the energy for these changes, which comes originally from the sun, could have gotten from the magnetopause to the surface of earth. "The first part, the sudden increase, can only be explained by a disturbance at the magnetopause propagated by means of hydromagnetic waves," says Dr. Kavanagh.

Another problem was how the plasma got into the magnetosphere in the first place. Presumably this too comes from the solar wind. Theoretically, however, the particles should not be able to cross the magnetopause boundary between terrestrial and solar magnetic fields if the magnetosphere were quiet.

The existence of waves—and evidence now shows that there are always waves there—permits the particles to cross over.

The hydromagnetic waves—along with whistlers—are also involved in formation of auroras. Waves vibrating at certain frequencies can trigger bursts of particles to strike the upper atmosphere. There they excite oxygen and nitrogen atoms, which then radiate light in characteristic colors.

Auroras occur mostly near the polar regions for the same reason that geomagnetic observatories cluster there. Many field lines come to ground at the poles, and the field strength is lower than elsewhere, so charged particles can penerate nearer the surface. The polar field is about 0.25 gauss; the equatorial, 0.90. (A toy magnet is rated at 100 to 200 gauss.)

But geophysicists want observing stations at all sorts of locations from pole to pole, says Texas Christian University Prof. A. A. J. Hoffman, who does his observing at Dallas. One reason for choosing that location was that there was no similar observatory within 1,000 miles.

Prof. Hoffman's observatory is located on 1,000 acres of land donated by the Southwest Center for Advanced Studies. Buildings, which had to be constructed of nonmagnetic materials, were put up by Texas Instruments, Inc., which was testing magnetometers at the time. Arthur W. Green of Texas Instruments is associated with Prof. Hoffman in the work.

Observations at Dallas have been going on since 1963. A major object is a record of hydromagnetic waves from solar minimum—in 1964 and 1965—to maximum—expected in 1969 or 1970.