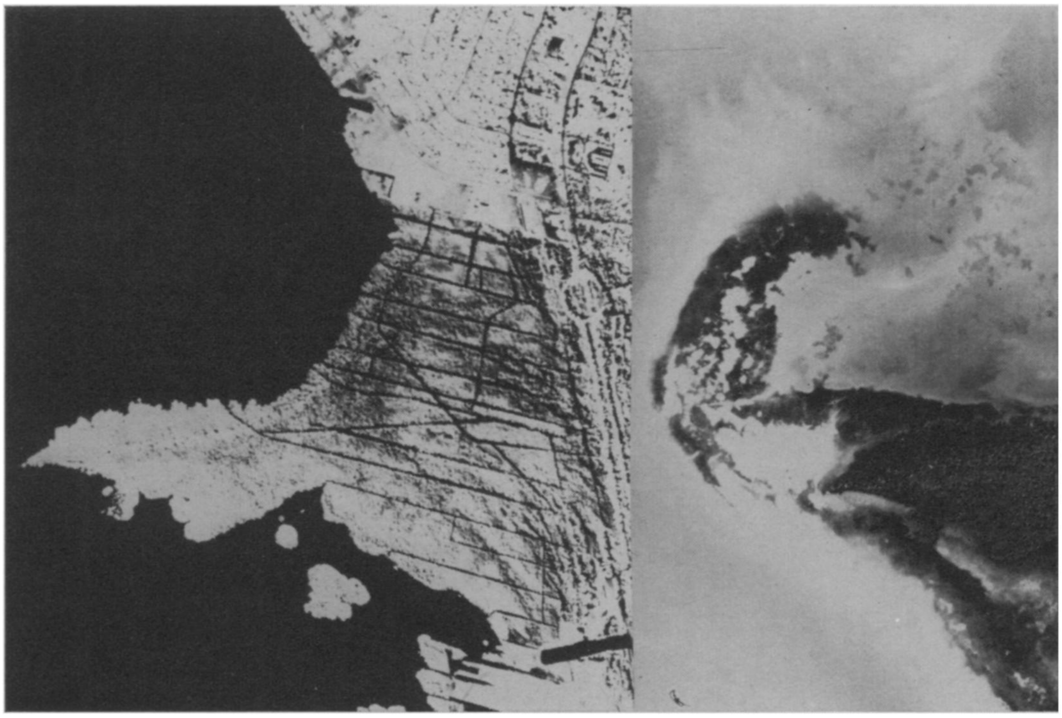
Beyond vision

Sensors aloft promise new aerospace growth

by Jonathan Eberhart



Geological Survey

Infrared view shows sharp shoreline; normal photo shows underwater features.

The attendance list looked like a subsection of the United Nations. Gathered at the University of Michigan in Ann Arbor recently were more than 700 scientists and engineers from the U.S., Australia, England, Canada, France, Iceland, Mexico, Brazil and Sweden. The Russians would have come, but visa troubles kept them away. From the U.S. alone came specialists from more than 30 universities and at least 50 private corporations.

The topic at this high-powered conclave was remote sensors, a family of electronic eyes that are being turned on the world to search for things that man simply cannot see. Slung from airplanes and mounted in satellites, they've been proposed for inspecting crops, watching ocean currents, even prospecting for oil.

So many Federal agencies have been coming up with potential jobs for sensors that many observers, such as Dr. Edward Welsh, chairman of the National Aeronautics and Space Council, feel that remote sensing is likely to become one of the major activities of the aerospace industry in coming years.

"There is no area in the space program which will expand as rapidly in the next five years," predicts Dr. Welsh. Although it's difficult to measure the market because so much of it is in classified military programs such as sky-spy satellites, he says, it would not be surprising if the field grew to $250 million a year by 1973.

The visible light to which the human eye responds covers only a tiny fraction of the electromagnetic spectrum. X-ray wavelengths can be 100,000 times shorter than those of visible light, while very low frequency (VLF) radio waves are up to 10 billion times longer.

With only a little stretching, man can greatly expand the range of things he can see. The near infrared, for example, which falls right next to the visible part of the spectrum, is just a little too red for the human eye (about 0.8 to 2.5 microns, compared to visible light, which ranges from a little more than 0.4 to about 0.7 microns). In the near IR, some vegetation reflects even more light than it does of the green wavelengths which our eyes can detect. At slightly longer wavelengths, ocean and river currents and even subsurface streams can be observed, because they are at different temperatures than the surrounding water. Infrared sensors are being developed that can measure temperature differences of half a degree, even from satellite heights.

Immediately on the other side of the visible spectrum are the shorter wavelengths of ultraviolet light. Because it is more subject to atmospheric scattering, UV radiation may not find ready application in monitoring the ground from space. Satellite-borne UV sensors have been proposed, however, for such tasks as measuring cloud heights and air pollution. Only a ten-thousandth as long as UV radiations are the gamma rays that are already being used for airborne sensing of radioactive minerals.

Researchers are now working to develop sensors that can accurately take in more and more at a glance. Although airborne sensors will probably continue to be necessary for detail work such as checking on individual farms or surface features, the scientists' idea is to get as many sensors as possible moved up into a satellite. Satellite-mapping of the Western Hemisphere, for example, says William A. Fischer of the U.S. Geological Survey, could be done for only a tenth the cost of the same task from aircraft.

The Bureau of Commercial Fisheries would like a satellite to hunt schools of fish by looking for warm water and for chemicals evaporating from oil slicks given off by the fish themselves. The Navy Oceanographic Office wants to monitor winds, ocean storms and wave heights. The biggest booster of such earth resources satellites is the Interior Department, which has listed some 70 ways in which it would like to use them.

These and other plans, however, may well depend on the findings of a study to be carried out by the National Aeronautics and Space Administration, evaluating the dozens of proposed tasks to see, in cold numbers, which ones are the most likely to pay off.

The space agency has been studying sensors since early in the decade, but the fiscal 1969 budget is the first one ever to carry a separate item for an earth resources survey. The House of Representatives has left NASA's $12.2 million request for the study intact, shifting the emphasis a bit in the satellite direction, and the Senate is expected to act on it shortly.

A preliminary survey has already been completed by NASA, and its findings are expected to become available sometime in July. The study lasted an entire year, during which time a team of researchers narrowed 20 possible applications down to a select five. Though the data investigated were real, the study was largely to develop the methodology for the full-scale survey.

The figures have not been released yet, but they will be in the form of savings in dollars and cents, says J. Robert Porter of the space agency's resources program. In investigating hydrology, for example, the test survey team found that knowledge of the lateral extent of snow could have saved $10 million for the Bonneville Power System, by aiding water management.

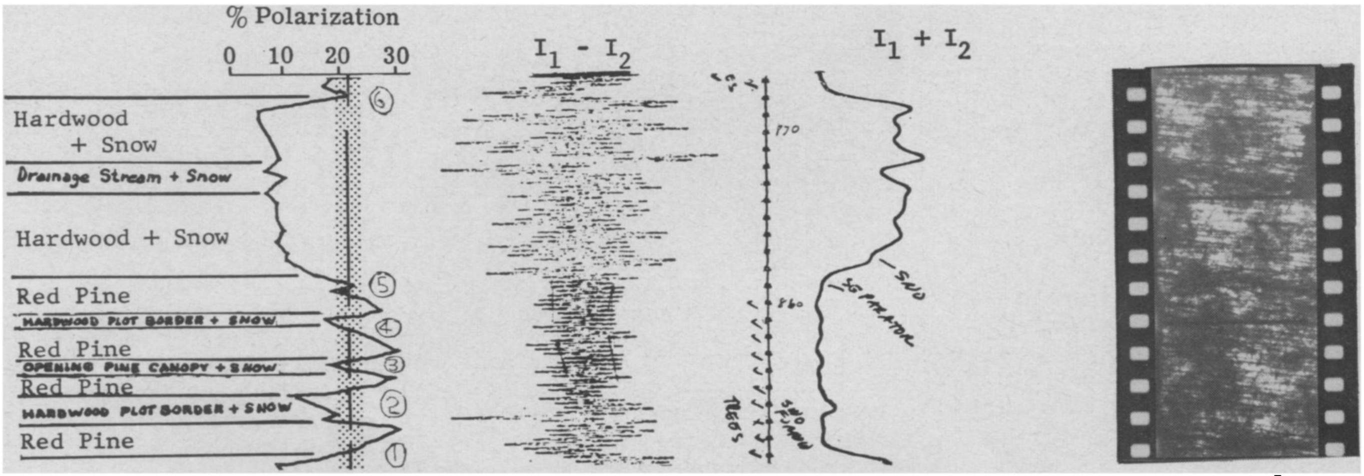
Another finalist was crop census, and it is likely that some sort of agricultural data-gathering would be a part of any earth resources satellite's role. The Department of Agriculture has a computer-card system to keep track of what's planted where in the country, accurate to within about 90 percent nationwide, says Porter. At the state level, however, the accuracy is only 75 percent, he says, and for individual counties the cards have only about a 50-50 chance.

While some investigators are deciding what the sensors should do first, others are developing sensor technology to new levels of sophistication. One important area is the use of two or more sensors at a time. Although one kind of sensor can provide valuable information—doctoral theses have been written about a single Gemini photo—a correlation of data from several at different wavelengths increases the amount of available knowledge by leaps and bounds. Targets reflect varying amounts of light at different wavelengths, and if two targets have the same reflectance at one wavelength, they are likely to differ at another. A number of reflectance measurements at different wavelengths comprise a target's characteristic signature.

At Purdue University in Indiana, one of several institutions working with multiple sensing, a computer has compared data from as many as 12 sensors to produce a map in which oats appear as a field of O's, wheat as W's, corn as C's and so on. It is possible, says project head Prof. King-Sun Fu, to detect the differences between early and late corn, between alfalfa or soybeans and merely luxuriant weeds, and even between two fields of corn of different varieties.

The University of Michigan has gone even further, with a single unit capable of covering 18 separate wavelength bands. In practice, however, the smaller the number of sensors that can get the job done, the better. "Unfortunately," says a spokesman, "no one knows which or how many bands are optimum for a given task."

A different approach is polarimetry. One of the parts of a target's characteristic sensor signature is the relative degree to which it reflects light polarized in different directions. At Grumman Aircraft Engineering Corp., in Bethpage, N.Y., Walter G. Egan has been able to use this characteristic to identify stands of red pine, snow-laced hardwood and even a snowy drainage ditch. First he flew over each of these types of terrain in a small plane, scanning them with his sensors and noting the sum and difference in the amounts of polarized light reflected from the different targets over a range of polarization angles and at different viewing angles. Once he had the sum-and-difference signatures, he was able to fly over again and later identify the terrain he had crossed, solely by looking at the data from his sensors. In one case he discovered that an unexpected red pine signature on his data tapes was indeed a grove about which he had not known.



Grumman

Comparison of reflected light at different polarization angles, measured by sensors, reveals snow, tree types.

Most remote sensors operate like specialized cameras, measuring the radiation reaching them at a certain wavelength. A few, however, send out their own beams and measure the return.

Radar, for example, operating in the microwave regions of longer wavelengths than infrared, is a valuable tool for measuring ocean wave heights, among many other applications. A relatively new variation is side-looking radar, which uses either a long, narrow antenna aligned parallel to the motion of the plane or satellite, or an electronic system to simulate a long antenna with a conventional unit. Looking out at right angles to its direction of travel, side-looking radar can penetrate darkness and heavy cloud cover with such clarity that it may be possible to locate individual ships by scanning the ocean from satellite altitude, sky-spy style.

Side-looking radar also enables extremely fine-resolution terrain photography and mapping. Geologists and seismologists have a particular interest in radar, since it can often penetrate the first millimeter or so of surface to reveal fault signs that would otherwise have been masked by weathering.

Not all sensors will be usable in satellites, however. Lasers, another possibility, will probably be flown aboard planes for any ground measurements. And some tasks, observes NASA's Porter, are likely to require a mixture of both types. If an infrared sensor aboard a satellite, for example, locates a "hot spot" of wheat rust, an airborne sensor may be necessary to pick out affected portions of individual fields.

An elaborate two-week test of a wide range of sensors is now being conducted in California by the U.S. Geological Survey and NASA. The program involves some 50 scientists, hundreds of miles of carefully selected land and water test sites, and myriad sensors including: film and TV cameras, with filters for different wavelengths; infrared scanners and radiometers to show the effects of different surface conditions; and radar and passive microwave sensors for data on land use, soil moisture and other properties.

Officials differ about a resource satellite's chances. Dr. Gerald B. Collins, director of the U.S. Fisheries Biological Laboratory in Seattle, hopes to be using satellite oceanographic data to track salmon by late 1970. At General Electric in Philadelphia, which aspires to build the spacecraft, advanced systems specialist Dr. Harold Lorsch agrees that such a satellite could be in orbit within two years, but feels that tight budgets and the evaluation of the different tasks will probably stretch the program to twice that long.