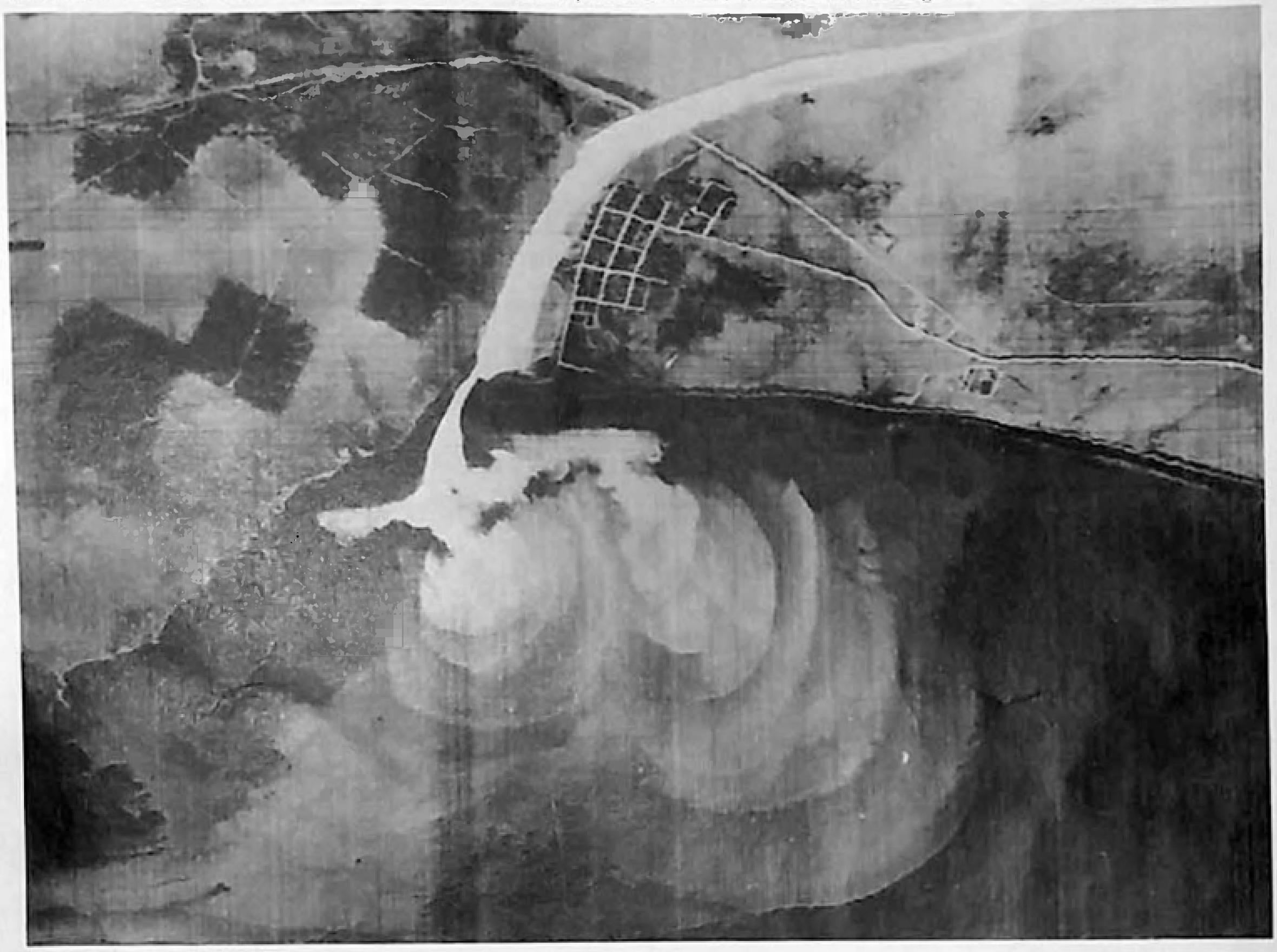
This high-altitude infrared photo clearly shows sedimentation patterns in the Quinault River discharge into the Pacific at Taholah, Wash.



Spotting Pollution from Space

by Kurt R. Stehling

The potential is there, but a full-scale program would require development of new and improved sensors, and establishment of a data management system of high efficiency.

Ecologists and environmental scientists have long been aware that pollution, far oftener than not, is more than just a local phenomenon. During the past few years there has been a growing demand for an observation technique that would permit the course and extent of a specific pollution phenomenon to be traced on a regional, and even global, basis, if necessary.

Small aircraft or helicopters, ships and shoreline observation stations are only part of the answer. Large portions of the oceans and the upper atmosphere do not lend themselves to such surveillance, and even large inland waterways like Delaware Bay or the St. Lawrence River are difficult to cover systematically. Yet in cases where a tanker dumps oil far out in the ocean, well removed from normal shoreline or light aircraft observation, or where an oil slick spreads over a 50- or 100-mi area (or, as in the Torrey Canyon case, over many hundreds of miles), the need for an overview of the situation becomes imperative.

The answer lies either in larger aircraft, capable of flying at higher altitudes, or, as has been mentioned more and more frequently lately, in spacecraft complemented by aircraft. For not only would aircraft supplement satellite observations and aid in photo interpretation—always a difficult problem—but they would be used whenever clouds obscured the earth's surface or whenever sudden, highly localized pollution required immediate observation. In addi-

tion, they would serve as flying test beds in the development of new and improved spacecraft sensors.

It should be noted that remote sensing and evaluation of pollutants in the atmosphere, in or on the water, and on land by high-flying aircraft or spacecraft are not prospects for some distant future. They are possible today. In addition to a good deal of experimental work and a number of years of experience with aircraft, we already have photos taken by Gemini and Apollo astronauts that prove pollution can readily be observed from space.

The pictures taken from aircraft, Gemini capsules, Apollo 7 and 9 spacecraft, and Nimbus satellites reveal the presence of sediment, chemicals, oil and other industrial effluvia, as well as thermal pollution, in such bodies of water as the Gulf of Mexico and the Chesapeake and Delaware Bays. These pictures also show smog, smoke and sulfur dioxide over industrial areas like Los Angeles. In fact, there is scarcely a single form of pollution today that cannot be observed or monitored by an aircraft or spacecraft using the proper sensor.

Seeing the evil clearly

The availability of proper sensors is of course crucial to the effectiveness of any spacecraft system for detecting pollution, and much work remains to be done in this area. Microwave radiometry is a possible technique for passive pollution sensing, but using it to detect oil slicks on the ocean surface will not be feasible without further research. In fact, an extensive aircraft program would be required to determine whether or not factors like foam, salinity, atmospheric absorption, rain scattering and waves cause specular obscuration of ocean-emitted microwave radiation that would make it impossible to obtain unambiguous measurements of oil slicks and other surface phenomena.

To date, microwave radiometry has been used to detect sea ice, make sea-state measurements and measure thermal ocean current boundaries. So far, all experiments of this nature have been aircraft-based, but the Nimbus E and F satellites, scheduled for launch in 1972 and '73, respectively, will carry 19-ghz (1.5 cm) and 39-ghz (0.8 cm) radiometers, the main purpose of which will be atmospheric thermal and water vapor analysis.

Still, if some qualities of the sea make it difficult to get significant measurements, others help. The luminescence produced by many pollutants may constitute an important signature detectable by sensitive optical instrumentation aboard aircraft or spacecraft. The Interior Department has already used Fraunhofer-line spectral techniques to detect bioluminescence in the sea, even in daylight, and while the luminescence signature of biota would obviously have to be differentiated from that of pollutants, this kind of optical discrimination is feasible.

Moreover, since some chemicals—DDT is an example—are luminescent on land as well as in water, optical techniques for spotting luminescence could have wide application. One now under study involves laser stimulation of fluorescence in the blue-green (300-400 angstrom) region.

Industry has shown keen interest in developing remote earth sensors and applying them to the problem of pollution. TRW, GE, Westinghouse and Raytheon are among the companies that have already developed spectrometers, microwave radiometers and radars, laser altimeters and emitters, television sensors and cameras for this purpose. Others either now have or are planning remote pollution-sensor programs. HEW, along with other agencies, is funding several pilot programs in this area, and more can be expected.

Reporting the evil effectively

However, observing or sensing pollution is only part of the problem. If a remote sensing program—with all its potential for rapid scanning of an entire continent or hemisphere, by day or by night, and in many cases even on an all-weather basis—is to be successful, it must be accompanied by a data management system of high efficiency. It serves no useful purpose to have pictures by the thousands flowing in from spacecraft, satellites or aircraft if those pictures cannot be distributed rapidly to those areas that require them.

If, for example, a satellite should discover a large oil slick far out at sea and, equally important, if it could determine which tanker in the area was responsible for the slick, this information must be transmitted with all possible speed to the responsible agency on the ground, so that further movement of the slick can be monitored, and hopefully eliminated, and the identity of the tanker established so that legal action can be taken. Without a data system to do this, the task is only half completed.

UPCOMING SATELLITES WITH POLLUTION DETECTION CAPABILITY

Year	Name	Direct	Inferential*
1970	Tiros M		●
	Nimbus D	●	●
1971	ITOS A		●
	ITOS B		●
	ITOS C		●
1972	Nimbus E	●	●
	ERTS A	●	●
	Skylab	●	●
1973	Nimbus F	●	●
	ERTS B	●	●

*Inferential—capable of inferring smog, currents, etc., from observation of winds and clouds.

SOME POLLUTANTS OBSERVABLE BY REMOTE SENSING

Pollutant	Environment	Platform	Sensor
Oil	Coastal waters	Aircraft Spacecraft	Camera Microwave radiometer
Heated water	Coastal waters and lakes	Aircraft Spacecraft	IR radiometer Microwave radiometer Near IR photography
Phenols	Estuaries, Rivers	Aircraft Spacecraft	Spectrophotometer Spectrometer Fluorimeter Fluoro-photography
Sewage	Estuaries, Bays, Rivers, Near-shore ocean	Aircraft Spacecraft	Spectrophotometer Polarimeter IR radiometer
Smog, Smoke, Dust	Atmosphere	Aircraft Spacecraft	Photography IR radiometer Spectrometer
DDT	Soil, Water	Aircraft	Fluoro-photography Fluorimeter Spectrophotometer
SO_2, N_2O_5, NO_2	Atmosphere	Aircraft Spacecraft	Spectrophotometer Spectrometer IR radiometer

Above, a view of the coast of Southern California from Apollo 7 shows pollution obscuring the details of the Los Angeles area and extending from Banning westwards for 100 mi to Malibu. Below, a plot of the sulfur-dioxide concentration, as measured by a Barringer Correlation Spectrometer from an aircraft flying over the Los Angeles basin, correlated well with surface sulfur-dioxide measurements.

The use of computers for analyzing and storing data would surely be a large part of any data management system of this kind. Part of the system could be programmed to detect recurring patterns in the data collected. For example, possibly a good deal would be learned about pollution patterns in coastal waters if data were available daily on the near-shore eddy system.

NASA, in establishing its Earth Resource Technology Satellite (Erts) program, is planning to extend its picture handling and general data management system. However, if a national pollution detection and evaluation system were to come into being, either parallel to or in conjunction with the Erts program, data management facilities would have to be enormously expanded.

The need for speed

The facilities would have to be capable of quickly receiving, reducing and analyzing spectrometric, radiometric and photographic data from spacecraft or aircraft. They would also have to correlate such data with "ground-truth" measurements needed to complement or supplement the data from space and then relay it rapidly to the concerned local or regional agencies.

Space data on sedimentation in river estuaries, for example, would have to be coordinated quickly and efficiently with information from the U.S. Coast Guard Data Buoy program, which uses buoys with such instrumentation as pH meters, water analyzers and oil detectors, to make needed ground-truth measurements. The easiest way to do this might be to relay all the information via satellite to a central data station.

Certainly any such data system would require improved facsimile systems and microwave links to handle the large masses of analog or digital data that would constantly be coming in. Ecologists see the day coming—and they think it is not too far off—when a national center for monitoring and assessing atmospheric and water pollution will be established, or, if not that, they anticipate at least the establishment of a number of regional pollution control centers similar to the network of U.S. regional weather analysis centers.

When various remote sensor platforms such as buoys, aircraft, helicopters, blimps and spacecraft can work together so as to supplement and complement one another, and when the information from all such platforms can be integrated into a national data management system, a major step forward will have been taken in the fight against pollution. It is entirely conceivable that remote pollution detection may yet prove to be one of the most important fallouts of the space age. ■

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