

BIOGRAPHICAL SKETCH

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Mr. North was born in Schenectady, New York; was graduated from Davis and Elkins College, Elkins, West Virginia, with a Bachelor of Arts degree in history and political science; and has done graduate work at Utica College of Syracuse University. In 1962 he attended the Air Force's Photo-Radar Interpretation School and subsequently served as a photo interpretation officer with that organization. In 1965 he joined Raytheon Autometric Company's Rome, New York, office and worked in support of various remote sensor evaluation programs and associated projects of the Rome Air Development Center. In 1968 he joined Raytheon's terrain sciences department and was responsible for the system's integration for the NASA/U.S. Geological Survey, Southern California Remote Sensing Test Program. In addition, he was the on-site program manager for a side looking radar survey in Ecuador, South America. In 1969 Mr. North joined the U.S. Geological Survey where he is assigned to the Geographic Applications Program and works in association with the Department of the Interior's Earth Resources Observation Systems Program (EROS) and with the NASA Earth Resources Aircraft Program. During 1970 he was responsible for two special projects involving the application of remotely sensed data to environmental problems. The first project resulted in the publication of a booklet entitled "Environmental Conditions and Resources of Southwestern Mississippi" and the second, in the preparation of a report entitled, "Remote Sensing of Environmental Pollution." During the summer of 1970 he was selected to serve as the alternate representative of the Department of the Interior on the National Aeronautics and Space Council's Interagency Ad Hoc Study Group on the Earth Resources Survey Program. Mr. North is a member of the Association of American Geographers and the American Society of Photogrammetry. He was named to the 1961-62 edition of Who's Who in American Universities and Colleges and the 1970 list of Outstanding Young Men of America.

REMOTE SENSING
OF
ENVIRONMENTAL POLLUTION

by

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ABSTRACT

Environmental pollution is a problem of international scope and concern. It can be subdivided into problems relating to water, air, or land pollution. Many of the problems in these three categories lend themselves to study and possible solution by remote sensing. Through the use of remote sensing systems and techniques, it is possible to detect and monitor; and in some cases, identify, measure, and study the effects of various environmental pollutants. As a guide for making decisions regarding the use of remote sensors for pollution studies, a special five-dimensional sensor/applications matrix has been designed. The matrix defines an environmental goal, ranks the various remote sensing objectives in terms of their ability to assist in solving environmental problems, lists the environmental problems, ranks the sensors that can be used for collecting data on each problem, and finally ranks the sensor platform options that are currently available.

Examples of remote sensor data relating to various environmental problems will be shown during the oral presentation of this paper. These examples have been extracted from a special report entitled "Remote Sensing of Environmental Pollution." This report was prepared by the Geographic Applications Program of the U.S. Geological Survey for the Department of the Interior's Earth Resources Observations Systems Program, and for the Earth Observations Program of the National Aeronautics and Space Administration.

INTRODUCTION

Several days ago, during the first part of this International Workshop, many of you heard a paper outlining the various steps required to carry out a regional assessment of environmental quality through the use of remote sensing. The objective of this paper is to concentrate on one of those steps and look in detail at many of the detrimental factors that tend to lower the quality

of an environment. We are going to examine some of the problems of land, air, and water pollution and discuss many examples of how remote sensing devices can detect, identify, measure, monitor, or determine the effects of various environmental pollutants. Within each category an attempt will be made to show what can be observed, interpreted, and/or monitored from currently available experimental and operational spacecraft, high and low altitude aircraft, and ground based platforms. Examples of special processing, enhancement, and analysis techniques will not be discussed in detail, since they have already been, or will be, covered in several of the other papers during the workshop.

The illustrations shown during the oral presentation of this paper were taken from a special report entitled "Remote Sensing of Environmental Pollution" prepared by the U.S. Geological Survey, with substantive contributions from many different governmental agencies and commercial firms. This report covers more than 50 of the environmental problems faced by this nation. Many of these may be problems in your own country and if they are not, they represent potential problems that you may face in the near future.

REMOTE SENSING SYSTEMS

Various remote sensing devices can be used to collect the different kinds of data relating to pollution. In many cases a single sensor can provide the necessary data while for others, a specialty sensor or combination of sensors may be required.

Cameras:

Perhaps the oldest, best known, and most widely used remote sensor is the camera. You will probably find this to be the easiest, cheapest, and most flexible sensor to use. With lens options and different film/filter combinations, much can be accomplished with a camera system.

Infrared and Multispectral Line Scanners:

A second family of sensors includes the infrared and multispectral line scanners. Infrared scanners are built to detect the thermal infrared, or heat energy emitted by objects. They are most useful in detecting heated effluents from power plants, industrial processes, or monitoring the surface temperatures of rivers, lakes, and streams. They can be used during the day or night, since they record energy emittance and not the sun's reflected energy. Various models of these scanners are available commercially and can be carried about in suitcase size boxes and used in small aircraft.

Multispectral scanners operate on the same principle as the infrared scanners except that they record data in other portions of the spectrum, in addition to the infrared. Only a few of these sensors are being flown experimentally in this country. They are very expensive to operate and maintain, and often require a computer system to effectively analyze the raw data.

Radiometers:

Radiometers are non-imaging sensors which measure emitted or reflected electromagnetic energy and graphically display this information on a strip chart recorder. They can be built to be sensitive to a range of energy from the ultraviolet portion of the spectrum to the infrared region, and are useful in recording spectral signatures for various objects. When flown in conjunction with a thermal scanner, they can provide temperature measurements of the ground or water which can then be correlated with the different grey tones of the thermal imagery. By using radiometers and scanners together, it is possible to eliminate the need for taking temperature samples on the ground. Another application of these sensors involves using them to determine the thickness of crude oil slicks lying on water surfaces.

Side Looking Radar:

Side looking radar is an all weather, day/night sensor that is particularly effective in imaging large areas of terrain. A special advantage of this sensor is that it penetrates most clouds and thus, if you live in a perpetually cloud covered region of the world, it may be practical to acquire radar coverage instead of photography. This sensor, while not specifically designed for pollution detection, is effective in monitoring strip and open pit mining operations and other large scale changes to the landscape. It could also be used to monitor extent and level of content changes in large industrial waste ponds or tailings dumps and for monitoring oil spills.

Correlation Spectrometer:

Another specialty sensor is the correlation spectrometer. This non-imaging sensor was built to detect quantities of gases in the atmosphere from either an aircraft, or hopefully, spacecraft platform. This device measures the concentrations of a single air pollutant in a column of air between the ground and the platform and then prints out the concentrations on a strip chart recorder. Even though it is undergoing development tests, it has demonstrated its usefulness in detecting, from aircraft, sulfur dioxide and nitrogen dioxide, two pollutants that are major

components of smog. These sensors can also be placed in mobile vans to be moved about on the ground to check on various smoke-stack emissions.

Decibel Recorders:

A decibel recorder is a device to measure the relative intensity of sound. The sensor detects and records various noises on a strip chart recorder thus producing a graphic record of its intensity. Such devices could be used to determine whether or not housing should be allowed near such things as airports, expressways, heavy industry, etc.

Fraunhofer Line Discriminator:

The Fraunhofer Line Discriminator was built specifically to detect and measure fluorescence. Currently undergoing flight development tests in a helicopter, the device has effectively detected concentrations of Rhodamine WT dye as small as five parts per billion. This alone is encouraging since this dye is often used to study current and mixing patterns in water bodies. By mixing portions of the dye with particular pollutants, it may be possible to determine to a greater extent what the fate of these substances may be once they enter a stream or lake. It is hoped that additional instruments will be built to detect small quantities of such things as crude oil, fish oil, pulp mill wastes, and other substances that fluoresce.

Scintillation Detectors:

Scintillation detectors are often referred to as aeroradioactivity equipment and are placed in low flying aircraft to detect and monitor gamma radiation. The sensors record radioactivity in counts per second, and by plotting flight paths and sensor readings, individual ranges or radioactivity levels can be assigned to specific areas. These instruments are useful in monitoring radioactive waste material disposal areas and in checking radioactivity levels of nuclear power plant effluents.

SENSOR/APPLICATIONS MATRIX

With the sensors that have just been described it is possible to detect and monitor; and in some cases, identify, measure, and study the effects of various environmental pollutants. There are, of course, many variables involved and once a basic photographic coverage has been fully interpreted for current and potential pollution sources, new decisions requiring supplementary data will be necessary. As a guide for making these decisions, a special five-dimensional matrix has been designed. The matrix defines an envi-

ronmental goal, lists the environmental problems, ranks the sensors that can be used for collecting data on each problem, and finally ranks the sensor platform options that are currently available.

Figure 1 shows the matrix for water, air, and land pollution problems. To use the matrix one simply reads the numbers and letters in each of the blocks, and checks them against the key to see what they mean. Each block represents a decision involving two factors. For example, if the environmental problem is oil spills, the matrix indicates that remote sensing is an excellent way to detect, identify, and monitor such spills and that it represents an excellent input for environmental planning and modeling. This is shown by the use of the number (1) in the appropriate blocks. Remote sensing is only a fair way, however, to determine the effects of oil spills on the environment, since this requires supplemental ground level sampling and analysis. This is shown by the use of the number (4). In the blocks involving the sensor/problem interaction, the matrix indicates that a multispectral scanner is the best, or (A), sensor for providing data, but that either a camera with color infrared film, a side looking radar system, or a microwave radiometer would be good (B) choices to provide additional oil spill data. The last of the matrix blocks suggests that an aircraft flying at altitudes of 600 - 6,000 meters would be an excellent, or (1), platform for the chosen sensor or sensors.

To show the overall range of effectiveness of remote sensing to assist in solving environmental problems, the numbers in the Remote Sensing Objectives block have been totaled. By checking the total for each environmental problem, one is able to determine which problems are most amenable to solution by remote sensing.

ENVIRONMENTAL PROBLEMS

A. Water

Water pollution is a world-wide phenomena, and irresponsible human attitudes and activities will probably create an even more critical problem in the future. Water pollution is not a local problem for once a pollutant has been added to the water it is carried downstream into lakes, underground aquifer systems and eventually the oceans. Multiple demands for water will continue to increase, especially near the urban centers of the world. As this demand increases, we must remember that the discharge from one user becomes part of the water supply for the next. Thus, it is critical that each time water is used it must be released in a safe condition. Remote sensing can detect and monitor many of man's activities regarding the use and misuse of water.

The following list represents a few selected examples of various water pollution problems in the United States. By examining remote sensor data covering these subjects and then studying the matrix, one may gain a better understanding of how effective remote sensing is in trying to find a means to solve these problems.

1. Incompatible Urban Water Uses
2. Municipal Sewage Discharges
3. Algae
4. Contaminated Ground Water Systems
5. Acid Mine Drainage

B. Air

The Earth's atmosphere is the most mobile of the three basic components of our environment. It is a dynamic system which has neither regional boundaries nor ownership attached to it. Nature contributes particulate matter to the atmosphere when a volcano erupts, when a forest burns, and when winds blow across a barren area. Man does a comparable thing when he burns fossil fuels, drives his automobiles, or runs his factories. In fact, where concentrations of people are the greatest, so are the concentrations of air pollutants. Because cities have become heat and particulate anomalies, they are beginning to affect the climate of areas around them. Polluted air masses also cost these same areas a significant number of days of sunshine per year. Add to this the fact that respiratory illnesses and even deaths increase with high levels of air pollution, and one can see the severity of the problem we face.

Remote sensing systems have a significant role to play in the collection of air pollution data. They will not replace the present ground monitoring systems and laboratory analyses which are performed, but they can add a new dimension to air pollution control by providing a regional perspective, by detecting sources and some specific types of pollutants, and by determining representative sample points. The combination of both the more common ground sampling networks and the synoptic view provided by remote sensors can provide an effective detection and monitoring system. Eventually we may even be able to plot and trace concentrations of various pollutants around the globe in much the same way that we presently monitor cloud and weather systems.

The following list represents examples of air pollution problems that are also included and ranked on the Sensor/Applications Matrix.

1. Smog
2. Dust Storms
3. Fire and Volcanoes
4. Contrails from Aircraft and Ships
5. Ore Smelter Smokestack Plumes

C. Land

The land resources of the world are neither unlimited in areal extent nor equally capable of supporting human activity. Some of it has been abused and some of it has actually been destroyed for any future productive capability by exploitation and uncontrolled growth. In areas where the land is adaptable to a variety of productive purposes, the demand is greatest and the competition between various land uses is most intense. At present, land use policy is usually determined by who will pay the highest price for each parcel of land. In the years ahead it will become increasingly important for each nation to decide what value it places on each activity and each parcel of land. Each of you should make these decisions based on scientific data and human values in an attempt to establish an environmentally sound master plan for future development. In this way each activity will be allocated the proper amount and type of land, many land pollution problems will be eliminated, and the quality of the overall environment will be improved.

Land pollution problems are different from air and water problems because with land ownership is involved. Parcels of land belong to someone but no one owns the air or a river and besides, unless they are detected at their source, water and air pollutants drift or float away. Land problems, however, remain stationary and until the owner and probable cause are identified and forced to correct the situation, the problem will remain.

Remote sensing can locate and identify these problems and monitor any remedial actions that are taken. The following list of examples from the matrix will illustrate various land problems and how they can be observed by remote sensing.

1. Parking Lots
2. Garbage and Solid Waste Disposal
3. Hillside and Coastal Housing Developments

4. Open Pit Mining
5. Underground Fires
6. Underground Gasoline Leaks
7. Lumbering Activities
8. Disasters

CONCLUSION

On February 10, 1970, the President of the United States made an address to Congress on the environment. In this speech he said:

"... We came only late to a recognition of how precious and how vulnerable our resources of land, water, and air really are...The time has come when we can wait no longer to repair the damage already done, and to establish new criteria to guide us in the future...The tasks that need doing require money, resolve, and ingenuity--and they are too big to be done by government alone. They call for fundamentally new philosophies of land, air, and water use, for stricter regulation, for expanded government actions, for greater citizen involvement, and for new programs to ensure that government, industry, and individuals all are called on to do their share of the job and to pay their share of the cost...The fight against pollution, however, is not a search for villains. For the most part, the damage done to our environment has not been the work of evil men, nor has it been the inevitable by-product either of advancing technology or of growing population. It results not so much from choices made, as from choices neglected: not from malign intention, but from failure to take into account the full consequences of our actions."

This message applies not just to Americans, but to the citizens of all the nations of the Earth. If you too can accept this as a challenge, and perhaps employ some of the remote sensing techniques you have learned about at this workshop, we can all work together to build a quality environment for the many generations who will follow us here on the Earth.

GLOSSARY OF TERMS

Acid Mine Drainage - Phrase used to describe the acidic water which commonly drains from strip and underground coal mines. Its presence can usually be inferred whenever a stream has a bright yellow/orange color. This color is produced by a liquid called "yellow boy" which is the result of the chemical reaction of the acidic water with iron.

Aeroradioactivity Equipment - Sensor or instrument that is used in low flying aircraft to detect and monitor gamma radiation.

Anomolies - Quantities which increase uniformly with time.

Correlation Spectrometer - A sensor built to detect gasses in the atmosphere. This device analyzes the column of air between the sensor and the ground and then plots out the concentrations of each gas on a strip chart recorder. By plotting these readings along the line of flight, a verticle profile map of gas concentrations can be made. It is used primarily to detect sulfur dioxide.

Decibel Recorder - A sensor used to measure the relative intensity of sounds.

Effluent - Term used to describe any liquid discharge.

Enhancement - Process by which certain details or grey tones of a piece of remote sensor data are magnified and/or intensified.

Flourescence - Property possessed by certain substances of emitting light following exposure to external radiation.

Fraunhofer Line Discriminator - A remote sensing device built specifically to detect and measure flourescence.

Infrared Line Scanner - A remote sensing device built to detect the thermal infrared energy emitted by objects. The word scanner is used in connection with this sensor because the detection system involves the use of a rotating mirror which directs the incoming radiation through a detector and onto a piece of film at the rate of one scan line per rotation.

Matrix - A form which shows the linkages between two or more interrelated subjects.

Multispectral Line Scanner - A remote sensing device which operates on the same principle as the infrared scanner except that it is capable of recording data in the ultraviolet and visible portions of the spectrum as well as the infrared.

Platform - Term used to describe the vehicle or equipment on which a remote sensing device can be mounted. An aircraft or spacecraft is often referred to as a sensor platform since it is capable of having sensors attached to it.

Radiometer - A non-imaging sensor which measures emitted or reflected electromagnetic energy.

Remote Sensing - Term used to describe the use of instruments that measure properties of objects without coming into direct contact with them. It is also used to describe a series of related problem solving activities involving data acquisition, collection, processing, distribution, and analysis.

Rhodamine WT Dye - A red dye used in hydrology studies. The WT indicates a specific type of rhodamine which has a peak fluorescence of between 5,800 and 5,820 angstroms.

Scintillation Detector - A remote sensing device built to detect gamma radiation with energy levels greater than 50 Kev (thousand electron volts).

Side Looking Radar - An all weather, day/night remote sensor which is particularly effective in imaging large areas of terrain. It is called an "active" sensor since it generates its own energy which is transmitted and received out the side of the aircraft to produce a photo-like picture of the ground.

Smog - Term used to describe a polluted air mass comprised of a mixture of smoke, fog, gasses, and other particulates.

Spectral Signature - Quantitative measurement of the properties of an object at several wavelength intervals.

Tailings - Term used to describe the material separated as residue in the preparation of various products, grains or treated ores.

