Future And Present Needs Of Remote Sensing In Geography

by

DAVID S. SIMONETT

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A paper presented to the Fourth Symposium on Remote Sensing of the Environment, University of Michigan, Ann Arbor, Michigan, April 11-14, 1966.

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PRESENT AND FUTURE NEEDS OF REMOTE SENSING IN GEOGRAPHY*

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ABSTRACT

The most pressing present need in remote sensing in geography is not the immediate development of newer, fancier remote sensing devices. The fundamental problem remains that of learning how to interpret and evaluate the information contained in different parts of the electromagnetic spectrum using existing sensors. Additional short-run needs in geography include: 1) the identification of categories of information required by geographers which are not normally obtained by other investigators, 2) the development by commercial manufacturers of a variety of preprocessing instruments which parallel first through fourth order photogrammetric devices, 3) the development of cooperative research programs with engineering departments, 4) the development of research combining empirical and theoretical studies of geographic information content of imagery as a function of system resolution, dynamic range, frequency etc., 5) the utilization of GEMINI space photography for research and teaching, 6) the development of courses in remote sensing and geography departments, and 7) the acquisition of multiple copies of unclassified radar, infrared and multispectral photography for use in geography departments through allocation of funds by appropriate federal agencies.

Numerous examples for future needs of remote sensing in geography are given in the eight panel reports prepared at the conference on the Use of Orbiting Spacecraft in Geographic research, Houston, Texas, January 1965. Four future problem areas noted in this paper are; 1) the development of hardware and software to encompass multiple alternative routes to automated data handling and manipulation, 2) the development of operational real-time data recall and handling both for research and classroom use, 3) the optimization of all-weather data collection systems, and 4) the development of new instruments for remote sensing based on the use of proxies or surrogates for conventional data.

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1. INTRODUCTION

The scope of geography is broad. A measure of the breadth may be obtained by reading the proceedings of the Conference on the Use of Orbiting Spacecraft in Geographic Research held at the National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, in January 1965. At this meeting eight panels met to consider the impact on geography of future earth orbiting spacecraft carrying remote sensing devices such as multiband cameras, infrared radiometers, high resolution radars and others. The eight panels dealt with 1) energy and water budget, 2) settlement, population and historical geography, 3) resource utilization, 4) geomorphology and glaciology, 5) transportation and linkages, 6) urban geography, 7) mapping, imagery, and data, and 8) plant cover and soils. In their interest in these areas geographers are certainly not alone. However the geographer's emphasis in research in all these areas lies in seeking understanding of the spatial arrangement of natural and cultural systems, of spatial interaction and flow, and the aggregate characteristics and patterns of man's activities on the earth (Tobbler, 1966).

In the collection of data over such a wide range of human and natural phenomena, uniformity of collection and comparability of format are rarely achieved even within a single advanced society. Data is rarely comparable from country to country and in underdeveloped lands is lacking to a high degree.

Among the most valuable contributions remote sensing can make in the field of geography is the collection of uniform data over short periods of time on a world-wide basis. Our knowledge of spatial phenomena and spatial interaction and the theories we have erected in geography (Nordbeck, 1965) are to a greater or lesser degree based upon information widely scattered in space, time, quality, and quantity. Multi-sensor, remote sensing from spacecraft and to a lesser degree from aircraft, will provide a near-synchronous datum for evaluation of future change, will help fill the gaps in data now spliced by inference, and will add the new dimensions of generalized observation and review coupled with multi-band spectral reconnaissance, a potentially powerful combination for the generation of data and ideas. The knowledge obtained in this manner will stimulate much research and will inevitably bring revision of many existing theories.

In addition to the obvious gains for geography in a new look from space, in the ability to test and revise old theories, and to work from the whole to the part, from overview to anomalous detail, there are many attractive practical advantages to spacecraft observations. The advent of spacecraft-based remote sensors has served to remind geographers not only of the vast gaps in our knowledge of remote areas, but also those existing even in advanced societies. It has also brought home forcefully that a spacecraft is peculiarly suited for broad-scale observations of a type which we have been forced to acquire up to now by laborious piece work.

Many interests in geography thus converge in the expectation that remote sensing (especially that which may be obtained from spacecraft), has the potential to wreak many changes in the data gathering, handling, and analytical methods employed in the field. It is certain that spacecraft remote sensing will bring significant changes in teaching methods, subject matter, and in the use of illustrative materials in the classroom at all levels from grade school to the university, and in the character of at least some of the spatial generalizations which constitute the mental equipment of geographers.

2. PRESENT NEEDS FOR REMOTE SENSING IN GEOGRAPHY

The most pressing present need in remote sensing in geography is <u>not</u> the immediate development of newer, fancier remote sensing devices. The fundamental problem remains that of learning how to interpret and evaluate the information contained in different parts of the electro-magnetic spectrum using existing sensors. This is the one overriding problem and it arises from the need to compress research into a relatively short time in order that space-derived imagery may fruitfully be used. Multi-band photography, and infrared and radar imagery will become available in large quantities in the late 1960's and through the 1970's. Time is running out for developing personnel trained in the use of such data.

Additional short-run needs for more efficient research on geographic type problems with remote sensor data include:

1) the identification of categories of information required by geographers which are not normally obtained by other investigators and for which no substitute is available (this is especially true in dealing with cultural objects), and the development of suitable data-collection programs.

2) the development by commercial manufacturers of a variety of pre-processing instruments of differing complexity for use with radar and infrared imagery which parallel the first order, second order, third order and fourth order photogrammetric devices built up over three decades of work with aerial photographs

3) the development of cooperative research programs involving cross-discipline research with electrical engineering and other engineering departments

4) development of research combining empirical and theoretical studies of geographic information content of imagery as a function of system resolution, dynamic range, frequency etc.

5) The prompt analysis of GEMINI space photography, over and above that given in the preparation of the Atlas from Space by NASA (Leestma, 1966).

6) the acquisition and use of space photography, modest though the quantity be, for normal classroom use where relevant,

7) the development of courses in remote sensing in geography departments or through sharing with a number of geoscience departments, and

8) the provision through Housing, Education and Welfare and other government agencies-- of funds to purchase multiple copies of unclassified radar, infrared, and multispectral photography for use in geography departments throughout the U.S. (This is of course equally as important for geologists, foresters, botanists and others.) Each of these needs will be briefly discussed in turn.

2.1. INFORMATION NEEDED

Among the types of information which geographers need, but which are not presently being obtained by other investigators in substantial quantity are laboratory and field measurements of photometric quantities (spectral reflectance, absorptance, transmittance and emittance) in the visible, infrared and passive microwave region and the equivalent backscattering measurements with radar, of most cultural objects both of commercial and native construction. A number of studies of this type are being made under military contract already and the compilation of such data into part of a central catalog would be worthwhile. However there are many areas which still remain to be touched on. Most of this work is carried out by commercial organizations, institutes of technology, aeronautical laboratories, and electrical engineering departments. It need not remain exclusively so and there is a fruitful opportunity for cooperation between geography departments and electrical engineering and related departments in cooperative research. To my knowledge very little of this cooperative work is being engaged in. It is especially important at this time when new instruments for automated data collection and scanning are gradually being evolved. Latham (1963) has earlier made this same point, especially in regard to making instrument designers conscious of the need of geographers and other geoscience users.

Geographers are familiar with studies funded by the Geography Branch of the Office of Naval Research in remote sensing. However, many other agencies actively support both applied and basic research in this area, including Geodesy Intelligence Mapping Research and Development Agency (GIMRADA), Waterways Experiment Station, Vicksburg, Mississippi, U.S. Corps of Army Engineers, Army Signal Corps Laboratories, Fort Monmouth, New Jersey, Wright Patterson Air Force Development Center, Dayton, Ohio, Rome Air Development Center, New York and a good many others. The wide coverage of studies funded or initiated through these agencies may be seen by scanning any D.D.C. abstract list. A great deal of this applied research is not classified. Certainly, in the near ultraviolet, visible and near infrared relatively little security classification is to be found. Most fundamental measurements of a spectrometric type are not classified. Sizeable quantities of imagery in the radar region are now unclassified and are potentially available for study.

The concept of multiband spectral reconnaissance which motivates a good deal of the thinking in remote sensing today (Holter and Legault, 1964; Molineux, 1964) requires that a considerable catalog of empirically-derived data over rural landscapes or urban phenomena (Thomas and Marble, 1965) be obtained in order that appropriate probabilities may be assigned to identification of either discrete or aggregate phenomena. Since the geographer in many instances is concerned with the distribution and spatial ordering of aggregated phenomena (central business district, industrial parks, suburbia, rural urban fringe, and of course lumped categories of agricultural activity) it is appropriate to examine data in a variety of resolutions and from different altitudes.

Geographers and other geoscientists usually insist on the highest possible resolution in all sensors with which they work. However, this may by no means always be desirable. Major geologic structures have been uncovered by a number of investigators (Cameron 1965, Dellwig, Kirk and Walters 1966) utilizing radar images with resolutions of 200 to 600 feet in azimuth. Testing of imagery in different wavelengths with different resolutions for its empirical information content is an urgent need at present. At the University of Kansas we are attempting to do this in the radar wavelengths using a number of systems of different resolution and various electronic methods of degradation of image resolution. However, it is clear that it needs to be done in many places as well (Murray and Carey, 1964) and in different regions of the spectrum.

Mr. D. S. Lowe of the Institute of Science and Technology, University of Michigan has recently suggested the development of a multiband (5 band) scanning imagery for spacecraft use. This imager would employ channels tentatively covering the following spectral regions:

Channel 1 - .4 to .45 microns
Channel 2 - .6 to .7 microns
Channel 3 - 1 to 1.3 microns
Channel 4 - 2 to 2.4 microns
Channel 5 - 5 to 13 microns

The resolution of the system will be 1,000 feet.

This gross resolution would be unsuitable for detailed studies. However, since each of these spectral regions are recorded on magnetic tape this system has a number of valuable properties of interest to computer-oriented geographers. The information on reflected and emitted energy is derived by beam splitting, and recorded on tape. This data is compatible and internally geometrically consistent to a higher degree than is feasible using normal photographic recording techniques. There are many research areas where data of this resolution could be valuable in tape format for geographic studies. Geographers need deliberately to focus some attention on low resolution sensors in anticipation of comparable spacecraft data.

2.2. DEVELOPMENT OF NEW INSTRUMENTS

The development of simple instruments for working with imagery which does not follow visible reflectance optics is also essential. For infrared and radar images devices are needed which correspond to fourth order photogrammetric instruments such as mirror stereoscopes, radial-line plotters and so on. Even the commercial production of simple flicker devices which enable the eye rapidly to detect change between two geometrically comparable images of the same area (Goodyear, 1965) would be invaluable. The use of a change detection device (Shepard, 1964) for analysis of image films which had previously been through the automatic mosaiking process described by Anson (1962), would make for a sharp improvement in our capability of studying spatial change and spatial diffusion processes. Because of its obvious military application, it has been mainly military agencies who have concerned themselves up to now with change detection devices. However the problem is of vast concern also to professional geographers and to almost all civilian agencies concerned with extraction of data from images.

Commercial demand for such devices cannot develop _in vacuo_. Many users in many disciplines in commercial organizations and universities need to have access to imagery in the infrared, passive microwave and radar regions to enable such demand to develop. The orderly production of photogrammetric instruments of all ranges of complexity has taken decades and has been based on a very large market for the simplest instruments and a smaller but still significant market for complex and expensive first-order instruments. This demand cannot be generated by the present handful of departments in botany, forestry, geography, geology, hydrology and so on now using unclassified and classified imagery outside the visible region. It is seen therefore that the key to continued advance in this work is the wide-spread dissemination of imagery of all types.

2.3. WIDE DISSEMINATION OF REMOTE SENSOR IMAGERY IS NEEDED

Many geographers have expressed concern over the utterly inadequate dissemination and use of remote sensor imagery other than conventional aerial photographs. The view is commonly expressed that significant further advances in remote sensing await the ready availability of appropriate imagery. For efficient disbursal of imagery a major investment on the part of Housing, Education and Welfare, the National Science Foundation and other federal agencies seems appropriate for all the geosciences. I seriously doubt whether the existing pace of data diffusion is adequate for the jobs which lie ahead. Diffusion is inherently a slow process.

2.4. REMOTE SENSING EDUCATION IN GEOGRAPHY

Another area of pressing urgency is that of education for application of remote sensors in geography. It is important that education and research go hand-in-hand for in all except the visible part of the spectrum in which we have years of experience, detailed knowledge of the advantages and shortcomings of the other parts of the spectrum is modest indeed. Except for photocartography and photogeology and similar geoscience uses of photography efficient education in the use of remote sensing is rare. Even the education of photo analysists today still rests mainly on the use of panchromatic film. It is worth emphasizing that this is a universal need and is not confined to geographers or indeed to geoscientists alone. The first formal courses in Remote Sensing in the universities in the U.S. I believe are those this semester at the University of Kansas and in the coming summer at the University of Michigan. The situation is little better for the instrument design engineers. Radar is taught in a few institutions for example but the prime emphasis is on its military and navigational use. To my knowledge only one degree program in optical engineering exists in the United States. However this is supplemented by some renewed interest in physics programs oriented towards optics and infrared. Education for data handling and automation is available in many areas and institutions but infrequently with remote sensor applications in mind. The pressing need then is for integrated remote sensing courses which involve contributions from a variety of departments in a multi-disciplinary approach on university campuses.

For the geographer there are many practical advantages which redound from cooperative teaching and research at this time, not the least of which is obtaining access to and familiarity with modern instrumentation, part of which is a type suitable for teaching and analysis in senior undergraduate and graduate courses. Research in the use of remote sensors can also be most efficient in a multidisciplinary group. Numerous examples exist of errors in interpretation by groups consisting only of users or of engineers. Furthermore, each group tends to perform experiments (or theoretical developments) in which some significant factor is omitted that would have been obvious to members of the other group.

Also related to these education needs is the empirical analysis and re-analysis of existing spacecraft photography, and IR satellite imagery by geographers. Some 100 usable color photographs are now available through commercial organizations obtained from the various GEMINI Flights. For the expenditure of $1.50 and $3.50 respectively anyone in this audience may obtain a single 70 mm positive transparency and 8 x 10 color enlargement of the Hasselblad 70 mm color photographs obtained on these missions. These fall far short of the potential resolution possible from spacecraft not only with photography but also with radar systems but they are nevertheless the repository of considerable information and should be analyzed and utilized in classroom teaching now. These methods of remote sensing from spacecraft will enable us to use a single photograph to obtain an integrated view of a large area which "has required normally vast feats of cartographic exertion." (Alexander, 1964). Studies already made by geographers of spacecraft photography include those by Morrison and Chown (1965), Bird and Morrison (1964), and Bird, Morrison and Chown (1964). Additional unpublished studies have been collated by Leestma (1966) for the NASA Atlas from Space.

3. FUTURE NEEDS FOR REMOTE SENSING IN GEOGRAPHY

Numerous examples of future needs for remote sensing in geography are given in the eight panel reports prepared at the conference on the Use of Orbiting Spacecraft in Geographic Research, Houston, Texas, January 1965. I do not propose to repeat these here. In addition a report by Holter et al (1966) may be consulted. This latter report contains a twenty-page summary of present and projected applications of remote sensing from spacecraft prepared by seven geographers at the University of Michigan. It leans heavily on the Houston conference report but adds some additional material. These two documents represent useful companion papers to the present discussion and should be read in parallel with it.

For our purposes here I would like to stress four future problem areas requiring considerable work by design engineers if the demands of geographers and other earth and social scientists interested in remote sensing are to be met. They are:

1) The development of hardware and software to encompass multiple alternative routes to automated data handling and manipulation,

2) The development of operational real-time data recall and handling both for research and classroom use,

3) The optimization of all-weather data collection systems, and

4) The development of new instruments for remote sensing based on the use of proxies or surrogates for conventional data.

3.1. THE DATA PROBLEM AND AUTOMATED DATA HANDLING

The environment we sense remotely is extremely complex. For remote sensing to be successful in describing the environment, vast quantities of information received from sensors must be analyzed. The amount of information received initially is often many orders of magnitude greater than the amount the analyst provides at the end of his study. Automation of as many of the processes between initial sensing and final reporting needs to be a major goal of the long-range remote sensing problem. It is a truism that practically everyone concerned with remote sensing has recognized the data handling problem as of at least equal importance to that of quantification of the various forms of terrain signature.

The number of information elements obtainable per day with remote sensors are staggering. Approximately 1800 elements are observed per second with the Tiros satellite in which an element is about 1.5 miles square. Thus in a day this crude resolution system produces information about 1.5×10^8 surface elements. Complete utilization of these data on a daily basis is not yet operational, although the Tiros satellites have been in orbit since 1960. Furthermore, little use has been made of the data for non-meteorological purposes, although resolution may be adequate for studies such as those on emissivity reported by Kern (1965) and Buettner, Kern and Cronin (1964).

A nine lens camera has been proposed for space. This will produce images with a 30 m resolution and will cover an area about 450 km wide. Thus, each 30 m of orbit will have about 15,000 observed ground elements for each lens so that, neglecting overlap, 10^7 ground elements will be observed per second. In a day (assuming five hours suitable for photography) this amounts to 1.5×10^{12} elements per day for this system. The radar proposed for spacecraft use has a resolution element of 15 x 15 meters. The swath width is only 40 km, so that the total number of elements per frequency and polarization is about 1.4×10^6 per second. With three frequencies and three polarizations, over 10^{12} elements of image per day would be obtained from this system.

It is of course not necessary to turn to spacecraft to acquire data collection abilities of alarming magnitude. Modern side-looking radar systems can collect information during one routine day's flying on from 10^8 to 10^9 elements per day for a single radar frequency. To put this another way, radar imagery covering 70,000 or more square miles per day may be collected if desired from aircraft.

If we were to continue attempting to analyze this information without automation and without reducing redundancy the entire U.S. population of qualified analysts (assuming that photo interpreters can interpret other images), would be busy for years analyzing one day's images. Furthermore, combination of the multiple images mentally is a very inefficient method of analysis. It seems obvious therefore that automation of some type must play a large role in analyzing these data.

In any program of automated or semi-automated pre-processing of imagery there are five components for appropriate decision making by humans which machine methods need to emulate, namely, a) matching of known and unknown signatures; b) comparison of textures; c) analysis of spatial arrangements, d) evaluating the context of associated objects, and e) variations through time.

Signatures may take the form of simple gray-scale average values, probability density functions for area-extensive discrete objects, and for aggregates of objects, autocorrelation functions, emission and reflected spectra, or radiometric and scatterometer data as a function of viewing angle. They also would include edge effects measured as acutance on image film, and as the second derivative of film density. Image transformations via optical means including the one-dimensional and two-dimensional Fourier transformation (Evans et al, 1965) also represent categories of "signatures." Among the various forms of automatic photo reading of interest in this regard is that by Hawkins and Munsey (1963) which involves an optical-photographic system combined with various mapping masks to mechanize automatic decision process. In this system the image resolution attainable with photography is largely retained, while the complex logical decisions possible with electronics are readily performed.

Image texture variations are also an important basis for identification. For any given image scale and resolution there is a wide range of coarseness or fineness of gray-scale variations on film both for discrete area-extensive single-value objects and for aggregates of objects. Some examples of a simple scale of texture variation involving five sub divisions from very coarse to very fine are given in Morain and Simonett (1966) in a later paper in this symposium. Variations in texture very greatly aid the human interpreter in image analysis, and development of masking techniques and software systems for analysis of texture would be helpful.

Two additional descriptors which aid interpretation and identification of objects, namely spatial arrangement and context, jointly constitute structure. By spatial arrangements is meant the identification of an object by means of characteristic shapes which, together with the context, serve to enable a firm identification. Context involves the aggregate mix of associated elements, both internal to a given aggregate and external, including adjacent aggregates. Steep and gentle gradients between various aggregates also are important. Spatial arrangement and context constitute much of the decision base for discrimination in any geographic problem. These are precisely the areas of greatest difficulty in pattern recognition. It is probably fair to say that pattern-recognition devices capable of acceptable non-linear geographic (spatial) decision are both most urgently required and most difficult to develop. A number of promising first steps are given in Nilsson (1965), Blum (1963), McCormick (1963), Sebestyen (1962), Narasimhan (1962), Brain et al (1964), Leland et al (1963), Rosenfeld (1962a, 1962b), and Sanford et al (1964).

Finally, changes through time of natural and cultural systems constitute an important basis for identification and for study of spatial processes, especially cultural diffusion processes (Yuill, 1965). A prime need for the future will be first-order instrument systems which can reconcile image geometries, detect complex changes, and filter out irrelevant information. The non-linear computer known as man does a fairly acceptable job already in this area and it will be a tour de force to ever approach his capability.

When all the above components which man manipulates to arrive at his decision are considered it becomes evident that the best single solution to this problem is man himself. However, for portions of the decision process man could lean heavily on instrumental pre-processing crutches. It is very doubtful if there is a "best" machine solution to the problem, thus it will be appropriate for a number of alternative software and hardware "solutions" for certain steps to be developed. For example, an automatic photo reading and change detection device could preprocess data for the human interpreter to rapidly make a decision to leave or to discard what is apparently erroneous information. The dimensions and locations of the objects which change could then be electronically recorded for comparisons and calculations.

In the preceding paragraphs we have touched briefly on some logical processes which are involved in remote sensor image interpretation using manual and semi-automatic , and ultimately automated, means. These, however, though of considerable complexity, still represent only an early or intermediate step in data analysis, namely the unambiguous identification, or identification within acceptable probability limits, of discrete objects, aggregates, or patterns which may be mapped as a source of data for practical and theoretical study. This still falls short of the ideal data handling systems for geographic problems, which would have the ability to extract discrete information concerning change through time, second derivitives of geographical density functions, rather than simple location of objects, and would produce special attribute maps (Garrison et al, 1965).

3.2. THE NEED FOR A REAL-TIME CAPABILITY

While most of the problems in remote sensing are concerned with resource problems which have a relatively long time constant in which significant changes are measured in years or decades there are a number of important natural processes and aspects of man's activities on the earth which need monitoring at very short intervals of time. The time constant for these areas may be matters of hours or at the most days. Significant natural events which demand a real-time capability for efficient response by man involve potentially disastrous aspects of the natural environment especially those relating to the weather such as flooding of streams and great storms at sea. Moore and Pierson (1965) have argued for a real-time data link utilizing spacecraft-derived radar scattering cross section measurements to estimate wave heights and from this to infer the low level wind field. A geographer concerned with studies of climate is not in this instance interested in the real-time capability which is demanded by the oceanographer and meteorologist.

There are, however, areas in which geographers require a real-time capability. These involve critical urban problems of concern not only to geographers (Garrison, 1966) but also to transportation engineers and local government, state and federal agencies. The urban geography panel at the Houston meeting on the use of orbiting spacecraft noted for example that "Settlements change form and function faster than conventional measurements can monitor and the nature of the urban problem has transcended the ability of almost all contemporary monitoring systems." This is of course especially the case with problems of flow of people and goods into, through and from cities. In the Megalopolis of the eastern seaboard of the U.S. the monitoring of flows efficiently in real time over arteries of commerce and communication is a necessary prerequisite to further research in the ills of our urban agglomerations, and in designing appropriate means to attack the problem.

The current military development of aircraft to ground data link systems have many potential peaceful uses particularly in these urban regions where existing surveys are notoriously high-cost. The formalized demand for real-time systems for the monitoring of ocean waves and for meteorological phenomena is already in existence and major governmental agencies are in principle committed to the idea. In speaking for real-time capability for studying urban problems geographers speak not only for the small coterie of professionals in universities but also for an unorganized group of regional development associations, traffic engineers, and state and federal agencies which have not as yet collectively come to recognize in remote sensing from fixed ground installations, aircraft and ultimately spacecraft, some possible alternative approaches to pervasive problems of the urban environment.

3.3. OPTIMIZATION OF ALL-WEATHER SYSTEMS

A real-time capability of handling natural catastrophies and urban flow phenomenon, to repeat the two areas discussed above, requires that the remote sensing systems have all-weather capability.

An all-weather or essentially all-weather capability is confined to remote sensing in the passive microwave and radar regions. For certain types of remote sensing observations where spatial resolution is relatively unimportant and temperature resolution is critical passive microwave systems will have a role to play. Only a relatively modest input of effort has been made in developing microwave scanning and radiometer systems and this effort should be viewed more critically as new needs for real-time applications become apparent. For those cases where temperature resolution is unimportant and where good spatial resolution becomes critical the only sensors which can obtain data irrespective of the weather or time of day are synthetic aperture radar systems (Ellermeier and Simonett, 1965).

For these reasons considerable additional research is needed by geographers and other geoscientists on the information content of multifrequency radar systems. At the same time radar engineers need to think of future radar designs for real-time application. This thinking should encompass a broader radar spectrum than normal, extending from say 3 mm to 1 meter. Finally the development of radar imaging systems which are not as narrow spectrally as those in common use today also seems appropriate. These suggestions obviously will require new instruments in new frequencies not commonly utilized and will be very expensive. Benefit-cost studies and alternative allocation studies will also need to be made before any such systems are put to use.

3.4. NEW INSTRUMENTS BASED ON REMOTE SENSOR PROXIES

At the Houston conference on The Use of Orbiting Spacecraft for Geographic Research, (1966) the panel on urban geography devoted considerable attention to the search for possible proxies or surrogates for information now laboriously collected by traditional means, for which perhaps alternative remote sensing measures may be developed.

The concept of a surrogate or a proxy is not in itself new. Every soil scientist who has mapped soils on the basis of natural vegetation communities very highly associated with a particular soil series is using vegetation as a proxy for the soil itself. In the paper by Moore and Pierson (1965), the utilization of radar scatterometry to measure the ocean roughness and from this to infer the low level wind strength and perhaps also direction is another example of the use of a proxy. In this case the waves are sensed in their own right to provide information for the oceanographer, but at the same time they also provide information related to wind strength. Wind strength influences oceanic evaporation most notably in large tracts of the trade wind belt. Evaporation in turn influences the magnitude of the energy injected into the atmospheric circulation. Benton et al (1962) have described some of these critical relations between wind strength and inequalities of moisture injection into the atmosphere. Each of the steps in this chain of reasoning are related to one another by physical processes and the longer the chain and the poorer the correlation of each step the less useful the initial proxy is for the final measure being sought. The soil surveyor or meteorologist or climatologist in these two instances is however working exclusively with natural phenomena and the chain of reasoning follows sequentially from the physical principles involved. The merit behind the connotation of proxy or surrogate introduced by the urban geography panel at Houston lies however not in this type of linked reasoning but rather in the search for new or alternative measures for conventional data.

To illustrate the thinking of the members of the urban geography panel it is perhaps best to pose some of their surrogates in the form of a series of questions:

1) Would it be possible to utilize integrated measures of the electrical noise derived from large urban centers as an acceptable measure of power use? Could this also be used as some kind of guide to an index of economic activity?

2) In studies of urban morphology for which we currently use standard land use survey techniques is it possible that a new proxy in the form of nightime color photography of urban lighting may be used to increase the detection of critical urban aggregates?

3) Is it possible to use a remote sensing device which detects road vibrations as a measure of traffic flow?

Other examples are given in the urban panel report and these certainly suggest a fruitful area of interaction between geographers and other earth scientists and instrument manufacturers. Perhaps this may serve to reinforce the arguments made earlier on the desirability of joint research between the engineering disciplines and those in the earth and social sciences.

It will be seen that these types of proxies do not involve the same continuity of physical processes involved in the earlier examples. They in truth represent a leap in reasoning and hinge on the notion that many critical areas in studying the modern urban landscape go undocumented because of the difficulties of collecting data. The degree to which remote sensing can meet this challenge of proxy measures will be one yardstick of the success of the whole remote sensing field in the years to come.

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