Proceedings of

the

SYMPOSIUM

on

POTENTIAL APPLICATION OF REMOTE SENSING TO ECONOMIC DEVELOPMENT IN DEVELOPING COUNTRIES

Hosted by

SMITHSONIAN INSTITUTION

November 19-20, 1970

Supported by

AGENCY FOR INTERNATIONAL DEVELOPMENT

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A.I.D. SYMPOSIUM ON THE UTILITY OF REMOTE SENSING

AS AN AID TO DEVELOPING COUNTRIES

November 19-20, 1970

List of Participants

Chairman: MR. CHARLES E. JOHNSON
Consultant to Office of Science and Technology
Agency for International Development
Washington, D. C.
(Formerly with National Security Council, White House)

LIEUTENANT COLONEL JAMES A. ABRAHAMSON
Space Assistant
National Aeronautics and Space Council
Executive Office of the President
Washington, D. C. 20502

DR. EDWARD ACKERMAN
Executive Officer
Carnegie Foundation
1530 P Street, N. W.
Washington, D. C. 20005

MR. LUIZ BRASIL
Organization of American States
1735 I Street, N. W.
Washington, D. C. 20008

PROFESSOR ROBERT N. COLWELL
School of Forestry and Conservation
145 Mulford Hall
University of California
Berkeley, California 94720

MR. B. K. WESLEY COPELAND
Office of the Foreign Secretary
National Academy of Sciences
2101 Constitution Avenue
Washington, D. C. 20418

DR. MILO L. COX
Deputy Director for Field Review and Evaluation
Office of Agriculture and Fisheries
Agency for International Development
Washington, D. C. 20523

iv

DR. PETER DUISBERG
Inter-American Geodetic Survey
Drawer 934
Ft. Clayton, Canal Zone

DR. DAVID ELLIOT
National Aeronautics and Space Council
Executive Office of the President
Washington, D. C. 20502

MR. WILLIAM A. FISCHER
Office of the Director
U. S. Geological Survey
Room 5213 - GSA Building
Washington, D. C. 20242

MR. WREATHAM E. GATHRIGHT
Member of the Planning and Coordination Staff
Department of State
Washington, D. C. 20523

DR. ARCH C. GERLACH
Chief Geographer
U. S. Geological Survey
Room 5212 - GSA Building
Washington, D. C. 20240

MR. H. ROBERT GRIBBEN
Manager, Advanced Development
Raytheon/Autometric Operation
Raytheon Company
4217 Wheeler Avenue
Alexandria, Virginia 22304

DR. MICHAEL GUCOVSKY
United Nations Development Program
Room A-3204
866 United Nations Plaza, Third Floor
New York, New York 10017

DR. ORRIS HERFINDAHL
Senior Research Associate
Resources for the Future
1755 Massachusetts Avenue, N. W.
Washington, D. C. 20036

MR. MARVIN R. HOLTER
Chief, Earth Observations Division
NASA/Manned Spacecraft Center
Houston, Texas 77058

√

DR. DAVID L. LANDGREBE
Director
Laboratory of Applications for Remote Sensing
Purdue University
1220 Potter Drive
West Lafayette, Indiana

MR. RICHARD LEGAULT
Associate Director
Willowrun Laboratories
Institute of Science and Technology
University of Michigan
P. O. Box 618
Ann Arbor, Michigan 48107

MR. JOHN G. LIGHTFOOT, NESA/CDE/ENGR
Room 4710
Agency for International Development
Washington, D. C. 20523

MR. BILL LONG
Environmental Affairs Specialist
Office of Science and Technology
Agency for International Development
Washington, D. C. 20523

MR. EDWARD MARASCIULO
Deputy Director for Argentina, Paraguay, and Uruguay
Bureau for Latin America
Agency for International Development
Washington, D. C. 20523

DR. ROBERT MILLER
Remote Sensing Technical Coordinator
U. S. Department of Agriculture
Agricultural Research Service
Room 332, Administration Building
Washington, D. C. 20250

MR. JAMES R. MORRISON
Cooperative Projects Division
of International Affairs
National Aeronautics and Space Administration
Washington, D. C. 20546

DR. HENRY MYERS
Consultant, Office of Science and Technology
Agency for International Development
Washington, D. C. 20523

DR. ARCH B. PARK
Chief, Earth Resources Survey
National Aeronautics and Space Administration
Washington, D. C. 20546

COLONEL LLOYD RALL
Defense Intelligence Agency (DIAMC)
Room BF-863
Washington, D. C. 20301

A

DR. JOHN A. REINEMUND
Chief, Office of International Geology
U. S. Geological Survey
800 - 18th Street, N. W.
Washington, D. C.

PROF. HUMBERTO RICCIARDI
United Nations Secretariat
Room 3245-A
United Nations Building
New York, New York 10017

MR. EDWARD RISLEY
Director of Earth Sciences
JH 702
National Academy of Sciences
2101 Constitution Avenue
Washington, D. C.

MR. KIRK P. RODGERS
Director, Office of Regional Development
Organization of American States
1725 Eye Street, N. W.
Washington, D. C. 20006

MR. GLENN E. SCHWEITZER
Director, Office of Science and Technology
Agency for International Development
Washington, D. C. 20523

MR. SCOTT M. SPANGLER
President
Remote Sensing, Inc.
8249 Travelair
P. O. Box 12835
Houston, Texas 77017

DR. KURT B. STAEHLING
MSC Executive Office Building
Washington, D. C. 20500

DR. ROBERT A. SUMMERS
Manager, Advanced Programs and Technology
Earth Observations Programs
NASA Headquarters
Washington, D. C. 20546

MR. PETER THACHER
United States Mission
to the United Nations
799 United Nations Plaza
New York, New York 10017

B

DR. DALE W. JENKINS
Director
Ecology Program
Smithsonian Institution
Washington, D. C. 20560

MR. ARTHUR W. JOHNSON
Deputy Director
National Environmental Satellite Service
National Oceanic and Atmospheric Administration
Washington, D. C. 20233

DR. WOODS THOMAS
Director, Division of International
Programs in Agriculture
Purdue University
West Lafayette, Indiana 47906

MR. MERLYN VEREN
Room 5241
New Senate Office Building
Washington, D. C. 20510

MR. KENNETH VERNON
Director
Office of Engineering
Agency for International Development
Washington, D. C. 20523

MR. MERTEN M. VOGEL, EA/ENGR
Room 3320-A
Agency for International Development
Washington, D. C. 28260

LIEUTENANT COLONEL W. E. WILLIAMSON
Office of Science and Technology
Executive Office Building
Washington, D. C. 20506

A.I.D. Symposium

on the

POTENTIAL APPLICATION OF REMOTE SENSING TO ECONOMIC DEVELOPMENT IN DEVELOPING COUNTRIES

November 19 and 20, 1970
Botany Seminar Room (Room 531W), Natural History Building,
Smithsonian Institution, 10th and Constitution Avenue,
Washington, D. C.

HAIRMAN: Mr. Charles E. Johnson, Consultant to the Office of Science and Technology, Agency for International Development.

PROGRAM

hursday, November 19

9:15 - 9:30 AM	Greetings and Introductory Remarks Mr. Glenn E. Schweitzer, Director, Office of Science and Technology, A.I.D.
9:30 - 10:00 AM	Item No. 1: What are the economic considerations in assessing the role of remote sensing in country development? Dr. Orris C. Herfindahl, Senior Research Associate, Resources for the Future
10:00 - 10:30 AM	Discussion of Item No. 1
10:30 - 10:45 AM	Coffee

D

Thursday, November 19

10:45 - 11:45 AM	No. 2: To what extent has information obtained in surveys of earth resources been used by developing countries? To what extent have developing countries used information collected through remote sensing?
(30 minutes each)	Dr. John A. Reinemund, Chief, Office of International Geology, U. S. Geological Survey Dr. Milo L. Cox, Deputy Director for Field Review and Evaluation, Office of Agriculture and Fisheries, A.I.D.
11:45 - 12:30 PM	Discussion of Item No. 2
12:30 - 2:00 PM	Lunch (Dutch)
2:00 - 2:30 PM	No. 3: What type, quality and quantity of earth resource data has been and will be required by developing countries? Mr. Kirk P. Rodgers, Director, Office of Regional Development, Organization of American States
2:30 - 3:00 PM	Discussion of No. 3
3:00 - 3:15 PM	Coffee
3:15 - 3:45 PM	No. 4: What is the need in developing countries for monitoring environmental and ecological characteristics? How will remote sensing help to fill this need? Dr. Dale W. Jenkins, Director, Ecology Program, Office of Environmental Sciences, Smithsonian Institution
3:45 - 4:15 PM	Discussion of No. 4
4:15 - 4:45 PM	No. 5A: What are the capabilities and costs of commercially available remote sensing systems?
(15 minutes each)	Mr. Scott M. Spangler, President, Remote Sensing, Inc. No. 5B: What are the costs and capabilities of commercially available services for the reduction, analysis and interpretation of remote sensing data? Mr. H. Robert Gribben, Manager, Advanced Development, Raytheon Company/Autometric Operation
4:45 - 5:15 PM	Discussion of Nos. 5A and 5B

E

Friday, November 20

9:15 - 9:45 AM	No. 6: From the perspective of the developing countries how will the new technology enhance capabilities to collect, analyze, store and disseminate earth resource data? Mr. Richard R. Legault, Associate Director, Willowrun Laboratories, Institute of Science and Technology, University of Michigan
9:45 - 10:15 AM	Discussion of No. 6
10:15 - 10:30 AM	Coffee
10:30 - 11:30 AM	No. 7: From the perspective of the developing countries, what type of U. S. research and development activities should be emphasized?
(20 minutes each)	7A: Data acquisition systems? Mr. Marvin R. Holter, Chief, Earth Observations Division, NASA/Manned Spacecraft Center 7B: Data analysis? Mr. William A. Fischer, Office of the Director, U. S. Geological Survey 7C: Data storage and dissemination? Dr. David L. Landgrebe, Director, Laboratory of Applications for Remote Sensing, Purdue University
11:30 - 12:30 PM	Discussion of No. 7
12:30 - 1:30 PM	Lunch (Dutch)
1:30 - 2:00 PM	No. 8: What kinds of institutions are required in developing countries to exploit the technology in the acquisition, analysis, storage and dissemination of earth resource data? What are the kinds of costs involved? What kinds of manpower are necessary and how can training requirements best be fulfilled? Dr. Robert A. Summers, Manager, Advanced Programs and Technology, Earth Observations Programs, NASA Headquarters
2:00 - 2:30 PM	Discussion of No. 8
2:30 - 2:45 PM	Summary
2:45 - 4:30 PM	Summary Discussion and Future Steps

PREFACE

The participants in this symposium attended as experts and not as representatives of their organizations. Therefore, statements and comments presented herein represent personal opinions and not necessarily the views of their organizations.

Many of the participants spoke without the benefit of prepared texts or notes. Their recorded statements received minimal editing to reflect the informal tenor of the meeting. In some instances, comments peripheral to the main topic have been omitted for the sake of brevity.

INTRODUCTORY REMARKS

Glenn E. Schweitzer

On September 15 the President proposed the abolishment of AID and the stablishment of new mechanisms for carrying out foreign assistance activities. In his message he proposed the establishment of a new development institute to bring the genius of U. S. science and technology to bear on the problems of development.

One of the areas of technology which reflects the genius of the U. S. scientific community is remote sensing. AID is now in the process of trying to restructure the program in terms of both organization and program emphasis. More specifically, it is putting together FY 1972 projects and is laying the basis for FY 1973 and beyond. AID is also in the process of preparing instructions to all field missions describing remote sensing and how it relates to AID programs, and outlining what the AID's role in the international workshop should be and what the OAS program means for AID and the kaleidoscope of activities related to remote sensing.

The basic purpose of this symposium is to provide an analytical basis for program directions in AID. There has been much talk about the benefits of remote sensing to developing countries. Actually there is no concrete basis on which to make judgments. Discussions at this symposium may provide AID with concrete information needed when approaching budgeteers to try to gain support for certain programs.

The question is not whether developing countries are going to use remote sensing. They are doing it. In Uganda planes are used to look for uranium. In Sudan, Khartoum was photographed from a DC-3 and that photography was used to determine where the streets were to be constructed.

The questions asked are how useful can remote sensing be in economic development and specifically what should AID and its successor organization do to help developing countries know how to use this technology wisely, when to use it, and to what extent to use it. Also, the steps that must be taken to help the developing countries have the capability to use it must be determined.

The developing countries want data by the cheapest and most efficient means. AID hopes this symposium will clarify

at least one option for obtaining data, namely by flying airplanes or eventually flying satellites.

The suggested time frame for this discussion is the 1970-75 period.

Specific AID programs and projects will not be developed unilaterally in Washington. This is the first step of a process which eventually involves direct dealings with developing countries.

Any project or program ideas obviously must coincide with and be responsive to the interests of the developing countries. Technologies must not be implanted upon them.

As remote sensing technologies are discussed they must be cast in the context of developing countries. AID urges that problems of cost and personnel be focused upon in the context of what the developing country can or cannot do in as concrete terms as possible.

The purpose of this symposium is to lay the basis for an action program in the foreign assistance area. AID staff present today will listen to the advice received, consider it, and then perhaps translate it into projects. This is not going to happen on the basis of current information. The case of whether this technology, which is in competition with a wide spectrum of other programs, is a useful technology to pursue in the developing countries has not been made. AID hopes that those present today will help make that case.

ECONOMIC CONSIDERATIONS IN ASSESSING THE ROLE OF REMOTE SENSING IN COUNTRY DEVELOPMENT

Orris C. Herfindahl

Remote sensing can be used to generate much information so far as economic development is concerned. One of the main areas of application--perhaps the most important--is that of natural resource information.

Natural resources are a kind of "capital" that yields productive services just as does man-made capital. In many cases, of course, they are analogous to unfinished capital goods such as a machine tool or building that is under construction. That is to say, investment must be undertaken before the capital instrument can begin yielding productive services. This is most clearly the case with potential mineral-bearing lands, but it is also true of such things as dam sites and frequently of agricultural land itself.

Natural resources are not identical with man-made capital goods. While there are many types of differences, two that are of importance for our purposes are these:

1. The precise location of some natural resources can be determined only by the expenditure of money (mineral lands, fish, and even agricultural lands in the case of "new lands").

2. Even though the location of a natural resource is known, as with agricultural land in use, it may be possible to increase output by making use of increased knowledge of the characteristics of the resource.

Since natural resources are a kind of capital, it is obviously true that the more natural resources a country has and the better their quality, the better off it will be so far as the size of its economic product is concerned. There is tremendous variation among countries in the value of their natural capital in relation to other forms of capital. This ratio will tend to be equal to the fraction of total national income generated by natural resources themselves, which is something different from that fraction of total national income generated by the natural resources industries.

This ratio--income generated by natural resources to total national income--tends to be very low for developed countries simply because the other forms of capital--human capital and man-made capital instruments--are of dominating importance. In underdeveloped countries where these forms of capital are not present in great abundance, natural resources can have a considerably greater importance in a relative sense. In some cases the form of the natural capital exerts an evident influence on economic activity and colors many aspects of the country's economic and political life.

By and large, however, natural resources do not have the importance in the economic activity of underdeveloped countries that many people attribute to them. However this importance is assessed; it seems to be declining in Latin America, at least. In this region, about 59 percent of the labor force was engaged in agriculture and mining in the period 1935-40, but by 1965 this percentage had declined to 47 percent, a decline of about a fifth in the ratio itself.

A similar decline has taken place in the percentage of gross national product originating in agriculture and mining in Latin America. For the period 1935-40, this was 35 percent as against 27 percent in 1965, the relative decline in this percentage being a little larger than that for labor force participation in agriculture and mining.

While the percentage of national income originating in agriculture and mining would be roughly similar to the percentages for GNP, the percentage of national income going to the owners of natural resources (as distinct from man-made capital) would be much lower. The national income or GNP originating in the natural resources industries includes incomes generated by labor and man-made capital engaged in these industries. These greatly outweigh the income generated by the natural resources themselves.

What lessons can be drawn from these percentages--bearing in mind that the relevant percentage is much lower? The conclusion is that even very sizable increases in the effective quantity of natural resources is not going to have a tremendous effect on the level of a nation's income. Note that this is not the same as saying that investment in natural resources, whether to find them or to find out more about those whose location is already known, is not worthwhile. It may well be, but investment in information on natural resources cannot be expected to provide any royal road to economic progress. It simply is not quantitatively possible.

Outlays on information as an investment

The assembly of information on the physical aspects of a country is an investment, that is, it involves outlays of money now which will yield a return only in the future. Therefore, we can say immediately that expenditure on information assembly is to be evaluated as any other investment. The preferred method is to see if the discounted cash flows (or their equivalent) have a positive value. That is to say, the question is whether the present value of the additions to product minus the present value of all of the costs of the project (maintenance, etc. as well as initial capital costs) is positive, using a discount rate that reflects the productivity of investment in other activities of comparable riskiness (which in this country, for example, would be much higher than the rate of interest paid by the government on its securities).

Evaluation of information as an investment poses many difficulties, the major one being that benefits are often rather indirect and diffused, but this is not always the case. In general terms, natural resource and other types of information can be put to the following different types of use:

1. The evaluation of investment opportunities, both public and private. Obviously these may vary from well-defined and discrete projects such as irrigation projects to complete programs of mineral exploration from the earliest stages on. The "investment opportunity" may be public and private investment involving regional development as one of the variables (e.g., infrastructure investment). Background information on a regional basis may be useful for these decisions.

2. Improvement of current production operations involving natural resources and other capital.

3. Satisfaction of direct consumer demands for information (e.g., maps for recreational purposes).

4. Aid in the discharge of governmental functions not related to investment or improvement of current production (e.g., tax collection).

Problems in evaluation

The most important consideration in evaluating any proposed program for gathering more information--whether this is an attempt to estimate numerical values or only a "judgmental" evaluation--is to evaluate the program as a part of the whole relevant system. In principle, this is not necessary, of course. If there were available a good estimate of the derived demand for information at the level of one of the components of the whole system, quite a bit could be done with partial evaluations. The reality is, however, that good estimates of the derived demand for information are not available. The result is that if parts of the system are left out of consideration, some kind of assumption must necessarily be made (and this is often done implicitly) which relates the activities under examination to those parts of the system not under scrutiny. These assumptions are often seriously in error, usually with respect to the (derived) demand for information. If we force ourselves to consider the whole system, errors of this sort are less likely to be made.

There are various ways to describe the components of a system for generating information by use of remote sensors in satellites. Note that many of these components involve intergovernmental considerations or operations:

1. Determination of investment and operating program after initial formulation of the system.

2. Physical launch and satellite operation.

3. Data retrieval, processing, and storage.

4. Dissemination of processed data.

5. Use of processed data by technical agencies of government or private entities.

6. Use of the product of technical agencies by investment decision agencies of government or private entities.

7. Provision for feedback from entities in 5 and 6 to those in number 1.

A complete discussion of the problem of evaluating remote sensors in satellites is not possible here, but perhaps a series of somewhat disconnected comments can serve to give some indication of what is involved in the problem.

While any complete system will involve the components or functions listed above, there are various ways or modes in which the system could be operated. One way to approach the problem of specifying a system is to think of basic modes of operation and of combinations of basic modes. One way to generate a series of possible basic modes is to suppose that the mode of operation will depend on choices made from several dichotomous bases of classification. Thus we might have multiple objective vs. single objective; multi-country vs. single country; complete areal coverage within a country vs. limited coverage; and repetitive vs. one-time. Obviously some of these could and should be subdivided, but taking the classification scheme as it is, there would be twelve different basic modes possible if every dimension must be present in a mode. However, on certain specifications of the classification basis, basic modes could be combined. Thus, it might operate on one group of objectives on a multi-country basis, meaning that the same group of objectives is a target in several countries while the satellite simultaneously operates on single (and different) objectives each with respect to a particular country.

The point of these remarks is that there are many ways to run a satellite remote sensor program. It is to be expected that the economic viability of these different modes of operation, some basic and some complex, will differ greatly. Therefore, I suspect there is not much point in talking about economic viability except in connection with a specification of the particular way in which the system is to operate. In particular, we cannot discuss the economic viability of remote sensors in connection with single objectives unless we are prepared to specify the operation of a whole system involving only that single objective. Of course, many of the components of an evaluation of complete systems must be estimated objective by objective.

It has already been asserted that evaluation of a complete system is desirable on the ground that omission of some of the components, or functions, is likely to lead to error because of incorrect assumptions relating the components under examination to those excluded.

To see why this is so, let us remind ourselves that the demand for any productive service is a function of the marginal physical productivity of that service times the price of the product produced with the aid of the service.

Without explicit attention to the whole system, the implicit assumptions often seem to be that: (1) marginal productivity does not diminish with more information, implying that there is no limit to the amount of information

that can be absorbed at a constant price for the service; and (2) marginal productivity of information is the same in country X (underdeveloped) as in country Y (developed). What is productive for us will be productive in El Salvador, for example.

With respect to the second point, it should be obvious--but obviously is not--that the lack of or deficiencies in information user facilities and institutions in a country has to mean that the current demand for information is zero so far as that country is concerned. There will be no addition to product even though mountains of information are made available.

Marginal productivity of a productive service, such as information, refers to the addition to product brought about by using another unit of the productive service. This additional product will depend on the quantity of this and other productive services already in use. I believe there is a tendency to think that information on natural resources is lacking or does not exist unless it is in the form in which it would be expressed by technicians making natural resource surveys. This is not the case, for the lowliest peasant using methods of cultivation and seed varieties that have enabled continuous agriculture for decades or even centuries obviously is in the possession, perhaps implicitly, of some rather useful information. Perhaps this is even clearer if one looks at it from another direction. Ask a peasant why he does not grow corn in a nearby area not now under cultivation. The chances are excellent that he will have what is a rational answer even by our standards, and even if it is not, it may be the operationally correct answer, a rational explanation existing of which he is unaware.

Suppose that we are not so naive as to make the gross error of thinking that more information will be very productive because we believe (erroneously) that the present quantity of information is very low. We have already pointed out that additional information may be indigestible, the ability to use it simply not being present, but additional information may be unproductive because it is the wrong kind of information. Some productive services are reasonably homogeneous, such as common labor, for example. An increase in the quantity of common labor will mean an increase in the same kind of productive service already in use. No so with information. It has so many dimensions and can be expressed in so many different ways that it may or may not represent an effective addition to the stock of information already in use by those making investment and production decisions.

By the same token, the duplication of already existing information does not constitute an addition to the effective stock of information. Contrast this, again, with the provision of more common labor where duplication does constitute an effective addition to productive services. The lesson should be clear.

One specific application of the ideas we have been discussing deserves special mention--information in relation to new lands, or nuevas tierras. New lands do not obviously constitute a source of demand for large quantities of additional information. Three considerations indicate caution. First, there already exists a great deal of information about these potential lands, and much of it indicates rather conclusively that large areas do not have economic potential with presently usable techniques. Second, the fact that existing boundaries of cultivation are where they are indicates the existence of a very important piece of information: there are (as of this moment) insurmountable obstacles to the extension of cultivation across the line. Third, although there are indeed considerable areas that are potentially usable, the kind of information that is needed to make them actually usable is, generally speaking, of a rather detailed management type or at a level of detail that no one seems to contemplate generating by using remote sensors.

When a proposed program is evaluated by the cost saving method, the usual implicit assumption is that a demand for the information exists and is large enough to pay for the total cost under the old method. This implicit assumption is warranted in those cases where the activity or product is subjected to the test of the market, but if this is not the case, as is often true of information, serious error can result.

Suppose that 100 units of product X are being produced each year at a total cost, including return on investment, of $10 each and that they are being sold at a price of $10. If a new method of production will reduce the cost by $1, it will be true that social product will be increased by at least $100. Actually, the increase will be somewhat more because of the larger quantity that people will wish to buy at a price of $9. The total increase in social welfare will be approximately $100 plus 50 cents times one-half the increase in the quantity produced and sold.

Suppose, however, that the article in fact has no value, that there is no demand for it. It still will be true, of course that social product will rise if the same quantity continues to be produced at a lower cost. In our example, the increase would be $100. But suppose an economist states: We cannot estimate the value of X on the market, but whatever it is, we can be sure that at a lower price its users would

like to have more. Therefore, when the cheaper method of production is adopted, let us increase the output at the same time--say by 20 percent. Far from increasing social product, this change would reduce it by $80 ($9 x 120 minus $10 x 100 = $80).

It turns out, however, that all these calculations based on cost saving are of little importance in comparison with the important fact--there is no demand for product X. Social product could be increased by $1,000, not by using a cheaper method of production, but simply by not producing it and using the productive services released by this decision for producing something that is wanted.

Government expenditures ought to be included in any evaluation. One must recognize, however, the great complications that are introduced into evaluation of these programs by the fact that different governments are involved. There is not one but at least three different evaluations to be made. First is evaluation with all countries involved in the system combined--viewed as one society, in effect. Second is an evaluation from the point of view of the United States. A little headway can be made on this evaluation if it is done strictly on a economic basis, but if noneconomic considerations of aid policy are introduced the problem is greatly complicated. You will note that cost sharing rears its ugly head in this evaluation. The third evaluation is that of the participating country (the United States being viewed as taking the initiative). This evaluation presumably would be on a strictly economic basis, would have to have the cost sharing aspects of the proposition spelled out, and would be no different in principle from the economic evaluation done by the United States.

An expanded information program via satellites may harm participating countries by effects operating through personnel. First, even if decisions on participation were based on careful calculations, there is a possibility that the salaries of government officials used in such calculations would not reflect their true marginal productivity to the economy in question. I am not sure whether this consideration is important or not, but I think I have seen cases where able people continue to work for a government that pays them salaries much lower than they could get in private business in the same country or abroad.

Apart from the factor just mentioned, it cannot be denied that the governmental employee in an underdeveloped country will look with great favor on the opportunity to join a program connected with satellites. Not only may there be a little additional money, but there is an undeniable air of glamour.

The question is, can the underdeveloped country afford the diversion of talent from other tasks?

Expenditures on information, including those directed to remote sensing systems using satellites, will be made ahead of the time when productive services are realized from them. Since this money (read productive services) could have been used either for immediate consumption or to produce other capital goods, it is essential that outlays and benefits in connection with the program under evaluation be dated and discounted. There is no point in amassing information ahead of the time when it will be used. Indeed, given the demands for information, the object of the game is to postpone actual generation of information as long as possible, recognizing, of course, that undue postponement involves increases in certain kinds of costs.

* * * * *

Any program of technical assistance to aid in the determination of needs for resource information and of the appropriate way for using remote sensors to generate this information should be formulated and executed with great care, for the opportunities for serious error are considerable. There is no standard set of data that a country should have by a certain date. Since the amount of money and technical talent a country can afford to devote to the generation of data, with or without help, is always limited, the data to be generated next year should depend on what data already are available and on the prospective demand for data in succeeding years.

Data demands from both governmental and private users are highly dependent on the capacity to use data. Demands cannot be determined from the existing body of data and the physical situation in the various resource sectors of the public and private parts of the economy. Rather, the capacity to use data and demands for data are intimately bound up with the political and bureaucratic processes by which the various governmental programs that are potential data users are determined and executed. The extension of technical assistance touching closely on these matters is delicate, and has distinct limits.

A nonintrusive, almost opportunistic, type of technical help is called for. Instead of trying to "solve" a country's resource information problem by laying out a general program, making ad hoc suggestions could result in effective, lasting, and acceptable technical help. In time, these suggestions would take on overall form if from the beginning they had been

made on the basis of a coherent set of orienting ideas on the management of resource information programs.

Information on the technical possibilities for the use of remote sensors, including those carried in satellites, needs to be disseminated, but the far more difficult task is that of securing an adequate understanding of the possibilities for use of and a proper expression of demand for information. Experience in Chile and other countries strongly suggests that this cannot be accomplished only by contact between technical experts from the outside and a counterpart set of experts from within the country receiving the aid. There is an indispensable need for face-to-face working contacts between personnel at high and lower levels in the information-producing agencies and in the customer agencies who are the actual and potential users of this information.

Obviously there is considerable variation between the different fields of resource information in the degree to which users are aware of technical possibilities for using data generated with the aid of remote sensors. In many countries, but not in all, the gap is less in the case of exploration for petroleum and minerals and in the planning of large water structures than in the case of other activities such as regional economic planning and the management of agricultural, fishery, and forestry resources.

DISCUSSION

MICHAEL GUCOVSKY:

I would like to make basically two points. One, that the macro analysis is all right but there are questions of micro which can't be overlooked where the picture might be different.

That is, speaking from the point of view of developing countries, the pressure is always great to move at the pace faster than whatever the given existing pace is. In practice, many times the actual existence of a given resource in a region, even though on the average we look at the country statistics, this contribution will be on the order of magnitude that Dr. Herfindahl was telling us, but it is the quick development of that given resource that would actually provide the catalyst for other economic activities in the countries.

This happens all the time. If you look at the investments that the World Bank makes -- I was just looking the other day at the railroad going across North Africa. The only reason that the bank can justify an investment for that railroad now is because there happens to be a resource there that can be exploited relatively quickly. This in fact would set off a process of development with additional far-reaching effects.

We should not only be influenced by whatever the average statistics show us on the role of natural resources but we should actually look at what the role of natural resources could be in any given development situation in a micro sense.

I think we may reach conclusions that in specific cases would be different for a country as a whole or for groups of countries than the conclusions pointed out here on the basis of the average contributions of the natural resources.

My second point is related to the question about time. I share the skeptical note introduced about using sensors for gathering information. I agree about the need to make specific analysis in each case and see when it is justified and when it isn't, but I think one of the elements which I think he omitted is the question of time.

I think to the extent that using sensors, whether satellite-carried or aircraft-carried, can in fact reduce the time of collecting information for which an established demand is determined, then this is an important consideration because developing countries are in a great hurry.

The pressure continues to reduce the time it takes to gather information from three years to one year, from five years to two years, and if there are any time advantages I think they should be looked at carefully because they are a benefit from the economic point of view.

New lands were dismissed but the fact is that developing countries (such as recent programs in the Amazon, Peru, and Africa) are set on opening up new areas. They are set on putting through roads to new areas. So development is going to occur spontaneously, uncontrolled.

The question is if we can, through the use of sensors, accelerate the collection of information that could be put to use for controlling some developments that would take place anyway in new lands.

USE OF EARTH RESOURCES SURVEYS AND REMOTE SENSING DATA IN DEVELOPING COUNTRIES

John A. Reinemund

From experiences of the U. S. Geological Survey in the use of information on current projects, some problems that exist now, have existed, and are probably going to continue to exist and perhaps be intensified once one gets into the field of wider application of remote sensors technology in the developing countries shall be discussed.

Problems include why the U. S. Geological Survey has not had better use of data from resources surveys and other types of remote sensor activities in the past; what the reasons are for the lack or incompleteness of use of the data; and what can be learned from this that can be put into concepts for future programs.

It is quite appropriate that one considers this now. The amount of money invested by developed countries, international organizations, and private industry in earth resources in the developing countries is very large. Natural resources projects alone have involved about $800 million, and billions of dollars are spent in total by the various countries in bilateral assistance.

Much experience now exists from which one can draw. When one is talking about earth resources surveys, one is talking about a wide spectrum of investigations that translate into applications of earth science techniques to problems of agriculture versus geological subjects.

The area of discussion will be confined to information from the geological surveys as applied to studies of minerals and water, geological hazards and land utilization, and engineering problems.

Geological surveys encompass a very broad range of activities. They draw upon a wide spectrum of techniques ranging from topographic surveys involving ground control surveys and photogrammetry to geologic field mapping itself, geochemistry, geophysics and remote sensors, some of which have been used and some of which have not yet been applied to any appreciable extent in the developing countries.

Remote sensors are only one range of tools used in resource surveys. Many of these tools are still quite new,

glamorous, and untested, but some of them have been used a long time, particularly aerial photography and aerial geophysics. They should be thought of as a great number of exploration techniques which are now being developed.

Activity in the field of detectors is an example. Some of these can be applied by aircraft. One activity program involves experimentation on carrying mercury detectors in aircraft. The detectors seem to be fairly successful if kept close to the ground and in certain environments.

USGS is now experimenting with new uses of the old concepts of radiometric surveys and magnetic surveys for mapping purposes as well as with new types of photography in the remote sensor realm. These are all tools of the geologist, and a geologist who wants to use them has to be better trained than the geologist used to be.

Future programs of AID must consider the training of people in developing countries so they can make use of available techniques and required data.

About two years ago a geologist employed by U. S. Steel made a significant discovery of an iron ore resource in North Central Brazil by looking at a published photogeologic map. The map showed that the particular area was a deposit of cretaceous sedimentary rocks. Because the textures of the aerial photographs did not agree with that interpretation a plane flew reconnaissance passes with a magnetometer and picked up a magnetic anomally. Since the geologist was looking for manganese particularly, he then dropped in by helicopter and found that the material which had been mapped as cretaceous sedimentary rock was, in fact, rubble from an iron formation and the material which is quite commonly called Conga in Brazil. This very large iron ore deposit will now be developed jointly by U. S. Steel and the Brazilian Government.

About the same time a cooperative project was being undertaken by the National Department of Mineral Development in Brazil and NASA through the Brazilian Space Agency to experiment with the use of remote sensors to assess the iron resources in an area that was well-known and mapped in considerable detail in the 1950's and early 1960's by the USGS. Through the use of NASA aircraft the very significant fact that color infrared photography shows up Conga beautifully was discovered by this experimental project.

Different remote sensors tell different things about the possibility of a resource in the same place. One sometimes gets a picture from the use of several sensors that

one cannot get from using one. Also one sometimes can be misled by an interpretation that has been made on a particular sensor. Therefore it is necessary to have ground check.

The information has to be put into a place where it can be used. Similarly one has to have people trained to use it.

In the state of Mineiros in Brazil a local villager brought in a sample of peculiar looking rock which on analysis turned out to have a fairly substantial phosphate content. The Brazilians, with some help from the USGS, began to study the area in which this phosphate was found and discovered that it was in precambrian rock, which is not the kind of rock that is typical of normal marine phosphate. Investigations showed the geology of the area as silt stone overlain by a green claystone. Lapping over and eroded away for the most part was again cretaceous sedimentary sequence.

After about a year of investigation of this phosphate it was evident that there was no economic deposit. There are a few million tons of high-grade phosphate and quite a bit of low-grade.

The first observation made by the phosphate specialists was that it was stratigraphically controlled but it was controlled by the present surface to a certain extent. The question was how one goes about exploring for it if this was indicative of a substantial phosphate deposit in that part of Brazil, because these rock types are prevalent in Mineiros. At the present time there are no remote sensors that would touch this. The phosphate itself was hardly distinguishable in hand specimens from the surrounding rocks. Aerial photographs would have been ineffective.

The distribution of the phosphate makes it very likely that it may have been leached down from the overlying cretaceous rocks. Before the cretaceous was stripped away it was readopted in the underlying Precambrian. If that is the case it is important to know.

It is also important to know what the parameters that controlled that distribution were because a wider investigation would possibly find a substantial deposit elsewhere.

Important implications of the problem of the use of remote sensing challenges the people working on the parameters for the use of remote sensors. There may be presently unknown techniques that could speed up the exploration process for this, but one has to rely on the traditional methods. Geochemistry was tried and was found unsuccessful.

It is important that the completion of this study be published and be put into the record so that something usable for wider exploration may be developed at a later date. Practical off-takes of work underway have significance in terms of the thinking about use of remote sensors in the future.

An important consideration is the publication of results of everything that is done. At the least material should be put into a library, file, or data system where it is accessible. Secondly the training and the development of people who know how to use this information is important.

Different agencies use different categories of surveys. The U.N. refers to its large number of projects as pre-investment surveys. The standard pattern is one of doing quick photogeology over a big area, quick geochemical exploration and geophysics, and then narrowing down a target and doing detailed work in this area. This has resulted in a reasonable rate of discovery. Some agencies, including OAS and UNESCO, utilize the integrated survey approach, studying all aspects of the resources and the development possibilities of a particular basin. Other agencies employ mineral resource inventories, and multi-purpose surveys are another favorite category.

One should never expect to get out of an inventory survey the development of techniques that are going to lead to the discovery of ore deposits. An inventory is only a catalogue of what is had at the time. Pre-investment survey of the type that the U.N. undertakes is not going to result per se in some of the offtake that other types of survey might generate. When evaluating information resulting from a survey one must keep in mind the purpose of the survey and not expect the information to achieve a purpose other than what was intended.

Earth resources surveys can be classified. The first type is the reconnaissance survey, a broad sweep of territory to try to find mineral targets and to try to determine the potential. As time goes on there are fewer areas that need that kind of survey. Satellite imagery and some types of aircraft remote sensing imagery would be more applicable to reconnaissance than to highly detailed surveys. District studies are studies of particular mineral districts where targets have already been partially identified. Topical studies are studies of particular phenomena, for example, volcanoes and earthquakes.

There are differences in the economics, possibilities, and objectives in each remote sensor application.

USGS has already demonstrated that volcanic activity can be monitored. A survey was conducted in the Philippines after Tol erupted in which infrared imagery was used successfully between the time of the first eruption and the time of the second eruption. There was a significant change in the heat pattern and the second eruption was fairly well predicted on the basis of that.

A large number of the volcanoes in the Philippines and those in Central America have erupted and there is hardly a major city in those areas that is not potentially threatened. The possibility of monitoring something like this by satellite automatically becomes beyond any economic consideration. It is probable that if there had been a satellite monitoring the Andes region in Peru, the major fracture that wiped out the town of Yungay within five minutes could have been anticipated on the basis of the gradual change in the fracture condition and the grayish areas that were eating into the side of the mountain.

In the field of the geological hazards remote sensors play a very signficant part. However, there are some points concerning the future of standard geological surveys that need to be made. One of them is the interrelationship of different types of surveys. One tends to lead to the other if the information from one can be put into the hands of people who can use it in planning and in carrying on other surveys in the same area dealing with related resources.

Following is an illustration of this principle. About 20 years ago a quick reconnaissance of the geology and resources of Thailand was undertaken. This resulted in a published bulletin and in a very sketchy map which led to the identification of certain mineral localities, many of which are in the northern part of the country. Under an AID program these were subsequently investigated to see what could be done with them, and in the course of that investigation a certain area was identified as having a concentration of mineral localities. AID paid for an aeromagnetic survey of that area to determine what was controlling the mineral situation.

About that time the work on the Mekong program began. The decision to build the Mekong Dam in this area meant a good part of that district would be flooded. That leant urgency to undertaking a study of the area. This was undertaken under U. N. auspices. The British did the chemistry and USGS did the geology and geophysical interpretations. A published paper resulted which included discovery of several significant mineral deposits including copper deposits that are now being explored.

Studies of salt were also undertaken because AID had a concurrent program in the Khorat Plateau within the Mekong Basin studying water supply problems. USGS determined that the salt was several thousand feet thick in places and also had gypsum associated with it. This led to the consideration of whether the salt basins had potash in them. AID recently sponsored a short investigation to see whether there was a reasonable potash content. A core study utilizing new techniques of analysis of isotopes of bromine indicated that there is a good possibility of a substantial potash basin and this could lead, depending on the economic considerations, to further study and drilling for potash in that area.

One investigation tends to lead to another if one can get the results of each one prepared in a usable way.

This principle applies to the remote sensor activity too. One must get the remote sensor information into the hands of the users and get it prepared, packaged, and interpreted in an understandable form.

That particular problem can be illustrated by present activity in Saudi Arabia. A program is being carried out in conjunction with the Saudi Arabian Government of experimentation with the use of a four-channel radiometer in an aircraft. Each channel shows a different kind of radiation and combined certain patterns emerge that can be interpreted into the geology for mapping purposes.

Data acquired this way takes years to interpret unless one has a computer, a computer center, and a digitizer because raw data must be put into digital form to feed into the computer. One then needs a plotter to plot it out. Because this production has to be set up and because people have to be trained to use it, a computer center had to be installed in Saudi Arabia. However, teaching the people the necessary techniques presents a problem because this is a very sophisticated field.

Work being done in Liberia provides another example of problems encountered. USGS began a project of systematic geological survey and mineral assessment of the country about seven years ago. There were almost no counterparts available so mapping was necessary. The Department of Defense was unable to complete new aerial photography from which to make some new base maps on schedule because of bad weather and priority problems. From old aerial photography USGS started preparing rough maps using form lines from zero, and immediately every agency in the government of Liberia, AID, and all the other assistance agencies wanted copies. USGS very quickly began a production-line preparation of base maps for Liberia.

Eventually there was such a demand that a series of shaded relief quadrangle maps resulted, but these still cannot be produced fast enough.

USGS then ran a carefully controlled geophysical survey with radiometric and magnetic techniques closely controlled for mapping purposes. From this survey it was determined that there probably was potash of agricultural significance in the soil.

The combination of magnetic and radiation patterns gives us a powerful mapping tool--a standard tool which has hardly ever been used before. One does not have to think in terms of satellites or in terms of far-out types of remote sensors having application in the developing countries. Here we have practical tools that could be used.

USGS extended the radiometric work into the Continental Shelf and discovered three sedimentary basins that seemed to have good oil possibilities. The payments of the oil companies to get leases essentially covered the cost of the airborne geophysical survey.

When one gets involved in a project of this kind, offshoots begin to take form. AID's planning projects should be given some considerable thought because the implications in terms of a wider variety of uses of the products and the potentialities for economic pay-off are good on the average.

Aerial photography has been used very widely and very successfully in the developed areas of the world. But it is certainly not being used to the potential it could be. A good illustration of that is the situation in Indonesia. There are many different sources of aerial photography but there is no central registry. This is not true everywhere but it is a critical situation in many countries.

If this is the situation with ordinary aerial photography certainly one has to face up to this problem seriously when one gets into remote sensor activity, into the satellite coverage, and into other types of remote sensor data.

With the guidance and help of the USGS the Pakistanis set up a National Stratigraphic Library in which all the records of oil exploration from the oil companies, from the university activity, from governmental projects, from all sources is systematically catalogued and can be recovered and utilized. A very serious problem in most countries is having no central registry under which information is catalogued and stored so it can be extracted.

The concept that has to be built into developing countries is to use the information that is developed, to

organize it, and to train the people not only at the operating level but also at the management level. Unless this can be done, attempts to use more remote sensors more widely is simply going to compound the problem that already exists.

USE OF EARTH RESOURCES SURVEYS AND REMOTE SENSING DATA IN DEVELOPING COUNTRIES

Milo L. Cox

For the last six years the Natural Resources Division of the Inter-American Geodetic Survey has been working throughout Latin America on the utilization of integrated natural resource surveys, on the needs for data for development, and on ways to accomplish this so that there would be people within the country who carry it out after the original initiators left, especially in an emergency situation.

Several arbitrary levels of earth resource surveys and data gathering have been worked out. The first type of earth resource survey would be the private or individual observation level. The second would be the rather general qualitative studies made. The third one would be an integrated survey, a combination of semi-detailed people in a team. One now comes to the introduction of the spectrum of new tools. Integrated surveys depend very much on black and white photographs, sophisticated aircraft instrumentation, color, infrared, radar, and multispectral band. The remote sensing from the satellites in the last level.

The scientist or the resources surveyor can benefit considerably by the use of the most modern tools but if at the same time by shortening his experience with the subject he really does not know what any native person knows, he can miss badly.

Examined historically, the first three maxims led to the development of specialized departments which developed special languages. They secondarily included information on other fields. Of course, the methods were normally field methods--tables. If topographic maps, usually at scales of 1 to 50,000 or smaller, were available they were used as base maps. Another important source of information was census data on the people and the crops. This data, of course, was only available on levels of political subdivisions. There has not been much real effort to relate the information obtained by the census to the needs for information of the countries.

When one talks about remote sensors and earth surveys, one is really talking about land or water use and people. Perhaps the first very important remote sensors were for general use in resource studies using air photos as well as

some of the automatic meteorological stream recorders, electrologging, and various other devices not normally included in this field. Now air photos have become basic photogrammetric tools for making accurate photographic maps.

With powerful leadership from the Australians who wanted to study remote areas, a breakthrough occurred about 1954. This was the idea of using the air photos and multidisciplinary teams of specialists coordinated by an "integrator" to get information needed to make specific decisions.

At first the areas studied were quite remote and relatively underpopulated, so the teams were primarily physical scientists. These evolved into teams that included economists and rural sociologists. Undoubtedly in the future social psychologists and even political psychologists will be involved in this. The idea was to characterize an area at a predetermined level of detail in order to meet a rather specific planning need. Naturally the next step was the formation of integrated natural resource institutions instead of single-purpose institutions, where there were teams made up of people representing all these fields.

In Latin America there are three of these. One of them is the Office of Natural Resources Evaluation (ONERN) in Peru. One is the Institute of Natural Resources (IREN) in Chile. The third is CETENAP which has recently gotten underway in Mexico.

These started independently and as a result there was a communication gap. Now the planning offices and the resource agencies are both getting competent enough to communicate, and because of that they are someday going to be able to come up with the kinds of data they need.

Most countries, however, do not have this capability yet. Perhaps AID could help them develop it. But many of them are contracting either special field resource surveys through the UN or integrated surveys through various contracts.

Sometimes the emphasis is on a single use. In Panama and Nicaragua the primary emphasis was on the determination of land ownership and land capability for the purpose of making tax evaluations, and secondary emphasis was on the identification of obvious projects. In the last 10 years in Latin America alone about $30 million has been spent on this kind of survey. In every project the idea of the analysis of the data for other purposes, such as agricultural development, agrarian reform, or institution building is always stressed, but very rarely have there been any significant results along these lines.

In Nicaragua, for example, $10 million is being spent on a natural resource inventory. No provision was made to analyze the information or use it except for tax evaluations.

In Panama several hundred mosaics, maps, and soil analyses from a $4.3 million project were, essentially, archived. There are very few people within the government or the planning agency that would even know how to read the legends on this information. After three years this material has been rediscovered and AID is working in it with a group of volunteers from various Panamanian agencies to see what can be utilized in an agricultural sector analysis and also to predict some of the needs of land in the next 10 years or so.

In spite of the fact that the data would be in a different form and level of detail if the purposes had been thought through in the first place it is quite useful. But there is a good possibility that unless a thorough analysis is recommended the material may be archived.

Furthermore, in some countries it is virtually impossible to even get a copy of many US/AID studies or find a reference that they have been done if they are more than 10 years old.

A way out of this impasse is for the Planning Board to archive what has been done in the past. However, this is a field in which the methods have to vary in the case of each country.

Infrared color, multispectral band, and radar have hardly been used, even if one is talking about the airborne types. However, Panama and Colombia now have 1:170 side-looking airborne radar mosaics and from that a 1:250,000 map was made in the Darien range of Panama which was essentially better than previous attempts, but whether it was improved enough to justify the extra money is another consideration. However, because of cloud cover, it was difficult to do this with regular air photography.

This example is now becoming rather contagious. Brazil and Venezuela have signed or are just about to sign contracts to have large areas of the Amazon covered with side-looking airborne radar. As part of an early study Chile used infrared photography for better differentiation of some of its forest species. Mexico is about to photograph much of the country in color at 1:25,000. The Mexicans think they will get improved photo interpretation for soils and geology, and land use. The cost is estimated to be about five percent more. Mr. J. Simon of the Raytheon Company said that in East Pakistan there is a proposal for using thermal

infrared and black and white and false color at 1:30,000 for determining high water levels, areas of rice production, different kinds of rice, and cracks and failures in Polders. Another project in Thailand is related to hardpans for lateritic soils. One must cautiously consider the objectives and the uses intended for these.

In summary, when sensors--air photography and some of the conventional sensors as well as the new ones--are used selectively and when they are used to supplement needs for valid information, they already are extremely useful.

DISCUSSION

KENNETH VERNON:

These presentations have demonstrated with considerable force that there are many tools of remote sensing currently being used. One has to determine one's objectives and then determine which tools within this arsenal of capability will be used. There are many ways to get needed information at the particular stage of the developmental exercise in which one is engaged while saving time, effort, and money through the use of remote sensing tools as they have been discussed here.

In the operation hard rock study in India, a number of areas worth studying in greater detail were identified through remote sensing devices. Because the Indians were saved general ground operations they will concentrate on specific areas which seem to have the highest promise.

Countries are using data in their resources development. They are using remote sensing devices. The tool of the satellite is not used widely because it is not widely available yet.

ROBERT N. COLWELL:

The synoptic view is of importance in relation to the making of global inventories to uniform standards. By virtue of the large area that will be covered from a single camera station when ERTS-A flies, it becomes feasible for the first time to think of obtaining global coverage with only a limited

number of exposures. The fact that ERTS-A will be in a near-polar orbit ensures that virtually the entire globe will come under its surveillance; and the fact that ERTS-A will be in a sun-synchronous orbit ensures that nearly uniform lighting will prevail at the time when imagery is being acquired. The resulting uniformity with which features throughout the globe can be imaged by ERTS-A greatly increases the feasibility of mapping earth resource features to uniform standards on a global basis. This is especially desirable if global management of various kinds of earth resources is to be accomplished. Two or three examples will serve to document this important point.

If the managers of forest resources are to know what the total supply of sawlog timber or pulpwood timber is at any given time (on a global basis) uniform standards must be employed on a global basis in the mapping of these resources. A similar situation exists with reference to the inventory of range resources on a global basis to a uniform standard in terms of "animal-carrying capacity;" or to the inventory of hydrologic features to a given order of drainage, (e.g., second or third order). In these and many other instances, the making of uniform inventories on a global basis will be greatly facilitated by the acquisition of uniform imagery from ERTS-A. Part of the advantage that will be offered by ERTS-A is the synoptic view, but the acquiring of a uniform view on a global basis will likewise be facilitated by the uniform lighting, uniform scale, and uniform combination of films and filters used in the remote sensing process.

Judging from certain comments that have been made by the preceding speakers, I gather that there is some concern over the fact that little operational use appears to have been made to date of these remote sensing developments. In making such an appraisal we should reflect on the rapid progress that has been made through remote sensing research since the dawning of the space age, and particularly in the last five or six years. Part of this progress has been in development of the sensors, themselves; part in development of the aircraft and spacecraft for transporting them; part in the techniques for using such equipment (e.g., multistage sampling); and, part in the techniques used in analyzing remote sensing data. In view of the recency of these developments we should not be surprised or distressed by that fact that operational use is only now beginning to be made of such costly, complicated devices and techniques. While it is true that there are only a few instances to date where resource managers have found use for these new inventory methods, I feel that we are crossing the threshold in this respect and that many more uses and users will soon be found.

Furthermore, I feel that we should be agreeable to the making of a rather broad interpretation of the term "operational use" as applied to these developments. As one example let us consider the desires of certain ecologists and others to establish "environmental benchmarks." There is a genuine requirement for us to find out what this globe was really like (in terms of certain of its earth resource components) before man began having the tremendous impact that only recently he has had on it. The need for environmental benchmarks can apply to the atmosphere, to the land and its associated vegetation, and to the water -- all in relation to the various things that man has been doing, and can do in the future, to modify the environment. If only we can acquire suitable remote sensing data on a global basis, now, we will have acquired the basis for establishing these benchmarks, even though the complete analysis of such data might not be completed for years. ERTS soon will provide us with the necessary raw data. Viewed in this light we can consider that we are making important strides forward in the application of modern remote sensing techniques, after all.

I will conclude by citing one important instance in which modern remote sensing techniques are indeed being applied with a view to the wise development of resources in a sizeable area. As some of you know, the UN is helping to sponsor a project in Northwest Argentina in which for the first time a systematic look at multiple resources is being made in five or six provinces through the use of modern multiband, multidate, multistage remote sensing techniques. On my recent trip there as an OAS consultant I noted with interest the tendency of geologists to want to concentrate their study of remote sensing data on those areas that are well above timberline because they were able to obtain such a good look geologic features in these largely unvegetated regions. On the other hand the foresters excluded these very areas from their studies as they searched for important forest resources. After considering the matter further both groups decided that they should concentrate a major part of their initial effort on some of the most heavily vegetated areas of all, despite the increased difficulty of perceiving geologic features in such areas. They recognized that the potential value of their remote sensing efforts was mainly in the actual development of resources, and that this development could be limited very greatly by the cost of constructing access roads of the type required for removal of whatever resources they discovered. In those happy instances where both mineral and timber resources might be discovered in the same general area, a "cost-sharing" in the construction of access roads would be possible and thus resource development would be possible in places where it might not have been feasible based on the discovery of only one type of resource.

Finally, as we attempt to assess the benefits of earth resource survey programs, especially when such programs are based on remote sensing from aircraft and spacecraft, we must not overlook a very substantial "fringe benefit." I refer to the benefit that results when a large number of scientists, representing a host of different disciplines, work together as a team on some very worthy project. One such project is that of making a global survey of the earth's resources so that such resources can be more intelligently managed for the benefit of all mankind. Part of this potential benefit is tangible and can be measured in dollars; but perhaps an even more important part of the benefit is intangible and results merely from the uplift of spirits resulting when men work together mightily at a noble cause. No one could express this latter concept more eloquently than Aristotle did centuries ago when he said essentially the following, although in quite a different context: "The search for truth is in one way difficult and in another easy; for no man can master it fully nor escape it wholly. Yet each, through his own efforts, acquires a few important facts, and from the mass of knowledge thus assembled there arises a certain grandeur."

TYPE, QUALITY AND QUANTITY OF EARTH RESOURCES DATA REQUIRED BY DEVELOPING COUNTRIES

Kirk P. Rodgers

INTRODUCTION

Every developing country has different needs, and generalizations applied to all developing countries are not only useless, but quite dangerous. It is important to emphasize the importance of looking at demand for resource data in a developing country. Some of the worst mistakes made in the past have been because of a preoccupation with Problems of supply of resource data for development and not with the real demand for that data. There is too much concern about the means of collecting data - the aerial data collection systems, the approaches to mapping, the approaches to data analysis, to data storage and retrieval, etc., and it has been forgotten, particularly in the developing countries, what the data is being collected for. In the developing countries the major emphasis on earth resources data collection should be development.

Countries with scarce financial and technical resources have to be very cautious about how they invest in resource data collection and analysis.

FACTORS DETERMINING TYPE, QUALITY AND QUANTITY OF DATA NEEDED

a. Economic Factors

The first group of factors determing the type, quality and quantity of resource data which a developing country needs, and can effectively use are economic ones. Foremost is a country's present level of economic development. The type, quality and quantity of resource data needed by Paraguay, which is early in its development, is completely different from that which is needed by its neighbors, Argentina and Brazil. In addition to influencing the types and qualities of data needed, a country's level of development determines its capacity to finance data acquisition and analysis and to absorb and utilize the results. In some of the least developed countries the problem can be one of excess of data in relation to the capacity of the country to effectively use it.

Second and equally critical are a country's national goal and priorities for development, its projected rates of growth, etc. This is where the entire discussion about data needs begins. A country should collect precisely that data which it needs to plan and implement its development. This sounds simple and logical but unfortunately it has been overlooked many times, and in some cases in international and bilaterally sponsored programs involving agencies represented today. Some of the institutional factors which will influence very strongly the needs for data and the capacity to absorb information need to be examined next.

b. Institutional Factors

First of all, the availability of professional expertise in the country to carry out data collection and analysis is obviously critical. Experience has shown that it is unwise to import large quantities of foreign expertise to do the whole job of data collection, because frequently when they leave all that remains behind is a handsome report and no one able to continue the analysis or effectively utilize the information. In effect, unless there is a significant participation of the professionals from a developing country in the data acquisition programs a dead end may result. The limiting factor is the capacity of the country to absorb foreign expertise to complement its local capabilities.

Equally as important as trained local professionals is the level of development of resource survey institutions. In many parts of the world there are well trained professionals whose productivity is very low because they are not given adequate leadership and institutional support.

The limiting factor therefore can be the capacity of institutions rather than the quantity and quality of trained individuals.

c. Technical Factors

In addition to economic and institutional factors affecting approaches to resource data collection there are many technical factors as well. One of the most obvious is what type, quantity and quality of resource data already exists. After the economic needs for resource data have been identified and the country's institutional and professional limitations have been clearly identified, any plan for resource data acquisition must take full account of what data already exists.

Particular attention should be called to the very great extent to which Latin America has been photographed and the very small extent to which it has been mapped using that photography. The limiting factor here does not appear to be the availability of imagery of the environment but rather the capacities of the countries to analyze that imagery and convert it into forms of data which can be utilized in taking development decisions.

Another factor affecting a country's strategy for resource survey will obviously be affected by its size and its density and distribution of population. A very large country with a very sparce population is obviously going to approach the matter of survey of its phusical resources in a different way than a small very densely populated country. Its needs for development are quite different.

A country's development plan should be the principal guide to determining the type, quantity and quality of data to be acquired, but the specific strategies of data collection will obviously be influenced by physical factors. A large percentage of developing countries are located in tropical latitudes and the tropical environment presents some very special problems which influence the type of data required.

SOME CONCEPTS OF ENVIRONMENTAL DATA COLLECTION IN DEVELOPING COUNTRIES DERIVED FROM LATIN AMERICAN EXPERIENCE

First, resource survey in developing countries should be primarily development-oriented and not sciertific-research oriented. Resource survey programs should be developed in response to needs for resource data which are determined by national or regional economic plans for development which have identified development goals, have established priorities and have indicated the kinds of development projects which will be favored. In the case of Latin America, national economic planning boards exist in most countries which in the last decade have prepared economic development plans of varying duration which have stated development goals and indicated the courses of action which they hoped would be followed to reach those goals. These plans and programs must be taken into account when one speaks of developing programs for earth resource surveys in these countries. Investments in data collection should be made which are justifiable on the basis of overall development strategy.

Secondly, resource survey is expensive, time consuming and demanding in terms of the input of scarce professional talent. Data collection should not be open ended. Systematic inventories of physical resources which have as their

objective the acquisition of knowledge about the physical environment with no particular end in view are potentially very wasteful of scarce financial and human resources in developing countries. An exception to this statement are the general reconnaissance overviews of the environment which are intended to guide the formation of national development policies and focus later investigations of physical resources in areas of high development potential. Every country needs some kind of a reconnaissance overview of its physical environment so that it can intelligently plan its development. Of greatest concern is open-ended resource surveys that involve systematic mapping at medium and large scales of large land areas. A country has to have a rather high level of development to afford this. Also of some concern is the involvement of technicians in some developing countries in basic research in the new technologies of remote sensing. It is easy to attract first class scientists in developing countries to participate in expanding the knowledge of this latest and very glamorous technology, but if care is not taken they may in the process be diverted from tasks of greater immediate importance to their countries.

Thirdly, experience has shown that one of the most efficient ways to carry out development-oriented investigations of the physical environment is through a program which proceeds in phases. The broad overview of a large area which has been identified as of development interest should be followed by more detailed investigations in limited areas where possibilities for specific development projects are seen. The final phase of investigations should then concentrate on detailed study of those physical factors necessary to determine the economic and technical justification of a specific resource development project. The main point here is that the minimum investment should be made at each phase of the investigation necessary to justify proceeding to the next.

There is a great temptation on the part of scientists to want to extend their work in their particular discipline further than is economically justified because they want to produce the perfect geologic map or they want to make a major contribution to the knowledge of soil science in their country. It is difficult to restrain them but it must be done because financial and human resources are scarce in developing countries.

Finally, experience has taught that investigations of the physical environment should, as much as possible, be integrated and multidisciplinary in their approach. The objective is not only to economize on data collection and analysis by investigating several factors in the field simultaneously but more importantly to retain a wholistic view of the natural environment. What is being discussed here is basically the ecologic approach to resource survey.

In summary, data collection about the physical environment should be development-oriented, integrated, and should ideally proceed in a series of phases of increasing intensity of survey from reconnaissance of large areas to detailed study of individual projects. Data collection and analysis ideally should be a continuous and orderly sequence which culminates in specific development. This is the goal but it is rarely achieved without setbacks. Reconnaissance surveys which indicate the desirability to proceed to a greater level of intensity of study in certain promising areas go unheeded and the data simply ends up as a publication on a bookshelf or data is produced at tremendous costs but it ends up in sophisticated reports which cannot be used by decision makers. The interface between data producers and the economists and engineers who implement development is the critical one. Our real problem is communication between people and between institutions working in different aspects of development.

Looking ahead to the application of the new technologies of remote sensing in the developing countries, attention should be constantly focused on this critical need for an effective dialogue between data producers and data users. It is this communications interface rather than the ability to use technology that will determine success or failure of efforts to assist the countries.

DISCUSSION

HUMBERTO RICCIARDI:

I have to congratulate Mr. Rodgers for his excellent paper. He has covered the subject so well that my comments will be few in number. First, the subject of this item is a very important one. When I go to a resource specialist to discuss what we can do with space-developed technology he will normally say: you have to give us the technical capabilities of the space system and we will then decide how best to use the system. If I consider the subject with space experts, it is the other way around. They request the resource programme needs and then study how to apply space technologies. But, anyway everybody is interested in assessing the needs of the developing

countries to try to develop a plan, but as Mr. Rodgers clearly has demonstrated, and I quite agree, it is not possible to establish a general framework of requirements for all the developing countries. The only question that can be answered is how we determine the needs for resource data in individual countries.

This cannot be viewed as a scientific exercise but must be regarded as a very important practical step for development. Natural resources are a capital stock and it is clear that the possession of such resources can have a favorable influence on the level of economic development of people.

We heard Dr. Herfindhal say this morning that natural resources are unfinished capital goods. If it is so, it is also clear in my opinion that the investment to obtain information on natural resources should be subject to the same general criteria that governs investment in any type of capital goods. These are: priorities according to national policy and availability of capital. That, for each country, is a different question.

Of course we all agree that the first priority should be development, but I also believe that we can establish sub-priorities in this area, and I would allocate a first sub-priority to the collection of information in areas that allow for immediate investment decisions. I accept the objections that can immediately be raised, such as: (a) such data is often difficult to evaluate; and (b) it is also not possible to specify the product of some type of data. The solution, in my opinion, is a country adjustable plan--and the plan is the responsibility of the country--that will allocate priorities and funds according to the information obtained.

The goals should be to obtain data according to the requirements of the users of resources information and, in that sense, the objectives in different areas can change with time. The total procedure requires flexibility, timely analysis of progress made, and, reassessment of partial targets as data evaluation procedure progresses. Now, what can we do to help the less developed countries? We have to realize that in many cases both the capacity available to plan the use of new technologies is limited, and they do not have enough information to evaluate the potential of the technology as it relates to their problems. They need our help to make their own decisions of the type, quality and quantity of resource data required.

I want to emphasize that this is a decision they have to make. But we have to provide enough information to the people with managerial responsibility so they can make their decisions. Of course, that does not mean we intend to oversell the technology. Furthermore, it is necessary to also give the information needed to assess the implications of such decisions, even in the commitment of trained people, institutions, financial implications and so on. They will have to know what is needed to achieve the minimum capability necessary to obtain a "critical mass" (in terms of atomic physics) which would allow them to start a concentrated and active plan.

REMOTE SENSING OF THE ENVIRONMENT AND ECOLOGY OF DEVELOPING COUNTRIES

Dale W. Jenkins

INTRODUCTION

In the industrially developed nations there has not been much awareness of the pollution problems or of the effect of wholesale environmental degradation until the last few years. Before this time the concern was expressed only by a few conservationists and ecologists. Suddenly environmental quality and pollution have become major areas of concern.

It is not surprising that the developing countries that do not now have extensive pollution problems are not overly concerned. In fact, some developing countries have made it clear that they do not want to be held back from developing their resources and industrializing because of the lately discovered dangers of pollution. Some have even indicated that some pollution might be considered an indication of affluence.

Environmental degradation is, however, another matter since this results in decrease in food production and in economy. Unfortunately this is usually not realized until it is very difficult to do anything about it. This is similar to experiences in developed countries.

Science has systematically created a powerful and rapidly growing body of knowledge which advanced countries have used to produce spectacular feats of modern technology. Pressures are enormous in the underdeveloped world for sharing this new life including nuclear power plants, electronic machines, great increases in food production, synthetic chemicals and significant increase in human longevity. Numerous intensive efforts are being made to apply modern technology to the problems of increasing food production and decreasing health problems. Ambitious programs for transforming river basins, reorganizing agriculture, and change in land use are being attempted in tropical and arid areas where the ecology is little known or ignored.

Modest improvements in agriculture and particularly grazing and use of forage rangeland in developing countries can mean the difference between subsistence and starvation, and between stable and unstable governments. The more intangible effects of increasing the efficiency of farming and forestry through new satellite (remote sensing) technology are potentially significant, particularly as population pressures will require that the earth be treated as one agricultural cooperative.

This paper points out some environmental and ecological areas critically requiring study and monitoring for effective management, and the capabilities of remote sensing to help obtain this information.

ENVIRONMENTAL POLLUTION AND DEGRADATION

The critical environmental world problems are of the same importance to able countries. The major critical environmental problems of the world are increased carbon dioxide, increased particulates and aerosols, increased quantities of biocides and biologically-active materials such as persistent DDT, the chlorinated hydrocarbon insecticides, and certain toxic heavy metals such as mercury and lead. Other problems are mainly local or regional but are of importance throughout the world. Examples of these are oil pollution of the ocean, eutrophication of lakes, rivers, and estuaries, atmospheric concentrations of carbon monoxide, sulfur oxides, nitrogen oxides, and other air pollutants especially over cities and industrial areas, and the effects of man-made changes on the environment. Certain presumed problems, such as critical decrease of oxygen, are not real environmental problems. The worldwide accumulation of biocides, such as DDT, has caused heavy mortality in various species of predatory fish and birds. Various other organisms are highly sensitive to various air pollutants or heavy metals and are excellent indicators or sentinels of pollution. A worldwide census and monitoring program is greatly needed. In the developing countries there is need to monitor some of these environmental factors and to develop baseline information looking forward to the day in the future when the countries encounter pollution problems.

There is no need for monitoring carbon dioxide in developing countries since only a few accurate measurements in isolated areas are necessary. There is a need to measure particulates and aerosols especially dust, in arid regions and in active volcanic areas. The distribution of persistent biocides and pesticides is worldwide. Large amounts of DDT

are still being used in developing countries for malaria and crop pest control and should be carefully monitored. Oil pollution of oceans is worldwide and should be monitored. Eutrophication of lakes, rivers, and estuaries is a locally-severe problem especially in heavily populated areas. Monitoring is required followed by actions to prevent water pollution. Monitoring of atmospheric contaminants is needed only in urban and industrial areas of developing countries. These may be local problems especially in areas with poor air ventilation. Monitoring should be carried out not only of specific physical or chemical factors, but on their effects on plants, wildlife, and man.

The most critical factors and conditions which need to be monitored are the effects of man-made changes on the ecology and environment. Large areas of the developing countries are in arid regions including desert, dry grasslands, and dry savannah or rangelands. These areas must be considered fragile or unstable areas since they are subject to severe and sometimes irreversible environmental and ecological changes. They are dependent on sufficient rainfall and some protection. If man permits overgrazing by introduced livestock, lowers the water table with bore holes, plows non-arable land, and sets fires, there will be severe damage to the vegetation with resultant wind and water erosion, causing dustbowls. If severe droughts occur the result may be irreversible barren desert. This is occurring in many areas. Some large agricultural areas of semi-arid regions have been lost due to salinization during irrigation with insufficient drainage and high evaporation.

Monitoring is necessary to fully understand the rate and extent of losses, and to predict and help prevent further loss. Greatly increased populations in certain areas have destroyed good farm land and lowered water tables. The construction of dams, particularly in arid regions, may cover valuable agricultural land and settlements and may result in a permanent body of water subject to siltation, eutrophication, salination, and growth of aquatic weeds and snails with attendant schistosomiasis.

How can remote sensing of these critical global environmental problems assist developing countries? Remote sensing can be of real value in monitoring particulates and aerosols. Dust clouds can be observed by photography, and general dust particulates in the atmosphere can be measured by special sensors. It is important to locate the major sources of dust particles. The problem of air contaminants such as carbon monoxide, sulfur oxides, nitrogen oxides,

and other contaminants is relatively local and contained in most developing countries. However, the technology is being developed for sensing these contaminants from aircraft and spacecraft and could be considered for limited areas of high population and industrialization. Remote sensing does not presently offer promise in sensing the presence or effects of DDT, chlorinated hydrocarbons, or toxic heavy metals except under unusual conditions of high concentrations causing death of large numbers of organisms, which is a rare event.

Remote sensing is, however, extremely valuable for monitoring the effects of man-made changes, particularly in arid and semi-arid areas. Nearly all of these changes can be monitored from aircraft and some by spacecraft if the changes are more extensive.

Some of the developing countries are aware they need ecological studies and careful monitoring of environmental degradation, daily weather and trends and cycles, study of their arid lands, the rates at which rangelands are turning into desert waste, rates of deforestation and its effects, and the overall effects of building of dams and of irrigation projects. A few developing countries are unconcerned about the importance of these problems and of the need for careful environmental and ecological study and monitoring.

WEATHER

There is a need for daily weather data in all of the developing countries. There is a need for long-term accurate weather data, particularly precipitation and related factors, to enable countries to determine trends and cycles in rainfall especially in the semi-arid regions which are subject to severe droughts. There is also a need for weather data allowing prediction of hurricanes, cyclones, floods, and other catastrophies.

Some of the developing countries have effective weather monitoring and have the capability to predict unusual weather. However, the measurement of climate in the rangelands, deserts, and forests, is usually limited or lacking. Most climatic measurements are made in the cities, and due to the extensive areas involved, these measurements do not apply to critically-important regions where data are badly needed.

The meteorological features which it is anticipated can be measured from aircraft and from satellites in the 1970 decade include the vertical temperature profile, precision

surface temperature, the infrared loss from Earth, the heat flux from the ocean, the albedo, vertical moisture profile, cloud light and continuous cloud cover, winds and movement of weather patterns, vertical distribution of density, global precipitation, global pollution including CO_2, HF, and other pollutants of a global rather than local distribution, aerosol and haze particles. Some of these features, e.g., cloud cover, are already being measured regularly over the world. More localized studies are being made by Nimbus III using balloons and other methods with sensors. Some of the above features are being measured from aircraft and sensors of different types are being developed to measure those features more accurately. It can be predicted that satellite measurements of meteorology will be of great importance to ecology, especially biome studies involving large areas.

ARID LANDS

Many of the developing countries are in the extensive non-arable arid zones of the world. These include deserts, seasonal grasslands and dry savannah. The small amount of rainfall and availability of any water is of critical importance. There is an acute need for accurate, regular, and long term weather data to show trends in climate and rainfall and especially to determine any periodicities or drought cycles to provide predictive emergency planning.

It is important for developing countries in arid regions to have accurate maps of the terrain showing potential dam sites, irrigation areas and water sources including underground aquifers.

Scientists find that the deserts of the world are expanding ever more rapidly under the inevitable pressure of human populations. Since Man is basically responsible for this increased desiccation of the environment, he is faced more than ever before with the challenge of adapting human societies to arid environments. Succession of balance and imbalance implies a tendency toward irreversible deserts, exemplified by the Saharan climate.

The rapid degradation of natural arid-zone vegetation throughout the world can be attributed to a combination of exploding human populations, modern veterinary medicine, boreholes for distributing water, and supplementary feeding of livestock. These factors are responsible for widespread overstocking of arid rangelands with numbers of livestock far in excess of the capacity of the natural vegetation to support them. The inevitable result is deterioration of the soil and vegetation. Toward the end of a prolonged drought

the effect is often dramatized by bare soil, starving people, and carcasses of livestock as in the Masailand of Kenya in 1961. With each drought there is an additional irrevocable loss of carrying capacity for livestock and people, despite the spectacular recovery of the vegetation when the rains come. Arid ecosystems are more delicate and more easily damaged than most of the world's ecosystems. On a global basis the deserts are expanding mostly as a result of overgrazing. The downward trend in productivity of the earth's arid lands is indisputable, and unquestionably it is accelerating at an unprecedented rate.

Although we are certain of this over-all trend, we need to assess the rates and magnitudes of desert expansion on a worldwide basis and to develop a major research effort in arid lands. A system for monitoring the trends in arid lands should be developed using remote sensing to measure productivity through chlorophyll intensity, geomorphological changes in erosion patterns, and moisture availability. With such information we could determine more precisely the rate of degradation of our arid lands. Satellite systems could focus international attention on the urgent problems of the world's arid lands.

The solutions to our arid-land problems do not lie simply in ever increasing irrigation. It has been well documented by archaeologists that the giant irrigation schemes of the past lasted for only a century or two; smaller schemes were of much longer duration. Salinization was the great problem of the past, as it is today, in developing large-scale irrigation schemes. With proper application of modern technology to achieve adequate drainage and regulation of water tables, salinization can be largely controlled; but salinization is not the only problem associated with irrigation. Changes in plant and animal life of the irrigated area, or changes in physical structure and living systems of the soil, may alter the habitat more significantly than salinization itself. The serious problem of schistosomiasis in irrigated lands is well known. Despite the multitude of problems involved, it is possible to increase the productivity of arid land through irrigation.

RANGELANDS

Rangeland is non-arable pasture land, and some desert and forest land, that provides the major part of forage and browse used by wildlife and domestic livestock. About 7 percent of the world's land area is cultivated agriculture, and about 46 percent is potentially grazeable which includes

primarily grassland and some desert and forest. About 21.9 million sq. mi. or 42 percent of the land area is forest, 12.6 million sq. mi. or 24 percent is grassland, and 17.4 million sq. mi. or 34 percent is desert. There are no reliable statistics on wildlife but the world domestic livestock is estimated to be about 1 billion cattle, 1 billion sheep, 350 million goats, 100 million buffaloes, 11 million camels, 550 million pigs, 64 million horses, and 65 million mules and asses. In many lesser-developed countries 80-100 percent of livestock sustenance comes from grazing native grasslands. Production may be considerably below the level of potential productivity due to inadequate quantity and/or quality of feed due to misuse of forage, and inferior or inefficient grazing animals for converting roughage to useful protein. There is an enormous need for improving use and management of range and herbivore grazers, due mainly to the gross inadequacy of national and worldwide data on range inventory and resource analysis.

The non-arable rangelands which comprise nearly half of the earth's land mass represent a vast reservoir of renewable cellulose, fiber, and plant protein which can only be converted efficiently and economically to useful animal protein by domestic and wild grazing animals. Unfortunately most range areas have very low production due in part to misuse or mismanagement resulting from lack of ecological knowledge of the ranges, i.e. the biological and physical interactions between the grazing animal, the land, and the environment. Improved inventories are urgently needed to provide the ecological information required for intelligent management of rangeland, the increased forage, and animal products.

Better information is needed on 1) acreages of useable grazing land by ecologically-appropriate classes, 2) the ecological characteristics of each kind of range (phyto-sociology, plant succession, present range conditions, climate, vegetation-soil interrelationships, and the autecology of important species), 3) the special management problems associated with different ranges, 4) indices of potential productivity and carrying capacity of each kind of range, 5) better information on the numbers and kinds, including wild herbivores, that make use of the ranges, and 6) season and duration of use. This information is required to set land-use and development policy in making management decisions to develop ecological and cultural maxima.

Remote sensing is an extremely useful tool for making inventories of rangeland resources especially in developing countries which presently lack the basic inventory data needed for developing and implementing intelligent range management.

It is necessary to survey both the ranges and the wildlife and domestic animals. The remote sensing survey techniques of range vegetation and the range environment has progressed rapidly and can presently be used.

Immediate benefit of remote sensing include 1) improved inventories and analyses of range and related resources, 2) more accurate land use maps for policy making and planning at national levels in the development of a country's natural resources, 3) increased awareness of the importance of range resources as a source of animal protein, and 4) an enhanced understanding of the relationships between vegetation and environment, including climate as it influences vegetation production and changes over time.

With resolutions from 100 to 400 feet the following can be accomplished from satellites or aircraft: 1) identification of regional forest, grass, and brush lands and potential grazing land of the world; 2) mapping of broad soil vegetation boundaries, identification of land conversion and disturbance, e.g. overgrazing and erosion; 3) monitoring of seasonal development and plenology of vegetation, temporary standing water, soil moisture from rain, and extent of burned areas; 4) location of areas which could feasibly be converted to higher or more intensive use, and prime grazing land with respect to transportation routes and market centers; and 5) observation of large migrating herds of wildlife.

The use of remote sensing for making censuses and counting wildlife and domestic animals is at present limited to surveying animals the size of sheep or larger. The present techniques include use of black and white, color, and infrared film, and infrared optical scanning. The present state of the art allows survey from low altitude aircraft.

Animals can be observed and their movements, migration, and effects on the environment determined. Larger animals, particularly larger ungulates as deer, elk, and cattle can be distinguished by an infrared thermal scanner in the 8-14 micron range with a 3 milliradians (3 ft./1000 ft. alt.) field of view with a 1°C temperature differential between the animal and its background. This is a compromise between temperature sensitivity and resolution. Successful population census counts have been made of white tailed deer. Cattle, sheep, and horses have been differentiated and counted using panchromatic black and white film at 1/5000.

The effects of overgrazing are obvious at fencelines when compared with non-overgrazed areas. Cattle resting are readily seen around trees where the vegetation is removed or trampled. Cattle and game trails are readily seen in heavily grazed areas. All of these features are readily seen on infrared film taken from 5,000 ft.

Locusts are a severe plague in many of the developing countries. The use of airplane survey has greatly increased man's capability to combat this plague. Remote sensing can be of great value in surveying conditions suitable for locust outbreaks and for charting the rate of advance and effects of the hordes of locusts. Insect damage to trees and agricultural crops is readily observed using infrared photography.

The International Biological Program in the United States involves detailed studies of various biomes. The Grassland Biome study is presently the most advanced, and remote sensing has been used to make ecological surveys of this 15,000 acre area in eastern Colorado. Multispectral sensing with 10 channels in the visible region and 3 in infrared was flown at 2400 ft. altitude in 1/4 mile flight patterns with two meter resolution. The objective was to see if different plant associations and species could be identified. Blue-grama grass could be distinguished, and also heavily grazed could be differentiated from light grazed grass. Buffalo grass, Western wheatgrass and bare soil were clearly separable. This was the first known examples of successful wild land species mapping and of remote sensing of grazing pressure on a single species. A thermal map was made from data of these channels in the infrared from 4800 ft. altitude. Color coding was used and seven temperature levels each with two degree F were mapped with different colors.

FORESTS

Forested areas in developing countries are extensive. The major areas include the Amazon basin, the central African region, and the forests in central Asia and South-east Asia. The different forest types are the humid tropical forest, dry tropical forest, rain or cloud forest, savannah, scrub and thorn forests, pine, and palm forests. Some of the areas are now rather extensively cut over from timbering and destroyed for agriculture, grazing, or by fires. It is common practice in tropical areas to cut out forest for farming (milpa or slash-burn) for a few years and then return it to forest. Selective cutting of large trees is also practical in some areas.

Forest survey in tropical regions in quite difficult on the ground and airplane photo surveys have proven to be more effective. There is a great need to survey the forests more accurately and to determine the rates of forest destruction and change.

Remote sensing of forest areas has been developed to permit accurate identification of tree species and types, timber yield estimates, and general survey of forest conditions including disease and insect infestation. Forest surveys have also been carried out in developing countries.

A survey of wild oil palms of Venezuela was made in 1948 by the author for FAO to determine the abundance of edible oil, using kodachrome and black and white photography. The palm-producing area of the Orinoco River and tributaries, the Caribbean coast, and Lake Maracaibo were photographed. The species of oil palms were identified on the ground and the oil yield measured. Air photos were studied with a stereoscope and planimeter and the total wild palm oil and cultivated coconut production was estimated for Venezuela. Use of black and white and color photography in 1948 permitted fairly accurate estimates of wild oil palms in inaccessible tropical forest. This air and ground survey required only one month, while an equivalent ground survey would have required at least two years.

Alternation or change of natural ecosystems is an expected phenomenon. Without change--that is depletion, erosion, pollution, accrual, or epidemic--the problem is seldom recognized. This, perhaps, is the easiest type of information to procure by repetitive aerial surveillance and has been exploited with photography in the visual wave lengths. Thus, old conventional aerial photography may gain value with time as indices to change, but until repetitive aerial reconnaissance is widely practiced, long-term and widespread change, man caused or natural, will often be difficult to assess. Once trends of change or the consequences of our technology are evaluated, alternatives can often be developed from the same data.

In study of the ecology of an area, repetitive multispectral sensing, or sequential survey can show many changes and dynamic processes. The following have been remotely sensed or show promise for remote sensing in the future:

Fire--including fire, smoke, burn area, and revegetation
Wind--damage to crops and forest
Flooding--extent of flood and damage assessment

Waterlogging of soils
Erosion--increase of gullies, and river erosion
Disease--crop and forest diseases, local and epiphytoties
Insect infestation--crop and forest, and locust plagues
Drying--low moisture in plants, drought
Grazing--overgrazing, animal traisl
Salinization--mineral deficiency, e.g. chlorosis
Harvesting of crops and indication of yield
Lumbering--volume of timber cut
Weed infestation and spread
Radiation effects on survival and growth
Planting and growth
Revegetation and pioneer plants
Leaf out and flowering, color change, and leaf fall
Maturing of fruit and crops
Succession of vegetation communities
Vegetation zones and community boundaries
Cultivation of non-arable land; fencing
Change of land use

AQUATIC AREAS

Water is extremely important to the economy and development of nearly all the developing countries. The presence of lakes, ponds, rivers, streams, estuaries, and the ocean are of major significance. Every developing country needs more accurate information on the extent, variation, composition, productivity and other factors abour their water resources. This is especially true in the arid and semi-arid regions where the water supply and management are critical.

Recently there has been a major development in developing countries to build dams to provide irrigation water and electricity and other benefits. In Africa the major dams are the Aswan in Egypt, the Volta in Ghana, the Kariba in Southern Rhodesia, and the Kainji in Nigeria. A series of dams have been built on the Mekong River in Laos and Thailand. Dams have also been built in India, tropical areas of Asia and South and Central America. In many cases there have been critical problems of siltation, eutrophication, huge growth of aquatic weeks, growth of snails, enormous increase of human schistosomiasis (bilharzia), variable fish populations, and severe salinization and water logging of irrigation projects. In addition to covering fertile river valleys with water, and displacement of human populations, the areas below some of the dams have suffered severe ecological changes. Survey of watersheds, water courses and dam sites, and extensive environmental and ecological studies are needed before construction of a dam. Regular monitoring of the watersheds, changes in the resulting lakes and many other

environmental and ecological factors must be carried out. Proper management of reservoirs requires knowledge of the daily weather, trends and cycles of precipitation, evaporation, flood warnings, siltation, aquatic weed growth, and other factors.

In estuaries, there is need to know the fish and shellfish populations, intrusion of saline waters, effect of destruction of wetlands, effects of pollution, and eutrophication. In the oceans it is necessary to know the location of upwelling areas, currents and streams, temperature, cholorphyll, sea state, location of fish schools, and other factors. Such knowledge is of great value in increasing fish and shellfish catch and production which may be critical to the economy and diet of the developing country.

Remote sensing has been shown to be of value in surveying water relations in the ecosystem. It has been used or has great promise for help in measurement of rainfall, streamflow data, estimating evaporation, transpiration, and consumptive use of water. Remote synoptic sensing of soil cover, soil moisture, and ground and water temperature has been accomplished.

Streams and rivers have been studied with remote sensing. It is possible to survey water velocities, thermal pollution, turbidity, sediment transport, floods, algal blooms, and some of the biological character of water. Lakes can be sensed to provide data on underwater depth and contour detail, turbidity, sedimentation, silting, water circulation, eutrophication, and pollutants. Estuaries would have the same observable characteristics as streams and lakes, and, in addition, intrusion of salinity.

Oceanographic features being studied with multispectral sensing include sea surface temperature, shape and pattern of shorelines, depth of shoals and continental shelves, edges of currents and streams, upwelling, surface drift, discharge from estuaries and rivers, sea ice and icebergs, sea roughness, sea state, waves, sediment, turbidity, primary productivity by spectroscopic measurement of chlorophyll A, bioluminescence, plankton and algal blooms, fish oil slicks of surface schools of fish, and oil slicks and outfalls. Some of these features have already been measured from aircraft and satellites and others are being proven feasible through research.

Improvement of commercial fishing productivity by locating cold water upwellings, biologically rich areas, and thermal boundaries associated with ocean currents has great promise. The feasibility of using remote sensors in aircraft and satellites to obtain this information has been demonstrated. Color photographs taken during Gemini and

Apollo missions have been used to identify upwelling zones where fish nutrients are brought to the surface. Analysis of the Nimbus infrared radiometer data has led to the detection of major thermal boundaries often associated with fishing grounds.

Water temperature measurements are very revealing with regard to the flow patterns of rivers, estuaries, and tidal regions. The temperature of the water may be measured from aircraft or spacecraft using infrared imaging instruments.

Thus we see that remote sensing from aircraft and satellites is a very promising field for studying the environment and ecology of countries both developed and developing. The potentials and limitations are being determined and optimal methods are being developed. It will be of great interest to see how much use will be made of these techniques in the future.

DISCUSSION

EDWARD ACKERMAN:

I have nothing with which to disagree. Dr. Jenkins gave an interesting and comprehensive account. He tells us that remote sensing indeed does have uses in monitoring and for basic data about the elements of the environment, but there are a number of individual objectives, both from a logical point of view and from the point of view of the individual parts or elements of the environment.

I think what I have to add is merely to try to generalize a bit about the matter of these needs. Dr. Jenkins referred to one type of need when he pointed out what the professional might consider as a need.

Another type of need, of course, is the perceived need in the country itself, which from the point of view of immediate action is the important one. That is, what is on the ground, and what is the system that we are going to work with in all of the developing countries? What do people there think their needs are for monitoring?

In most cases, as Dr. Jenkins suggested, people in the developed countries consider the needs for monitoring the

environment as perhaps a good deal less important than some of the professionals outside do.

I got an object lesson in this myself just recently when asked by the National Academy of Sciences to go to Central America for preparing a conference on the environment next February. We very quickly found that there was a good deal less interest in the environment per se than we have been led to believe from our contacts here. After a day or so we found that the touchstone to any interest in the environment at all was through the process of development. Inscfar as we were interested in income growth, employment growth, and the development of resources in the country, there was interest in the environment.

Indeed, this is what the Central American conference is going to turn out to be, and I hope it may be a rather successful one. So that attitude is one I would say is perhaps the prevailing attitude as I know it in the developing countries.

On the other hand, there is another group of countries where I think the perceived needs are much greater. Here I will take the example of a mining company which discovered an important, potentially profitable metal deposit. The company invested some millions of dollars in exploration proving the ore reserves of the deposit. The company laid plans for an open pit mine and a smelter to be located some distance away. But it happens to be a country which has had some experience already with industrialization and where the density of population is rather high in relation to its resources. So for the past year and a half the mining company has been attempting to get approval to proceed with its operation. However, a great deal of opposition has arisen among the people of the country generated, I would say, by conservationists both from the biological side and from the lay side within the population. They have succeeded in holding up and, indeed, at the moment, it looks as though there is probably a 40/50 chance of there being no mining operation at all. But in any event, if it does proceed, it will have to be much different than what the company originally planned.

The point is this: Even in a developing country, when the experience with industrialization has been long enough, say over a period of 10 to 20 years, concerns for the environment do arise that may get in the path of economic development and hinder it. So a consideration of the environment itself as part of development is in the interests of what has been thus far considered the normal objectives of the development quite apart from the environment. I think that there are a number of significant examples around the world.

The perceived need for monitoring perhaps is not great in a majority of the developing countries at the present time. The need for establishing a data base, however, for later monitoring may be very great and this may be an important problem for AID and others to consider, because the environment can get in the way of development as time goes on and the perceived needs within a given country become intensive.

KURT B. STEHLING:

I must concur that the developing nations which are just on the threshold for receiving the dubious benefits of an industrial society are not particularly concerned with the effects that these dubious benefits may have in the environment.

It was brought home to me last year in Tehran where I exclaimed about the tremendous smog bank resulting from the motor cars they have there. A Persian gentleman told me the average Persian is so eager to get an automobile he wouldn't care if mustard gas came out of the exhaust pipe.

Now, I thought Dr. Jenkins' comment on the weather was a particularly pertinent one. Some of you may suspect that the weather network that is established throughout the world, the satellite weather network, APT network and other networks, is a working model of an earth resource or satellite application system that is working very well indeed. Even the People's Republic of China has contacts with the United States on satellite weather exchange, as do the Russians.

I would also suggest that that model be continually kept in mind and hopefully NASA will keep it in mind on the ERS program. I hope it will monitor itself on the weather network.

You may also have heard in even the poorest countries there is usually an eager bunch of students willing to build an "automatic picture" receiver that will pick up images from a meteorological satellite, whether Tiros, or ESSA, or Nimbus, or ITOS, or the Synchronous Meteorological Satellite.

That sort of network and the understanding that comes with it might well serve as an introduction to countries that are on the verge of becoming developed and might make it easier for acceptance and also it might bring local participation into the picture.

Another thing is this question of ecology that was raised. I know the Smithsonian has been interested. I think again there is much more that can be done.

I wanted to mention oceanography. We had a big coastal engineering meeting for the last two days. The coastal processes in many developing nations are very significant parts of their ecology and perhaps their economy. We know what just happened in Pakistan in the coastal region. Early meteorological warning there, which was available but wasn't used; I wouldn't have done much good because one couldn't move the people even if one told them the water was coming in great waves, any more than the people of Mississippi didn't move when the hurricane came.

Nevertheless, we have a responsibility to increase meteorological knowledge for ATP receivers and higher resolution coupled with the program for environmental studies.

The other area is the question of implanted sensors on the ground. I mentioned that this morning. Surely remote sensing means not only seeing something from a distance of the earth but also putting a sensor in the remote region, whether seismic or hydrographic sensor. We have learned that we can develop small lightweight devices and land them by parachute, including buoys or free floating buoys which can be useful in supplemental and complemental earth resource satellite network.

COSTS AND CAPABILITIES OF COMMERCIALLY AVAILABLE SERVICES FOR THE REDUCTION, ANALYSIS, AND INTERPRETATION OF REMOTE SENSING DATA

H. Robert Gribben

First, it it useful to review what commercial capabilities existed three years ago.

The 1967 American Society of Photogrammetry "Services and Equipment Guide" provides the following data for "service" capabilities of some 340 commercial firms surveyed.

1967 ASP Services and Equipment Guide

SERVICES			
Photo Processing	110	Geophysics	3
Drafting	110	Land Use Surveys	5
Field Survey	120	Photointerpretation	11
Photogrammetry	120	Photogeology	50
Consultants (Data Processing, Engineering, Photogrammetry, Surveying)	110	Resource Surveys	7
Research and Development	100		

The predominant capability was in mapping, surveying and photogrammetry, and supporting functions for these disciplines. Far fewer firms were engaged in photo interpretation and resource surveys. The predominant capability addressed the question of "Where is something?" rather than "What is something?". There is a good deal of evidence that this emphasis or ratio is shifting. Some of the factors causing increased capability in remote sensing are: (1) increasing government support of earth resources and remote sensing R&D; (2) increasing acceptance of the orthophoto (and other remote sensor map substitutes) by the mapping community; (3) increasing national and international attention to the environmental problems and remote sensors; and (4) the need of aerospace industry to shift emphasis as a result of shifting national attention.

There are no complete listings of the number of firms engaged in remote sensor exploitation. A review of FORTUNE'S "500" in Table 1, for example, shows that half of the nation's top 50 firms in 1969 either made use of remote sensor surveys, had some capability in some phase of remote sensor exploitation, or produced equipment for, or related to, remote sensing.

The current supply of commercial capability exceeds the current demand for remote sensor exploitation services. This is based upon many factors, the primary ones being: (1) the great number of responses being received from industry to government requests for proposals; and (2) the improbability that any remote sensor exploitation job is not being performed because of a lack of commercial capability.

Not all commercial capability is "outstanding" nor can all earth resource requirements be satisfied with the existing commercial capabilities. In terms of numbers, there is more than enough commercially available capability to satisfy the current demand. There are very few firms, however, probably less than a dozen, that currently possess a good capability. The user must ultimately judge the quality of this capability. The client must put industry to the test. The client must assess what is being proposed or offered, and the client must ask "what, really, has this company done before; what are its people's experience; has the company ever done what it claims it can do; how deep is the capability; have these people ever worked as a team on such a project; and who are their customers and were they satisfied?"

Existing commercial capability can be improved, and the stimulus for improvement can be in three areas: (1) A capability must be proved. This occurs when useful information results or when a problem is solved as a result of having performed the sensor survey. This "proof" is differentiated from the numerous studies which conclude that--"airborne radiometers ought to be good for this or that." Rather, when the client or user derives some benefit from the survey, the survey is successful and the capability is proven. (2) As more "successful" surveys are conducted, more funding will be funneled to the survey and this will stimulate the growth of the capability. (3) A detriment to commercial growth could occur if government replaced industry in the performance of the remote sensor survey. Rather, government should continue in the role of sponsoring research, development and tests; spinning off technology; monitoring programs and setting and enforcing standards.

A short case history of the development of a commercial remote sensor exploitation capability is as follows:

Table 1. -- Top 50 Firms from 1969 FORTUNE'S "500"

COMPANY RANKING	MAKE USE OF REMOTE SENSOR SURVEYS	HAVE CAPABILITY IN SOME PHASE OF REMOTE SENSOR EXPLOITATION	PRODUCE EQUIPMENT FOR REMOTE SENSOR EXPLOITATION
1		X	X
2	X	X	
3			X
4		X	X
5		X	X
6			X
7	X	X	
8	X	X	
9	X		
10	X	X	
11	X		
12			
13	X	X	
14			X
15		X	X
16	X	X	
17		X	X
18	X	X	
19	X		
20		X	X
21		X	X
22			
23		X	X
24	X	X	
25			
26		X	X
27		X	X
28			
29	X	X	
30		X	X
31	X		
32			
33		X	X
34	X		
35	X	X	
36		X	X
37			
38	X	X	X
39		X	X
40			
41		X	X
42			X

COMPANY RANKING	MAKE USE OF REMOTE SENSOR SURVEYS	HAVE CAPABILITY IN SOME PHASE OF REMOTE SENSOR EXPLOITATION	PRODUCE EQUIPMENT FOR REMOTE SENSOR EXPLOITATION
43	X	X	
44	X	X	
45		X	X
46	X		
47	X	X	
48			
49			
50	X	X	
TOTALS	21	31	21

1956	-	SLR developed by/for military.
1957-58	-	First SLR tests for military applications.
1969-60	-	New SLR equipment--first SLR Manual--initial studies of alternate uses.
1960-70	-	Continued development of military equipment, concepts, techniques, and initial declassification efforts.
1962-64	-	Contract and independent development studies for mapping and other uses.
1966	-	Geoscience Potentials of SLR investigated--unclassified.
1967	-	"Radar Mapping of Panama" completed--topographic and thematic maps.
1969-70	-	First unclassified commercial SLR surveys.
1970	-	Capabilities and interest growing, new applications found, competition begins.
1971	-	????

Throughout this whole development cycle, a cadre of people gained necessary experience and understanding to successfully use the SLR tool. This "commercial" capability development cycle is not unlike conventional aerial photography years ago, and now a common-place tool in a host of resource survey operations. It is significant that substantial effort is still being devoted to the discovery of new uses for the aerial photo, and there is every reason to believe that such will be the case for SLR and all other remote sensors currently finding their way into our inventory of tools.

The second point discussed here is Cost. The commercial remote sensor exploitation firm views the resource survey as a complete information cycle.

First the "client" has a requirement which must be defined. Second, data must then be acquired to provide raw materials for processing and analysis. Third, processing and analysis of remote sensor data, together with existing data and field work, generates information for satisfying the requirement. Fourth, the information must be disseminated (communicated) to the "client" to fulfill his requirement.

Costs for these dependent elements are difficult to separate from one another. The remote sensor is a tool--a tool to be used properly in conjunction with ground surveys, existing data, and field checks. Cost data are difficult to express "by the pound, square kilometer, or yard" because of the number of variables involved in the pricing. For example, Table 2 lists some of the prime cost considerations for a commercially run survey.

Table 2. -- Typical Cost Considerations for Resource Surveys

WHERE?

- Location of area
- Size of area
- Environment
- Logistics
- Political/Security
- Taxes/Fees/Permits

WHEN?

- Urgency (Project term)
- Time of year
- Frequency of survey

WHAT?

- Subject of interest
- Level of detail/scale required
- Extent of prior work
- Special requirements

HOW?

- Sensor availability
- Facility, equipment, personnel
- State-of-the-art techniques

A simple example is the requirement to prepare a 1:250,000 scale surface drainage map of 10,000 square miles. In one case, the area is in the United States; we have six months to do the job; the sensor is the ERTS-A RBV furnished free; and I can use my own facilities, equipment, and personnel. The cost is probably less than .05¢/square mile. In the second case, the area is East Pakistan; we must do the job now--during the storm, and weekly during the disaster period; security and training considerations require the use of local Pakistani facilities, equipment and people; and because of technical considerations, SLR is the only feasible sensor approach. The cost can be as high as $50, or $100 per square mile.

A brief summary follows:

There are few truly experienced firms today capable of remote sensor data reduction, interpretation, and analysis. The number is growing, but significantly, the current supply exceeds the current demand.

Improvements to this commercial capability can be expected if (a) additional successful programs are realized; (b) funding for resource surveys increase; and (c) Government continues to sponsor R&D and application studies and establishes and monitors performance standards.

The costs for the remote sensing portions of a resource survey are not easily separated--nor should they be. The elements of a remote sensor survey are interdependent, and closely tied to field work and other elements of the development project.

The costs for seemingly identical remote sensor products can vary widely, due to the many factors involved. Therefore, to be meaningful, costs for exploitation of remote sensors should be generated on a "project" basis and as just one more part of the overall program.

CAPABILITIES AND COSTS OF COMMERCIALLY AVAILABLE REMOTE SENSING SYSTEMS

Scott M. Spangler

A remote sensing project, regardless of the sensors used, and regardless of whether it is for a developing country or for private individuals searching for oil and gas in the United States, consists of four steps: Mission Planning; Data Acquisition; Data Reduction; and Data Interpretation. Each step is essential to, and drastically affects the performance and cost of the next step.

For example, if the objectives of the project are set forth precisely and the mission planning is carried out well, the data acquisition step will be much more efficient and much cheaper.

Conversely if step one is not carried out well, probably there will be mis-starts, poor data, and a lot of reruns in the data acquisition phase. If the data acquisition and the ground verification phases of the project are not carried out well there will be additional expense in data reduction. If data reduction is not carried out well, data interpretation may be meaningless, resulting in a worthless project for the money.

A list of the commercially available airborne remote sensing systems are shown in Figure 1. They are listed according to their place in the electromagnetic spectrum.

The sensors listed here are commercially available. In addition, there are a number of proprietary devices such as the Input system offered by Barringer and Associates and a number of systems that are really basically research and development instruments.

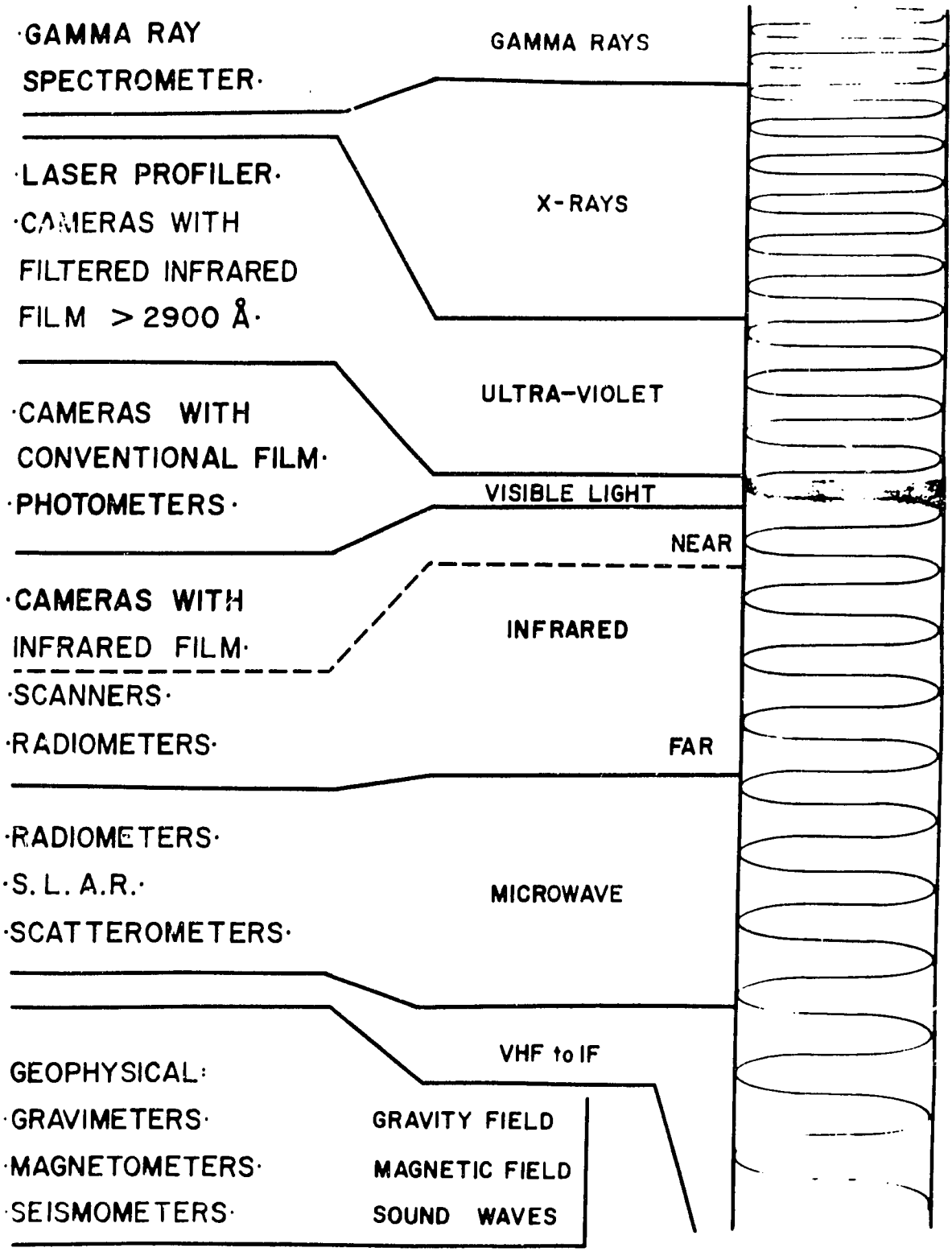
One of the important new trends in this remote sensing field is what is commonly called multisensor operation. Multisensor operation is looking at one spot on the ground with many different sensors and recording data from different parts of the electromagnetic spectrum simultaneously. As aircraft platforms, better sensor specifications and improved data recording devices are developed, multisensor operation becomes a reality.

Aircraft can be equipped with six sensors, all of which can be operated at the same time. All the data collected by

Figure 1

~~EXHIBIT 2~~

SENSORS COMMERCIALLY AVAILABLE



the sensors are reported inflight on computer compatible magnetic tape.

In addition, the flight parameters, such as ground speed, miles along track, miles across track, pitch, yaw and roll, are recorded. The aircraft is a very stable platform, but variances in all flight parameters need to be corrected to be sure one is looking vertically (or at whatever angle is picked) at the target, and that all sensor data are synchronous.

The advantage of this approach is obvious to those concerned with natural resource inventories. Ultimately the point will be reached where it is feasible to consider making one pass of an airplane carrying all the equipment required to carry out a complete natural resource inventory.

There are four elements which the project manager must consider when he is looking at the cost of a remote sensing program. First is the sensor or sensor systems; second and most costly is the platform; third is navigation; and fourth is ground verification.

The least governable of these is the sensor system. It must be chosen according to the job to be done and the data the scientist requires. However, the project designer should keep in mind that his sensor system design materially affects the cost of the platform, navigation and the amount of ground verification required.

Basically, there is a design trade-off that amounts to obtaining sufficient, accurate and useful data versus the electrical power requirements, payload, altitude and speed limitations of the platform and the costs of getting ground data verification.

As an example, consider a small thermal mapping project of less than one thousand square miles. It is feasible to use a Bendix triple C-1 thermal scanner which is inexpensive. One man can carry it. It can be mounted on a single-engine aircraft and one can make extensive ground measurements to verfiy the data because the area is not very large.

On the other hand, for countrywide surveys, or surveys in excess of 100,000 square miles, one might spend four or five or ten times as much for the sensor system and get a Texas instruments RS-14 which requires a much more sophisticated platform, but can function from 35,000 feet, and can obtain data at a rate of 4,000 square kilometers an hour. In addition, it substantially reduces the amount of ground data verification needed because it has its own internal calibration sources.

Again, the trade-off between the very expensive system and the very inexpensive system is an important decision to be made by the project manager.

Once a sensor system has been chosen, the selection of a suitable platform which meets the payload and power requirements of the sensor system can still vary and it can affect the costs of the navigation and the ground verification.

To illustrate, if one selected a platform which has a sophisticated inertial or doppler navigation system, the flight-line accuracy will be such that the requirement for ground survey points can be eliminated or substantially reduced.

Navigation in remote sensing is the science, or rather the art, of locating a sensor system in the air above a specified ground target, or, inversely, of later locating on the ground an anomaly discovered in the data.

Obviously, airborne remote sensing is of very little use to a geologist in a remote area if he cannot take a helicopter or other very efficient means to get to a precise location corresponding to an anomaly that he has discovered in the data. Ideally, all navigation would be performed by the platform totally independent of ground surveys. Then one has the cost of training and transporting to the field. Practically, however, this does not yet exist, and ground verification work is a major cost consideration in a remote sensing project.

The cost factors that govern the sensor system are as follows:

Because this field is in its infancy, the cost of almost any sensor other than an aerial camera, will include R&D amortization. The manufacturers are not making enough of any one kind to recoup their cost.

The second cost, of course, is capital cost of making the sensor. The operating costs include operator training; the living expenses of the operator on the project; and the supplies, the magnetic tape, film and other parts for the sensor.

The most important cost factor in a sensor system, however, is its effect on the platform cost. Its weight directly affects the size of the aircraft needed. Power requirements also affect the amount of power needed on the aircraft and the sensor's altitude and speed limitations also affect the choice of platform.

The factors affecting airborne platform costs are:

One cost factor in the selection of an aircraft is the capital or lease cost, which is obviously the major item. One item people sometimes overlook because they are used to aerial photo missions is aircraft modification cost. This can be significant if one is using a very sophisticated system. As an example, the Falcon Fan Jet flown by Remote Sensing, Inc. cost new about $1.5 million. The aircraft modification, not including any sensor equipment cost another $0.5 million.

The operating cost, of course, is an important economic factor but the project manager has to keep in mind there is quite a difference between the per-hour cost and the per-square-mile cost.

Finally, for a mission in a developing country or remote part of the world, where maintenance facilities are usually inadequate, it is very important to consider the reliability of the aircraft platform.

The cost factors in navigation and ground verification are:

The need to locate the sensor data in space in X, Y, and Z coordinates. In addition, ground reference data must be provided. In a thermal project, for example, ground temperature measurements may be required, or, as another example, moisture content and soil type samples would be required if it were, for instance, a soil survey or engineering construction project.

The first cost factor is training of the crew. Generally, ground crews do not require extensive training. A high school graduate can do most of the work, if supervised. The problem is locating the people, teaching them the specific mechanical skills and impressing upon them how critical the ground data verification is to the project. Other cost factors are: transportation of the ground crew to the site, their living expenses, and equipment (which varies from inexpensive pieces of aluminum foil for use as targets, to very expensive electronic surveying mechanisms).

Finally, a very important cost factor is time. Ground verification is usually the most time-consuming part of the project. This extends the time required for the project and affects overhead, living expenses, etc.

To conclude, the Agency for International Development asked us to summarize the costs of commercially available systems. We present the data in figure 2. For several of them we had to rely on quotes from other companies. But even on those systems which we offer ourselves or with which we are familiar, it is very difficult to quote a specific price; too many other factors come into consideration--size of the project, where it is located, whether you can use multi-sensor operation, whether you can use inertial navigation or doppler navigation, do you have to have ground crews. The cheapest aircraft that would carry the sensor were used in each case.

Line mile cost was listed first in Figure 2 because a project manager usually will receive quotes on a line mile cost basis. This is the figure most people use.

However, if you can take photography from 40,000 feet versus 5,000 feet, even though the line mile cost using a jet aircraft is as high as $18 a line mile, the cost per square mile is one-fifth of the cost per square mile for low-altitude photography. ($2 per square mile at 40,000 feet versus $10 per square mile at 5,000 feet).

This holds true in all the imagery systems: the various aerial photography techniques, the infrared line scanner, side looking radar imagery, and radiometry if it is an imaging radiometer.

In the competitive, mature remote sensing fields such as aerial photography (where there are many competitors renting or leasing their equipment, and some who own their equipment) all competitors have to bid the same rate eventually.

For those familiar with aerial photography prices, the reason these may be a little high is, in this case only, we have included cost of data processing. That is the normal way it is quoted. Usable data is guaranteed. If there is delay due to bad weather, for example, we absorb the cost. We did not consider costs due to weather risk, location, etc., because we did not know whether the project was in Southern Texas (where there is a high probability of clear weather) versus for example Northwest Washington State or the Amazon Valley, where a large cost estimate for standby must be included.

Let me repeat that we had a lot of reservations about putting these cost estimates on paper. You can see we listed a sizeable range for most of them to indicate the possible variance. However, I felt it was pertinent and relevant to show at least approximate figures!

FIGURE 2

SUMMARY OF COMPARATIVE COSTS

TECHNIQUE	LINE MILE COST IN $	PER Sq. Mi. COST IN $	REMARKS
PHOTOGRAPHY	4	10	LOW ALTITUDE – 5000 Ft.
	18	2	HIGH ALTITUDE – 40,000 Ft.
INFRARED LINE SCANNER	5	13	LOW ALTITUDE – 5000 Ft.
	15	2	HIGH ALTITUDE – 40,000 Ft.
RADAR IMAGERY		5-10	LINE MILE QUOTES UNAVAILABLE
RADIOMETRY	5-15		PER SQUARE MILE COSTS ARE DEPENDENT ON LINE SPACING
SIESMOMETRY	1200-2000		"
MAGNETOMETRY	5-10		"
GRAVITOMETRY	30-80		"
GAMMA RAY SPECTROMETRY	3-10		"

634

Let me reiterate that the important costs to be considered by the project manager, or the planner, should be the second column, that is the cost per square mile, not the cost per line mile.

To conclude, I would like to re-emphasize the importance of mission planning. Through awareness of the cost factors affecting the overall cost of a remote sensing mission, and through careful pre-mission planning, the project manager can effect significant reductions in the per square mile cost of data acquisition.

DISCUSSION

LLOYD RALL:

I think both speakers have given us a very fine summary of a very difficult area because it is hard to talk dollars and cents for many of these factors that have been covered.

There are just a few items I would like to highlight. The aircraft with some six sensors on board did not all have magnetic tape play-out. There was a conventional aerial camera on board with photography to process. We are stuck with an age-old system, but it is a good one.

Also, I think Mr. Spangler was being a little bit too conservative by saying that we are stuck by not having the capability of finding where we are without having to go into the field on the ground with the slow process of cutting our way through to control points and establishing control. In fact, the state of the art today permits the aircraft system to establish control point positioning. We are doing it in the Defense Department with the Hypernas II inertial reference unit in the RC 135/USQ 28 system. There are four of these vehicles equipped and flyable which are capable of positioning themselves to a high degree of precision. By trilateration we can extend ground control into areas such as I think the average would be over 450 miles with a 19 foot standard error. We could produce standard accuracies of 10 feet without every going on the ground.

This begins to save us a lot of money because going on the ground is one of the big factors that costs a lot of time and lots of money. You have to know where you

are. Where is the point we looked at and photographed? Where is the sensor information?

Big airplanes have a precision platform on board. These aircraft are, to us pedestrians, similar to a Boeing-707 size airplane, but nevertheless the state of the art gives us this capability.

The unit of measure has been a problem in my area in defense. We talk about cost per square mile and cost per linear mile. It really doesn't mean much in some of these techniques. You really have to relate it to data elements per dollar to really mean something.

We have not yet got ourselves down to a way of measuring the factor yet. Certainly so much a square mile means very little when referring to some of the techniques we are talking about today. It does for photography but not for some of the other sensors. In the extreme case you could engage a contractor to fly a certain sensor a certain number of square miles and he could do just that and give you very few elements per dollar.

The age-old weather problem has been alluded to several times by other speakers. Weather satellites' information involves 7 million square miles of the earth, principally in the equatorial belt, 10 degrees north and south of the equator which is perpetually cloud covered and almost impossible to photograph. Assuming that you could get reasonable survey accuracies into some of this area, there are still some 3 million square miles of that of which we have talked about here today that is difficult data to acquire.

That is the very reason that the side-looking radar mapping program in Panama, the Darien Gulf, was done. No matter how much you paid for that photography, you couldn't do it with the perpetual cloud cover. We had planes there for years waiting to photograph that particular area. The Chief of Engineers of the Army wanted that area photographed to help plan one of his alternate canal routes.

It wasn't until we could bring enough technology together to get on with the side-looking radar that were able to produce a planning map, a mosaic such as you see there today, which is a poor man's version of a medium scale, 1 to 250,000 scale, but nevertheless it is adequate to do the planning job that was called for. There is an awful lot of the world that is like that and we will be facing a serious weather problem over and over again. Indonesia was mentioned today a couple of times. That is a very typical bad weather area; hard to and hard to get at.

In addition to having the navigation system on board the aircraft I mentioned earlier, I think we should consider other positioning systems such as the doppler, using Navy's very available navigation satellite Doppler system to help position ourselves to the world geodetic system or to a major land mass datum. This has now been developed to the point where it can be done with a small geoceiver which is man-packed. It can be set up easily; two men can track the satellite and position themselves within about 10 meters, and that seems to me another technique that we should be looking toward when we are trying to keep costs down and assisting countries. We have to position our data somehow and this seems to be quite an economical answer.

NEW TECHNOLOGY IN COLLECTING AND ANALYZING EARTH RESOURCE DATA

Richard R. Legault

INTRODUCTION

Advances in sensor technology now allow us to sense radiation from the ultraviolet to the microwave regions of the spectrum. A number of consequences result from these expanded capabilities.

First, it is now possible to collect information under a variety of weather conditions. Poor visibility is not necessarily a major barrier.

Second, the spatial recognition of objects which depends on recognizing the objects' shape and surrounding context, is now made easier because of the possibility of selecting spectral bands in which the necessary degree of contrast are best represented.

Third, the availability of data in many spectral regions simultaneously permits the identification of objects by the spectral distribution of their reflected or emitted radiation. In addition, such spectral identification can be made automatic by the use of modern computing technology.

The result of these three considerations is that we are better able to obtain a maximum amount of information from the vast amount of data our modern sensors are capable of collecting. The ERTS multispectral scanner and the Houston airborne multispectral scanner will be premium tools in this expanding technology.

As of today, remote sensing has come a long way in the United States. We have already gone beyond the point of making simple surveys. In fact, such services as the U. S. census, agricultural statistics service, soil surveys of the USGS and hydroelectric surveys of the Corps of Engineers render parallel surveys by means of remote sensing unnecessary. We have gone on to crop identification, yield prediction, and disease recognition as areas in which our capabilities can best be utilized.

However, remote sensing survey techniques may still have immense value in developing countries where sophisticated statistical services have not yet appeared. For example, cultivated area acreages are well known in the United States -- but aerial

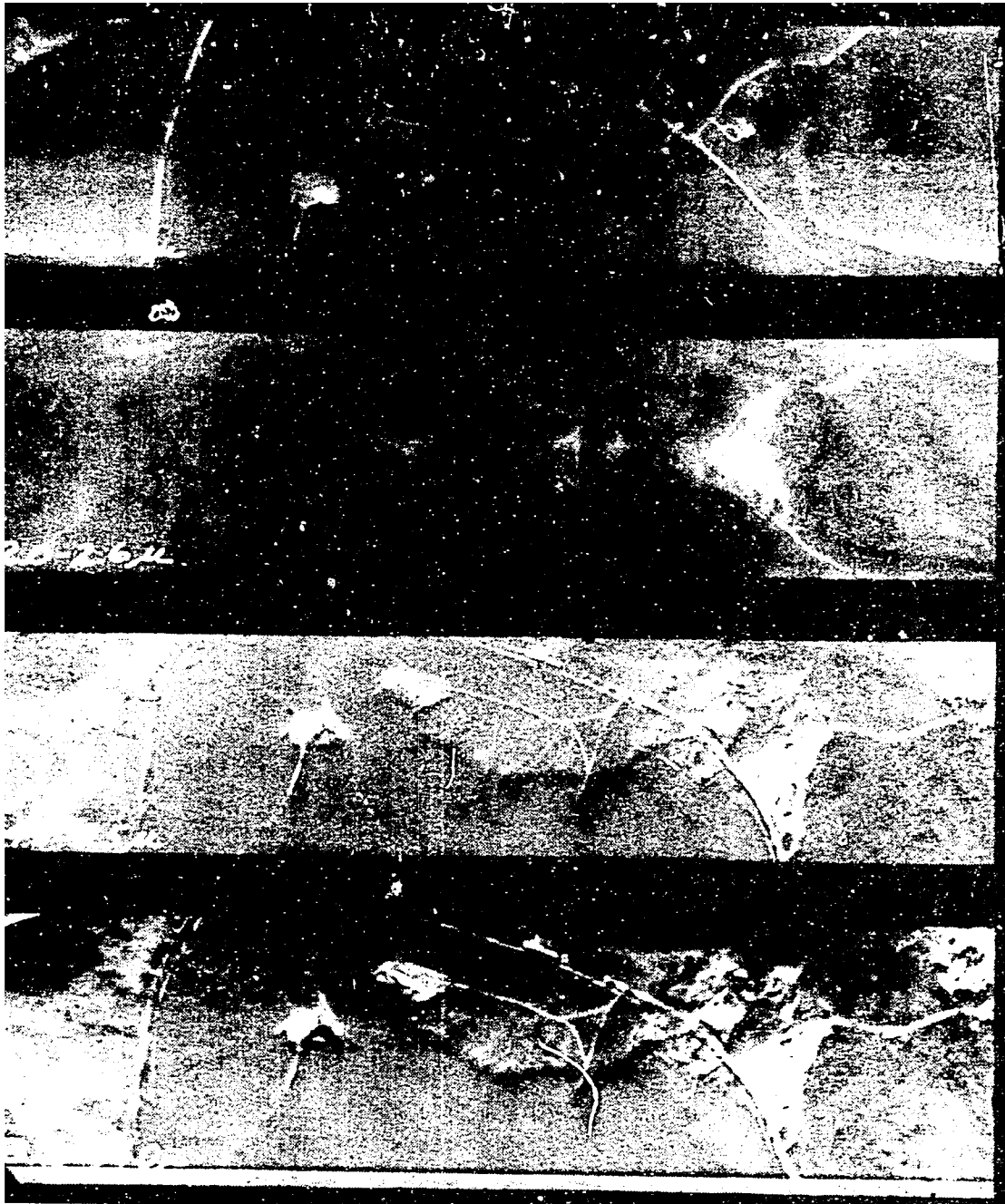
surveys to determine their extent may be of significant value to planners in developing countries. In these countries, there may well be great value in modern sensor and recognition technology in areas no longer applicable in the U. S. It is, therefore, useful to go back and examine some of the past studies that have been made and consider their applicability elsewhere in the world. The data selected for this paper were collected in the period 1960 to 1965. The system used for data collection was the Michigan DC3 aircraft, camera systems, quite old, and the multispectral scanner.

SINGLE BAND CONTRAST ENHANCEMENT

It is generally known that the contrast between the object that we seek to find and its background can be enhanced by appropriate selection of the spectral band. We gain insight into the appropriate selection of the spectral band by laboratory measurements of reflectivity and emissivity for both the target objects and background objects. Others have been produced by simple filtering of photography or by the multispectral scanner that we fly at The University of Michigan. More advanced infrared scanners and various radars will be covered briefly later in this paper.

In the first example, Figure 1, we see a picture of a fairly rural area. The scene contains roads, some fields, and a few buildings. We note that in the 0.32 - 0.38 band, most of the contrast in the scene has been eliminated except for the roads and the one fairly bright, tin-roofed building in the scene. As we look at the other bands in the imagery, 2.0 - 2.6, 4.5 - 5.5 and 8.2 - 14.0 microns, we see much more general contrast highlighting various terrain areas, but the building no longer stands out quite as clearly as it does in the 0.32 - 0.38 micron band. Figure 1 illustrates two points. First, that some objects appear in one spectral band that do not appear in others and secondly, appropriate selection of spectral bands eliminates unwanted contrast. The illustration used here demonstrates a possible application for census of housing in developing countries, where occasionally tin-roofs are used. Because no single band is useful for all identification purposes, the ability to select one band for a particular identification and still another band for others provides the power to solve several problems simultaneously. Because the selection of spectral bands depends on the object we seek in the backgrounds, collecting more than one band is important if we would have optimal contrast for all types of problems.

A major resource for any country, be it developed or developing, is the water of that area, and one type of water resource is the ground moisture itself.



BUILDINGS
STINCHFIELD
WOODS

6 Sept 63

1545 Hrs

103C
& 104C

Very clear contrast is to be expected because the reflectivity of moist soils is in general much less than that of dry, independent of the type of soil. Thus, in an infrared aerial photograph collected in the 0.85 - 0.89 region, we expect to find moist areas which are darker than those that are drier. Thus, if we are looking for water or moist soil photographically, we should consider the 0.7 - 1 micron band as being most appropriate. If we allow ourselves not only photographic equipment but also the IR scanner equipment, we find even more appropriate bands for detection of water.

Figure 2 is a diurnal cycle of a bog area collected in the 4.5 - 5.5 micron region. In this imagery, we are looking at emitted radiation from the terrain rather than reflected. In the 4.5 - 5.5 micron region, we must, of course be careful to filter out any reflected radiation to insure that we look at only the emitted signal. The bright area in the pre-dawn is the water; the reason for this is that the earth in the surrounding terrain cools considerably more during the nighttime than does the water. This cooling is, of course, attributable to the thermal capacity of the water being greater than that of the terrain. We see that after dawn, the contrast begins to fade until by mid morning, the water appears cooler than the surrounding terrain. Thus, although contrast varies at different times of day, water is clearly detectable both day and night, provided that we have an atmosphere that allows us to see through it in the 4.5 - 5.5 micron region.

We should note that atmospheric transmission is considerably superior in the longer wavelength band and in general we can see through more haze in the infrared region than we can in the visible.

Because emitted radiation is closely connected to the temperature of the terrain, we may also expect to see a seasonal dependence on the contrast. In June, the water at post-midnight is hotter as is expected. In September, water is still warmer than the surrounding terrain, although some of the surrounding terrain is of comparable temperature. By the middle of winter (in Michigan), the water has, of course, frozen and is considerably colder than the surrounding terrain. The interpretation of infrared emission imagery must therefore take into account both the time of day and the season as well. Because the water shows so clearly in this imagery, the detection of both standing water and surface soil moisture is greatly facilitated or greatly simplified in the emitted infrared bands.

The remote detection of reflected electromagnetic radiation is indicative of the surface condition of the terrain. There are also, however, a number of applications in which people seek to determine subsurface conditions, such as for

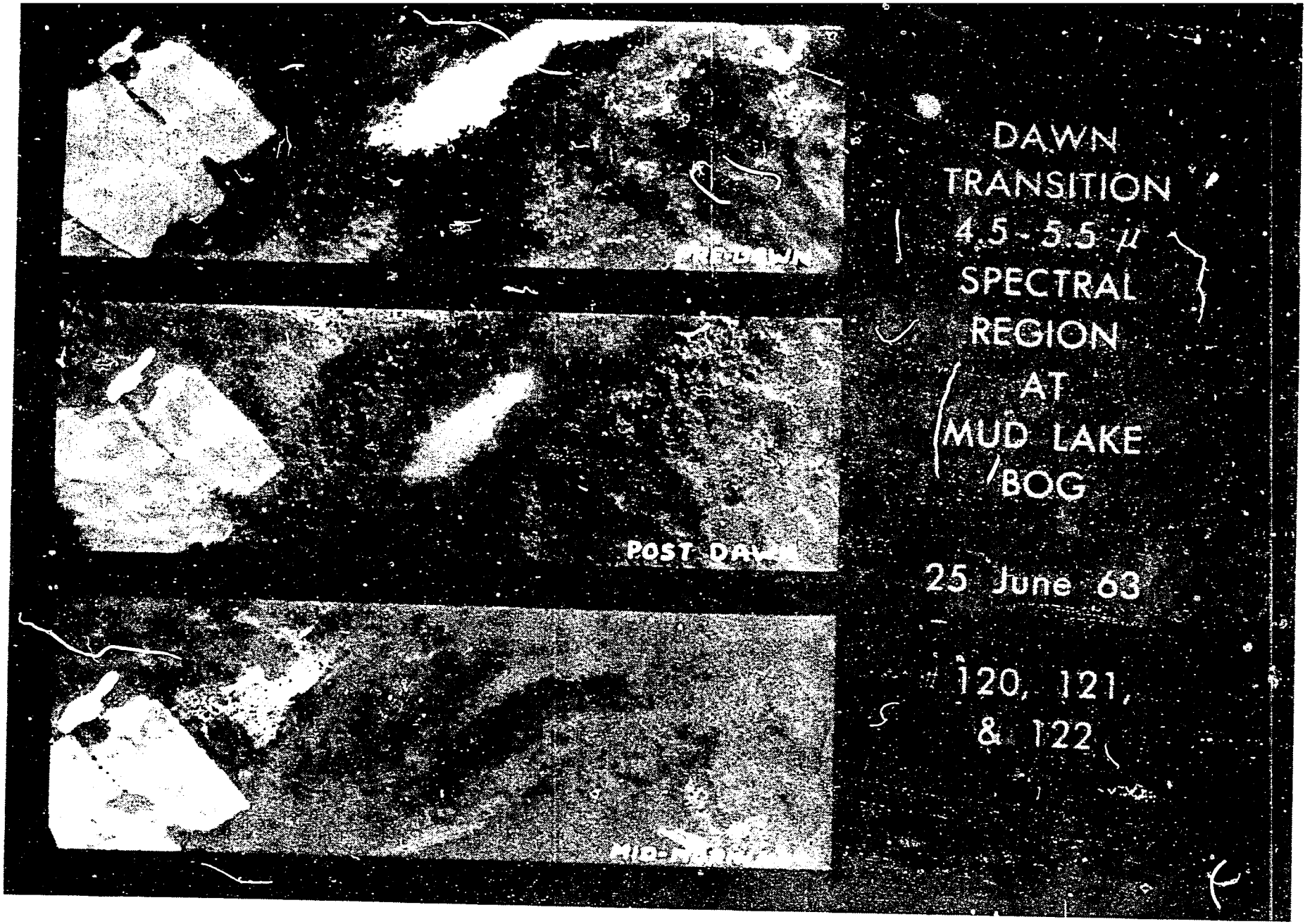

DAWN
TRANSITION
4.5 - 5.5 μ
SPECTRAL
REGION
AT
MUD LAKE
BOG
25 June 63
120, 121,
& 122

Figure 1

69A

example, subsurface water. Generally, one must infer subsurface conditions from the surface condition.

In an area of sink holes in Florida, sink holes are produced when limestone substrata are dissolved by water, forming a cavern which eventually erodes to the point where the surface collapses. When the surface collapses, the sink hole is easily detectable, but by then it is too late to do anything about it. The detection job, in general, is to determine potential sink hole areas prior to collapse. The eroded cavern underneath the surface presents a much different thermal capacity than does the surrounding solid terrain. As a consequence, we see a thermal contrast in the areas of the sink holes.

Sink holes can be detected where no surface manifestation has yet occurred. The presence of sink holes was determined after imagery had been collected and supporting ground truth had determined that sink holes did in fact exist in this particular portion of the terrain. Thus, we may see that subsurface phenomena can under some circumstances be detected by measurements of the electromagnetic radiation from the surface of the terrain but that such detections are the consequence of secondary effects measured from the surface.

In Figure 3, we move from the passive detection systems to the active systems of radar. Figure 3 is a Westinghouse imagery of an agricultural area around Garden City, Kansas. The upper image is polarized horizontal-horizontal and the lower, horizontal-vertical. The wavelength is K-band. One's attention is drawn to two areas. The area marked A, a small circular light outline in the middle, is a swamp area. Its counterpart in terms of water content is the area marked B -- an irrigated area with an overhead spray. The C area in the upper image contains sugar beets whose rather broad leaves are efficient reflectors because of differences in orientation. Today we really have very little information about the interpretation of radar imagery, because of problems of the separation of geometrical from optical properties. As work progresses, however, we certainly may expect increased sophistication for interpretation of radar imagery.

So far, we have covered fairly simple systems for collecting imagery in single spectral bands. From them we may draw some fairly elementary conclusions. First, there is great reason to carry a multiplicity of sensors aboard any platform. We see that for various applications, different spectral bands give us optimal contrasts and that we should consider not only photographic instrumentation but infrared and radar as well. These may be separate instruments in different wells in the aircraft, and in fact, we at Michigan for

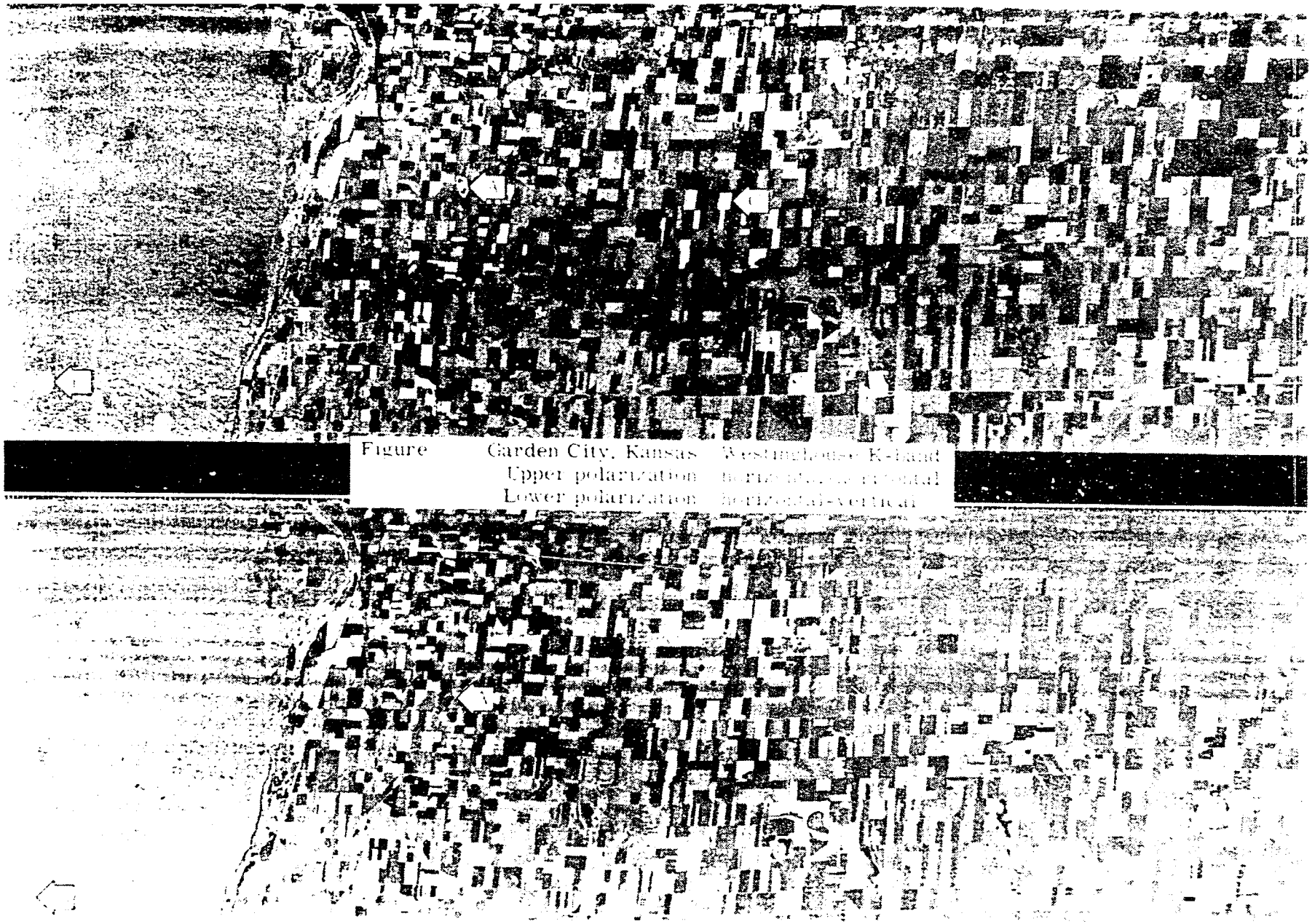


Figure Garden City, Kansas Westinghouse K-band
Upper polarization horizontal-horizontal
Lower polarization horizontal-vertical

Figure 3

70A

many years did carry separate instruments in a multiplicity of bands and do today. There are, however, other aspects of spectral discrimination than the simple single band contrast enhancement which we will turn to next.

MULTISPECTRAL PROCESSING

The basis for multispectral processing is the distribution of the received radiance from terrain objects. Recognition is based upon this spectral distribution of radiance for each resolution element of the scene. As a consequence, we must have a single aperture instrument such that for every resolution element on the ground, we are able to measure this spectral distribution of radiance. Today, there are a number of such instruments.

The basic instrument is an electro-optical scanner that is commonly used for infrared imagery. In place of a single detector is an entrance slit for a spectrometer whose dispersing element is either a prism or a grating. The dispersed spectrum is detected by a number of individual point detectors placed in the dispersed spectrum. The detector outputs are recorded in either analog or digital form on magnetic tape.

The first of these instruments was built at the University of Michigan in the 0.4 to 1 micron band. Subsequently, NASA has sponsored the development of a 24 band instrument in the 0.4 to 14 micron spectral band; the ERTS A instrument is the first of the spaceborne multispectral instruments with 4 bands in the 0.4 to 1 micron region. The EREP package of the Apollo Skylab project is a 10 band instrument in the 0.4 to 14 micron region. While these instruments sound fairly complex, they are, in fact, fairly simple. Although the main intent is to produce data for multispectral processing, the imagery can be used as if it were produced by single band instruments, and the interpretation would proceed as discussed above.

Figure 4 shows a panchromatic mosaic of a California farming area with various fields of rice, safflower and some bare fields and roads. In Figure 5, we show the same area but collected in separate spectral bands with a multispectral scanner whose dispersion is achieved by a prism, with a common spatial aperture for all spectral bands. The signals from the 18 channels are then analyzed using standard statistical discrimination techniques to identify the objects in the scene, in this case, the various fields. The parameters of statistical procedures are obtained by taking training samples of the various object types such as immature rice, mature green rice, bare earth, roads, and safflower.

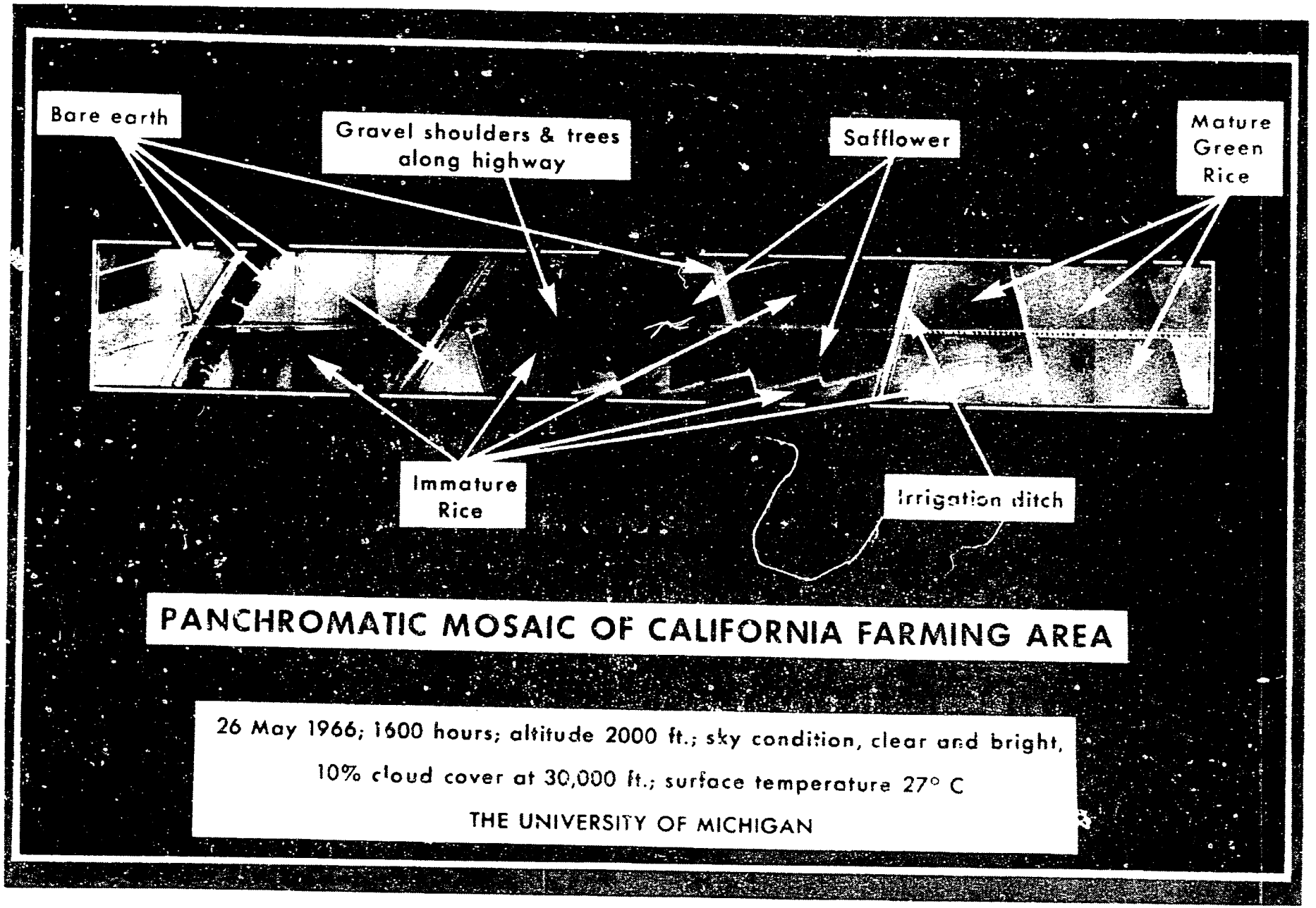

Bare earth
Gravel shoulders & trees along highway
Safflower
Mature Green Rice
Immature Rice
Irrigation ditch
PANCHROMATIC MOSAIC OF CALIFORNIA FARMING AREA
26 May 1966; 1600 hours; altitude 2000 ft.; sky condition, clear and bright,
10% cloud cover at 30,000 ft.; surface temperature 27° C
THE UNIVERSITY OF MICHIGAN

Figure 13

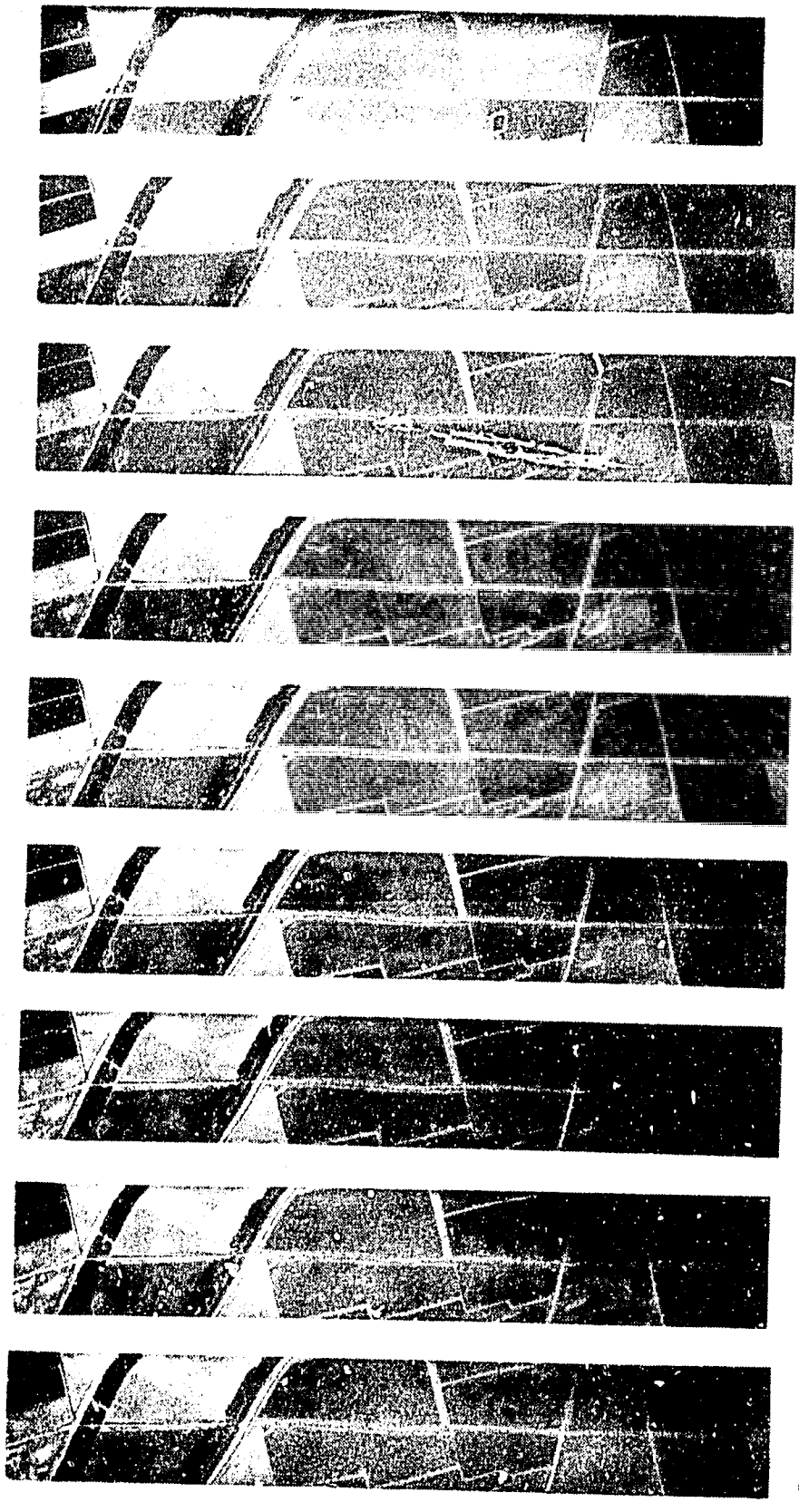


Figure 15

71B

In Figure 6, important areas of crop have been appropriately identified in the form of a digital recognition map. The importance of the multispectral scanner lies in the fact that we can automatically identify terrain areas as we have done in this case. We are able to perform automatic discrimination. The motivation for this is straightforward. Modern sensor instruments are capable of producing information much faster than the human interpreter or a set of human interpreters can handle it. Multispectral methods provide a fairly simple and straightforward way to aid the interpreter in obtaining from the data collected by the sensors the information he seeks. We have, however, not replaced the human interpreter completely. He must specify the training sets for our statistical procedure. But the automatic interpretation device extends possible identification into areas beyond those which the interpreter can identify. It is also able to perform a number of other routine tasks for the interpreter such as the measurement of area, the measurement of parameters of areas, and other numerical properties.

We saw before that one of the purposes of multispectral processing is to extend the ability of the interpreter to identify certain areas both spatially and temporally. There are a number of atmospheric effects which interfere with this extension of the learning set. Objects in the scene have different optical characteristics depending upon the illumination and viewing angles used. Certainly shadowed and sunlit areas look considerably different. As a consequence, we find variations in the spectral signature of objects that are not related to the terrain itself but rather variations in the atmosphere, transmission, illumination and backscatter. These atmospheric variations are, of course, noise to the system. There are, in fact, three rather general methods used to eliminate these variations. The first is to pick some transformation on the data, the result of which is to leave the multispectral data relatively invariant under variations in the atmosphere. The second is to use ancillary instrumentation to measure the atmosphere in terms of such quantities as illumination at the sensor platform. Laser probes can be used to measure backscatter. The third is to select scene references to be used essentially to measure atmospheric effects.

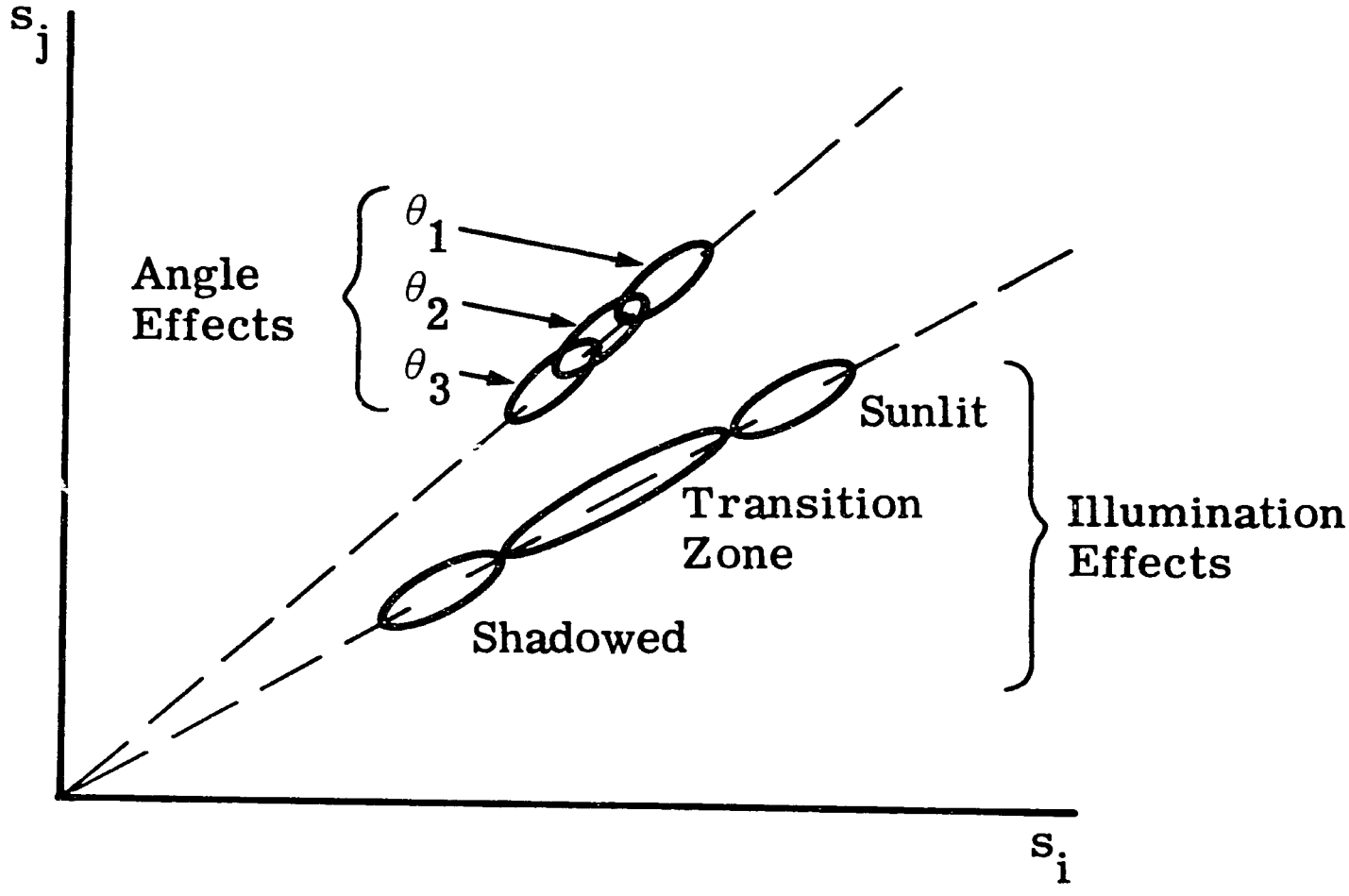
In Figure 7, we illustrate these effects. The two axes represented are signals from channel i and channel j, both spectral channels. Variations in angular effects have been shown to be approximately linear as are those for illumination effects. As a consequence, we might expect that the ratio of adjacent spectral channels (S_i/S_{i+1}) will be invariant with respect to variations of the atmosphere.

AGRICULTURAL AREA, DAVIS, CALIFORNIA
DIGITAL RECOGNITION MAP

Symbol	Crop
•	Bare Soil
(	Safflower
+	Immature Rice
▪	Mature Rice

Figure 2

AGRICULTURAL AREA, DAVIS, CALIFORNIA
CROP ACREAGE



ILLUSTRATED EFFECTS OF MULTIPLICATIVE FACTORS ON SIGNAL SCATTER DIAGRAM

Figure 7

These preprocessing techniques are in very early stages of development. So far, they have enabled us to extend signatures in some cases for as much as a year in time and over a hundred miles. But there are still many cases where such extension is not possible. The perfection of these multispectral recognition techniques will come, I believe. It is not possible to say, at this time, how far we will be able to extend signatures but it is our expectation that they will be extendable over long periods of time, certainly within seasons of years and within many thousands of miles.

The implementation of these automatic recognition techniques is, of course, somewhat more sophisticated than the human interpretation that we discussed in Section II. It requires fairly standard general purpose digital computing equipment that is easily implemented. That such recognition techniques are worthwhile seems obvious. Whether or not they are practical for developing countries, in terms of scale of operation, we are not in a position to say, although it looks very much as if they would be.

CONCLUSIONS

Modern sensor technology has developed a capability to construct images in almost all portions of the electromagnetic spectrum. The necessity for such multispectral imagery seems evident if we consider the problem of contrast alone, in some cases in simply making the target show some contrast to the background. Further the capability to produce multispectral imagery provides for automatic processing. If we consider the large areas surveyed in many of the developing countries, this automatic processing is certainly important in view of what must be a limited supply of trained photographic imagery interpretive personnel in the country. The development of the sophisticated or quasi-sophisticated processing techniques is, in fact, not as forbidding as it looks. The statistical recognition techniques are elementary, and are well known by most undergraduate scientific students today. The rather sophisticated remote sensing that we have been talking about is really nothing more than an extension of the aerial survey techniques which have such a long history in the field of development and resource identification. It is an enhancement in the capability that we have had for a number of years of aerial survey. It is an extension in two directions. First, it enables us to identify more objects, even with single band imagery, than we were capable of with standard aerial panchromatic film. Second, and perhaps in the long run, much more important, it gives us the capability to automate some of the more tedious jobs that we now present to the human interpreter, and and as a consequence, much larger areas of terrain can be covered in a much shorter

period of time with fewer trained personnel. It is our opinion that in developing countries, the use of automation, although it seems prohibitive initially, may in the long run be the best method to approach the inventory resource studies so important in making plans for both administration and project development of developing countries.

DISCUSSION:

JOHN G. LIGHTFOOT:

My comments are mostly questions. I followed you for a while and then when you started talking about the spectral band analysis I was not sure whether it was in the photography or in the laboratory where you do this spectral band analysis.

RICHARD R. LEGAULT:

You collect the data from the air. Our method for collecting this data is an airborne scanner; the data is put upon magnetic tape; we are flying a 12-channel scanner. We bring the 12-channel scanner data to the ground on tape, take the tape into the lab and put it through a computer.

The computer then makes the decision about the type of material in each resolution element.

MARVIN R. HOLTER:

One does not have to bring it back to the lab. It is feasible to put the computer in an aircraft. It is not such a big computer that you could not carry it in the aircraft if you wish.

MR. LIGHTFOOT:

What is the cost of one of the computers?

MR. LEGAULT:

We have a 12-channel analog computer including development cost; the total was $200,000. Now you could make a copy for around $30,000.

ROBERT MILLER:

If you are flying a thermal scanner on board you can put a Polaroid type back on it and get an image without going through the computer processing. That is one way. And there is the other way, the computer processing.

SCOTT M. SPANGLER:

You can also get a direct read-out on a piece of film by using a modulated light source, and get the same image directly out of the scanning instrument.

MR. LIGHTFOOT:

Do you do it on board today?

MR. LEGAULT:

You always carry a direct image output on these instruments, so you can see what you are doing. There are very good technical reasons. You get better dynamic range on the tape than out of the recording mechanisms. You don't know how to set up exposures and gains when you are taking the pictures and can lose information that way.

MR. LIGHTFOOT:

Are these wave lengths you used susceptible to cloud cover?

MR. LEGAULT:

Yes, except the radar; radar imagery is not.

MR. LIGHTFOOT:

Now that you developed this system for $200,000, who owns it?

MR. LEGAULT:

The U. S. Air Force.

MR. LIGHTFOOT:

Can it be licensed by these aeroservice firms? Is it still restricted?

MR. LEGAULT:

No, the restrictions were taken off years ago including radar. The multispectral techniques have been available in the public literature for quite a while.

MR. LIGHTFOOT:

We find that in the geophysical field the aircraft has to be altered and airframe stiffened up and a lot of things like that in order to use it in these overseas areas.

MR. LEGAULT:

Right. A number of us quoted costs the other day for the aircraft modifications. It depends on what you do. If you cut a single well in the bottom of the aircraft and don't disturb the structure, it costs as little as $5,000. It is just a hole.

MR. LIGHTFOOT:

How long would it be in your opinion before this becomes the tool of the trade to be used by the aeroservice people?

MR. LEGAULT:

I don't know. We are going to have to go back in history. How long did it take people to discover infrared film? Fifteen years before they discovered there were things they could do with IR film that they cannot do any other way. I think it depends upon two things: It has been said--if somebody is willing to pay the money they will do it. That is number one.

Whether they will invest the money themselves and get the technology up to snuff and learn how to do the interpretation we see some evidence of it. There are all kinds of commercial concerns getting into this business today because it looks like it will be a market.

MICHAEL GUCOVSKY:

I would like to make basically two points. One, that the macro analysis is all right but there are questions of micro which can't be overlooked where the picture might be different.

That is, speaking from the point of view of developing countries, the pressure is always great to move at the pace faster than whatever the given existing pace is. In practice, many times the actual existence of a given resource in a region, even though on the average we look at the country statistics, this contribution will be on the order of magnitude that Dr. Herfindahl was telling us, but it is the quick development of that given resource that would actually provide the catalyst for other economic activities in the countries.

This happens all the time. If you look at the investments that the World Bank makes--I was just looking the other day at the railroad going across North Africa. The

only reason that the bank can justify an investment for that railroad now is because there happens to be a resource there that can be exploited relatively quickly. This in fact would set off a process of development with additional far-reaching effects.

We should not only be influenced by whatever the average statistics show us on the role of natural resources but we should actually look at what the role of natural resources could be in any given development situation in a micro sense.

I think we may reach conclusions that in specific cases would be different for a country as a whole or for groups of countries than the conclusions pointed out here on the basis of the average contributions of the natural resources.

My second point is related to the question about time. I share the skeptical note introduced about using sensors for gathering information. I agree about the need to make specific analysis in each case and see when it is justified and when it isn't, but I think one of the elements which I think he omitted is the question of time.

I think to the extent that using sensors, whether satellite-carried or aircraft-carried, can in fact reduce the time of collecting information for which an established demand is determined, then this is an important consideration because developing countries are in a great hurry.

The pressure continues to reduce the time it takes to gather information from three years to one year, from five years to two years, and if there are any time advantages I think they should be looked at carefully because they are a benefit from the economic point of view.

New lands were dismissed, but the fact is that developing countries (such as recent programs in the Amazon, Peru, and Africa) are set on opening up new areas. They are set on putting through roads to new areas. So development is going to occur spontaneously, uncontrolled.

The question is if we can, through the use of sensors, accelerate the collection of information that could be put to use for controlling some developments that would take place anyway in new lands.

DATA ACQUISITION SYSTEMS

Marvin R. Holter

I cast what I want to say in a series of questions which I attempt to answer. First, what is data acquisition? Second, can developing nations carry on data acquisitions at the present time? Thirs, do the less developed countries want or need environmental data? And fourth, if additional data were made available to them, could they use it or would they use it?

Information about the environment is a very complex thing. It gets used all the way from the individual farm producer, up to national and international organizations for planning, taxing, control activities, etc.

With regard to data acquisition, data is not information. There is many times a very large and costly step between data and information so both of those terms will be used here and hopefully the distinction will be retained. Remote sensing here means principally sensors of electromagnetic radiation. There are other kinds of sensors which for one reason or another aren't very suitable from spacecraft to spacecraft.

In terms of the environment, it is not very profitable to focus exclusively on data from remote sensors. In order to get any information about the environment, some data from remote sensors and some data from contact sensors is needed. It is impossible to get soil bearing strength, for instance, remotely. Some other kinds of information about the environment, particularly with regard to the human inhabitants and the intentions of the human inhabitants must be obtained by censusing operations by communications with people.

Acquiring environmental data which is useful at all is not a matter just involving the ultraviolet visible infrared and radar sensors and elevated platforms. That information by itself is not useful without other sorts of information including stored _a priori_ information such as common farming practices: e.g. the knowledge that you are not likely to find rice in Northern Canada. _A priori_ information is one of the things that will make the data handling problem manageable.

The second question is: can the less well developed nations carry on data acquisition at the present time? It seems that there is little evidence that significant numbers of countries in the world remain without having various people who can handle data without a great deal of external help.

In almost every country there are some people operating their own personal cameras. There are Singer sewing machines all over the world. Most countries have at least one aircraft which they keep flying. There is much automotive and farm machinery. There are telephones, radio stations, television stations, and tape recorders. When people really want a level of technology, which approaches the level involved in simpler remote sensing, they will do it. The many radio amateurs in so-called underdeveloped countries demonstrate that a significant number of the local citizens are capable of constructing and operating and maintaining equipment of some complexity.

Question three: Do the less developed countries want or need environmental data?

As has been said, data has no intrinsic value at all. It acquires value only to the degree that the data can be converted into actions on the environment, which involves quite a number of steps. Thus, to be worth the effort and the resources to generate it, data must have some fairly direct and recognizable relationship to some other activity and in that other activity reside the economic. political, human or military or other values. So to talk about the value of data without discussing the actions that will result from employing it just makes no sense at all.

It is primarily the government end of the spectrum of users that is important here. At least, one can argue that the individual farm producer probably knows the environment of his farm fairly well. The biggest needs for data over large segments or entire countries resides with the larger corporations if they exist, the larger social units, and particularly the national governments.

It is an observed fact that countries don't invest all of the resources they could in gathering data and therefore they implicitly have made some judgment that it isn't worth doing it.

There is probably no government of any nation of whatever stage of development that does not feel a number of needs for some additional useful information relative to the environment. Apparently several factors contribute to this contradiction.

First, the costs and the effort involved in extracting useful information from aerial photography and other well developed sources of data is in fact quite high. The conversion of data to information is high.

Second, the useful information content of the more modern, less well developed, sensing modes such as radar and infrared is not well understood. We don't know what information resides, in most cases, in the infrared and the radar data. That is something we are now in the process of learning.

Third, models of the environmental dynamics of sufficient validity and exactness don't exist yet. That is very important because any data generating system only tells what the situation is at the instant of observation. The real value to be extracted from that sort of data is prediction of the future course of events. In order to predict we need methodologies that fit the processes that go on.

In this regard, the present remote sensing programs as they are carried out now can't be successes unless other programs such as the International Biological Program (IBP), the International Hydrological Decade and similar things are successful because it is the responsibility of those other programs to generate those very necessary models.

On the other hand, it will probably be difficult for the IBP and similar programs to achieve their objectives without trying to use some remote sensing.

The Pawnee Grassland in Colorado is abouta hundred miles by a hundred miles. It's unrealistic to think that we can get a very detailed census of that area for purposes of the IBP with only observers on the ground. There may be a reciprocal relationship between remote sensing, earth observation programs and all these other programs. They appear to be just sub-elements in a single larger environmental program.

Individual agencies needing environmental information are very numerous, very diverse, not well coordinated, even in well developed countries. And so, even in the U. S., much less any less developed countries, the aggregate national needs for such environmental information have not been brought together at one place at one time. This has a very direct relationship on the budgetary resources that are devoted to it. We might have a different situation in the U. S. if, somehow, in one place at one time we could bring together and summarize in one statement what the total needs for this

Kind of information are. At the present time, the arguments for budgetary support are done on a one-by-one basis and no one ever sees what the total value to the nation of this kind of capability is or could be.

Fifth, the relationships between specific information needs relative to the type of economy and its stage of development doesn't seem to be very well formulated and clearly understood. Certainly the kinds of information, the amounts of information that one needs must have or must be strongly influenced by the level of the economy and the type of the economy. And many of the institutions in the U. S. may not be very suitable in their form for developing nations. For instance, unless I am misinformed, a very large fraction of the activities of the Statistical Reporting Service of the U. S. Department of Agriculture are directed towards restricting production, supporting prices in the face of excess productive capacity. Now any institution like that can't be very useful in a less well developed country which has a net deficit of food. So those are the five factors that bear on the reasons why other nations, even this nation, don't devote more of their resources to get environmental information.

Next, if additional data were made available to them could the less well developed countries use it?

The cost of extracting information from the data is high. The nature of the information residing in the more exotic data is obscure at the moment. These aggregate needs never seem to be pulled together in one place at one time. Even if those problems were solved, it's doubtful that the developing countries could use significant additional data without an additional change that has been referred to many times here.

In conclusion, at the moment, great infusions of additional data, even at no cost to these countries, are unlikely, without some additional elements, to produce much of use to them. The above line of reasoning leads to the conclusion that data acquisition is not the pacing item in improving environmental management.

The answer to the major topic here is that a great deal of additional research and development on the part of the U. S. or anybody else in data acquisition is needed. The needs are principally in research in the extraction of useful information from environmental data. A good deal of research needs to be done there. Second, adequate models of environmental dynamics do not exist. And third, some understanding

and ability to improve all these social political cultural matters is needed. The relationship of human beings to the environment is a very complex affair. In order to have any significant impact on that relationship the center of gravity of what is now called remote sensing research and development must be shifted very markedly in the direction of learning about how to advance from the data into meaningful and productive actions with regard to the environment. The data acquisition is a necessary -- but a long way from a sufficient -- condition for doing something about the environment.

DATA ANALYSIS

William A. Fischer

The EROS program of the Department of the Interior, though justified on domestic uses, was from the onset designed as an international system. The design of the system was based on the desire for certain types of information. The system should be used for the purposes for which it was designed rather than forcing a whole world solution from it.

It is desired to define a system that would obtain data having the fewest possible variables, and, thus would be the most easily usable by the broadest spectrum of technicians and scientists. To achieve this the data must be first orthographic (map-like) upon acquisition so that it would require little processing to meet the mapping needs of the developing nations.

Secondly, the data has to be as uniform as possible, and not include a broad spectrum of reflective angles. To accomplish this a narrow angle system that would have to be applied from space is needed.

Thirdly, the types of information that were most needed and could be effectively used were determined. The list includes: land form, including land form in the near-shore areas, beneath the water; the distribution of cultural features; the distribution of surface water; and the distribution of vigorous vegetation, hopefully divisible into natural and agricultural.

And lastly, knowledge of water body dynamics was required. It was intended to derive this by observing the distribution of silt and the movement of silt in water.

The capability exists for effective use of this kind of information and the technology exists to extract this information from the data in a routine manner. Thus, the problems of the use of data and information are not insurmountable.

The line in Figure (1) going across the top image is a power line. It is straight on the ground. In this aerial view that line is distorted by the perspective character of the image. On the bottom image the same power line is seen when you look straight down on it as you do using a narrow angle system from space.

THE EFFECTS OF PERSPECTIVE ANGLE ON RELIEF DISPLACEMENT

Off-Axis Perspective View

Near-Axis Perspective View

834

Prepared by USGS in cooperation with NASA

The space image to be derived from earth orbit will be maplike upon collection. One needs, therefore, to develop a capability to cartographically annotate the images. Thereby one will have good quality planimetric maps of those areas that are imaged.

It is much easier to interpret the orthographic image than the perspective image. It is easier to tell a power line if it has the same shape on the image that it has on the ground.

To verify the orthographic character of space photographs a 500,000-scale map and a 250,000-scale map that combine the conventional line map with images taken from the Apollo and Gemini spacecraft have been prepared. The line maps and the images match perfectly.

These "photo image" maps demonstrate that the sum of information contained in the image and in the line map is greater and more usable than the information presented only in the conventional line map.

Another obvious use of space data is to update existing maps. In one case a section of highway was built between the time the map was made and the image was acquired, and the space photo was used to update the extent of the highway. In another case, it was found that a road on the map was misaligned and the alignment was corrected on the line map from Apollo photography.

Agencies concerned with map revision problems should be alerted to this potential use to permit them to make timely and effective use of the data.

Change in the angle of the sun even if the terrain is homogeneous, the terrain looks totally different because of a change in illumination angle. For this reason the spacecraft should be put in sun synchronous orbit to minimize this effect. Furthermore, one sees a much larger area in an instant of time from space. Space photographs will help geologists and geographers classify land forms and recognize anomalies that then become targets for further investigation.

Color infrared photographs are analogous to the system that will be flown in ERTS-A. In such photographs water is black, vegetation is red, and sediment is blue.

To achieve an easy capability to separate information one designs the collection system with this in mind. If the information is correctly structured upon collection, the problem of extracting and using the information is vastly eased.

Using the multiband images obtained in the Apollo 9 SO-65 experiment, ERTS-A bandwidths, some of the types of information considered to be most needed were extracted using automatic mapping techniques. These include: distribution of vegetation, as done in the vicinity of Phoenix, Arizona; distribution of surface water, as done in Alabama; distribution of sediment in water, as done at the mouth of the Colorado River; distribution of cultural features, as done in the Ft. Worth area; and change through time, as done in Dallas, Texas.

The potential resources exploitation problem was touched upon briefly. This far, the existence of space imagery has reduced rather than increased the likelihood of exploitation. As an example of this, a circular structural feature that had not been previously recognized was noted on a photograph taken from Apollo 9. This feature is close to a large copper mining area in which the copper is being produced from large circular deposits. Following identification of the feature, aeromagnetic data were obtained and comparable anomalies exist over known deposits and the new found circular feature. The Indian tribe that owns the land was alerted to these findings and although we are not at all certain at this time that the feature represents a copper deposit the tribe is in a far better position to negotiate a fair price for the property now than before the space photograph was taken.

Structural geologic interpretations do require some degree of geologic sophistication but the potential returns are large. Recently the Geological Survey of the State of Alabama working cooperatively with the U. S. Geological Survey mapped a large number of previously unknown linear structural features in Alabama. Analysis of these structures and comparison with water well production records show that wells drilled on or near these structures produce at substantially higher rates than wells drilled elsewhere in the region.

Land use information requires more sophisticated interpretation. It can be interpreted from space imagery; maybe not in all the detail that one wants but nevertheless in great detail. There are agencies within developing nations that need land use information and can use it.

There is a data collection system aboard the spacecraft. It may not be able to collect data in all parts of the world because of tape recorder unavailability but it will probably be available on ERTS-B. This will collect data from other sensors on the ground. A sensor in Mt. Rainier watches for change that might indicate forthcoming eruption. Since people are used to using point source information it can serve a variety of purposes.

Lastly, space photographs can very effectively display the difference that results from a differing policy. In one case it was the straight line boundary between Texas and New Mexico, made visible by differing land use practices. Texas is experimenting with withdrawal of ground water for irrigation purposes; New Mexico is forbidding it. This suggests two things: One, that one nation may appear undeveloped with respect to another. There are going to be diplomatic problems, and second, that images of this kind can help AID to evaluate a development problem. AID actually is a using agency, especially in the policy sense.

Recommendations are suggested as follows: Everyone agrees training is needed. Begin it now. Decide now how it is going to be supported and who is going to have that responsibility. This training should be extended into areas that are commonly forgotten. One thinks only of remote sensing training. For example, at Sioux Falls, South Dakota, a major facility for training, for duplication of data, and for extraction of information is being developed. The Bureau of Indian Affairs is reorienting the curriculum of the Indian technical schools in the reservation nearby to emphasize data processing and traffic handling techniques. So there is a training effort underway to get the skilled labor that will be required.

The community should be alerted to the activity that is going on in Arizona. Here is a site in which we are trying to gather together the total spectrum of users. It is important to inform AID of that development and to invite their participation.

The training program should be focussed on the first satellite and it should not be made too comprehensive or too complex.

Country representatives should have a place to go in the U. S., possibly Sioux Falls, where they can view the data when it is received and get guidance in its use at that time. Many of the benefits that come from these data are short-term phenomena.

U. S. scientists that are now in foreign countries for training purposes should be recalled or at the very least a longer period of home leave should be provided and training should be included during that time.

A catalog of equipment that is simple and available should be developed to assist the countries in their selection of information extraction or interpretation equipment.

A remote sensing program is not going to go away. It is here. Positive steps need to be taken to assure effective use and effective benefit to the U. S. from such a program.

DATA STORAGE AND DISSEMINATION

David Landgrebe

This paper describes the research and development which will lead to the capabilities for future remote sensing systems.

The major components in the hardware portion of an Earth Resources Observation System may be diagrammed. There must, of course, be a sensor system which views the Earth, but it must be kept in mind that the surfaces of the earth itself are part of the system as is the intervening atmosphere.

There will necessarily be some additional processing activities that must take place on board the sensor platform. These may include data calibration, the merging of ephemeral information analog to digital conversion. Data return may be provided by a telemetry system in the case of an unmanned sensor platform.

On the ground, there is always a need for some preliminary preprocessing followed by the application of one or more data-reduction algorithms. Finally, a block is included to indicate the consumption by the user of the information thus generated.

There are a few additional parts of this diagram which are of interest. We emphasize that the two terms, data as compared to information, are not synonymous. However, the line of distinction between them is not always clearly defined. For example, a photograph, i.e. an image, may make information immediately available to a human interpreter; however, the same image can only be data in a machine-oriented information system. This lack of conciseness is part of the problem that now exists in seeing what the uses for these kinds of systems will be. It is a matter of succinctly focusing on specific problems.

The interface between data reduction and information consumption is particularly difficult. At this point in the system there is an interface between people of different background and different disciplines. This is a factor in why so much collected data is not being used. Somehow they must be brought together and this stagnation circle broken down. Again, it would seem that the answer is to focus on specific problems.

There are two basic kinds of systems, those which are pictorially oriented and those which are numerically oriented. This dichotomy can often be seen in the manner in which sensors are chosen or designed. For example, a photographic camera is a sensor well suited for pictorially oriented systems. The images produced are rich in spatial resolution and detail. These are characteristics important to a pictorially oriented system.

The dichotomy will also often show up in the manner in which data is transmitted or preprocessed. In ERTS, for example, there are two sensor systems, a TV system and a scanner. In the telemetry of these two, the TV system uses analog telemetry signals, an approach which is better suited for providing high quality imagery back on the earth. For the multispectral scanner system on the other hand, a digital telemetry system was chosen to preserve the very large dynamic range in the data which such a sensor system can provide. This is important for a numerically oriented system.

The most obvious indication of the dichotomy is in the type of analysis to be used on the data. The typical (though not the only) way in which data in a pictorially oriented system is analyzed is through photointerpretation. In the case of numerically oriented systems, it is customarily done by machine or manually aided machine operations.

Though a useful viewpoint, the dichotomy is not complete in that one can certainly have useful numerical information coming from a sensor system designed for pictorial purposes, and vice versa. Much more sophisticated photointerpretive and photogrammetric techniques can be brought to bear, but a considerable amount of subjective information can be produced in addition to objective measures.

Numerically oriented systems tend to have different capabilities. A numerically oriented system can perhaps provide ready access to a different type of information than one can obtain readily from a pictorially oriented system.

Soil mapping has been done for some time on the ground and more recently has been aided by aerial photography. The numerically oriented system provides a speeding of the overall generation of the soil map by merely objectively marking a specific boundary between soil types when the soil type may only be gradually changing from one to the other.

In the case of the pictorially oriented system, there is a well developed technology in the U.S. today. This is not to say that further development is not in order and taking place, but these types of systems have been in both military and civilian use for some time on an operational basis.

This same degree of development may or may not exist in any given developing nation. Furthermore, it is important to note that a pictorially oriented system is generally easily acceptable to the layman because he can more readily understand that information in image form.

One of the advantages of this type of system is that it is well suited for producing subjective information. Also, relatively simple systems are possible and indeed very effective. On the other hand, large-scale surveys tend to be relatively difficult to carry out. This is because a large quantity of data (imagery) is needed and a large number of people capable of analyzing the imagery is required.

In comparison the technology for numerically oriented systems is much newer and not yet well developed. Further, since the techniques rely upon abstract principles, this approach tends to be less readily acceptable to laymen.

Numerically oriented systems are well suited for producing objective information from data and because of the possibility of machine processing or machine aided processing large-scale surveys will become feasible by these means. The systems necessary to carry them out, however, tend to be relatively complex.

The essential characteristics of remote sensing research itself have a direct bearing on the international scene.

First, remote sensing research is or should be both multi- and inter-disciplinary. The distinction between these two terms is to be emphasized. Progress toward useful systems never comes as fast if one has the users or applications scientists on one hand studying remote sensing and the remote technologists continuing their studies on the other without a close interrelationship. This is the same interface referred to earlier regarding the consumption of information. Thus, the term multi-disciplinary means that all disciplines must be represented and term inter-disciplinary means that they must function together.

In the applications area, research is more efficiently done on a local basis. This is true, at least in part, because it is easier to focus on a specific problem when one is near it. Thus, it appears desirable to conduct applications research near its point of application and to conduct research toward advancing technology at technology centers. However, it is necessary for this close working relationship to develop at a single location.

In summary, several points of conclusion have been reached. First, there must exist well understood long-term research objectives lest the research done and the knowledge gained be inefficiently and uneconomically achieved.

Second, research and education are an inseparable pair. The intent, indeed the necessity, here is to use the new technology while it evolves. The educational activities must be closely fastened to the research in order that this transfer can take place rapidly.

It is reasonable that the basic studies and development of technology can be best done in this country. Specific studies should be pursued in the developing nations for their applications as well as in this country for U.S. applications. This is desirable parly for reasons of education and partly for reasons of the need to do the research on a local basis.

In the development of technology particularly, there is still some distance to go in understanding the dichotomy of system types. There is still some tendency to judge one type of system within a context more appropriately suited for the other. There is also some tendency to consider the two types as being in competition.

It is most important that the barrier which exists between the users and the technology developers (remote sensing engineers) be broken. This can best be done by focusing on specific problems.

In this respect it will be necessary to judge how useful the capability to remotely sense data will ultimately become. If it appears that it will be a broadly useful capability with wide applicability, then it is advantageous not to attempt to solve all things at once.

Finally, the manner in which the remote sensing community of this country communicates with foreign countries should be regarded. Since the complete technology of remote sensing does not yet exist, let alone the knowledge of how to apply it, it is a mistake to attempt to show foreign nations how to achieve these advantages. Rather, cooperative programs seem much more appropriate.

Not only will this lead to a macimum rate of development in the foreign nations, but also to a direct benefit to the United States in the form of a growth and development of our own capability, thereby accruing a double return for the dollar spent.

REFERENCES

1. Fu, K. S., Landgrebe, D. A. and Phillips, T. L., "Information Processing of Remotely Sensed Agricultural Data," Proceedings of the IEEE, Vol. 57, No. 4, April 1969, pp 639-653.

2. MacDonald, R. B., "Automatic Data Analysis Techniques for Earth Resources Information Systems." To be presented at the 1971 IEEE International Convention, Session 7G, New York, March 25, 1971.

DISCUSSION

WOODS THOMAS:

The kinds of things we have been talking about give me the impression that, in a very fundamental way, we are dealing with a situation of a "tool" in search of a "job." In particular, we appear to be searching for ways in which remote sensing might be useful to the developing nations.

This is a perfectly legitimate thing to do. It might be useful to look at this issue in two ways.

First, given the state of the remote sensing art and science, this conference and others like it can be very helpful in identifying uses having high payoff potential in the solution of problems faced by the developing nations.

Second, it seems quite clear that remote sensing is in its infancy and that there is great need for continued research and development of the technique itself. A very careful appraisal of the information and data needs of the developing nations might be a highly significant factor in determining the kinds of research and development routes to follow in expanding the capabilities of the remote sensing technology. We need some vehicle whereby the people working on the technology might be encouraged to move in the direction of developing capabilities which will, in fact, have high payoff potential to the developing nations.

My second major impression deals with the nature of the demand for remote sensing services.

We have talked about two or three broad categories of demand. One is the demand for information useful in long-range economic planning. Here, we need to ask some hard questions. We need to appraise the utility of the "grand plan" as a tool of economic development. We need to appraise the types and kinds of information which will, in fact, contribute to the utility of this process. There seems to be little point in "putting a razor edge on a soapstone," particularly when the costs of doing so might be extremely high.

A second demand category consists of locating and characterizing natural resources as potential investment

opportunities. This is legitimate and may have important payoffs to the developing countries. The question, here, seems to turn on the capability of remote sensing to provide the types of data needed.

There exists a third demand category which, I feel, has not surfaced adequately during our discussions. This is the demand for current data and information which will be useful in short-run decision-making by both the private sector and the public sector. It has been my observation that one of the real limitations to improved resource use in many developing nations is the dearth of reliable, current information which will permit the normal economic forces at play to do the resource allocation, utilization and development job that they must if economic progress is to be accelerated. If remote sensing has or can develop the capability of providing a current, accurate flow of such information to the economy, this might very well be one of the highest payoff uses in the developing nations. A careful study of this demand category needs to be made.

Let me make one final point. It deals with the educational function touched on by several of the speakers. In the context of the developing nations and, perhaps, that of the developed nations, there appears to be a human capability gap of the most serious order. Effective application of remote sensing to the solution of real problems requires two kinds of talents. One is in-depth technical knowledge of the problem, per se. The other is in-depth knowledge of the remote sensing technology. Generally, these talents are embodied in different individuals with little or no overlap. Closing the talent gap will necessitate finding some means of creating sufficient knowledge overlap to permit effective joint research and development activities. What is needed are educational programs which bring together, in interdisciplinary fashion, the sets of knowledge on the application and the technique sides of the coin. In this manner, individuals concerned primarily with the hardware and software problems of remote sensing will be informed and knowledgeable about the application issue; conversely, people concerned primarily about the application of remote sensing to specific problems will be informed about the technique side as well. It would seem completely feasible and highly desirable to develop graduate education programs designed specifically to achieve this end. One can imagine, for example, a graduate program in which computer science types might take a "minor" in one of the fields where remote sensing has great potential; e.g., forestry, soils, etc. Conversely, graduate students majoring in forest mensuration, soil science, crop science or other fields might take a minor in remote sensing. In both cases, theses and dissertations might involve research on developing methodology for expanding the applicability of remote sensing to the solution of real problems.

In terms of the training function that perhaps in a general way what we need to do is to develop educational programs which bring together the interdisciplinary kind of notions or the multidisciplinary kind of notions so the people concerned with the hardware or software problems really are informed and knowledgeable about the applications side and the people that are worried about the applications side of knowledge of the other side as well.

I think it's possible to develop a graduate program which would do this.

GLENN E. SCHWEITZER:

I have a couple of specific questions to try to sharpen the focus.

The first has to do with what I would call sophisticated research and development. Let's start first with sensor sitings. There are certain kinds of features in the Tropics, in the developing countries, which have not particularly been the targets of sensor siting research.

One is the coffee blight in Brazil. Before anyone could talk about using IR film they had to see if it was useful.

People are trying to use photographs of Ethiopia to count the number of huts to find out how many people live there. We don't know within 10 percent the national population. But I suspect that our sensor siting research has not been particularly concerned with those kinds of problems and the interpretation of photographs have been particularly concerned with what is the best way to count huts. It's tedious to count them manually. So my question is, in these areas of sophisticated research and development, AID has three choices.

We can forget about it and assume the domestic agencies will take care of it. A second approach is we can try to put body English on what NASA and the other agencies are doing by saying look here is a real problem that we are concerned with in Ethiopia. How do you count huts quickly? We can try to keep stressing to NASA and other agencies when you talk about your siting -- about your sensor siting programs, interpretative programs, remember some of our interests.

We can give a research contract and say go out and tell us how you do demography in a remote area.

I wondered what the reaction of the group was to -- am I right in assuming some of our research has neglected some of the problems unique to the developing countries?

We talked about the prophylactic approach to disaster. If you look for different kinds of features, you know the landslide is coming, that sort of thing, that has to be -- I am not sure there is a lot of research directed to that in the states but in the developing countries that is an important question.

Is there an area of sophisticated kind of research and development in remote sensing which is not really receiving the attention from the domestic agencies that it should and is there something that AID should do to redress that omission if there is an omission?

KIRK P. RODGERS:

I think that working in the developing countries we sense that in this whole area the technology is much more advanced in terms of applications in the sense of understanding the physical environment and not as far advanced in terms of the social and economic environment.

In other words, the application of the techniques to census, to all kinds of statistic collection, the data for which is absolutely indispensable to all forms of planning and project implementation. We have to sense that the physical scientists are way out ahead of the social scientists in terms of the applications of these technologies.

HUMBERTO RICCIARDI:

I would like to refer to the remark by Dr. Thomas that this is a tool in search of a job. The problem we have here is due to the fact that we still do not have complete information about the possibilities afforded by this new technique. I know you will immediately say that we are still in the experimental stage, but with the information available to us at the present it should be possible to state what we can expect.

But this is what we do not have, and this is why it is impossible to establish relevant communication between the social scientists and the geoscience researchers. We cannot expect to await the launching of the first satellite before deciding what we can do in the future.

In my opinion, it is essential to have now a more detailed explanation of what we can expect from the use of remote sensing in the future, and when I refer to remote sensing I am not thinking only of the first ERTS satellite.

This is the kind of information that is not yet available and which is the most valuable kind of information we can give to the users. We must not forget that the users are the goal of our interest in this subject.

MICHAEL GUCOVSKY:

I think along the same line I think AID could also perform a useful function in making a clear distinction between what can be done applying existing needs with aircraft carried instrumentation and what is in store for the future in terms of drumming up support for various projects in the future. To me this is one of the problems.

B. K. WESLEY COPELAND:

I would like to address the question of what AID can do. AID should attempt to get realistic information to the proper individuals in developing countries regarding the capabilities and cost of using remote sensing techniques. In most of the areas in which the Academy has been involved in developing countries, we have found a large gap between the social scientist and the physical scientist. Everyone has his own niche and tends to adhere to it; consequently there is communication problem, among other things, which prevents a real world assessment of some of the new techniques.

One of the things AID could do in this area is to put together a smaller group, such as this one, which would be composed of specialists in agriculture, natural resources and organization. This group would go to developing countries to make presentations and answer questions regarding this newer technology of remote sensing. I feel this kind of exercise would be most useful in bringing the awareness required in developing countries to fully exploit this area in realistic terms of cost, personnel training, timing and expected benefits.

INSTITUTIONAL AND TRAINING REQUIREMENTS FOR EXPLOITING REMOTE SENSING IN DEVELOPING COUNTRIES

Robert A. Summers

INTRODUCTION

Remote sensing activity in developing countries will emphasize aircraft and ground truth data collection which will be integrated with such space-derived data as may be available assuming the first generation of research space systems function satisfactorily. There is a need to develop an indigenous analytical capability so that practical problems of the country involved can be analysed and, more particularly, that information may be extracted from the spacecraft, aircraft, and ground data to yield decisions and actions.

Training and technical assistance in ERS systems and techniques are the first order of business in the developing countries and institutional details will evolve from existing structures in each country according to its own special social, political and economic characteristics. The initial programs which would exploit the early trainees should be accommodated -- in the early phase -- within the existing institutional structures.

It is useful to note that there are basically four innovative features to the earth resources survey program. First, and most obvious, is the availability of the space platform; second, the development of improved sensors which can providee precise quantitative measurements through a broad range of the electromagnetic spectrum; third, the emerging capability for automated information extraction from data, e.g., terrain feature identification and crop stress detection; and fourth, the development and utilization resource and environmental models which relate remote sensing inputs to decision-oriented information. The third and fourth points are of particular significance, when it is recognized that it is indeed information for decision making that is sought, and not just data. Data by itself may well be considered useless or, in fact, less than useless if the cost of storage is involved.

SOME RELEVANT STUDIES

A number of studies has already been conducted under the title of "Cost-Benefit Studies," although the dollar

value results may not be the most important aspect of these studies.

In Figure 1 there is an extremely simplified modeling of an ERS system as utilized in some of these studies. There are, the observation system including spacecraft, aircraft and ground components; the data is utilized as inputs to earth-science-based models providing interpretations or predictions useful for the management decision process; and the loop is then closed through management actions to the resource problem, and in turn to the earth conditions.

Some important conclusions were deduced from this type of approach.* First, there was defined a critical need for the development of these earth-science-based predictive models which can make effective use of remote sensing data and which also are compatible with the management decision process. Second, the forthcoming ERTS and Skylab flight systems, together with aircraft and ground data coverage, will provide outstanding opportunities to develop and validate some of these essential predictive models. Third, in many cases of dynamic earth phenomena, for example, water management and crop production, there is a first order interaction of meteorological phenomena and prediction.

Some economic studies provided some of the first total system concepts, and perhaps more importantly, required a detailed look at the users, the uses, and the methods of use of the data. Figure 2 tabulates a number of studies that have been sponsored by NASA, user agencies, and other organizations. The studies generally fall into two categories; first, expert opinion, based on a simplified overview such as the GE, Westinghouse, Cornell, and IBM studies and perhaps, in its economic portion, even the National Academy of Science Summer Study; and second, those based upon detailed system studies utilizing earth science models and management decision models. Examples of these are the work done by Planning Research Corporation and Mathematica.

Figure 3 indicates some of the advantages and disadvantages of the two approaches to economic studies. While, from an economic point of view, the expert judgments may have some value, they do not provide necessary insight into the operational

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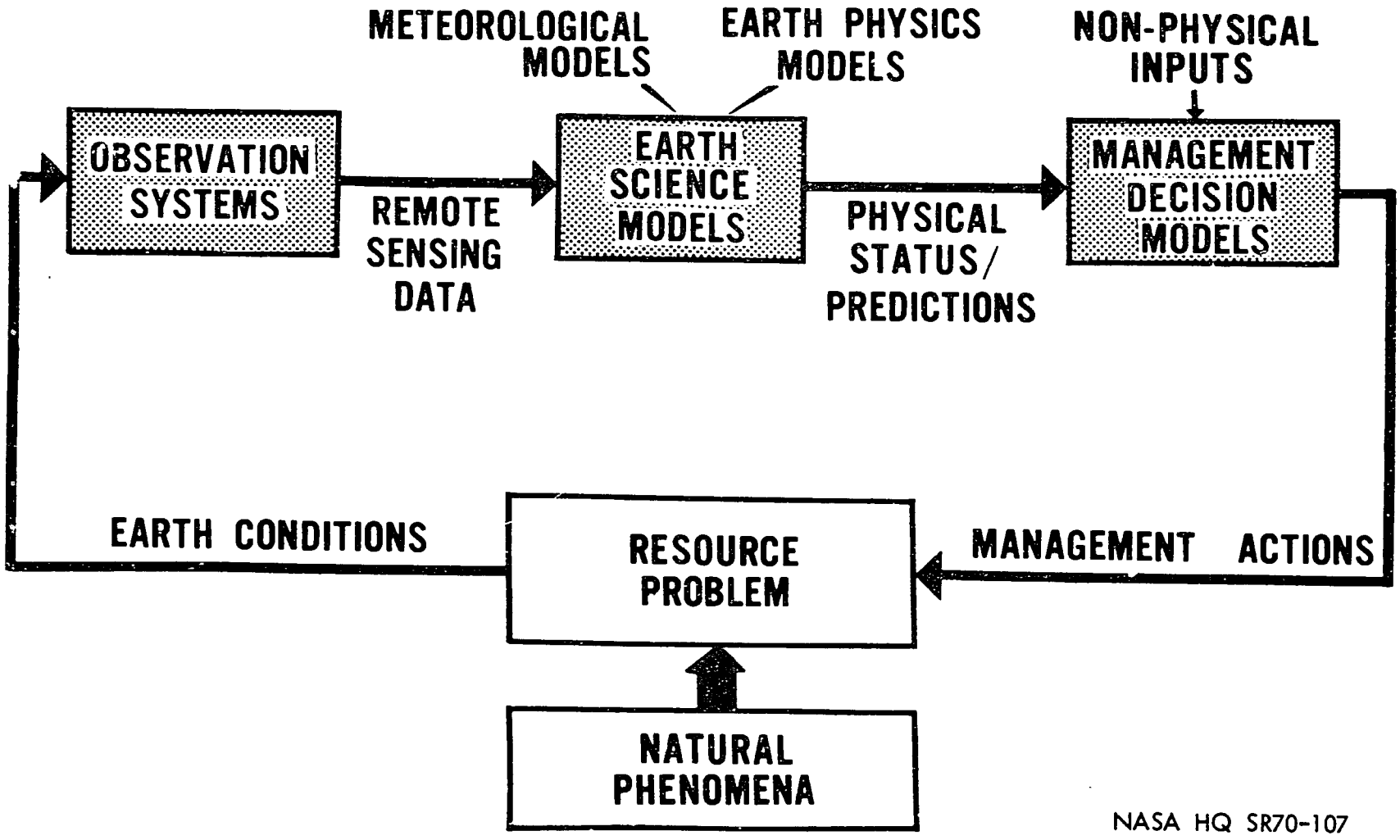
* "Systems Analysis Techniques in Earth Resources Satellite Systems Planning," R. A. Summers, Proceedings of the Sixth International Symposium on Remote Sensing of the Environment, October 1969, University of Michigan, Ann Arbor, Michigan.

MODELING OF AN OPERATIONAL ERS SYSTEM



NASA HQ SR70-107
11-4-69

FIGURE 1

98A

ECONOMIC STUDIES FOR EARTH RESOURCES SURVEY

CONTRACTOR	SCOPE	SPONSOR	COMPLETION DATE
PLANNING RESEARCH CORPORATION	Detailed system studies in regional water resource management, wheat production, and wheat rust control	NASA	1969
MATHEMATICA	Cost-benefit study of satellite system for estuarine and coastal management	RCA	1969
MATHEMATICA	Cost-benefit study of satellite system for grazing land management	RCA	1968
PLANNING RESEARCH CORPORATION	Case studies in power dam management, rice production, wheat rust control, malaria control, and tuna fishing	NASA	1968
UNITED AIRCRAFT CORPORATION	Market survey of potential private sector users	NASA	1968
NATIONAL ACADEMY SUMMER STUDY	Review rationale for and benefits of space applications	NASA	1968
GENERAL ELECTRIC COMPANY	U. S. and world benefits to shipping, fishing, and resource extraction	National Council on Marine Resources & Engineering Development	1968

FIGURE 2A

ECONOMIC STUDIES FOR EARTH RESOURCES SURVEY (Cont'd)

WESTINGHOUSE CORPORATION	Benefits to existing Department of Interior operations	U. S. Department of Interior	1967
CORNELL UNIVERSITY	U.S. and world benefits to agriculture, forestry, and range management	U. S. Department of Agriculture	1967
IBM	U. S. and world benefits of orbiting research laboratory	NASA	1966
STANFORD RESEARCH INSTITUTE	U. S. and world benefits of orbiting research laboratory	NASA	1966

FIGURE 28

98

ERS ECONOMIC STUDIES

I. EXPERT JUDGMENTS

PRO

USEFUL UPPER BOUNDS

ALL INCLUSIVE IN APPLICATIONS AREA

CON

NO INSIGHT INTO

- o OPERATIONAL REQUIREMENTS
- o ERTS EXPERIMENTS
- o DATA MANAGEMENT REQUIREMENTS
- o R&D PROGRAM PLANNING
- o RELATIONSHIPS BETWEEN ECONOMIC AND TECHNICAL PARAMETERS

II. CASE STUDIES

PRO

PROVIDES INSIGHT INTO

- o OPERATIONAL REQUIREMENTS
- o ERTS EXPERIMENTS
- o DATA MANAGEMENT REQUIREMENTS
- o R&D PROGRAM PLANNING
- o RELATIONSHIPS BETWEEN ECONOMIC AND TECHNICAL PARAMETERS

CON

NOT ALL INCLUSIVE (ADDITIONAL SUPPORTIVE CASES MAY BE OMITTED)

DIFFICULT TO ACHIEVE CREDIBILITY EARLY IN R&D PHASE (MUST POSTULATE TOTAL CONCEPTUAL OPERATIONAL SYSTEMS)

MUST ASSUME R&D ACCOMPLISHMENTS A PRIORI

FIGURE 3

11/10/70

requirements, ERTS experiments, data management requirements, R&D program planning, and relationships between economic and technical parameters as do the detailed case study approaches.

Figure 4 briefly summarizes the numerical results of one of the case studies previously listed.* These dollar values constitute cost and benefits accrued over a 20 year operational period and discounted at 10 percent (discounted cash flow approach). All numbers relate the application of a single, principally space-based system to three specific applications, namely, water management, wheat production and wheat rust control. These have been on a U. S. national basis and have been based upon a rather detailed look at the interactions of the remote sensing data/information with the existing resource management institutions in the United States as associated with each of the three applications. There are, of course, a number of significant defects in the study not the least of which is that solely a spacecraft system was looked at rather than considering the complementary use of aircraft. This constituted merely an analytical expedient rather than any considered judgement. In other words, at that point the analyst simply felt unable to determine a reasonably optimum mix of spacecraft and aircraft. Another significant shortcoming was the employment of crude economic models; however, really satisfactory ones are rather rare.

In order to assist in an assessment of the utility of these economic studies and what steps should be taken next, an effort is being made to review most of the significant economic and total system studies and to make recommendations as to their value, how they may be utilized, and what further studies are needed.

TOTAL SYSTEM VIEW OF TRAINING AND EDUCATION REQUIREMENTS

It is more important at this time to consider the kinds of training and educational assistance appropriate to the various developing countries and regions and let this be the essential driver in the development of institutional details in each country, with the latter being molded by the particular characteristics of the country.

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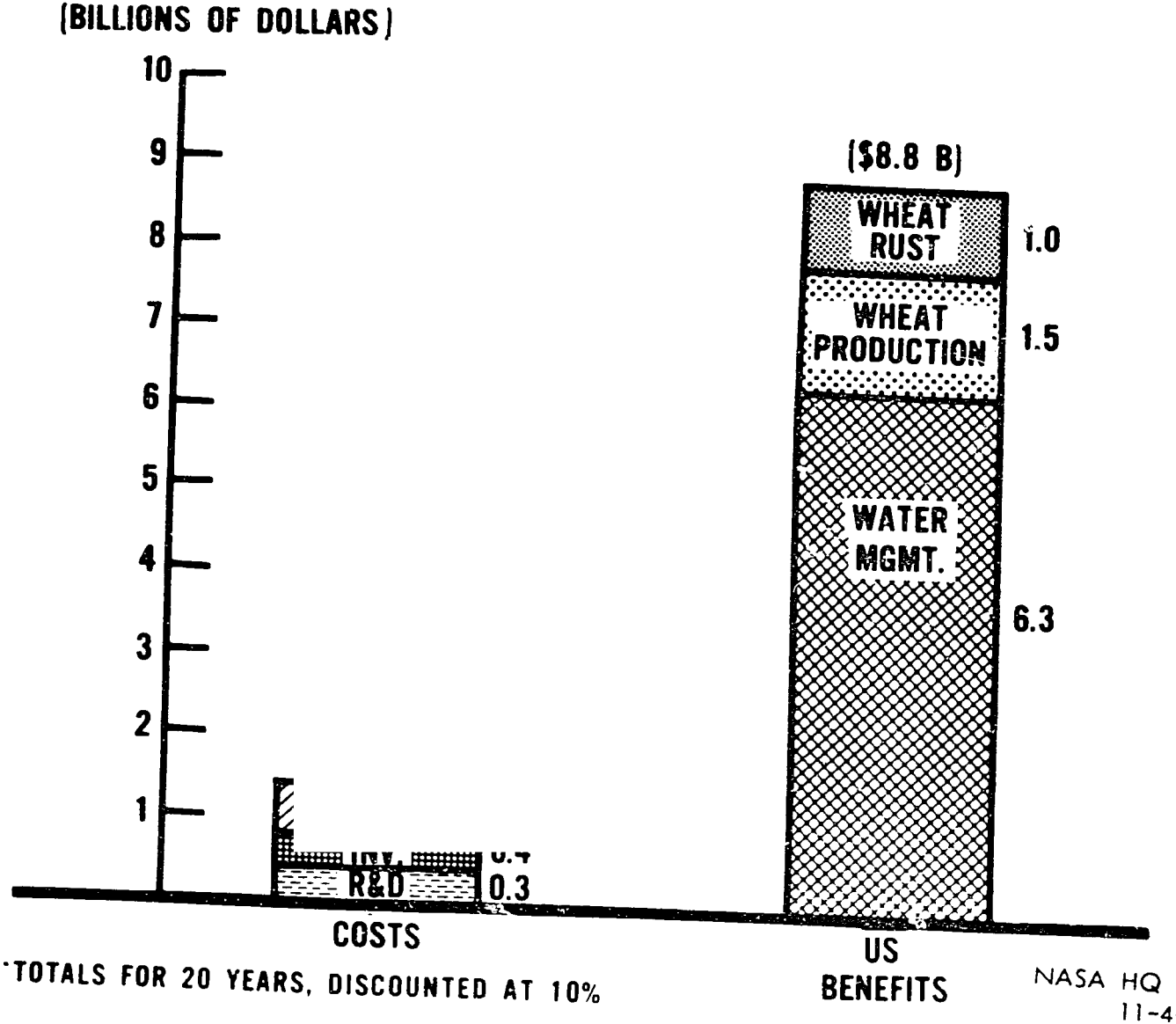
* "A Systems Analysis of Applications of Earth Orbital Space Technology to Selected Cases in Water Management and Agriculture," November 1969, Planning Research Corporation, Washington, D. C., PRC-R-1224, NASA Contract NASW-1816.

COST-BENEFIT ESTIMATES *

SATELLITE-ASSISTED SYSTEM FOR WATER MANAGEMENT & AGRICULTURE

(BASED ON PLANNING RESEARCH CORPORATION STUDY, CONTRACT NASW-1816)



*TOTALS FOR 20 YEARS, DISCOUNTED AT 10%

NASA HQ SR70-106
11-4-69

FIGURE 4

NASA has been giving some consideration to training and educational requirements with emphasis on a United States national point of view. How does this relate to developing countries?

As a start, study Figure 5 which is a piece of the total system chart, Figure 1. Again there are the essential elements of any system, namely: (1) the observation system for data acquisition in terms of spacecraft, aircraft or ground systems; (2) the initial data processing system which would include sensor system calibration, geometric corrections including rectification, and possibly atmospheric calibration (this function would correspond roughly to the ERTS ground data handling system); (3) the analysis and interpretation phase, including enhancement and manipulation of imagery, automated information extraction and the utilization of decision-orieted resource models. As indicated, the data or information is disseminated to users in off-line (meaning non-critical time dependency) and on-line (implying a strong need for timeliness) modes. Although termed an operational concept, the diagram is also relevant to the experimental phase.

On Figure 6 are listed categories of training users (not to be confused with users of data/information). Some of these are overtly related to the previous system diagram (Figure 5) while others are only implied. The operators of data acquisition and processing systems would include the operators of the ERTS, Skylab and aircraft data handling systems. In the case of responders to AFO's, i.e., so-called investigators, or experimenters, these are clearly in the analysis or interpretation phase. By resource managers are meant persons performing operational resource or environmental management jobs which could be assisted in the management decision process by information (interpretations or predictions) extracted from ERS data and resource/environmental models. New space systems planners will probably first come from the NASA or U. S. user agencies. University faculties, as well as undergraduate and graduate students, will be an important category particularly for the long term. Last on the list are the so-called senior policy and planning officials, namely those persons within government or possibly private enterprise who will make decisions on the beginning, conduct, and funding of programs.

Figure 7, shows in a matrix form, the seven "trainee" categories mentioned above to the needs for several instructional (or knowledge) categories. These include the emissive and reflective properties of terrain features, atmospheric propagation, sensors and data processing, analysis and interpretation of both imagery and taped data, the development and modification for resource and environmental models, and lastly

OPERATIONAL EARTH RESOURCES SURVEY SYSTEM CONCEPT
(Simplified Functional Diagram)

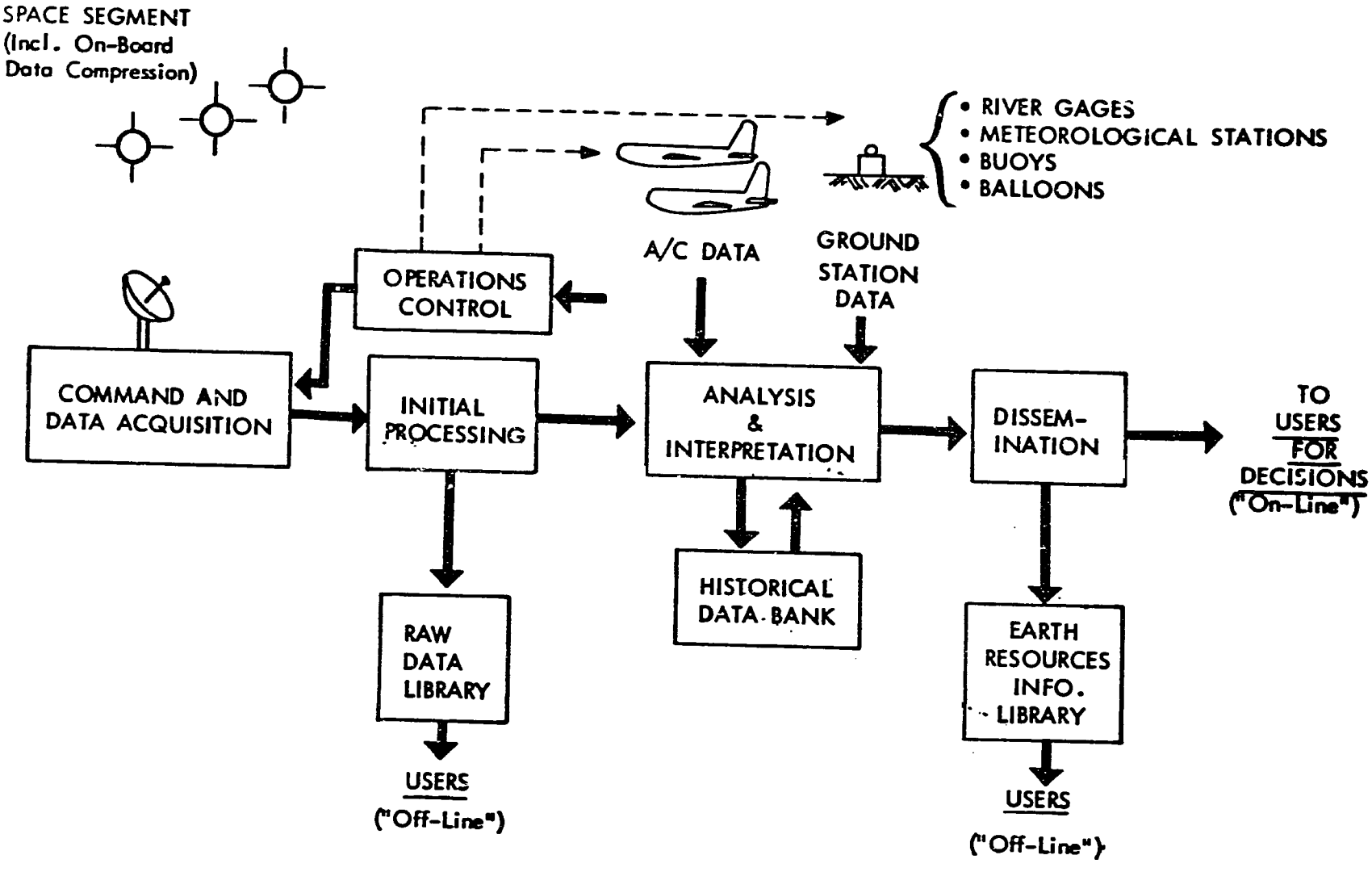


FIGURE 5

NASA HQ SA69-16331
5-8-69

NEEDS	TRAINEE CATEGORIES						
	System Operators 1	AFO Investigators 2*	Resource Managers 3*	New System Planners 4	Faculty 5*	Students 6*	Senior Officials 7*
1. Emissive and reflective properties of terrain features.		A		B	A	A	
2. Atmospheric propagation		A		B	A	A	
3. Sensors and data processing	A	B		A	A	A	
4. Analysis & interpretation of imagery		A	B	A	A	A	B
5. Analysis & interpretation of taped data		A	B	A	A	A	B
6. Development and modification of decision-oriented resource models		A	A	A	A	A	B
7. Utilization of decision-oriented resource models			A	B	B	B	B

Legend: A = detailed study
B = some acquaintance
* = interest to developing countries

NEEDS VS TRAINEE CATEGORIES

FIGURE 7

1003

the utilization of decision-oriented resource and environmental models. The letter A indicates that some acquaintance with the area is needed or would be helpful. The asterisks show that trainee categories 2, 3, 5, 6, and 7 are of the most interest in the developing countries.

Figure 8 relates the same trainee categories to the possible training and education mechanisms which might be utilized. These mechanisms run all the way from formal classroom lectures through text books, brochures and movies. The letter "A" indicates the mechanisms which is needed, the letter B that it is possibly or probably useful and, again, the asterisk indicating a particular interest to developing countries. Certainly on both this matrix and the preceding one there could be much debate over the appropriate letter for each cell.

There are courses, lectures, workshops, and other training activities already underway or proposed. Figures (9A, B, C, D), is a partial tabulation of some of these efforts including the U. S. government-sponsored International Workshop in ERS.

EVOLUTION OF CAPABILITY

An important step in the training and education process will be the development of meaningful experiments for ERTS and Skylab. These must, of course, include strong efforts from within the country involved for aircraft coverage and ground truth, as well as analysis capability. It is, however, important to recognize a few limitations: (1) The possible assistance from outsiders, while very useful, should not overwhelm the indigenous effort. (2) The effort must be directed at real practical problems of the particular country. (3) It must be recognized that both ERTS and Skylab are experimental systems with primary emphasis on U. S. coverage. Particularly in the case of ERTS, significant coverage outside the U. S. would be contingent on the successful and continued functioning of the video tape recorder. It should be noted that tape recorders have been among the least reliable of space subsystems, and (4) Any decision to invest in data acquisition or data processing should recognize that follow-on experimental and future operational space systems may have quite different parameters and data formats.

In the evolution of capability in any particular country, there are three phases: (1) the training of personnel who can engage in the R&D activities such as the AFO investigations; (2) the training of operational or near operational personnel, such as resource/environmental managers and (3) the development of a long-term educational base which can provide the research and management personnel required for future years.

MECHANISMS	TRAINEE CATEGORIES: System Operators 1	AFO Investigators 2*	Resource Managers 3*	New System Planners 4	Faculty 5*	Students 6*	Senior Officials 7*	General Public 8
1. * Classroom lectures		B		B		A		
2. * Laboratory training		B		B		A		
3. * Field training		B	B	B		A		
4. * On-the-job training	A				B	B		
5. * Regional Workshop/ Institute (2 wks-3 mos)		A	A	B	A	A		
6. Brief course (2-5 days)	A		B		B		B	
7. * University Fellowships					B	A		
8. * International Workshop (2 wks)		A	A	B	B	B	A	
9. Road show (1 day)							B	
10. * Textbook series		B	B	B	A	A		
11. * User's Handbook (comprehensive)	B	A	B	B	B	B		
12. GDHS Handbook		A	B				B	
13. Brochure							B	A
14. Movie							B	A

Legend: A = needed B= possibly useful
* = interest to developing countries

MECHANISMS VS TRAINEE CATEGORIES

FIGURE 8

101A

With assistance and training both at technical and policy levels provided to the developing countries, as they become interested in this area, the institutional details can be allowed to evolve from existing institutions as appropriate to each of the countries involved.

There is an active role to be played by international institutions, to equalize the opportunities to exploit ERS data in developing countries.

Early efforts should concern preparation for the analysis and interpretation of ERTS and Skylab data in conjunction with locally obtained aircraft coverage and ground data.

Effort should focus on the development and utilization of decision-oriented resource and environmental models with practical local significance.

A strong educational base should be developed for the long term.

The present documentation of the state-of-the-art in ERS is not adequate for training and technical assistance purposes.

In view of the above, the following are first priority recommendations:

(1) A strong effort should be made to provide training for both potential ERTS/Skylab experimenters and senior policy and planning officials. The experimenters should be prepared to focus on real and indigenous problems which they can attack largely on their own. Local aircraft and ground data support should be provided.

(2) Regional or national workshops should be organized as both national interest and technical capabilities evolve. These workshops could be modelled along the lines of the Arizona Regional Ecological Test Site and Workshop (multidisciplinary study of the arid environment) now being developed in the United States; particular emphasis is on the identification of regional users, uses, and methods of use and the intermixing of AFO experimenters and resource managers at all levels.

(3) The continuation and expansion of the Fellowship Program. This would be initially with U. S. universities, but gradually expanded to foreign universities as the necessary capabilities develop.

(4) The development of an authoritative and well-written text book series covering the ERS and remote sensing fields.

This series should be available in Spanish, French and Portuguese, as well as English. Perhaps the dynamic nature of the ERS field suggests looseleaf notebooks for these texts!

DISCUSSION

WREATHAM E. GATHRIGHT:

I think it was made clear the formidable character of the institutional training problems. I think the presentation, however, tended to take for granted that institutions flow from technology. I do not really think that is the case.

Yesterday we heard about institutional barriers to the development process as it exists today. It is not clear to me that by adding a new and highly complex additional problem we are going to get better institutional solutions. So I question whether this can be sort of counted on as a natural evolutionary process which I think Dr. Summers intended to imply it was.

I am less clear on what we can do about it, but it does seem to me we cannot take it for granted in this country, we cannot take it for granted in developing countries, we cannot take it for granted in the international organization that there will be adequate institutional responses.

Secondly, some of the responses that will be needed by institutions, probably there is a certain amount of commonality between the responses required for this kind of program and this kind of effort and the whole problems of the development process.

The failure of countries and their institutions to use data already available, the failure of institutions within countries to work and communicate with each other, are common to the development process and I think one approach that might be considered here is to try in some way to separate out the common problems and work on those because they are going to have to be worked on in any event, and then to try to measure the additional needs resulting from this particular kind of program.

Thirdly, I think Dr. Summers emphasized the importance of trending in data acquisition, data extraction, while

noting the importance also of getting around to the users and what they need. I would almost be inclined, and possibly for the same reasons, to go and start at the other end of the spectrum, to start with the user and work back and try to find a common meeting ground with the technology and to try to examine institutional and training requirements from that end working back toward the acquisition and extraction end.

Again, this is partly because if you do it that way, you will come up with some useful efforts applicable to the development process as a whole and that it will strengthen the development process as a whole, whereas if you start from the opposite end, perhaps it is or is not going to work out.

The more that can be done automatically through various processes of automation in terms of extraction of information, the better off everybody will be.

I recall Alvin Weinberg's comment at one point that if the telephone company had not started working on automatic dialing in 1900 we would today be a nation of switchboard operators. I do not think you can have a nation of people involved in trying to analyze and interpret all the data that is going to be available. The more weight that can be put on automation the better.

Fourth, there is a division of labor problem, and I think I was glad when Dr. Summers got around to international equalization. It may reach farther than that. It may be a question of what can most usefully be done in the particular country versus what can be most usefully done in a subregional, regional or international level. We certainly have not thought these problems through very well.

Finally, I think we have to think about the developing countries as participants in a global political and economic system, and what I have in mind here is the increasing concern on a global basis about a number of problems ranging from environment to sea beds to all manner of technology.

There will be new rule-making problems at the international level, new administrative problems, and already it seems to me that the developing countries are not able to participate efficiently or effectively in these kinds of discussions so that through some -- that is, the discussions that are in effect laying ground rules for using the technology you are talking about.

Now, how one advances along this line is not quite clear to me, but more effective participation is certainly going to be needed and it is simply a different aspect of development.

An institutional caveat is the reverse of what I have just said. While a great deal of attention is being given to global rule-making or the need for it, one sort or another of global analyses trying to fit individual nations into a broader picture, some answers are clearly not going to found on that basis.

So far as we are really talking about the concerns that nations may have about whether satellite photography is suddenly going to lay them open to exploitation by the advanced countries.

This question came to mind yesterday when Dr. Reinemund was talking about the more or less serendipital discovery of potential oil off the coast of Liberia. I could not help wonderning what Liberia's mining laws were, how much information the Liberians had when they granted the leases which in effect paid for the program, whether the Liberians got a fair shake out of all this or whether they were able to construct a contract that in some way would give them more later on.,

What I am saying here is that the answer to concerns about possible exploitation in space capabilities seems to lie within the purview of the countries as long as the data from space are available to them in a form that they can understand, that the countries themselves can enact if they wish to do so laws and administrative procedures to take care of the problem.

I had the feeling in general that Dr. Summers, while taking note of a great many parts of the system, to some extent started from the wrong end of the system and took too much for granted that if we did that the institutional changes that may be needed are just going to be with us automatically.

MICHAEL GUCOVSKY:

I would like to add I share the views of Mr. Gathright. We have to try to find a common interest to explore some of the opportunities at the practical rather than the political level and let the political level catch up with the practical arrangements that will evolve. The emphasis should be not first to resolve political issues, but first to demonstrate practical application, cooperation and then I hope that the political side would catch up with it.

The other way around, I am afraid, could be a rather lengthy process.

KIRK P. RODGERS:

I also would concur very much with Mr. Gathright. I think our problem here is one of communication between the expertise in the whole area of knowledge of the physical environment and the real decision makers who are the economists and the politicians. This is where we fail more often than not. We just do not seem to be able to talk in their language and maybe we have to reverse the whole process and start with the decision makers and try to begin to understand not only what their needs are but in what form do they need to have the information expressed so they can take their decisions.

SUMMARY COMMENTS

MR. SCHWEITZER:

I would like to refer briefly to the President's message of September 15 which is currently guiding the Executive Office.

The White House is taking the lead on how to most effectively shape our foreign assistance programs during the seventies. We anticipate that the legislative basis for this reorientation will be prepared by January 1971 and sent up to the Hill by February. We anticipate that it would not be enacted until about November or December of 1971 and the actual organizational restructuring will take effect on July 1, 1972. This depends on Congressional views but this is the strategy of the executive branch. In addition to the organizational restructuring there is somewhat of a program emphasis shift. There are two major thrusts of the AID program which have been very sharply separated in the latest thinking of the President.

The lending function or capital development function involves usually substantial amounts of money for very specific projects, whether it be a dam, a road, a series of schools, a sewage system, or development of a water basin. These are largely engineering tasks, or economic-engineering tasks which would draw upon technologies, whatever they may be, including remote sensing, to accomplish a specific job in a specific time frame.

There are a number of specific suggestions that were made during the meeting.

I have three questions raised by myself or my colleagues which we would like some guidance on because we didn't understand whether we really grasped what you were saying.

The first question--our understanding is that there is general agreement that the data acquisition costs are usually very small compared to the data analysis and interpretation costs.

Is that a fair statement? Whether it be two to one, five to one, ten to one, the use of the data is the big cost.

HUMBERTO RICCIARDI:

Somebody pays for the satellites in case we speak about satellites.

SCOTT M. SPANGLER:

It depends on the project. There are some projects in which the biggest expense is data acquisition, as Hydrology, or looking for water. These don't use the sophisticated mathematical techniques but just using visual inspection such as IR scanning film.

H. ROBERT GRIBBEN:

A second exception is at the present time the costs for acquisition of radar imagery does exceed the cost of the processing and data reduction. I think that will change.

MARVIN R. HOLTER:

Are you concerned with just processing and data reduction or taking it to the point where action is initiated?

GLENN SCHWEITZER:

So the decision maker can use it.

RICHARD LEGAULT:

Even in hydrology and radar I still insist it costs more to analyze this data. You have to account for the ground trips you make, the confirming ventures. That has to be considered part of the expense.

CHARLES JOHNSON:

With few exceptions, the cost of data acquisition is a small part as compared with analysis and other related costs. I think we should go all the way over to the point where it is ready for a user.

MARVIN R. HOLTER:

The key question is, did the client make investment decisions based on radar data or did he use that data to steer him to spend more money on other things somewhere meaning the operation decision?

GLENN SCHWEITZER:

I was talking of putting the whole sensing data into usable form.

SCOTT M. SPANGLER:

Such as a map of where to drill a core well.

GLENN SCHWEITZER:

I have to decide where to dig the well. You have to give me a map or something I understand. In order to give me that map, the bulk of your cost I understand is not flying the airplane. In this case it might be.

SCOTT M. SPANGLER:

In most cases the main cost is after you gathered the data.

MICHAEL GUCOVSKY:

Just to illustrate, the figure you gave us before, for a certain country, of $3.40 per square kilometer; what proportion roughly in that was processing and what proportion in flying?

SCOTT M. SPANGLER:

I can give you numbers but it's not fair because we offered to set up a photo processing and electronic processing lab and train their people which roughly doubled the cost of data reduction.

MICHAEL GUCOVSKY:

That is included in the $3.40 figure?

SCOTT M. SPANGLER:

In the hydrology case about 60 percent of the cost was in data gathering, including ground teams sent out to locate us and 40 percent would be in data reduction.

KURT B. STEHLING:

In the ultimate satellite case there may be zero cost of acquisition for a developing nation.

ROBERT A. SUMMERS:

ERTS data would be available presumably at the cost of photo reproduction, which is nominal.

GLENN SCHWEITZER:

I would like to ask a question about ERTS A and B, Dr. Holter said the resolution will be about a thousand feet. My specific question is: Under the most optimistic conditions for ERTS A and B, what kinds of specific applications could developing countries think about in relationship to that data that will be available from A and B, once again recognizing its test data; what are the specific applications at that resolution that might interest a developing country?

ROBERT A. SUMMERS:

The official position about the resolution is 300 to 600 foot range. I get into arguments of how much degradation comes about making copies.

GLENN SCHWEITZER:

Let us say 500 feet. What kind of applications are you talking about that would interest a developing nation?

ROBERT A. SUMMERS:

You could provide, based on the kinds of things that Dr. Landgrebe showed, land-use plots, indications of vegetation, surface water and bare soil and perhaps at last 10 classes of vegetation.

MARVIN R. HOLTER:

The kinds of uses that will be made of the data depend on the stage of the development of the country. There are at least three stages that make a big difference. There is some discussion of this in chapter 8 of the National Academy book on remote sensing written by Bruce Kelly of the Department of Agriculture.

It would provide these countries with something very cheaply and very rapidly that they don't have now and would be hard to get in other ways. It becomes a little more questionable of how much use it would be in Turkey, more heavily populated. They have a better ground statistical system. Turkey appears to know what its land use classification is. Turkey might use ERTS data for geological purposes.

GLENN SCHWEITZER:

Is it going to be useful to anybody really? Is a geologist in a developing country going to be interested in this kind of photography? I am billing ERTS as being of economic interest to developed countries.

ROBERT A. SUMMERS:

Nobody ever billed ERTS necessarily as an economic interest to developing countries, directly. It's a special system. The invitation is to participate in experiments to determine feasibility.

JOHN A. REINEMUND:

ERTS is an experimental system. That is quite right in our view. We are defining about a dozen specific projects in developing countries to test the ERTS system in various environments and through various problems. One of them is going to be orthophotography mentioned by Fischer. For example, right now we are helping Argentina on some mineral survey in the Andes, and trying to use conventional aerial photography in the Andes is difficult. You can't plot geologic data or any kind of data in reasonable spatial relationship at all because everything is so distorted. If we had some ERTS photography now in that area, it would be tremendously valuable.

The resolution limits are quite adequate for much of what we want to do. Another aspect of course is monitoring of active geological phenomena. We mentioned the Peru earthquake problem and other similar problems involving movements of glaciers, movements of landslide problems in certain areas. Quake activity, drainage activity, plus problems in bodies of water; a whole range of things.

GLENN SCHWEITZER:

Is it your feeling that there is sufficient potential in the ERTS kinds of resolutions and kinds of repetitiveness that it's at least worth exposing the developing countries to it, but not with the expectation that something will come out of it.

JOHN A. REINEMUND:

Absolutely. One of the things that is happening is the improvement in techniques and improvement in the system that is going on all the time. There is no reason to expect that it is going to stop. If we are talking about certain resolution limits now and certain capabilities, two years from now we will be talking about vastly improved ones.

GLENN SCHWEITZER:

One recommendation was a followup symposium involving people from the developing countries. This could be either sponsored by AID, sponsored in cooperating with OAS or a number of ways, but essentially a symposium to go over the same grounds we went over here having the technicians together with the economists with the development people.

HUMBERTO RICCIARDI:

A program was approved by the committee on outer space of the UN of technical panels to be convened during next year. The first panel of people from undeveloped countries will be convened at that time to discuss the program at the time of the Ann Arbor workshop. These are two different things: the workshop is one thing. The other is a panel of invited people to come here to study programs and to discuss the applications of what can be done for the developing countries or for their own countries in particular.

There will be a program, apparently with the FAO, to see how they can use remote sensing techniques for food management and food development resources. The meeting will be held in the first week of September 1971 in Rome. We are organizing this and the idea is to have a limited number of specialists. This is more directed to what exactly FAO should do but in a certain way is the same problem you have. A third panel is being sponsored by Brazil and probably Argentina. It will be held somewhere in Brazil, at two levels, during the months of November and December 1971. One level will be a meeting of three to five days for people on the managerial capability or directors of ministries or people that we have to explain to them, users or representatives. The second level will be ten to fifteen days of duration for observation and training of people coming from developing countries.

KIRK P. ROGERS:

OAS would, from a technical standpoint, be very interested in doing whatever we could to support efforts to bring into close contact the data users with the data producers. Particularly, I am thinking in terms of the data users insofar as the planning boards and some of the development agencies are concerned.

GLENN SCHWEITZER:

On the U. S. side we would want to compliment whatever efforts the U.N. takes on OAS. We would look at our efforts as being supportive of whatever initiative you people would like to take.

We will be in touch with you on whatever contribution U. S. might make either in terms of foreign assistance or technical agencies. You also obviously deal directly with NASA's interagency committee.

HUMBERTO RICCIARDI:

NASA is our national point of contact, and everything is routed through Mr. Jim Morrison.

GLENN SCHWEITZER:

AID plays a role in regional symposiums. We usually end up buying plane tickets for American scientists going to the meetings. In terms of resource people I suspect AID will be involved. My only concern is that in some instances the UN might give thought to what the U. S. Government or other governments might be able to do in terms of accelerating schedules when satellites are being launched. One advantage we have from operating bilaterally is that sometimes it's not so difficult to get the small amounts of money that are often required.

The next recommendation discussed was a traveling road show where you send two or three experts presumably familiar with the remote sensing technologies and let them travel around the world to expose people on location to what the technological opportunities are. I guess the notion was that since the U. S. did have expertise in this area we might think of having a team of Americans on a selected basis visiting a few countries just to exchange views in a more deliberate way than happens at a symposium.

JOHN A. REINEMUND:

I think this comment touches on the last two items, the one just brought up and the previous one on regional symposiums. This concerns a plan that is going into the formal recommendation to ECAFE, to the Commission for handling the regional remote sensor seminar in the ECAFE region this coming year.

This was a recommendation that has been made to the Commission by the Subcommission on Geology and Mineral Development of ECAFE at its meeting in August. After quite considerable discussion and in that meeting also I took the liberty of mentioning the workshop back here as a vehicle for a combining of the countries with what was coming on in remote sensors but the general feeling of the ECAFE representative was whereas that workshop was fine, it wasn't all that was needed because it wouldn't reach enough people in the individual

countries. They would like to have a traveling seminar that would visit the different countries with a panel of experts who could cover a fairly broad spectrum of user agencies, managerial as well as technical.

Now, I don't know what the fate of this will be when it gets into the Commission but I would guess considering the record of sponsorship of seminars and symposiums in ECAFE in the past that it will probably be picked up and sponsored.

HUMBERTO RICCIARDI:

In my opinion remote sensing and interpreting personnel training should mainly be related to specific commitments of the countries.

MARVIN R. HOLTER:

Before one embarks on investing in training, the government of the country must guarantee they will employ a man who is trained.

ROBERT A. SUMMERS:

This implies exposure and education with the so-called senior planning officials which I presume is the objective of some of these panels.

KIRK P. ROGERS:

We are seeing the beginnings of the end of the concept of international training centers or in some cases, even regional training centers. AID's posture in this area might be to encourage those countries which are interested in setting up and providing training not only for themselves but perhaps for neighbors. Initiative has already been taken by Mexico and Brazil in remote sensing. I would think that any effort that would encourage and support that direction would be probably very well received.

GLENN SCHWEITZER:

Next was a suggestion that AID pick a country for a case study and analyze cooperatively with that country. Presumably the economic planning ministry of that country shall analyze the kind of information that a ministry needs in the resource field to make rational investment decisions, and then to identify the gaps in the information that exists, identify those gaps which could be most cost-effectively filled by remote sensing approaches.

That was the general notion, i.e.: A real life case study of a real country with the objective of relating the remote sensing business to the country's overall resource development. This would not be a U.S.-run study. I am against U. S. studies. U. S. experts would be used as a catalyst to encourage a country to do it itself. This is basically the philosophy John Reinemund and his people follow. Every publication they put out is a joint one with the local people.

MARVIN R. HOLTER:

Remote sensing is a useful but not exclusive element in the information gathering business. There is then no point in trying to identify where remote sensing could fill gaps in any country that already does not have a reasonably mature information gathering system of some sort.

MICHAEL GUCOVSKY:

I think something that is desperately needed by the whole international community is a more comprehensive post audit of complete development projects which are in execution and have been underway for some time. The audit would trace the projects back to the very beginning when the data was collected which identified the project to determine what really happened. We are making over again the same mistakes because we do not have any kind of an automatic built-in mechanism to see what happens when development really occurs in relation to what we thought was going to happen when we extend the project. In some cases we can find the wrong kind of data was collected or inadequate data or too much data or something. Just to add in addition to this there are 10 of various research studies carried out by various agencies with UNDP financing or OAS or anyone else in Latin America with Africa, Asia, Nepal included by the way.

GLENN SCHWEITZER:

Another key recommendation has been that AID take steps to encourage developing countries to centralize their data collection operations and smoke out of their files what they already have. I interpreted this as meaning that we might take a country which is cooperating with NASA, say, in the space area, whereupon AID might consider whether it would be useful to cooperate with that country.

KIRK P. ROGERS:

We were fairly encouraged by some of the results of our modest attempt to provide some cataloging of existing map

information in the Latin American countries. It was followed up by some fairly vigorous action on the part of a number of countries to do a better job of centralizing their own information. I don't think any country has reached the stage where it developed what really might be called a data bank but there are trends in this direction.

I think that efforts that can be made by AID to encourage this are going to have a big payoff because what we certainly discovered, it has been mentioned several times in the conference, is the quantity of information already available which is not being utilized is really extraordinary and we have to think in terms of processing and organizing the new data that will be pouring out of our programs for the future but we have an awful backlog of information gained at considerable cost which is not being effectively utilized right now. The cost incidentally of the cataloging, the very modest effort we made as far as Latin America is concerned, country by country, was about a quarter of a million dollars so we are not talking about big money in terms of the first effort.

GLENN SCHWEITZER:

We talked a lot about sophisticated remote sensing today. There are a number of simpler techniques we should think about. AID, in Project Specific Situations, should always be conscious of the opportunities to adapt remote sensing technologies. This was in response to a Kenya example of a Cessna flying with a camera. That shows more or less that there's nothing special about remote sensing. In any kind of project, AID should be sensitive to what is on the shelf and viable in the U. S., and allow it to be adapted to a country's situation.

There was a suggestion from John Reinemund about a specific research project AID might consider, related to geology in the tropical areas where the vegetation and geological characteristics may be somewhat different than what we are accustomed to dealing with.

Finally, there was a suggestion that we should have a massive data collection activity to try to catalog in effect the same kind of thing Kirk did five years ago, namely that AID might undertake the same kind of activity on a country-wide basis or on a regional basis.

I would like to thank everybody for spending two days with us. We certainly appreciated it.

We have no illusions about the complexity of jumping into the remote sensing field in any serious way. We have no illusions

about the simplicity of convincing budget people around here that it's a useful area for AID and its successor organization to pursue but I would say we are ahead of where we were before this meeting.