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Eastern Regional Remote Sensing Applications Conference

A conference held at
the Tidewater Inn,
Easton, Maryland,
October 2-5, 1979.

NASA

National Aeronautics and
Space Administration

NASA Conference Publication 2173

Eastern Regional Remote Sensing Applications Conference

Dr. Nicholas M. Short, Editor
Goddard Space Flight Center

A conference sponsored by Eastern Regional
Remote Sensing Applications Center and
held at the Tidewater Inn, Easton, Maryland,
October 2-5, 1979.

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CONTENTS

SESSION 3

SESSION 4

SESSION 5

1980 PROCEEDINGS

EDITOR'S PREFACE

The first Eastern Regional Remote Sensing Applications Conference was both an experiment and an adventure. As members of an ad hoc planning committee for this conference, my colleagues and I at ERRSAC in truth did not know with assurance what to expect from our invited speakers insofar as quality, information content and utility of their papers were concerned. For this reason, primarily, we deferred any decision to commit ourselves to a conference proceedings until we could evaluate the conference presentation ex post facto. Suffice it to say, our judgment of these papers was so positive that we decided to "go" with a proceedings even before the conference closed.

But, in retrospect, it would have been wiser to gamble and announce a proceedings, with attendant requirements placed on each contributor, prior to the conference. As any of you who has ever edited a conference proceedings can no doubt attest, there are sure to be numerous problems in obtaining manuscripts and satisfactory illustrations from many, perhaps most, of the contributors. This occurs regardless of schedules and deadlines imposed on the contributors.

In our case, we set a new record for inevitable delays. Much of the difficulty was of our own making. Certain critical talks and all of the forums were documented only on open reel tapes. These tapes were recorded at the conference simply by placing equipment in convenient locations. The omni-directional microphone did its job all too well—not only was the speaker committed to posterity, all surrounding noises (coughs, dishes, etc.) were also added. After months of patient listening and careful reconstruction, we recovered essentially all of the talks not supported by a manuscript. The transcripts were sent to the speakers, who were able to reconstruct most of them. The forums were so hopelessly compromised in listening quality that, with genuine reluctance, it became necessary to drop them from a printed proceedings. Finally, after a year's efforts, almost every formal paper on the original program has been received in a state sufficient for publication.

These papers are reproduced here as submitted by the author(s), either written from "scratch" or edited from the transcripts. Illustrations are added by the contributors to the extent they deem necessary, but they have omitted many of the slides/vugraphs utilized during conference presentation, mainly because of unavailability of acceptable artwork.

As we prepare for the second conference now planned for March of 1981, the editor and his colleagues at ERRSAC are resolved to profit from our learning experience. We are announcing a proceedings in advance and will strongly urge each contributor to come to the next conference with a final paper in hand.

Nicholas M. Short

Proceedings Editor

PROCEEDINGS
OF THE
EASTERN REGIONAL
REMOTE SENSING APPLICATIONS CONFERENCE
OCTOBER 2-5, 1979

SESSION 1

INTRODUCTION

Philip J. Cressy
ERRSAC
Goddard Space Flight Center
Greenbelt, Maryland

We have looked forward with some anticipation to this conference. Not only has it been part of Regional Applications Program planning from the beginning, but for some of us it fulfills a fantasy we've had for nearly a decade. Conferences and symposia have been part of the Landsat program since 1972, the first one only five months after launch of what was then ERTS-1 (Earth Resources Technology Satellite). These conferences played a very important role in the assessment and dissemination of data applications and analysis techniques. The technology was new, research was intense, and the rate of discovery rapid. But "citizen participation" was low. While operational users appreciated some of the promise of Landsat technology, that promise had not been put to real tests. Operational opportunities and limitations were not yet well understood. And so, most often, the technologists talked to each other.

Several of us looked forward to the time when the technologists could leave the room, and the conference wouldn't miss a beat. We hoped for a time when people—"users"—could "confer" with one another at a conference. That's what we wanted for this conference.

It is surprising how seemingly little things become important, and have an effect. For instance, rather than meet in a large metropolitan area, with all its convenient distractions, we met in a small, historic town where attendees ran into each other wherever they went. Rather than sit auditorium style facing a stage, conferees sat around tables.

Because of such things, and because it was the time for it, and especially because the right people came, the conference did what we wanted it to do—but hardly dared hope for. People were not just attendees, they were participants. They didn't just sit there and listen—they shared with each other, and with us—they became animated, and infected us with their enthusiasm—they gave the conference a special spirit. It was electric, and we were a little sad to see it end.

In this Proceedings you will read some good words from that conference. Speakers report on a variety of attempts to grasp a complex technology and simplify it, make it useful. There is a freshness and directness that should tell you this work did not come from a sterile research facility. I believe your reading will be rewarded.

But these are just the words. I don't know how to capture the spirit in print. The words always sound better when you know the music. And for the "music", you had to be there!

WELCOME I

Stanley Freden
Missions Utilization Office
Goddard Space Flight Center
Greenbelt, Maryland

Good morning, ladies and gentlemen. I would like to welcome you to the conference on behalf of the Goddard Space Flight Center and NASA in general. I understand that there are about 160 people here. Approximately 115 of you are from state and local governments representing 19 states, Puerto Rico, the Virgin Islands, and the District of Columbia. I feel that this type of representation from every one of the governmental agencies within the region is really a tribute to the program, especially since it has been in existence for less than two years.

Some of you will be here to speak, others to listen. But I am sure that all of us are here to learn. Some of the states in the Eastern Region are very active in the program, while some are just beginning to become involved, and others are on the sidelines waiting to find out what is happening.

We have had to make some sacrifices to get where we are today. Last winter I had to send Phil Cressy to a Minnesota conference. But to make up for it, I told Phil that this winter I would go to Puerto Rico and the Virgin Islands. Seriously, though, this is the first conference of this type not just for ERRSAC (the Eastern Region), but for the entire regional program. There will be similar conferences for the Southern and Western Regions within the next month or so.

We hope that this will be a good conference—we're sure that it will be. We hope that you will enjoy it and that you will learn from it. We have looked forward to conferences of this type and hope that this is the first step in a really productive Remote Sensing Applications Program.

So, without further ado, I would like to introduce Mr. John Sherwood, who is Deputy Secretary of State Planning for the State of Maryland.

WELCOME II

John Sherwood
Deputy Secretary
Maryland Department of State Planning
Baltimore, Maryland

It is my very pleasant duty to welcome you to the State of Maryland on behalf of Governor Hughes, Constance Lieder, Secretary of the Department of State Planning, and all the people of our state. Even by Maryland's standards, this area is especially beautiful. I envy your opportunity to meet here on the Eastern Shore, and I hope that you will be able to take time to visit some of the very attractive surrounding communities, like Oxford and St. Michael's.

I also believe that it is appropriate for you to be meeting in Maryland, because the Maryland Department of State Planning has had a considerable relationship with NASA in connection with the application of NASA capabilities to our planning programs. We integrated ERTS-1 data with our land use planning process in the special project which ran from 1972 to 1974. At the present time, we are working with ERRSAC to input LANDSAT land cover data into our existing Maryland Automated Geographic Information System (MAGI). Tom Rugoski, who is our delegate here, will be speaking later on today, and certainly at any time you have the opportunity you might speak with him on an informal basis about what we are doing. I will be looking forward to talking with him following the conference to find out what he has learned, and what we can apply to our program.

The Department has long been committed to the use of airborne platforms. Assuming that the marriage can be made between our information systems and satellite imagery, the overall reliability and consistency of the process will certainly be improved. We look forward to that kind of technology transfer occurring as a result of the exchange that will take place here. In any case, we look forward to a continuing relationship with NASA. We have been most pleased with that relationship so far. I would like very much to stay to listen to some of the presentations, especially this afternoon's session on practical experiences that many of you have had. Unfortunately, I must leave immediately after these remarks.

Again, I do welcome you, and hope your conference is successful, and that your stay on the Eastern Shore is a memorable one.

NASA'S REGIONAL REMOTE SENSING APPLICATIONS PROGRAM

Richard H. Weinstein
NASA Headquarters
Washington, D.C.

It is a pleasure to be here this morning to discuss NASA's Regional Remote Sensing Applications Program. I will try to keep my remarks fairly brief, because the emphasis in this program should be on the states' activities rather than on NASA's. As an introduction, however, to set the stage for the symposium, I would like to give an overview of where the program stands now, and then tell you a little bit about future directions.

NASA's Regional Program is now completing its third year. About one year ago, when we began to discuss the idea of these conferences, it seemed that this would be a good time to stand back and review the whole program. This is the first of three regional symposia; similar symposia will also be held this year in the Western and Southern Regions.

In line with our original intention of reviewing the program, the first objective of this conference is to provide some kind of benchmark on the states' activities and progress in the use of Landsat — and to evaluate whether NASA is really meeting its objectives in helping the states use Landsat data more effectively.

Also, we hope this benchmark will provide useful information to the outside community, i.e., other federal agencies and the private sector. Federal legislation turns out to be the impetus for many of the uses that state governments are making of Landsat. The Congress is interested in state use of satellite data, because of proposed legislation to establish an operational Landsat system. The voice of the states has grown considerably in this regard and is making itself heard in Congress. Many important decisions will be made over the next year or two, and if the states truly feel that Landsat data can be used to meet their information needs, then they should continue to make their positions and requirements for this type of data known.

Technology transfer is an imprecise business. It is very difficult to define the point at which technology has actually been transferred, but at the risk of showing an incomplete picture, I'd just like to present a few indicators of progress.

Development of each state's Landsat demonstration program requires a lot of orientation, discussion, and negotiation. But once agreement is reached, the first real commitments of people and resources are for the training programs. Since NASA's Regional Program began in 1977, we have trained roughly 700 state personnel in techniques of satellite data analysis. This is hands-on, working-with-the-data type training, and it has been done through the three NASA Regional Centers. In

addition, more general orientation programs have been provided for an additional 1,500 people, many of whom are key policy people within the State agencies — the people who make the decisions on the development of operational systems.

We see the job of training as two-fold. The first aspect is short term and consists of preparing people to participate directly in the demonstration projects. A longer term aspect of this effort is perhaps more accurately described as education rather than training, and this involves the university community. In each of the states, universities have a very obvious role to play in producing the resource managers of the future. Remote sensing will ultimately become an operational tool only when we have a generation of resources managers who have been brought up on remote sensing. We have taken a number of actions to stimulate the building of university capabilities through the development of short courses, special summer programs, curriculum development and so on. As it turns out, each of our three regions has adopted a slightly different approach to university involvement, each with its own merits, and we hope to see more sharing of these techniques between regions in the coming year.

Another measure of progress, beyond the numbers of people trained, is the number of demonstration projects. Twenty-four states are either now involved in demonstration projects or have participated in completed projects. State interest has escalated rapidly, and demonstrations in 13 states were added in 1979 alone. We hope that this interest will continue until we have had the opportunity to conduct demonstrations with each of the 50 States.

A third measure of program maturity is the ever broadening involvement of user representative organizations, in particular, the National Conference of State Legislatures (NCSL) and the National Governors' Association (NGA). Their participation has added a truly national dimension to the transfer program. Representatives from each of these organizations will speak later, so I won't say any more about the scope of their activities, except to express NASA's appreciation of their effectiveness in facilitating state involvement in the program.

If the first objective of the conference is establishment of a benchmark, then the second objective, an outgrowth of the first, is inter-user communications. Although NASA can help users evaluate applications of Landsat data, I think the critical technology transfer probably occurs between users. We see this conference as an opportunity to introduce data users to each other and to provide an opportunity for you to start sharing successes, problems, and techniques as well as perceptions of future needs. In the long term, inter-user communication is probably more important than NASA's role, because NASA's role as a federal agency is directed at technology development and transfer, not continuing service. We hope that users, after some period of time, will become self-sustaining and although NASA will continue to work with the states and other users to update them with new technology as it becomes available, the primary communication as state programs mature will probably be among users—and with the federal mission agencies that relate to the states in a continuing support role.

The third objective of the symposium relates to industry. So far, most of your contact in using Landsat has been with NASA. As we look to the future, to how states will be using remote sensing

in 5-10 years, it appears obvious that industry must play a larger role. In fact, many state activities related to natural resources information (such as environmental assessments) are frequently provided through the services of private industry. Private industry is interested in developing capabilities for the use of Landsat data, but market demand is the determining factor. We hope that through this meeting (and the other regional symposia) you will be able to make some contacts with this developing private industry and learn what their capabilities are and how you can most effectively draw on them to meet your own growing needs.

Having discussed where we've been, I'd like to turn to where I see the program going and what our objectives are for the near term. The demonstration program will continue and hopefully involve additional states over the next several years, still using Landsat multispectral scanner (MSS) technology. By that time many of the states will probably have their own operational capability and will be well on their way to becoming self-sustaining. This coming year, we expect some leveling in state activities, and we hope to begin involving substate governments in a more substantive way. This includes counties, regional commissions, councils of governments and other similar entities. In many cases this involvement will be through state programs, but we are also looking for ways to involve them on a nationwide basis through appropriate representative organizations such as the National Association of Counties and their own working affiliates such as state county associations.

Federal agencies also enter into the picture, particularly when they drive state data needs. Many of the Landsat applications that the states have been suggesting as demonstration projects are, in fact, outgrowths of federal legislation, either directly fulfilling data requirements of federal legislation or in response to the general trend of federal legislation over the past 5-10 years toward comprehensive natural resource management. One important opportunity that may not have received enough attention to date is the possibility for direct involvement of some of these federal agencies in demonstration programs. If, for example, a state project was undertaken to meet the requirements of the EPA 208 Program or the HUD 701 Program, it might be to the ultimate advantage of both the state and the federal regulatory people who are responsible for approving state plans if some of these projects were conducted as three-way efforts including the state, NASA, and the appropriate federal agency. It is possible that this might lead to broader acceptance of Landsat data and state use of it in federally-mandated natural resources programs. Stimulating federal acceptance of Landsat data is desirable because this interaction between states and the federal agencies will continue long after NASA has moved on to other technologies. As you may know, NASA has worked cooperatively with a number of federal agencies to help them develop their own remote sensing programs. Hopefully, the amount of assistance you can receive from the resource-related federal agencies in the use of remote sensing for your own programs will be growing during the coming years.

Another thrust in our near term effort will be the increased use of private service sector capabilities. There is a definite need to stimulate increased participation of the private sector, to broaden the availability of continuing support for users of remote sensing. During the coming year, we will be looking for ways to involve the private sector directly in demonstrations—perhaps in follow-on projects. States that are interested in such a mode of operation could use this opportunity to provide a smooth transition to use of commercial capabilities.

Finally, although NASA, being a research and development agency, cannot assume the role of operational support in the use of MSS technology, there is a whole new range of technology that will be available for transfer to state governments and others in the near future. One of the reasons that we have targeted 1981 as a year to begin phasing down some of the multispectral scanner technology transfer activities with state governments is that in addition to having finished demonstration projects with each of the states, Landsat-D with the new, more capable thematic mapper sensor will probably be coming on-line in 1982. As most of you know, this sensor will open up a whole new world of applications because of its improved spatial and spectral resolution. Once the initial R&D has been done to determine the sensor's capabilities, we hope to begin working with the states, working with operational users to provide them with access to the new technology. New technology will become available for transfer to state governments not only from Landsat-D, but also from improved techniques for analyzing current data (e.g. improved change detection techniques) and increased use of geobased information systems.

In summary there is a lot of work remaining to be done, and although we have made some progress, we welcome your feedback to help NASA make the transfer program more effective and to suggest where you think the program should go, i.e., what your needs for the future are. Also, I want to give you the assurance that NASA is going to be around for a while, continuing the technology transfer job. We hope that this is the beginning of a very productive relationship with the states and we look forward to your assistance in making it effective.

NCSL: ROLE AND ACTIVITIES

Paul Tessar
National Conference of State Legislatures
Denver, Colorado

The National Conference of State Legislatures (NCSL) has been in existence for six years. The Natural Resource Information Systems Project, formerly the Remote Sensing Project, has been with NCSL for four of those six years. Most of you have probably heard of the National Governors' Association (NGA), but you may not have heard of the NCSL. We are similar in scope to the NGA, but we serve and represent 7,600 state legislators and their staffs. We are basically in the same line of work as the NGA, but with a different constituency.

The NCSL has three main goals. The first is to improve the quality and effectiveness of state legislatures. We have been involved in various types of activities such as providing assistance to individual legislators, committees, and entire legislatures, and to majority and minority caucuses. The main goal of our organization is to provide technical assistance to our constituency.

A second goal is to ensure for the states a strong voice in federal policymaking. This is a representation-type goal and goes hand-in-hand with the resurgence in the state legislatures that has taken place during the last 15 to 20 years. Since 1960, the state legislatures have become increasingly more active and have assumed more authority, striving to increase their influence on national policy. The NCSL works to see that the views of the 50 state legislatures are heard in the administration and on Capitol Hill. Our main office is in Denver, and we also have a branch office in Washington. That branch office is, for the most part, responsible for implementing the goal of representing state legislatures to the federal government.

The third goal of the NCSL is to foster interstate communication and cooperation. This goal is met, in part, by sharing legislation between states. Many of you have probably heard that the states are the laboratories of democracy, and many innovative approaches are tried in different states. Some work and some don't. The NCSL strives to stay abreast of these developments and to provide information between states on what has worked and what hasn't and how local conditions have affected it.

Within the Natural Resources Information System Project, we have four main goals. The first and most important goal, the one we have been working on the longest and hardest, is informing the state legislative community of Landsat and natural resources information systems capabilities, limitations, and costs. This is a technical assistance and service-type function.

The second goal of the project is to provide follow-up assistance to individual state legislators, committees, and other groups in response to the interest generated by our communication activities. So these first two goals are technical assistance and service, and they fall under the main NCSL goal.

Our third goal is to serve as a focal point for state feedback to NASA, the federal government, and other national organizations interested in natural resource data gathering and distribution, Landsat systems planning, and remote sensing technology transfer efforts. Our goal is to represent the states and state legislatures with the federal government and to see to it that their interests are taken into consideration in federal policymaking.

Our final goal is to provide information and support to the NASA regional remote sensing application program and, especially to the three primary Regional Applications Program (RAP) field centers. We work quite closely with the three NASA field centers—Goddard, National Space Technology Laboratories (NSTL), and Ames. The NCSL was instrumental in getting the RAP Program started. Sally Bay Cornwell, who was my predecessor, did a lot of lobbying at NASA headquarters to let them know that the states needed technology transfer assistance and that something like the RAP transfer program was needed. The NCSL activity and a GAO report led to the formulation of the RAP Program. I think this has been a very useful program and we are happy to be associated with it.

Now I would like to briefly discuss our past and present activities. We put out a number of publications, some of which will be familiar to you. Our first effort was a brochure entitled "Landsat—Down to Earth Views from Space." We expanded on that with "A Legislator's Guide to Landsat." About ten thousand copies of this brochure have already been distributed, and you all should have a copy of it in your registration packets. If any of you need extra copies to pass on to some of your legislators, we would be happy to send you some. We have recently completed a new report entitled "State Institutional and Technical Approaches to Landsat Utilization," which is currently being reproduced for distribution. In the report, we have chosen several states and looked at each of their institutional approaches in implementing Landsat capabilities, the technical approach they have taken, and what type of processing capabilities they have. The states we studied were Texas, North Dakota, South Dakota, New Jersey, Mississippi, and the Pacific Northwest states. The report will be available shortly.

A recent activity has been natural resource legislation surveys, in which we looked at federal laws, rules, and regulations and corresponding state enactments and regulations and analyzed the data requirements, particularly relative to satellite remote sensing. Essentially, we are looking at the federal mandates and the state responses to see if the state rules and regulations satisfy the federal rules and regulations in terms of data gathering. We have completed two areas: surface mining and coastal zone management programs. We have been publishing a monthly remote sensing newsletter for a little over two years now. Most of you are probably on the distribution list already. If you would like to receive it and don't already, please see me.

In the fall of 1977, we held a series of five regional legislative workshops on Landsat and we have compiled a composite of the proceedings. We also have the Colorado Landsat Conference Proceedings and State Legislative Recommendations on Landsat technology. The latter reflected some work done by our Landsat Task Force with the goal of making recommendations to NASA and the administration on future directions for the Landsat program.

We have also conducted several workshops. As I mentioned before, we held a series of five regional workshops about two years ago which were attended by about 200 legislators and legislative staff members, and also by about 200 other state and federal employees, private sector representatives, and university researchers. The workshop stimulated a lot of the legislative interest that we followed up on through the individual state workshops. To date, we have had seventeen briefings in twelve states, and this activity will be continuing. Several of these states (Virginia, Illinois, Maryland, and Ohio) are from this region.

Another general category of our activities is technology transfer assistance. We have been an active user-awareness agent, informing state legislators, committees, and staff about what Landsat is and what it can do. Virtually every natural resource, energy, and agricultural chairman in the House and Senate in every state gets our newsletter. Many of them have also received our "Legislator's Guide." We are trying to develop this base of awareness. As you well know, in developing the state programs, legislative support is very important, especially around budget time. One of our roles is to make the legislators and committees aware of what the technology can do and at the same time to caution them about some of the difficulties that other states have encountered. We do this with continuing technical assistance to our constituency.

We have also been quite active in representing state interests to the federal government. As I mentioned before, we have made formal recommendations on Landsat technology transfer from our Landsat task force (which has been renamed the Natural Resource Information Systems Task Force) and will be making more recommendations on the future operational Landsat system and other areas. We have provided a great deal of informal feedback from the states to the RAP Program and have worked very closely with them trying to tune their activities to meet the needs of the states. And we are also active in the Landsat-D Technical Users Working Group, as is the NGA.

We are participating in Five Agency Project activities. Five Federal agencies—the main data gathering and production and distribution agencies—are getting together to develop common classification systems and standard inventory procedures for federal data gathering. The five are the Soil Conservation Service, Geological Survey, Forest Service, Fish and Wildlife Service, and Bureau of Land Management.

We are also active in the NGA Earth Resources Data Council, and were involved in the Intergovernmental Science, Engineering and Technology Advisory Panel (ISETAP) Landsat Report in a major way. We have worked very closely with Leonard Slosky, the Staff Director for the Report, and helped pull the whole thing together, especially in the area of documenting state applications of Landsat.

Now I would like to focus on some of our current activities. We are just beginning a new project year, and with guarded optimism, we are forging ahead. One of the major revisions in our project over the last six and next six months is the change in the focus from Landsat satellite remote sensing and aircraft remote sensing to natural resource information systems. We feel that the whole broad topic of natural resource information systems will be of more interest and relevance to the legislators and our own constituency in general. We are tooling up and developing presentations more along those lines. We will be continuing with about eight workshops each year but with a focus on natural resource information systems. We may be working with some of your states, if we get requests from your legislators.

The Natural Resources Information System Task Force will be continuing. There will be a meeting next month, as a matter of fact, in Green Bay, and we will be making recommendations to the federal government on Landsat-D and on the Operational Earth Resources System. During the next year, we will also be doing another natural resource legislation survey, this one on soil conservation programs, comparing state statutes and examining their major provisions. Our newsletter has been renamed from the Remote Sensing Newsletter to Natural Resource Information Systems Newsletter, and six issues will be published in the next year. These are the continuing activities, albeit with a different flavor, but essentially continuations of what we've been doing in the past.

We've got several new initiatives this year, one of which is preparation of "A Legislator's Guide to Natural Resource Information Systems," which is currently in preparation, and we've got the first draft almost complete. My assistant, Loyola Caron, is working on that project. That's moving along well and Loyola is in contact with a couple of states from this region, namely Virginia and Minnesota, to develop case studies.

Also, we're developing the national legislative clearing house on remote sensing natural resource information systems and other NASA technologies, providing continuing individual technical assistance to state legislators and their staffs on what is available to them in the way of new technologies, and what the applications, benefits, costs, and limitations are. And finally, we're continuing our participation in the Five Agency Project on classification and inventory of natural resources.

I have mentioned our task force several times. This is basically a group of 15 members. The newest member of the task force is Delegate Judith Toth of Maryland, and she's going to be joining us at our next meeting. We've got several representatives from this region, including Representative Tom Anderson from Michigan. He is probably one of the more knowledgeable state legislators and was involved in the ISETAP Report effort. He is a member of the Space Applications Board, and he also is a former chairman of the NCSL Science and Technology Committee. Representative Monroe Flinn from Illinois, the House majority whip, is also on our task force. Bob Hansen, who's the director of the Legislative Commisssion on Minnesota Resources, also is a member. Representative Dale Locker from Ohio, the chairman of the House Agriculture Committee, and Senator Jerome Van Sistine of Wisconsin, who's the vice chairman of the Natural Resources Committee, are also on the task force. If any of these people are in your state, you may want to communicate with them. Let them know you're interested in remote sensing and I think you'll find them receptive to your ideas.

Finally, I would like to briefly discuss the involvement of the NCSL in the Five Agency Project. We are involved on three different levels in this project. Our staff and task force will be reviewing the outputs of the project, especially where the proposed changes have policy and fiscal implications for the states. We will also be partially involved in the NGA and CSG state government activities for the Five Agency Project.

We will also be involved in outreach activities with all 50 states, trying to involve interested state legislators in the project, and we will be working on an individual basis with the State of Minnesota. The Legislative Commission on Minnesota Resources will be looking at the Five Agency results from the perspective of an individual state legislature, with the idea that it would be representative of all 50 states and would voice similar concerns to all of them.

I am really happy to be here today and am very much encouraged to see the progress NASA has made in remote sensing technology transfer. When I came to the South Dakota State Planning Bureau six years ago, there was no such thing as a technology transfer program, neither in NASA nor in the U.S. Geological Survey, and I basically had to develop South Dakota's capabilities on my own, with a little bit of help from the EROS Data Center. Since I know what it takes to set up a state program, I think you should all be very grateful for the efforts that NASA has made to provide assistance to facilitate this technology transfer. I believe they are doing an excellent job, and I look forward to the continuation and expansion of the RAP program.

THE EARTH RESOURCES DATA PROJECT

Peggy Harwood
Council of State Planning Agencies
Washington, D.C.

INTRODUCTION

State needs for natural resources data are intimately tied to national and state priority issues such as energy, environmental protection, and renewable resources. Through the decade of the seventies, the number of programs addressing these issues increased dramatically. However, while the need for these programs was being widely recognized, demands also were growing for reductions or limitations to government spending. Caught between these sometimes conflicting mandates, states must search for cost-effective ways to continue or expand essential natural resources programs and services, while holding the line on budget increases.

Partly in response to these pressures, the Council of State Planning Agencies, in consultation with the National Governors' Association and NASA, initiated the Earth Resources Data Project in August 1978. The long-term goal for this project is to encourage the appropriate application of cost-effective science and technology to state natural resources issues and problems. The National Governors' Association (NGA) and the Council of State Planning Agencies (CSPA) are two organizations that represent the executive branch of state government on many issues affecting states. CSPA is an affiliate organization to NGA, and for some purposes, CSPA functions very much like a division of NGA. Therefore, it is important to review the fundamental objectives of both organizations.

The National Governors' Association was founded in 1908 as the National Governors' Conference. The NGA is the instrument by which the nation's governors collectively influence national policy and apply creative leadership to state problems. The states are sometimes viewed as "R&D centers" for developing and testing innovative ideas and techniques for resource management and other government functions. The governors, through NGA, are striving to encourage innovations in government and are promoting them with the federal government and within the states. NGA is organized into eight standing committees on major issues of importance to states. The Earth Resources Data Project is operated in consultation with NGA's Natural Resources and Environmental Management Committee chaired by Governor Lamm of Colorado.

The Council of State Planning Agencies was founded in 1966: (1) to provide staff assistance to state policymakers; (2) to improve planning opportunities for state government and also the planning techniques available; (3) to strengthen the coordination of government activities; and (4) to provide

a vehicle for collective action by state planning agencies. The close relationship with NGA is explained by the fact that state planning agencies usually are directly part of the governor's office or are headed by an official appointed by the governor.

It is important to emphasize that these organizations and their constituents are "issue-oriented," so that the need for data or information technologies, such as Landsat, will not be a part of their day-to-day thinking. State policy and planning officials have broad concerns for state programs and services relating to renewable resources, energy, and other equally important natural resources issues. This difference in orientation may explain why data activities often give the impression of being strikingly expensive when reviewed in the context of total program budget and why additional effort must be made to relate data programs and new technology to important state issues.

PROJECT OVERVIEW

The Earth Resources Data Project was established to provide a focal point under the auspices of NGA and CSPA to identify those issues associated with state use of remote sensing and related technology. One project goal is to elevate to the consciousness of state policy and program officials new technologies, such as Landsat, by association with major issues to which policy officials are attuned. The project also will be assisting the coordination between the states and NASA and continuing to promote communication on those issues. A related project objective will be to encourage technical assistance opportunities for states that will promote better use of remote sensing and natural resources data in state programs.

A very important part of the project is the Earth Resources Data Council (ERDC), an advisory group composed of state officials with knowledge of natural resource data issues. Another important activity is information exchange, via the CSPA newsletter, "State Planning Information Report," or SPIR, and the distribution of other information items. Unfortunately, the SPIR has limited distribution, mostly to state planning offices. One goal for this next year will be to expand distribution of either this existing newsletter—which is quite bulky—or that part that deals with state and federal activities in the area of earth resources data and related technology. The project also sponsors special studies or topical analyses of major issues relating to state use of Landsat and other natural resources data. Studies underway include surveys of pertinent state and federal programs collecting and distributing natural resources data, and a concept paper on the potential for a national "census" or assessment of natural resources. A new activity this year is a technical assistance element that provides some opportunities for the project to offer state services on request. The project will sponsor orientation workshops in conjunction with the National Conference of State Legislatures and NASA regional centers. The project also will be experimenting with resources teams of state experts to provide an in-depth focus on problems that use natural resources data selected by the host state.

EARTH RESOURCES DATA COUNCIL (ERDC)

The Earth Resources Data Council (ERDC) consists of ten individuals chosen from states in each of the ten standard federal regions to serve as the nucleus of a communication and advisory network

for the project and a policy recommendation group for CSPA and NGA. Members are responsible for maintaining contact with appropriate state officials within their regions. This network of state officials is a method for distributing pertinent information and obtaining the necessary feedback on natural resources data issues. The ERDC members in the NASA/ERRSAC region are Dennis Malloy from Vermont representing Region 1, Bob Mills from New Jersey representing Region 2, Ed Thomas from Maryland representing Region 3, and Don Yaeger from Minnesota representing Region 5.

MAJOR ISSUES

The Project has been working on several important issues during the past year, in cooperation with the NCSL. One important issue has been the final selection of certain Landsat D and D' System parameters. NASA has been soliciting input on these parameters from potential users on the Technical Users Working Group (TUWG). State representation on the TUWG is through the NCSL Natural Resource Information Systems Project and the NGA/CSPA Earth Resources Data Project. Among the parameters still undecided are the orbit altitude and sampling pattern and the types of products (i.e., map projections and tape formats) to be available from the system. Recommendations prepared by the Data Council emphasize that compatibility with existing Landsat collection patterns and data products is important to states.

A second very important issue is the development of an operational remote sensing satellite system. Currently, there is legislation introduced in the Senate to establish an operational Landsat System, in support of which this project has provided testimony. We have also provided background on state information needs for two policy studies initiated by the President, preliminary to creating the institutional setting for an operational system. One of these studies is looking into user needs relative to the potential for joint civilian/defense satellite ventures. The second study is exploring the role of the private sector in owning and operating the system. It is our understanding that the long-awaited decision is expected any day for designating the lead federal agency to manage civilian remote sensing satellite activities.*

A third important issue for the Project is state use of remote sensing—including applications, problems, successes, and technical assistance needs. As a special task for NASA Headquarters this summer, the Project surveyed eight states for their use of Landsat and related technology in four federal program areas: EPA 208 (water quality planning), HUD 701 (comprehensive planning), Surface Mining and Reclamation, and Coastal Zone Management. In addition, with the assistance of the Council of State Governments, the Project is sponsoring two reference catalogs for state use. One lists existing state resource information systems and remote sensing programs. The other lists important federal programs that supply data, and in some cases contribute partial funding or services

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*Since this paper was originally written, the President has designated NOAA as the lead agency for this activity. The Project has been active by providing input to NOAA with regard to state user needs. The ERDC and the NCSL/NRIS Task Force met with NOAA officials and formal recommendations on the Transition Plan were submitted jointly by Colorado Governor Richard Lamm, chairman of the NGA Committee on Natural Resources and Environmental Management and North Dakota State Senator Rolland Redlin, chairman of the NCSL/NRIS Task Force. The Project also has provided testimony on the subject before the Subcommittee on Space, Science, and Applications and the Subcommittee on Natural Resources and Environment of the House Committee on Science and Technology. Testimony will also be provided in hearings before the Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation.

that could support state data bases. Documentation and technical support to these state resource information systems is important. Not only have many of these systems provided cost-savings to their states in acquiring data, but they are proving to be important "sites" for developing Landsat and other new technology and transferring that technology to others within the state.

A fourth issue is federal data coordination. The high cost of data and the sheer magnitude of data requirements are also encouraging cooperation and coordination among federal agencies. Two examples are the proposed National High-Altitude Aerial Photography Program (or HAP) coordinated by the USGS and the Five Agency Inventory Project discussed next. HAP is unique in that at least 13 federal agencies are contributing funds to have the continental United States flown every 5-7 years with 1:80,000 scale photography. The NGA/CSPA Earth Resources Data Project is currently trying to establish a state "presence" in the selection of priorities via the Earth Resources Data Council.

FIVE AGENCY INVENTORY PROJECT

In June 1978, the Bureau of Land Management (BLM), the U.S. Forest Service (FS), the Soil Conservation Service (SCS), the U.S. Fish and Wildlife Service (FWS), and the U.S. Geological Survey (USGS) signed a cooperative agreement related to classifications and inventories of (renewable) natural resources. This effort has four basic tasks:

1. To develop a national site (land) classification system with four components: soils, water, vegetation, and landform;

2. To develop common terminology for use in inventories;

3. To survey inventory programs and methodologies in use by the five agencies for possible cooperation (including use of remote sensing); and

4. To investigate information management needs and practices of the five agencies for eventual sharing of inventory information.

Each of these agencies is responsible for management and/or primary data collection for the nation's renewable and nonrenewable resources. Often their mandates overlap either in the resource base or the geographic area of concern. Examples of the urgency with which these tasks are approached can be found in legislation passed during the 1970's:

● The Federal Land Policy and Management Act of 1976 (FLPMA) of BLM;

● The Forest and Rangeland Renewable Resources Planning Act of 1977 (RPA) of the Forest Service; and

● The Soil and Water Resources Conservation Act of 1977 (RCA) of the SCS.

Each of these acts requires the federal agency to conduct periodic inventories of all or part of the nation's renewable resources as part of a long-range program planning effort. For two of these acts, RPA and RCA, the interval of assessment is every 5 to 10 years depending on the initiation of the legislation. Not only are these efforts out of phase with each other, but they also employ different terminology, classification systems, and methodology.

Resolution of all or even a few of these problems will have important implications for states. The states will probably follow the lead of these agencies where they reach consensus to reduce the high costs for data collection. Also, the inventory "universe" is smaller at the state level. A larger role for states in coordinating multiresource inventories and in providing access to the inventory information may be the result.

Recently, the NGA/CSPA Earth Resources Data Project started working with the Five Agency Inventory Project on behalf of the states, in cooperation with NCSL and the Council of State Governments (CSG). The objectives for our participation are:

- to ensure Five Agency study results are compatible with state needs and investments whenever feasible;

- to document and distribute information on policy and technical implications for states; and

- to make sure that opportunities for state participation in the study are identified and acted upon.

In an effort to meet these objectives our involvement can be summarized by four tasks. First, CSPA has developed a list of state officials to review and comment on all Five Agency Project reports. Each state has identified a coordinator to whom all state comments are sent before being forwarded to us. The purpose of this process is to encourage in-state communication among agencies that normally may not interact. For example, communication channels may be better developed between the U.S. Forest Service and the State Forester than between the State Forester and Governor's office or even the State Geologist. This process also encourages a single state perspective to be developed when certain issues arise. A similar review effort with legislative committees in one or two states is being conducted by NCSL to develop a legislative perspective on specific activities. Second, the CSG is publishing a newsletter, the "Resource Management Report," that has project summaries and other related information on state and federal multiresource programs. The third task is a survey of similar state inventory efforts being conducted by CSG. Fourth, the three organizations are jointly compiling a list of state expertise that may be useful for specialized reviews.

ROLE OF THE STATES

Active participation of the states in the Earth Resources Data Project is an important ingredient for our success. Without your guidance and support, our efforts to represent state interests will not be effective as they might be. The Project provides several opportunities for state participation. The Earth Resources Data Council is composed of state officials from each of the ten standard federal

regions, who in turn are developing an informal network with other officials from each state in their region. Information exchange provides another avenue to share activities among states, and to learn about federal activities that may impact state programs. States also have the opportunity to review certain proposals and documents, and comment on their utility and impact to state programs. But perhaps the most important role of states—and one that is also independent of Project activities—is to strengthen in-state coordination and communication in natural resource data areas. A unified state voice is extremely difficult to ignore.

EARTH RESOURCES LABORATORY TECHNOLOGY TRANSFER PROGRAM

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NASA National Space Technology Laboratories
Earth Resources Laboratory
NSTL Station, Mississippi

The National Space Technology Laboratories/Earth Resources Laboratory (NSTL/ERL) approach to technology transfer of satellite remote sensing technology has been developed over several years and represents an effective program for the assigned region. The approach is rather basic and is virtually identical to that of the other two regional centers, with the exception of the university involvement in the ERL program. The ERL program is composed of the following components:

- Demonstrations

- A comprehensive in-house training program

- User awareness activities consisting of brochures, slide sets, documentation, et cetera

- University short course programs designed to stimulate the improvement of university capabilities

- A technical assistance effort aimed at providing the states with consultation in the areas of hardware/software systems and advice on specific applications.

NSTL/ERL is focusing on the transfer of Landsat technology in the context of geobased information system development. Proven applications, such as general land cover analysis and vegetative mapping, along with data handling techniques including software for effectively converting raw data to information, are being transferred to the states. Figure 1 illustrates the present status of the various demonstration projects.

How the states in the ERL region currently regard the value of the technology can be observed by analysis of their investment in the technology. At present, North Carolina has Geographic Information System (GIS) capability, but no Landsat capability. New Mexico has Landsat capability only. Georgia, Louisiana, Mississippi, Oklahoma, and Texas have GIS as well as Landsat systems. Florida, Iowa, Kentucky, and South Carolina are moving toward Landsat/GIS capability, while Alabama, Arkansas, Kansas, Missouri, Nebraska, and Tennessee are uncommitted to either system.

Also of interest is how the states are approaching the problem of institutionalizing the capabilities. Of the eleven states that are underway in a significant way, six are housing their capabilities within
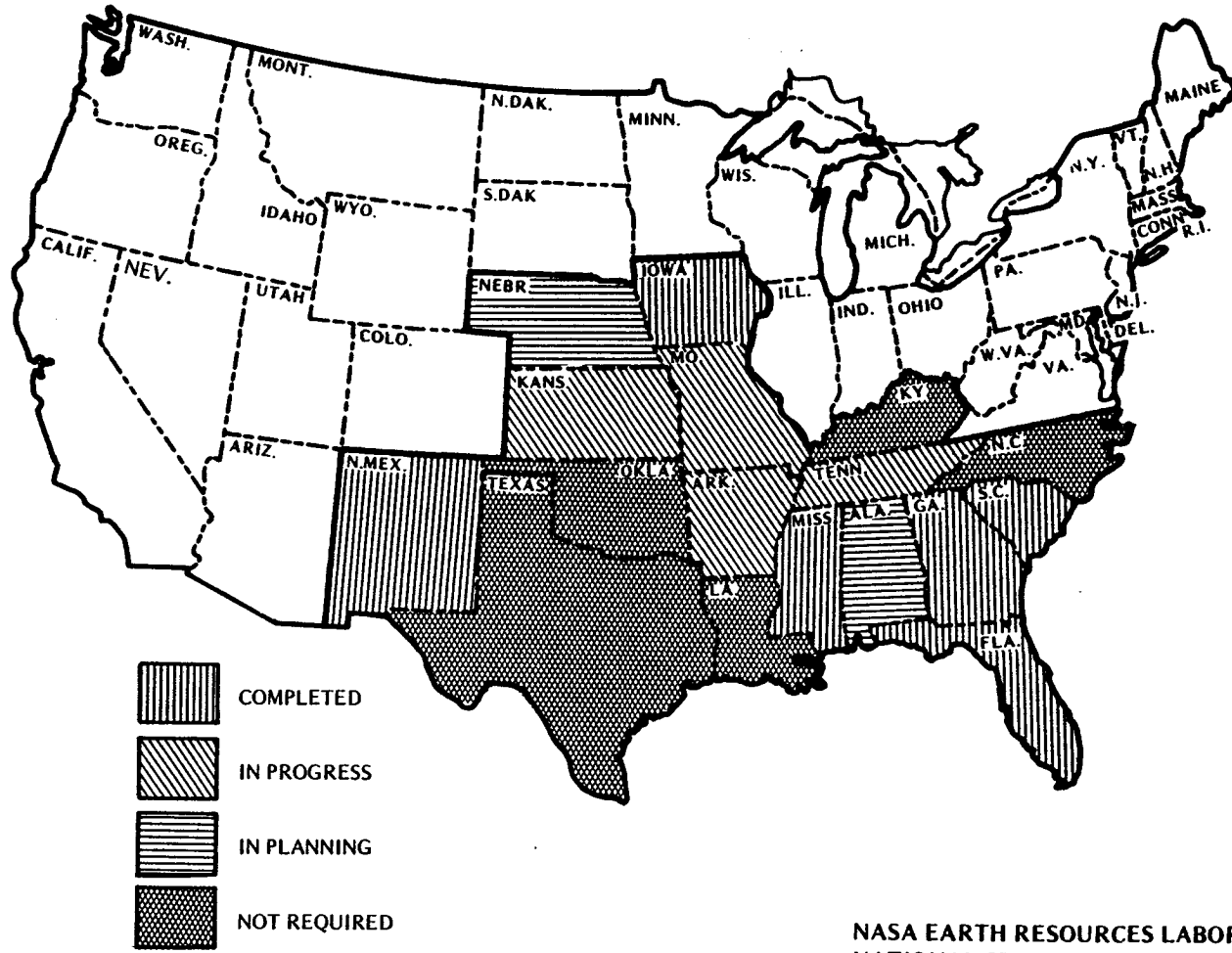
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NASA EARTH RESOURCES LABORATORY
NATIONAL SPACE TECHNOLOGY LABORATORIES

Figure 1. Demonstration projects status.

state government, four are developing a capability in cooperation with a state university, and one with a not-for-profit foundation.

Several funding approaches are being utilized by the various states in the region. Three states are operating with federal fund, and four through the state's executive branch (governor, single agency, et cetera). One is supported through legislature appropriations, one is operated jointly by state and federal funding, and one jointly by state, federal, and university funding. One state operates through joint-agency support.

ERL TECHNOLOGY TRANSFER

In summary, based on continuing contact with the states in the NSTL/ERL region, it appears that the Landsat technology is perceived as a beneficial data source, especially when it is linked with a geobased information system. Utilizing the current Landsat multispectral scanner technology always requires the use of qualifiers for particular applications in certain circumstances. Resolution and seasonal variations are specific drawbacks to the Landsat system. Data delivery problems, questions about the commitment to continuity of data, the many institutional questions, the high cost of the hardware and software, and the cloud problem are all recognizable problems. However, the potential benefits of the system definitely outweigh its shortcomings. The technology provides a means of obtaining a cost-effective landcover inventory with repetitive coverage and in a standardized format. There are also the advantages of seeing a large area in perspective and having a digital mapping base for use in information systems. There is little doubt that in the future, natural resource information will be handled in a digital fashion. Figures 2 and 3 show the status of the Landsat data systems in each of the states in the region.

SYSTEMS OPERATIONAL

IN PLACE-NEAR OPERATIONAL

IN PLANNING

GIS OPERATIONAL LANDSAT ADDITION IN PLANNING

UNIVERSITY CAPABILITY OPERATIONAL

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NATIONAL SPACE TECHNOLOGY LABORATORIES
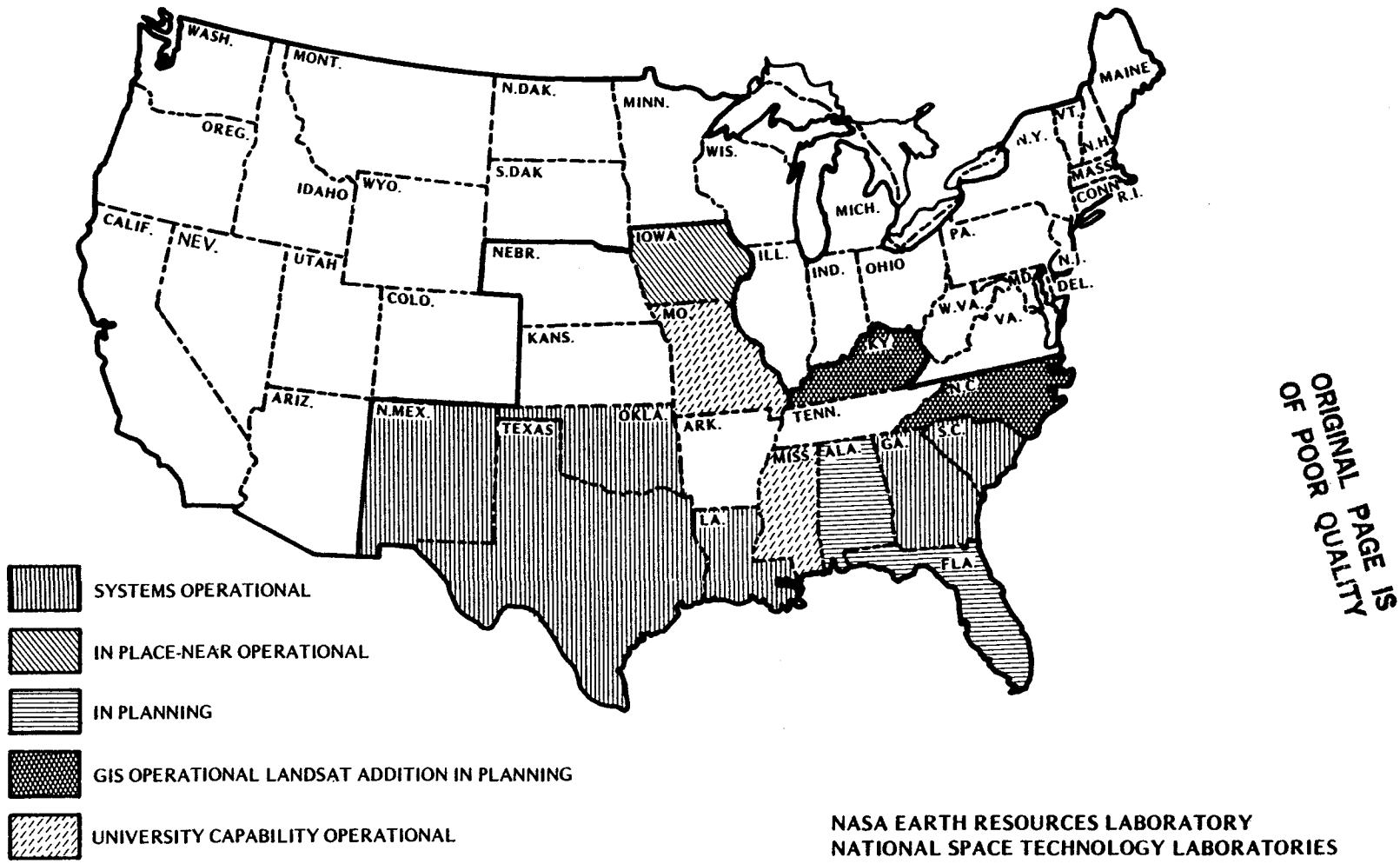
Figure 2. State Landsat/GIS data system status.
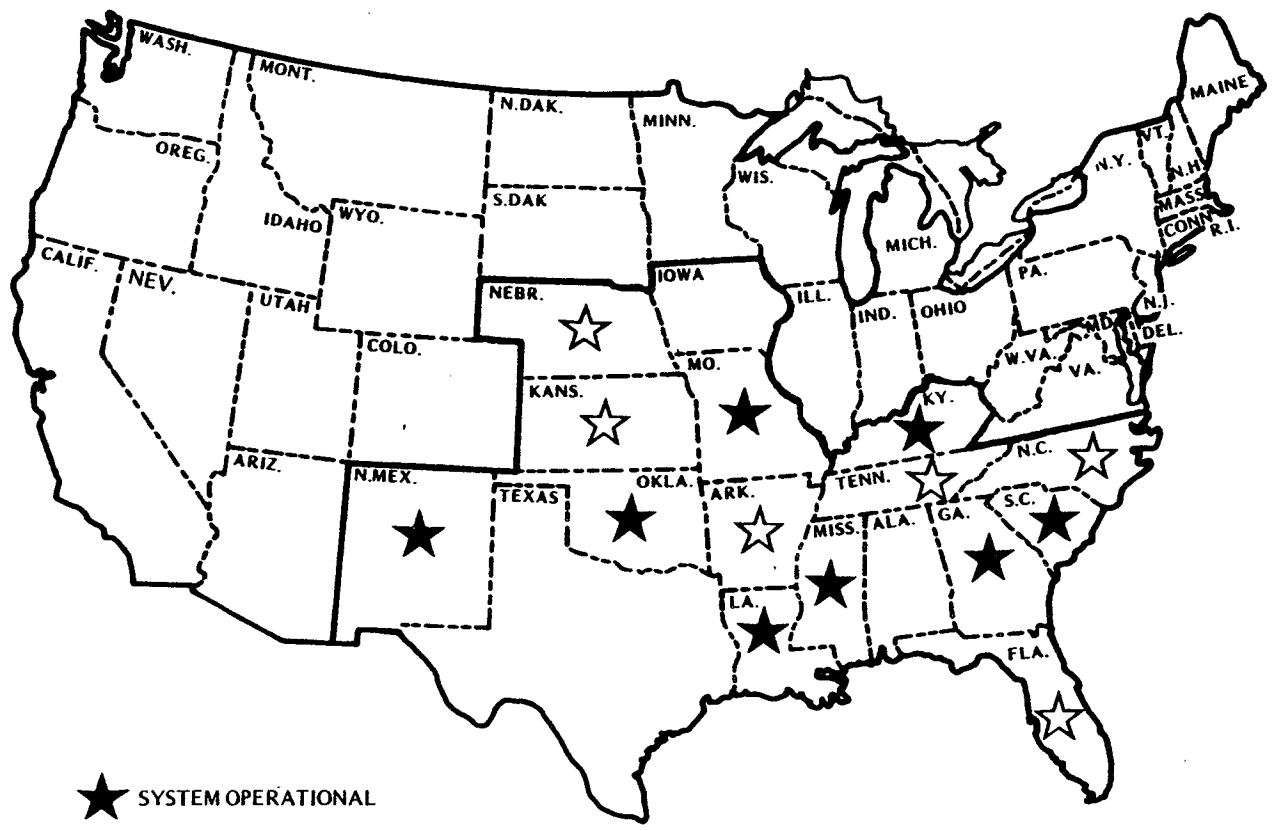
SYSTEM OPERATIONAL

IN PLANNING

NASA EARTH RESOURCES LABORATORY
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Figure 3. University Landsat Data Systems Status.

THE WESTERN REGIONAL
APPLICATIONS PROGRAM (WRAP)

Susan D. Norman
Western Regional Applications Program
NASA Ames Research Center
Moffett Field, California

INTRODUCTION

The Western Regional Applications Program (WRAP) encompasses Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming—a total of 14 states. The states in the west differ in many ways from the states in the eastern United States, but problems and solutions often have common elements, and a discussion of the WRAP approach may be somewhat relevant to your situation here. The institutional approaches, the operational alternatives and some of the representative Landsat projects that WRAP is engaged in will be presented.

UNIQUE ASPECTS OF THE WRAP AREA

The western United States has several features which both help and hinder the use of Landsat data. First, geographically the area is very large. Not including Alaska, the states in the WRAP region are an average of twice as large as those in the rest of the United States. A second difference is terrain. There are mountains as high as 10 to 12 thousand feet in most states in the region. This terrain presents problems of extremely limited road access, as well as unique technical processing issues for Landsat. A third aspect is federal land ownership. Between 80 and 90 percent of Nevada is under federal ownership, for example, and this situation exists in many of the WRAP states. A fourth issue is water, a very scarce resource. Planning for the wise and efficient use of this resource is a key management problem. Finally, forestry is a major area in the west; management of this resource is a key concern of state and local government.

These issues have affected WRAP in several ways. First, the size of a demonstration project is necessarily large. For example, in a follow-on project with the State of California, the state needs to examine a representative 10 percent of the state's area, in detail, to demonstrate feasibility. This translates to about 300 7½-minute quadrangles or 14 million acres. A minimum test area of one full Landsat scene is typical. Second, the responsibilities are often so complex that the task force concept is common. Task forces are composed of all interested agencies for the specific purpose of coordinating remote sensing activities. Third, resource management problems are so great and diverse that statewide Geographic Information Systems (GIS) are a major thrust in the Western Region. One-half of the WRAP states plan such systems as a way to more effectively manage resource information. Landsat can play a key role in these states.

HISTORY OF WRAP

The WRAP concept actually began with the Pacific Northwest (PNW) Project (Figures 1a, 1b). This project began in 1975 with Idaho, Oregon, and Washington participating. The project was a joint cooperative effort with USGS, the Pacific Northwest Regional Commission, and NASA. Several significant lessons were learned from the PNW Project (Figures 2a, 2b).

- Programs must be user-driven;

- Users must participate fully;

- We must listen;

- We must be responsive and flexible; and

- People are the key.

Most important is the user's role in the project; this has been a key element in the WRAP Program.

Figure 1 shows the demonstration areas within each state and illustrates various elements of state participation in the WRAP region. Since the area is large, travel funds for state personnel to visit Ames as part of their training program can be a significant contribution by the state. Examples of applications within one state are shown in Figure 2. The Puget Sound area in Washington state was a demonstration area for the PNW Project. It covers about 8,000 square miles and involved regional, county, and city governments (Figure 3).

CONCLUSION

Although the western states have a somewhat different remote sensing orientation than the eastern states, this overview may have given more perspective on your own states here in the eastern United States.
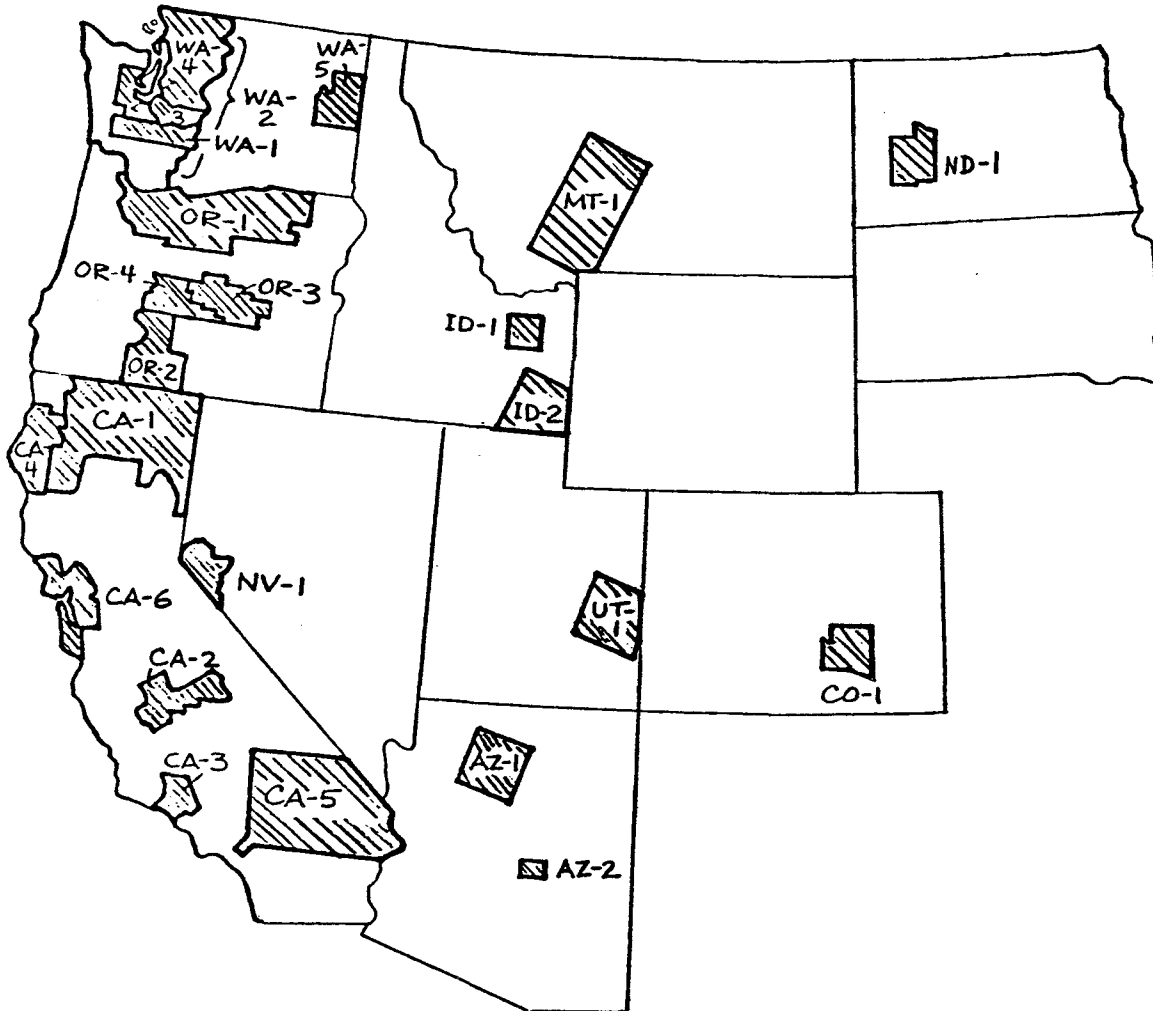
Figure 1a. WRAP demonstration areas.

ALASKA

HI-3

HI-2

HAWAII

HI-1
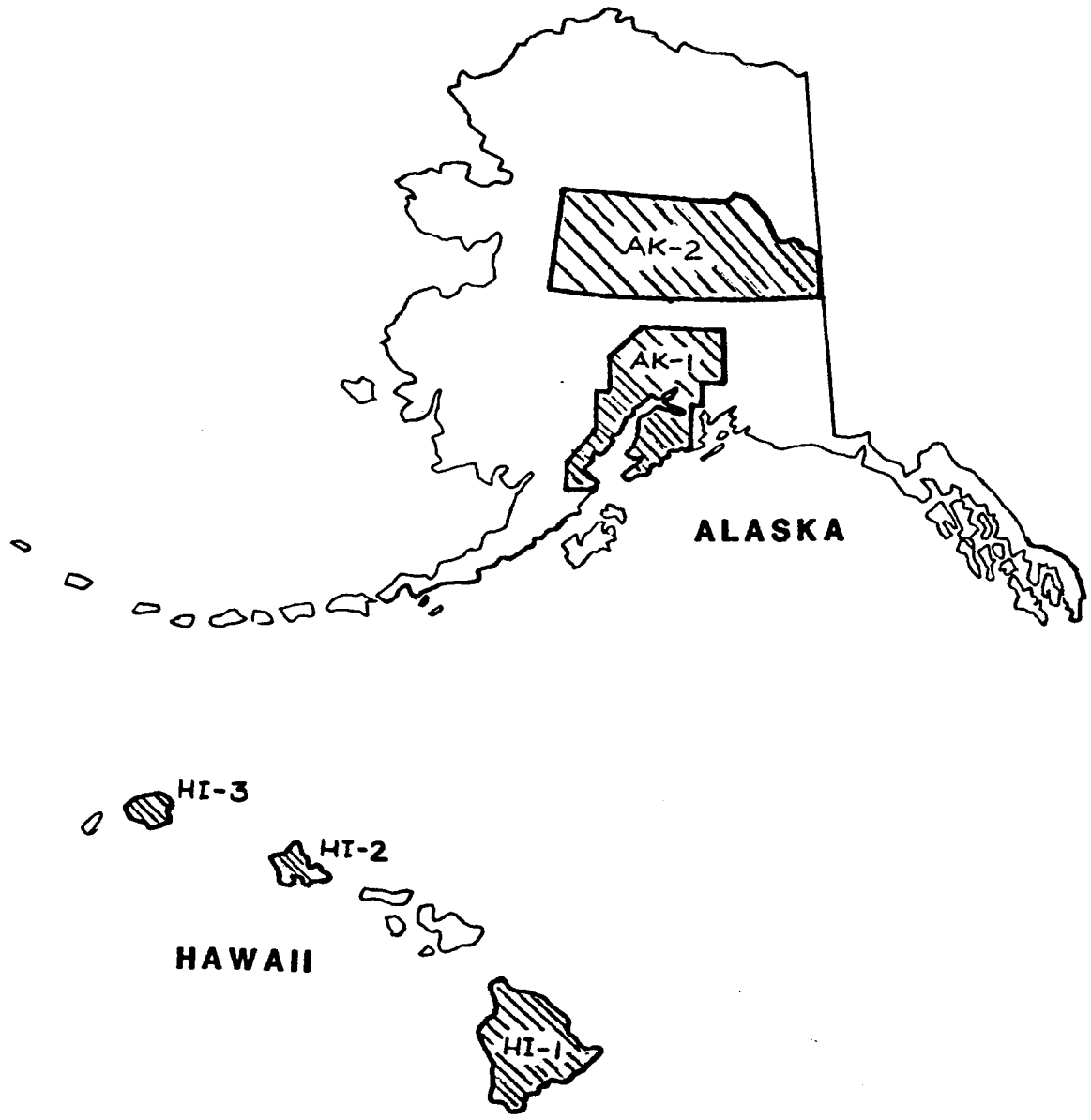
Figure 1b. WRAP demonstration areas. (Continued)

34
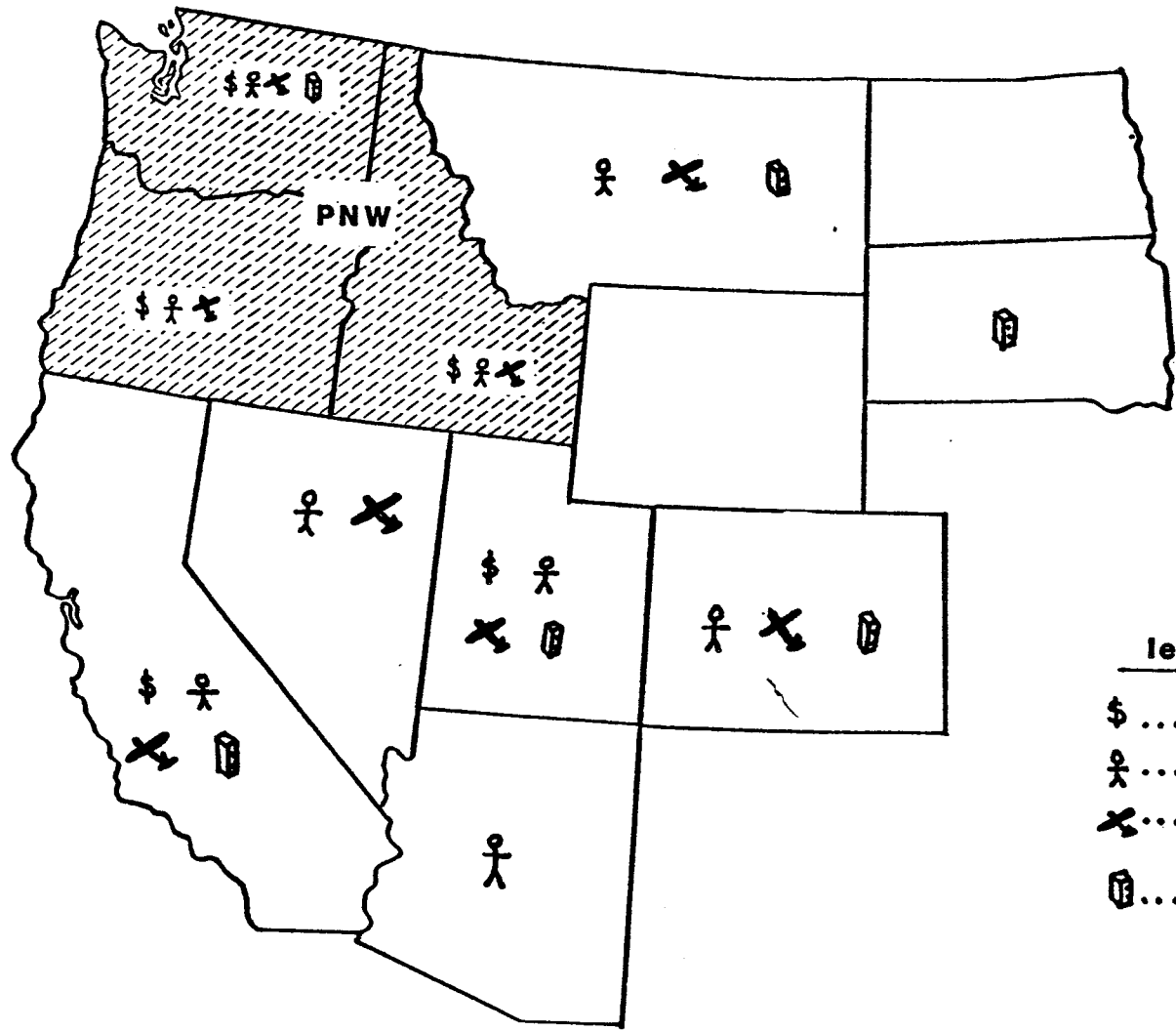
legend

$ ... funding

⚥ ... staff

✈ ... travel to Ames

▓ ... GIS

Figure 2a. WRAP state participation.

ALASKA

$... ⸙... ✈... ▯

HAWAII

⸙... ✈

legend

$... funding

⸙... staff

✈... travel to Ames

▯... GIS.
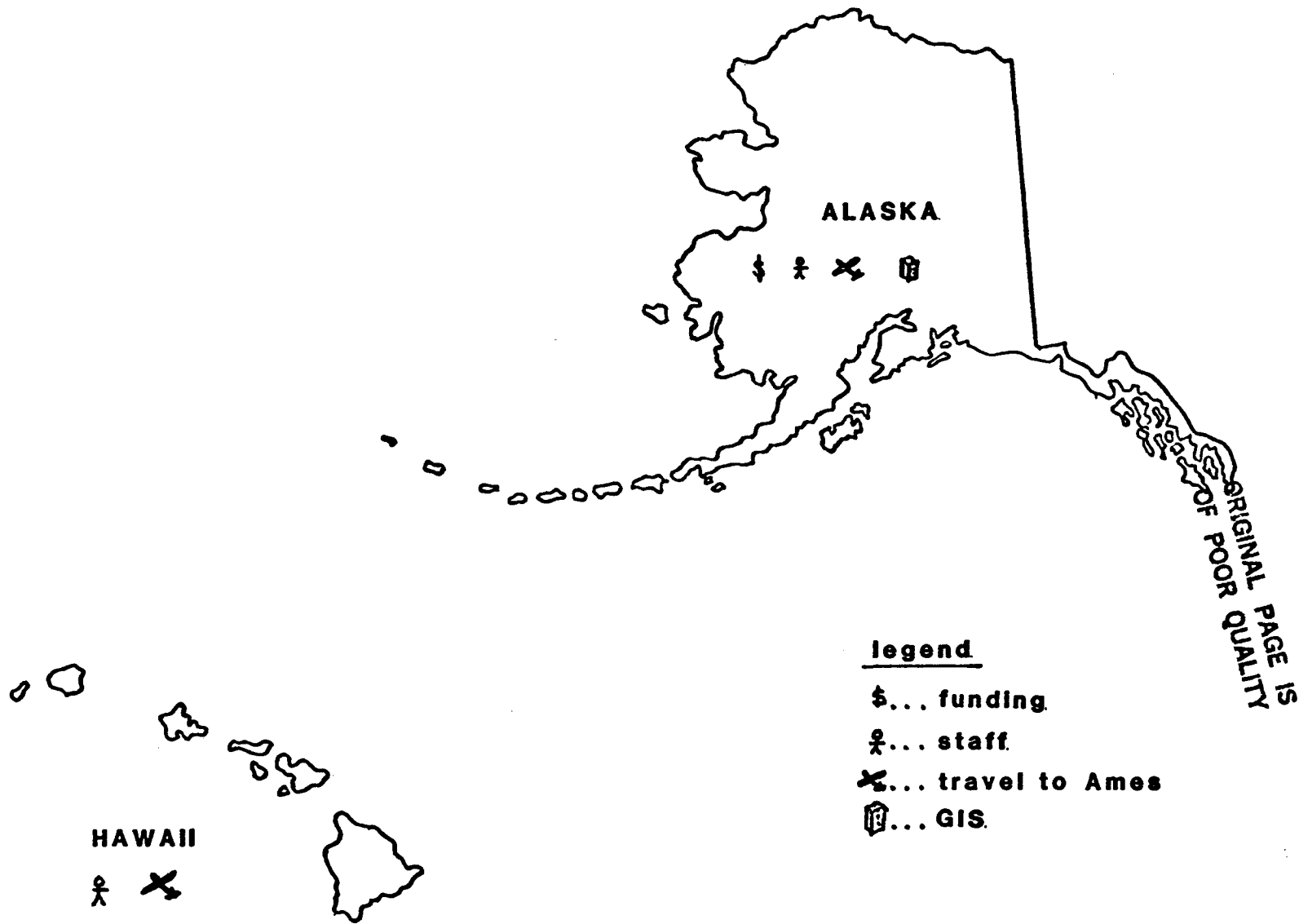
Figure 2b. WRAP state participation. (Continued)

LAND COVER INVENTORY DEMONSTRATION
USING LANDSAT CLASSIFICATION
WASHINGTON STATE - PUGET SOUND
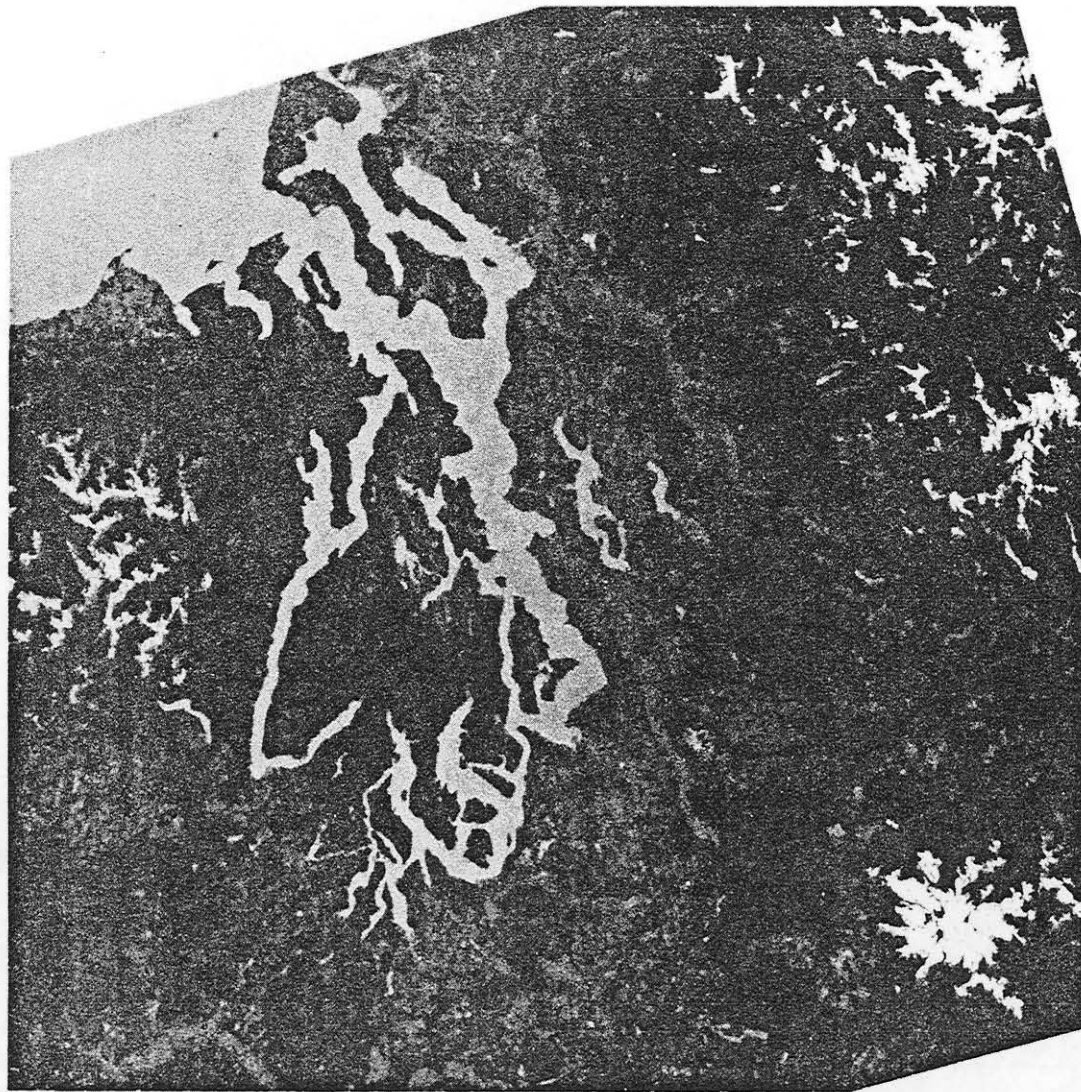
Land Cover

Residential

Wooded Residential

Mobile Homes

Commercial/Industrial/Quarries

Pavement

Cropland

Grass/Pasture

Clear Cut

Brush

Deciduous

Mixed Forest

Regrowth Conifer

2nd Growth Conifer

Old Growth Conifer

Water

Sedimented Water

Wetland

Barren

Ice/Glacial Debris

Snow

Shadow/Border

37

Figure 3. Land cover inventory demonstration using Landsat classification.
Original in color (contact author).

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NASA'S EASTERN REGIONAL REMOTE SENSING APPLICATIONS PROGRAM

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INTRODUCTION

Probably one-half of the people present here today have been officially or unofficially in contact with the eastern regional program for the first time through their invitation to this conference. So, for you this is an opportunity to learn something of what ERRSAC is doing, or trying to do, and some of the methods used. One of the main reasons for holding this conference is to allow the participants to share experiences, needs, and observations about what has worked successfully and what has not worked. You are much better authorities than we can be, at least in terms of what state resources and needs are, on whether or not the technology is going to work in your state.

I am going to show you in the next set of vugraphs some aspects of how the regional program works, and review what we've done over the past nine months. Those of you who were involved with us in Goddard projects will see that you're not alone.

Geographically, ERRSAC is the smallest of NASA's three regions. Alaska, for example, would overlay most of our region. However, there are more states in Goddard's region than in either of the other regions, and practically every state in our region has more people in it than Alaska. Transferring Landsat technology to state and local governments hinges on interaction with people, individually or as a part of agencies and organizations, and dealing with environmental and resource management information needs that vary from state to state.

ERRSAC'S GOALS

There are really two goals in the Regional Program. One is the establishment of capability for using Landsat technology in your state institutions, in your organizations, in something that can be called an operational mode. But this is only the first step. Most of you who are involved with us now are working on that first stage of establishing capability. Some of you are wondering what will happen next. We have a further responsibility to assist people in improving that capability, handling new data, introducing new techniques as they become available, and in building and nurturing the technology within their own organizations. To do this, we will undertake or support techniques for application development. We will provide workshops and documentation to pass this on to you, the user.

ACTIVITIES

There are several faces that ERRSAC exhibits to its user community. One is what we call a "user liaison" activity. This conference represents such an activity—an interchange of ideas and communications among people, and between us and people in our region. We have also provided numerous briefings to user groups. We have participated in state workshops, in New Jersey and New York, for example. We have attempted to develop communications with the federal agencies that place responsibilities on states, or which work with states in responding to federal regulatory actions (e.g., EPA).

We are also involved in what we would more generally call "user awareness" activities. We have a remote sensing information center which both assists us, and the people from our region working with us, in determining the availability and suitability of Landsat data. Our center has access to the EROS Data Center, for example, to conduct data searches. We provide a quarterly remote sensing newsletter, Reflections. Many of you are already on the mailing list; you all will be on it by the end of this conference.

You will have found in your registration packet some examples of the various brochures and surveys that we publish. In them we try to share with you observations on technology and applications that seem to have worked, or seem to have potential. We will attempt to summarize those projects which appear to have potential value to people in other states. We conduct surveys of equipment and facilities, hardware and software, applicable to remote sensing technology.

Last spring we initiated at Goddard a series of one-day remote sensing orientations. These orientations try to answer fundamental questions concerning such topics as: what Landsat remote sensing is about, what some of the applications are, and why and how to use computer processing. These sessions are intended for those who are interested in understanding enough about Landsat to determine whether to pursue it further. Seven of these workshops, for approximately 123 people, were held between March and July of 1979. Most of the participants were from areas close to Goddard, as you might expect. A number of attendees came from private industry, a lot of them in the environmental consulting business, where they are beginning to find themselves in situations much like that facing many of the state agencies. Landsat analysis will occupy only a relatively small, but important, fraction of the total amount of effort they have to put into various projects, and they are not sure they can afford the risk of examining the technology seriously on their own.

Our major effort is in state programs, to provide training and project experiences to people in state and local government. About 60 people have participated in our one-week training programs during the past year. These training activities are more properly called project preparation. We are really trying to prepare people to conduct a cooperative Landsat demonstration project, the intention being that the project itself will be the major learning experience. In one week, no one can become a remote sensing expert, but with enough grounding in Landsat technology and the use of Landsat as a tool for the interpretation of data, the participant can learn at his own pace, while working with ERRSAC in cooperate projects. Ordinarily, training activities are specifically linked with project activities. These one-week training programs are not conducted except in the larger context of state (or other user) programs.

There are a few other training activities besides this one-week project training course. For example, a training program was conducted in Vermont on the use of the ORSER software system obtained by the University of Vermont (from Penn State University) and installed in their computer. Our people spent a week with university and state people teaching them how to use their software system for Landsat data analysis. There will be a similar training program at Goddard, for people from the University of Maryland and the State of Maryland to use an analysis software system recently installed at the University of Maryland. In the future, shorter training sessions will be conducted on specific techniques and applications, arising both from this program and various research programs.

The core of our work, the most identifiable aspect at least, is the cooperative Landsat demonstration project. We emphasize the cooperative aspect, because the only way in which people can learn a new technology is by becoming involved in it themselves. ERRSAC is now involved in between 30 and 35 cooperative projects in a number of different states. The commitments that the user must make are personnel time, and use of state facilities and data, to the extent that they exist, and to the extent that the project demands. Personnel time is crucial and it is not something we can hide. We have to start out, with management's approval, to spend some fraction of a man-year on a cooperative project. On the other hand, ERRSAC's major role is to teach you as much about Landsat remote sensing as you need to carry out the project, to work with you in the development of the project, to assist you in working at Goddard and in carrying out key phases of the project, and to help you in final product development.

The major areas of project interest have been forest inventory, water inventory and water clarity, and land cover change detection. With so much of the northeast forested, a forest inventory is almost by definition a land cover inventory.

Another whole category of activity, unfortunately easily overlooked, falls under the heading of technical assistance. This includes assisting people in adopting software, in modifying software to work on their computers, in identifying hardware that they can use and can tie in to their computer systems. ERRSAC provides demonstrations of specific types of capabilities, briefings, and technical demonstrations for user organizations.

A second element of the regional program is the university community. Our main purpose is to work with state and local governments and transfer to them the capability of using a new tool. But it turns out, as we anticipated, that particularly in our region, the universities have a key role to play in this. And so, we do have a university program. It is secondary in terms of our priorities, but still an important part of the ERRSAC activity.

One aspect of this is our Summer Faculty Intern Program. In that program, faculty members from universities in our region come to Goddard for 10 weeks in the summer to acquire some intensive training, at a level that probably goes a bit deeper than state people have the time for, and to work on a mini-project for the duration of the summer activity. At this stage ten people from nine states have graduated from this program over the last two years, and they have become very useful resources for state and local governments in their respective states. They've gone back to their various

states with the capability of assisting people in processing and analyzing Landsat data, and even in knowing whether they should be processing and analyzing Landsat data.

We provide various kinds of technical assistance to universities in developing their own skills or their own capabilities inside of and outside of a statewide program. It is an investment that pays for us because it pays off for the states.

In at least ten states in our region (Vermont, Minnesota, and Wisconsin are good examples) universities are already closely tied to state agencies, and are or will be part of any statewide Landsat program. Roughly one-fourth of the 120 or so non-NASA attendees are university faculty, often official members of various state delegations. This reinforces, I think, the close, integral role that universities have to play in state Landsat applications in our region.

CONCLUSION

In conclusion, I hope this conference will be what we intended it to be—an opportunity to share with each other experiences and observations on the needs and technology that can help everyone. I hope you will share those observations with us as well, so we can serve you better. A number of people from Goddard's Regional Applications Center are going to be here today and tomorrow, and they will be able to help you with questions and details about ERRSAC programs, and the ways in which Landsat might be able to help you in your activities.

For those of you we have only just met, we will attempt to start dealing with you in terms of a Regional Program starting with this conference. We admit to not having pursued you. We are well aware of the limitations of resources, primarily manpower. And I would not encourage people to explore further the possibility of a cooperative Landsat applications program in their own state unless ERRSAC is prepared to work with them. We haven't been able to do this in the past year; we've had our hands full with the six or eight states we have been working with.

But this is the time for you to start developing those communications and relationships that can lead to our working with you in your state and substate programs.

SESSION 2

N83 21424

LAND USE PROJECT
(COMPARISON OF LANDSAT
WITH AIRCRAFT-DERIVED LAND COVER DATA
FOR A PROPOSED HIGHWAY PROJECT)

Thomas Rugoski
formerly Maryland Department of State Planning
Baltimore, Maryland
(now employed by Defense Mapping Agency,
Rockville, Maryland)

PROJECT OBJECTIVE

This project was one of several demonstration projects undertaken cooperatively between the State of Maryland and ERRSAC. The objective was to develop a general land cover classification with Level II separation for vegetation categories for a 95,000-acre study area in Howard and Anne Arundel Counties located in the north-central section of the state. We hoped to establish an acceptable accuracy rate for each land cover type identified.

DESCRIPTION OF STUDY AREA

Figure 1 shows the boundary of the study area and its approximate location in the Baltimore-Washington corridor. The corridor has a primarily suburban-type configuration with scattered areas of forested, agricultural, and open land and is expected to experience considerable commercial, industrial, and residential growth in the future.

The area was originally surveyed in 1977, as part of a State Highway Administration highway extension project. The Department of State Planning was contracted by the Highway Administration to create a data base at a scale of 1:24,000 and to encode the desired physical and cultural variables to permit computer analysis and mapping on State Planning's Maryland Automated Geographic Information (MAGI) System. The most important variable mapped for this project was a Level IV land use classification map comprising 78 levels of land use types. This map was prepared by the Earth Satellite Corporation which they interpreted from State Planning's high altitude infra-red photography, flown April 12, 1977 at an altitude of 65,000 feet.

The photography used for this project and the accompanying land use map provided the excellent source of ground truth necessary to do a good classification of a Landsat scene. After reviewing a series of black and white Landsat transparencies, it was ascertained that our area of study was designated the "Baltimore-Washington Scene" and had the Landsat worldwide reference system coordinates 16-33.

PARTICIPANTS

DEPARTMENT OF STATE PLANNING

PROJECT SITE

PORTIONS OF HOWARD AND ANNE ARUNDEL COUNTIES
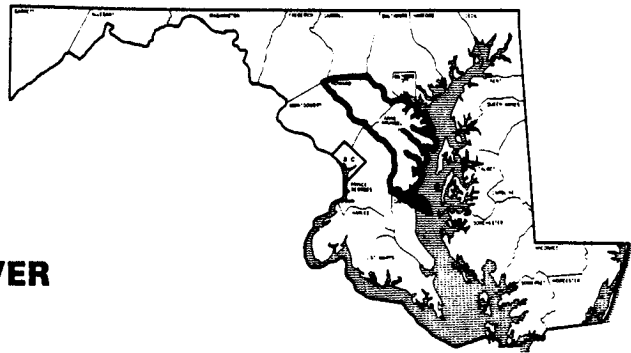
PROJECT GOALS

- **OBTAIN LEVEL II LAND COVER CLASSIFICATION**

- **COMPARE LAND COVER DERIVED FROM LANDSAT WITH TRADITIONAL SOURCE**

Figure 1. State of Maryland land use/
land cover project.

BACKGROUND - MAGI

A brief explanation of MAGI is in order, since it is State Planning's prime tool for analysis and assimilation of classified Landsat data. The computer-assisted MAGI system is used for the storage, retrieval, manipulation, and display of geographic grid-referenced data (see Figure 2). It was developed for State Planning by the Environmental Systems Research Institute of Redlands, California. Implemented in 1974, the system was designed to assist the Department in the preparation of its Generalized State Land Use Plan. Since that time, the system has been expanded and significantly improved, resulting in greater structural efficiency, lower operating costs, and greater user flexibility. The system has also been used extensively by other state agencies for land and water resources analysis.
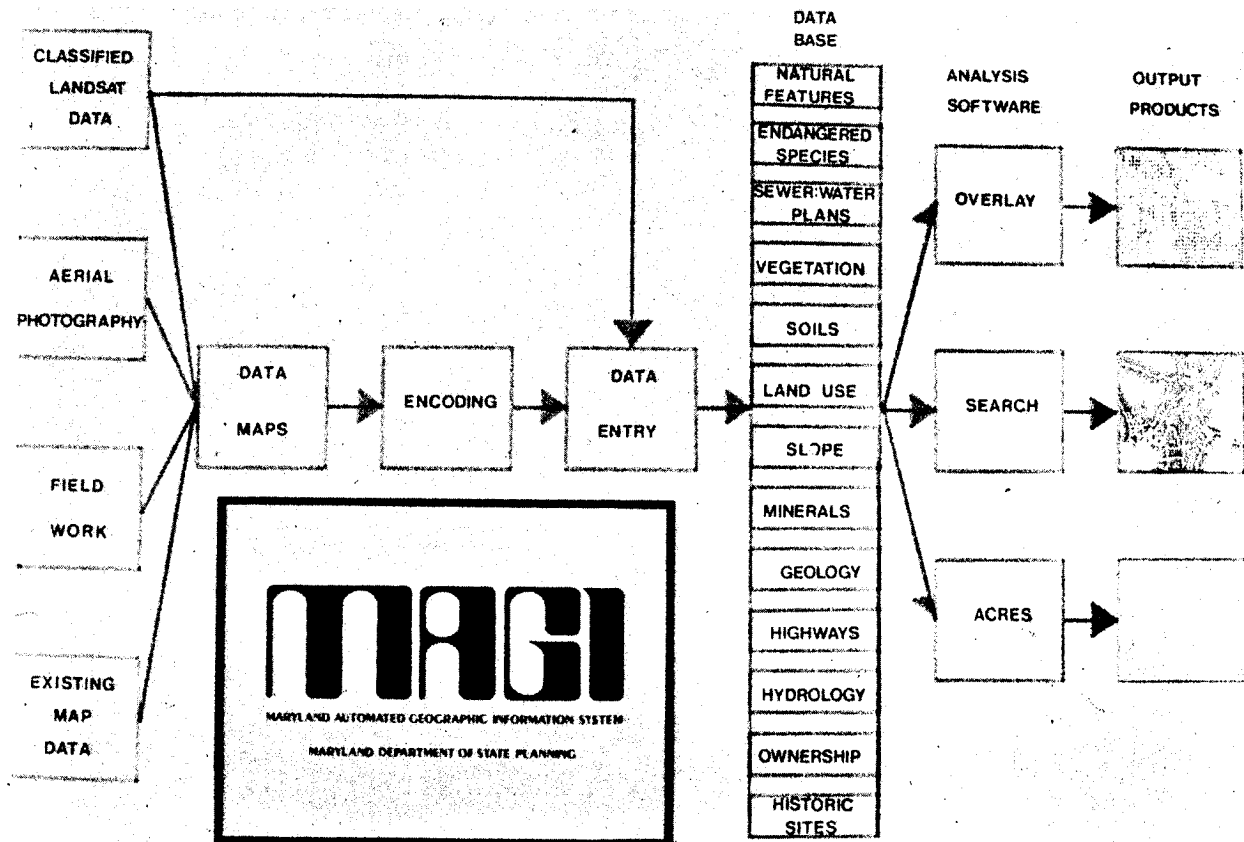
Figure 2. Maryland Automated Geographic
Information System (MAGI).

As initially developed, the MAGI system consisted of a central state-wide data base containing nearly 88,000 grid cells of 91.8 acres and a package of linked software subroutines. As now comprised, the data base includes computer-stored data as well as data base maps, technical manuals, supporting text descriptions (library lists), and tabulations. The MAGI software package is capable of manipulating data at any size and scale. Other larger scale, but limited area data bases, have subsequently been structured for special analyses within the state.

PROCEDURE

Our digital analysis for this project was done on the ORSER (Office for Remote Sensing of Earth Resources) System operational at Pennsylvania State University. The Penn State computer was accessed via telephone line, and all output maps were printed on the terminal at State Planning.

We were interested in three different types of output products: hard copy line printer maps, color polaroids, and a tape of the classified data that could be directly read into the MAGI system. With the implementation of a software package written for us by NASA, we can directly interface classified Landsat data with any of the 28 variables, or combinations thereof, already stored in MAGI.

The standard series of ORSER analysis routines was run on the study area. For display and ease of location purposes, we will concentrate only on a subsection of the study area centered around the Rocky Gorge Reservoir, a very distinguishable natural feature.

A program called NMAP was used to obtain a brightness map, with the values grouped into a desired number of categories, of the subsectioned area. The primary use of the NMAP is to assist the user in recognizing and correlating blocks of Landsat data with similar blocks seen on aerial photography. From this map we can see a definite pattern of the darker symbols cutting horizontally across the center. This feature is recognizable as the Rocky Gorge Reservoir. The other symbols are associated with assorted agricultural fields, and forested and residential areas.

A UMAP was also run on the study area in order to obtain a map which displays areas of spectral uniformity and nonuniformity, with the symbol U representing the areas of highest uniformity. This type of map is especially useful in identifying statistically similar areas for input as training fields in subsequent analysis programs.

Training fields for each of the desired land cover classes were then developed and run through the STATS program. This program outputs the means, standard deviation, variance-covariance matrix, frequency histogram, and the eigenvalues and eigenvectors. This information was analyzed, and necessary changes were made in training fields that were not statistically acceptable.

Once acceptable values were obtained, the information was input into the classification routine with the following results. Several map versions of the classification were produced: one which identified water, with the major feature being the Rocky Gorge Reservoir; a second map displays the same water areas (shaded in blue) plus the surrounding forested areas; a third map again displays the water, plus the surrounding residential areas, and a fourth map displays the same area with all 11 land cover categories displayed.

To prepare the data for final output product generation we had to rotate, scale, and geometrically correct it. The ORSER system uses two methods to cartographically correct an image. The first computes correction formulas for known distortions and applies them to the data. The second uses ground control points located by coordinates on the image and on the control map and computes a series of polynomials that are used to rubber-sheet stretch the data. To achieve the most accurate correction we used both methods. This final output map was also scaled to 1:24,000 (quad scale).

A final output tape was also cut and sent to Goddard for generation of more sophisticated display products. The entire study area, after being processed on Goddard's IDIMS image analysis system, is shown in Figure 3.

The most important part, the accuracy analysis of the classified data, will be discussed next.
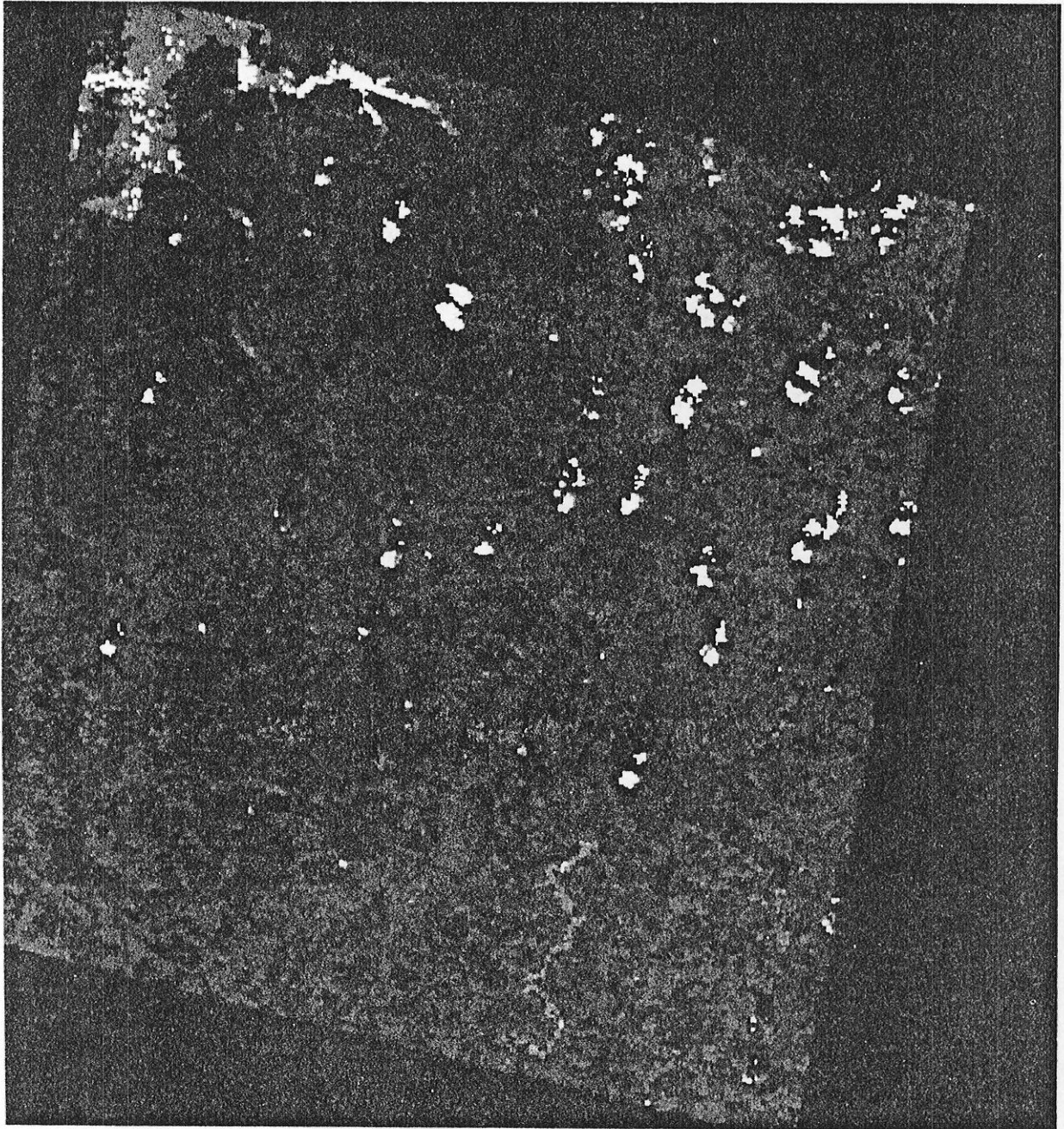
LEGEND:
   BLUE – WATER
   GREEN – FOREST
   PURPLE – RESIDENTIAL
   ORANGE – CROPS AND A   PASTURE
   BLACK – TRANSITIONAL
   WHITE – CLOUDS AND UNCLASSIFIED

Figure 3. Land cover map of study area, portions of Howard and
Anne Arundel Counties in Maryland.
Original in color (contact author).

49

RESULTS AND EVALUATION

To facilitate the development of this preliminary presentation, the accuracy analysis was performed on two subsections of the entire study area. Two 2,000-acre subsections were chosen as representative samples of the diverse land cover patterns that occur within the entire area.

The 1:24,000 scale land use map and the high altitude infrared photography mentioned earlier were determined to be the best source of ground truth for the analysis. Using these two sources, a land cover map was drafted for the same two subsectioned areas and later used as the basis for accuracy determinations.

The first step in the accuracy assessment was to determine the acreage figures from the same area for each land cover type using both the ORSER and photo-interpreted approaches. Tables 1 and 2 show the acreage and percent of study area figures determined from both approaches.

Table 1 shows that subsection 1, according to photo-interpreted figures, is a predominantly residential area (72.3%) interspersed with pockets of crop and pasture (23.3%) and forest (3.5%). The corresponding figures from the ORSER Landsat classification are residential = 50.3%, crop and

Table 1

Test Area 1 — Residential

Land Cover Types	Land Cover Classification				Land Cover Comparison* % Difference	
	Photo-Interpreted		Landsat-Derived			
	Acreage	%	Acreage	%	Omission	Commission
Residential	1,400	72	1,005	50	22	—
Crop/Pasture	451	23	690	35	—	12
Forest	69	4	132	7	—	3
Transitional	15	<1	2	<1	—	—
Water	—	—	2	<1	—	—
Unclassified	—	—	165	8	—	—
Total	1,935	100	1,996	100	—	—

*Note: The photo-interpreted data are taken as the standard.

50

Table 2

Test Area 2 — Rural

| Land Cover Types | Land Cover Classification | | | | Land Cover Comparison* % Difference | |
| | Photo-Interpreted | | Landsat-Derived | | | |
	Acreage	%	Acreage	%	Omission	Commission
Residential	226	11	280	14	—	3
Crop/Pasture	938	47	697	35	12	—
Forest	836	42	947	47	—	5
Transitional	—	—	—	—	—	—
Water	5	<1	—	—	—	—
Unclassified	—	—	73	4	—	—
Total	2,005	100	1,997	100	—	—

*Note: The photo-interpreted data are taken as the standard.

pasture = 34.5%, forest = 6.6%, with 8.2% of the area unclassified. The correspondence between these figures for residential and crop/pasture are only fair. This low correspondence can be misleading as to the accuracy of the ORSER classified data. This table also shows the omission and commission percentage differences. The omission rate of 22% for residential areas and the commission rate of 12% for crop and pasture areas can be placed in a better perspective when one realizes that the residential lot size in this area is, in many cases, quite large. This encourages the interspersing of grass-covered areas (lawns) and wooded areas between the actual housing units. This could account for the high commission error rate for crop and pasture and forest, and thus contribute to the large omission rate for residential. These would not be considered errors then, but would point out differences between the two methods of interpretation rather than real differences in the actual land cover.

Subsection 2 displays a predominantly rural landscape, with crop plus pasture and forest accounting for 46.7% and 41.6%, respectively, of the area and residential accounting for approximately 11.2%. The ORSER/Landsat figures indicate that the area is 34.9% crop and pasture, 47.4% forest, and 14% residential, with about 3.6% unclassified. These figures indicate a much higher degree of correspondence, as shown in Table 2. These omission and commission rates are much lower than the rates described for the first subsection. These rates alone, however, could still be misleading as to

the accuracy of the Landsat data. It was discovered that this area encompasses a feedlot activity dominated by the interspersing of poultry houses. These poultry houses were mapped from the aerial photography as part of the crop and pasture category, whereas ORSER interpreted them as being residential buildings. Taking this into account, these error rates could be reduced by as much as one-half. This, again, points out differences due to the methods of interpretation and not related to the accuracy of the interpreted areas. Taking this into consideration, the ORSER/Landsat classification for subsection 2 had an accuracy rate well within the acceptable limits for our needs.

The results of the accuracy comparison of Landsat and aerial photography were averaged over the two study areas. The success of the two classification methods, on the average, is shown in Table 3. As expected, the residential class experienced the greatest overall error rate. The other land cover types fell within 4 percent of each other.

Table 3
Comparison of Landsat and Aerial
Photography Study Results

State of Maryland

Land Cover Types	Landsat- Derived Avg. %	Photo- Interpreted Avg. %
Residential	32	41
Crop/Pasture	35	35
Forest	27	23
Transitional	0	<1
Water	0	0
Unclassified	6	—

CONCLUSIONS

Several conclusions were drawn as a result of this study:

- Delineation of deciduous and coniferous forested areas from Landsat data compared well with results from infrared photography.

- General classification of agricultural areas showed acceptable results.

- Delineation of residential areas had the highest error rates. However, the difference in interpretation and cover type assignment methods was determined to be a primary factor.

- The Maryland Department of State Planning will use Landsat-derived land cover data as an ancillary data source in the 1980 statewide land cover inventory.

The Department of State Planning has strong hopes of continuing the investigation into the usability of Landsat-derived data on a statewide basis. We feel the integration of Landsat data into the MAGI System, the prospect of using more detailed RBV imagery, and the finer spectral and spatial resolution planned for Landsat-D will greatly improve our data gathering capabilities, which will eventually aid in the executive decision-making processes.

THE VERMONT COOPERATIVE LANDSAT LAND COVER INVENTORY PROGRAM

Part I

Roy Whitmore
School of Natural Resources
University of Vermont
Burlington, Vermont

The presentation from the state of Vermont will be given by four of us who are very involved in various projects within the total Vermont Landsat program, Virginia Garrison, Gary Smith, Dennis Malloy, and myself. My job this afternoon will be, basically, to provide some background information concerning Vermont's involvement with Landsat. The Vermont project was conceived in the spring of 1978, when the School of Natural Resources at the University of Vermont applied for and received a grant from the University Applications Branch of NASA. That project had a few specific objectives, one of which was to increase our own in-house expertise so that we would be in a position to transfer various types of remote sensing technology to users within the state.

Several people from the University, myself included, received fairly intensive training at the Goddard Space Flight Center during June of 1978. At that point we had not yet become involved with the ERRSAC program. But while I was at Goddard in June of 1978, I received a telephone call from the Vermont Department of Forests, Parks, and Recreation at Montpelier. I was informed that it appeared that Vermont was going to suffer a severe infestation by forest tent caterpillers that year. There had been a fairly heavy infestation and subsequent defoliation during the previous summer, and the entomologists indicated that based on their field work and observations (egg and egg-nest count examinations, for example), Vermont was going to have a bumper crop in 1978. The Department of Forests, Parks, and Recreation learned that we were getting into the Landsat business, and they wondered whether there was anything we could do to help.

The bugs did come; however, the entomologists learned that somewhere in one of the early instars of the insect, there was a viral infection which greatly diminished the population. The result was that the defoliation was not as heavy as had been anticipated. However, we decided to go ahead with a Landsat analysis in spite of this.

Although we did not, at that time, have the capability to process Landsat data at the University, we did receive the cooperation and assistance of the Landsat group at Goddard (ERRSAC). One of the staff members of the Department of Forests and Parks and I came to Goddard with a variety of photographs and USGS quadrangles indicating the defoliated and nondefoliated areas. Through the cooperation of our neighbors in Canada we received some up-to-date Landsat imagery (July 7, 1978) in a very short period of time. Also, the computer tape of that image arrived at Goddard and

we decided to see what we could do through digital processing. We had no trouble delineating the general areas where the defoliation had taken place, but unfortunately we were unable to delineate specific areas which had been defoliated by the forest tent caterpillers, because of the much lower than anticipated populations that occurred. The defoliation did not follow the normal pattern; it took out select portions of the overstory of the forest areas while leaving other portions, and it did not affect the understory at all.

We did not give up however, at that particular time. We decided to work with another Landsat data set that was obtained on August 22, 1978. At that time, the trees which had been defoliated had refoliated. We were working under the assumption that there would be a spectral difference between refoliated trees and the trees which had not been defoliated. Again, unfortunately, we met with failure because we were unable to pinpoint the areas that had been defoliated.

We found this out after only about two days' work on the IDIMS system at Goddard. We had planned to stay several days longer, and we decided to utilize that time to see what we could do about a forest cover classification for the state of Vermont.

Vermont is a comparatively small state, and it would seem likely that because of its small size, we would already know everything that we needed to know about the forest resources of the state. In general, we do. We can tell you, for example, that the state is 75 percent forested, and we can give you some fairly reliable county figures. But there has been a great deal of interest in much more intensive data, going right down to the town level. The basic unit of government in Vermont is the town. There are 252 towns in the state, so if you divide Vermont's 10,000 square miles by 252, you get units of roughly 40 square miles in area. And there is a great deal of interest in having fairly specific information as to the area of forest cover in units such as this. People in the state government were unable to supply this type of information in a timely fashion.

In a very short period of time on the interactive system we were able to produce a Landsat classification product that checked against the aerial photographs we had with us, which was our available ground truth at the time. The product looked very good, and when we took these back to Vermont and showed them around, a great deal of interest was generated.

That is what gave birth to our first official project with ERRSAC, a forest cover classification for the state of Vermont. What we were interested in, primarily, was a Level II classification with three breakdowns: hardwoods, softwoods, and mixed stands. And, of course, we also wanted to assign some geographical locations to various acreage sizes.

We were quite pleased with the preliminary product that we generated. It was the first classification study done in the state of Vermont. It is an area located in the central portion of the state (Rutland area), roughly a 512 X 512 pixel area with six basic land cover type classifications: hardwood, softwood, mixed hardwood/softwood, agriculture/urban, water and unclassified. Since, as foresters, we were more interested in forest classification, we simply grouped all urban and agricultural lands together.

Subsequent comparison of the preliminary product with information available to us, including color infrared aerial photography of the state, showed that our classification was between 80 and 85 percent accurate. We did not follow up on that statistically from any other point, since we thought we had enough to get started.

At this point we began doing a lot of talking around the state, giving presentations to key committees in the state legislature and to other groups. At about the same time we began developing our own in-house capabilities at the University. As a result of this, ERRSAC sponsored a week-long remote sensing training course in Vermont. Many people became interested in what we were doing and wanted to know if the classifications that we had done could be expanded in order to cover some of their particular interests. Our immediate answer was "yes."

That led to the development of the current program, which has three specific objectives. The first objective is to demonstrate to state personnel the feasibility of using Landsat data for resource management. The second objective is to establish specific projects that meet the needs for resource management information, and the third objective is to assist state personnel in obtaining technical expertise in the processing and analysis of Landsat data. The third objective was met, in part, by the training session held in January, and since then we have been able to establish a phone line hookup between the state Agency of Environmental Conservation in Montpelier and our computer facilities at the University. We still have a long way to go, but progress is being made.

We have developed several specific projects, and currently our total program consists of three projects. The first of these is a further amplification of our forest inventory project to include a state-wide inventory and an improvement of our initial level II forest cover classification. The second has to do with a watershed land cover inventory, and the third project has to do with land cover change detection.

We have two principal concerns in the state, as far as land use is concerned. One of these is tracking the change from agriculture and forest to urban land use, and the other is the change from agriculture to forest. We have, in essence, two projects examining those types of changes at the present time.

Just a few additional words about the forest inventory project. Those of you who have had experience in working with "forest inventory" know that it is a very broad term. We in Vermont are fully aware that we will not be able to do a forest inventory, as it is generally accepted, in terms of specific species differentiation and volume per acre, with Landsat data. However, we do hope to be able to develop this Level II classification statewide, and to subsequently use these data as the first stage in a multistage sampling procedure for more intensive forest inventory work.

Part II

Virginia Garrison
Vermont State Department of Water Resources
Montpelier, Vermont

I am a biologist with the Department of Water Resources, and my major concern is with lakes in Vermont. In early 1979 I began working on a grant that the Department of Water Resources received from the Environmental Protection Agency (EPA) to classify all of the lakes within the State of Vermont that are larger than 20 acres in size. The grant was set up because Section 314 of Public Law 92-500, called the Clean Lakes Act, requires that all states classify their lakes by 1982 and establish a priority list for lake restoration. Under this law, in order to receive future funding, all lakes must be prioritized.

The grant was developed in 1978 before we were aware of Landsat's capabilities. The classification system was to be based on information gathered using existing facilities including outdated land use maps that were developed from aerial photographs taken in 1960. We were going to have carto-graphers use these maps to determine lake acreages and land use acreages in lake drainage basins. Considering that Vermont has 287 lakes larger than 20 acres, and since we were going to be using cartographers to do the work by hand, it was going to be a massive project, with a lot of people and a lot of time involved.

In early 1979, I attended an ERRSAC "hands-on" remote sensing training program at the University of Vermont to learn about Landsat. At that time, I realized that there was potential for the use of Landsat in our Lake Classification Grant.

In the Section 314 program, we are developing a priority-group listing for restoration. We are also identifying protection lakes which have primarily untouched forested watersheds —that is, they are not culturally influenced. We set up our priority lists according to our basic philosophy of eutro-phication in Vermont. We feel that if lakes are naturally eutrophic, they have inherent recreational value and they should not be changed. However, lakes whose rates of eutrophication have been accelerated by man's influence in their drainage basins may require restoration to bring them back to a natural state. These lakes would be high on our priority list for future EPA funding. In order to determine the extent of the cultural influence on a lake, we decided to use land use practices in drainage basins, and this was where we were going to use existing land use maps. However, I con-vinced Roy (Whitmore of UVM) to expand the Landsat signatures they had developed during a forest inventory, to include lake water, tilled farmland, untilled land, and residential areas. We could then obtain percentages of cultural land (i.e., residential and cropland) in lake drainage basins and this would help establish our priority lakes.

58

We are presently digitizing drainage basins from USGS maps, putting them into the IDIMS system at Goddard, and overlaid these digitized drainage basins onto our classified Landsat maps.

We are eventually going to cover all of the lakes in the state, but we have used a county in northeastern Vermont as our study area. So far we have digitized and overlaid 19 lakes on the preliminary classification. Gary Smith from the University of Vermont will discuss the problems and successes that we have experienced thus far with the program.

Part III

Gary Smith
School of Natural Resources
University of Vermont
Burlington, Vermont

Vermont's statewide inventory is steadily moving toward completion. At the present time, individuals from the University of Vermont, the Vermont Department of Forests, Parks and Recreation and the Vermont Department of Water Resources are engaged in extensive field checks of six 500 X 500 pixel test areas to verify classification accuracies and to identify problem areas. The training statistics and classifications for these six test sites were developed in May 1979 using the IDIMS system at Goddard, and represent the combined efforts of the three Vermont groups and ERRSAC personnel. As anticipated, difficulties in correctly identifying wetlands, tilled land and urban areas have presented the most significant problems. Work thus far has centered around Landsat scenes collected in August and September 1978. Work at the University of Vermont using ORSER suggests that a May scene might also be considered to aid in the delineation of tilled land and wetlands. The possibility of merging two or more of these scenes will also be explored. Additional trials within the capabilities of Vermont's ORSER installation will be conducted in Vermont, with the group returning to Goddard late this fall (1979) to complete the final classification on IDIMS. Final output products will be produced for the entire state and eventually for each of Vermont's 14 counties.

Part IV

Dennis Malloy
Vermont State Planning Office
Montpelier, Vermont

We have just begun a new project here which focuses on Landsat analysis of land use change detection in Chittenden County, which contains the City of Burlington and is the region facing the greatest development pressure here. It is our best candidate for this kind of study both because of the relatively rapid changes in land use and because it contains forests, lakes, several types of agriculture and a good mix of urban uses. As a further challenge to Landsat, much of the terrain is either hilly or mountainous.

We want to see what Landsat can do for us as far as detecting changes in the urban and agricultural uses over a 4- or 5-year period of time. We came down to ERRSAC at Goddard about a month ago with a number of maps and some color infrared photography, and we received a lot of assistance from Arlene Kerber and others. We attempted to pick the best scene in 1974 and the best scene in 1978 covering Chittenden County and to compare the two years, observing what kinds of changes had occurred, in urban and several other categories.

It really was a two-step process. First, we had to identify the best Landsat scene or image in each of the years. Some of the problems present in the Western Region apply to us in Vermont as well. Cloud cover is a significant problem, and snow cover is another problem. In 1974, we had little choice, because there was only one decent pass that Arlene was able to obtain for us, and this pass was in October. In 1978 we had the choice of a May, August, and November pass. We looked at those individual passes in 1978 to determine which was the best to compare with 1974.

It was a much more interesting task than I had anticipated. I had not really appreciated the seasonal differences that came into play in the Landsat imagery, and frankly we're still at the point where we are evaluating the three initial classifications that we had done—from May, August, and November 1978, each giving us tremendously different pictures.

We found that in May, before the leaves really come out in Vermont, the greatest level of detail in urban-type land uses could be seen. We felt that we could break down residential developments into two or three different classes, but they weren't clean. We found that because, in Vermont, fields are not really planted in early May, we were getting a lot of bare or plowed fields mixed in with the residential land uses, especially those under construction. We, therefore, had to opt for the August pass as the best picture of urban-type land uses. We have gone back to our agricultural people in the state, and we are asking them to analyze the three different seasonal passes and to offer their opinion as to which represents the best agricultural land use picture. And we are going to end up with two land use change analyses, one focusing on agricultural land uses and the other on urban type land use change.

A LAND COVER CLASSIFICATION FOR VERMONT

Roy Whitmore
School of Natural Resources
University of Vermont
Burlington, Vermont

M. Brian Stone
Special Projects
Vermont Department of Forests, Parks, and Recreation
Montpelier, Vermont

Vermont is a small state, occupying some 9,300 square miles. Approximately 75 percent of this land area is covered by forests. Information about this forest cover is needed for the development of management plans, to monitor and regulate forest practices, and to promote and encourage forest product development.

The current project grew out of earlier cooperative efforts by the Vermont Department of Forests and Parks, the University of Vermont, and the Eastern Regional Remote Sensing Applications Center to detect and assess the extent of defoliation caused by forest tent caterpillars. The effort was not successful but did result in reasonably good forest cover classifications of the test areas. Products developed from these efforts were shown to state and university personnel who saw the usefulness of such data. From these beginnings, the current program developed as a cooperative effort by the three agencies.

This program has three objectives:

(1) Demonstrate the feasibility of using Landsat data for resource management;

(2) Establish projects and meet state needs for specific resource information; and

(3) Assist state personnel in obtaining technical expertise in the processing and analysis of Landsat data.

Two projects were initially developed involving land cover classification. The first of these involved statewide forest cover classification, while the second involved an inventory of lakes and ponds with areas greater than 20 acres, and classification of land use within their respective watersheds. Subsequent investigation showed that the objectives of both of these projects could be met in a single effort.

State and University personnel collected ground truth information for a series of test areas across the state. The training data for these tests were interpreted from 1:80,000 color infrared and 1:20,000 black-and-white aerial photos. In consultation with ERRSAC personnel, suitable Landsat imagery was selected and reviewed for its suitability to the project. Due to orbit differences and the availability of cloud-free images, three scenes representing two different dates during 1978 were selected to provide the needed coverage. Computer compatible tapes for these three scenes were acquired for processing on the Interactive Digital Image Manipulation System (IDIMS) at Goddard.

Several preliminary classification maps were produced utilizing the training site data provided by state and university personnel during several work sessions at Goddard. These classifications delineated hardwood, conifer, mixed hardwood-conifer, tilled agricultural, untilled agricultural, water, and urban areas.

These products will be checked to determine the accuracy of the classification when extended beyond the training site areas. After fine tuning the classification, appropriate portions of each of the three scenes will be classified, merged, and a digitized boundary outline inputted to provide acreages for each category and a statewide classification map. Completion of this project and its subsequent products is expected in early 1980.

The forest cover classification data can be broken down to provide comparable data for specified areas such as counties, towns, and timber and watersheds. These same data will be used as the first phase of a multistage sampling procedure for a more detailed inventory of Vermont's forest resources. They will also provide land cover and use information for the lake and pond watershed inventory. Based upon activities to date, a practical program utilizing Landsat data for land cover and use classification appears feasible.

IRRIGATION SURVEY
IN SHERBURNE COUNTY, MINNESOTA

Dennis Beissel
Division of Waters
Minnesota Department of Natural Resources
St. Paul, Minnesota

Dennis Woodward
Formerly Division of Waters
Minnesota Department of Natural Resources
St. Paul, Minnesota

BACKGROUND

The Minnesota Department of Natural Resources, Division of Waters, is responsible for managing the state's water resources. One of the management tools used is a permit system which helps regulate and document water use. Since ground water, when available, is a more reliable source of water than surface water, it is preferred for high capacity water needs in Minnesota. The mid-70's drought prompted a large increase in ground water use, particularly for agricultural irrigation and municipal supply. There are approximately 3,600 irrigation wells in Minnesota, half of which were installed after the 1976 dry period.

The Division of Waters is completing a project to inventory the high capacity wells in the state. Municipal, industrial, and commercial wells can be located by file search, field inspection, and personal interviews. Irrigation wells can also be located this way if the owners have obtained the required water use permit (see Figure 1). However, approximately 20 percent of the irrigation wells in the state are operated without permits. Field checking of well locations can only be economically done on a case-by-case local project basis. Therefore, a search method is needed which provides a synoptic view through time and which can be applied statewide. A demonstration project, developed through ERRSAC with the Minnesota Department of Natural Resources (Division of Waters), was initiated with Sherburne County in east-central Minnesota as the project area (see Figure 1). Landsat data from the 1978 irrigation season were chosen for analysis.

INTRODUCTION AND PURPOSE

Approximately 70 percent of Minnesota's irrigation is with center pivot distribution systems whose diagnostic appearance on remotely sensed imagery is a circular pattern. Landsat imagery has been used successfully for crop identification and irrigation inventories in a number of states (Hoffman, et al., 1976). The circular irrigation patterns in Minnesota can be readily identified on Landsat MSS

- Irrigation Well
1 Sand & Gravel
2 Wind-blown Sand
3 Red Clayey Till
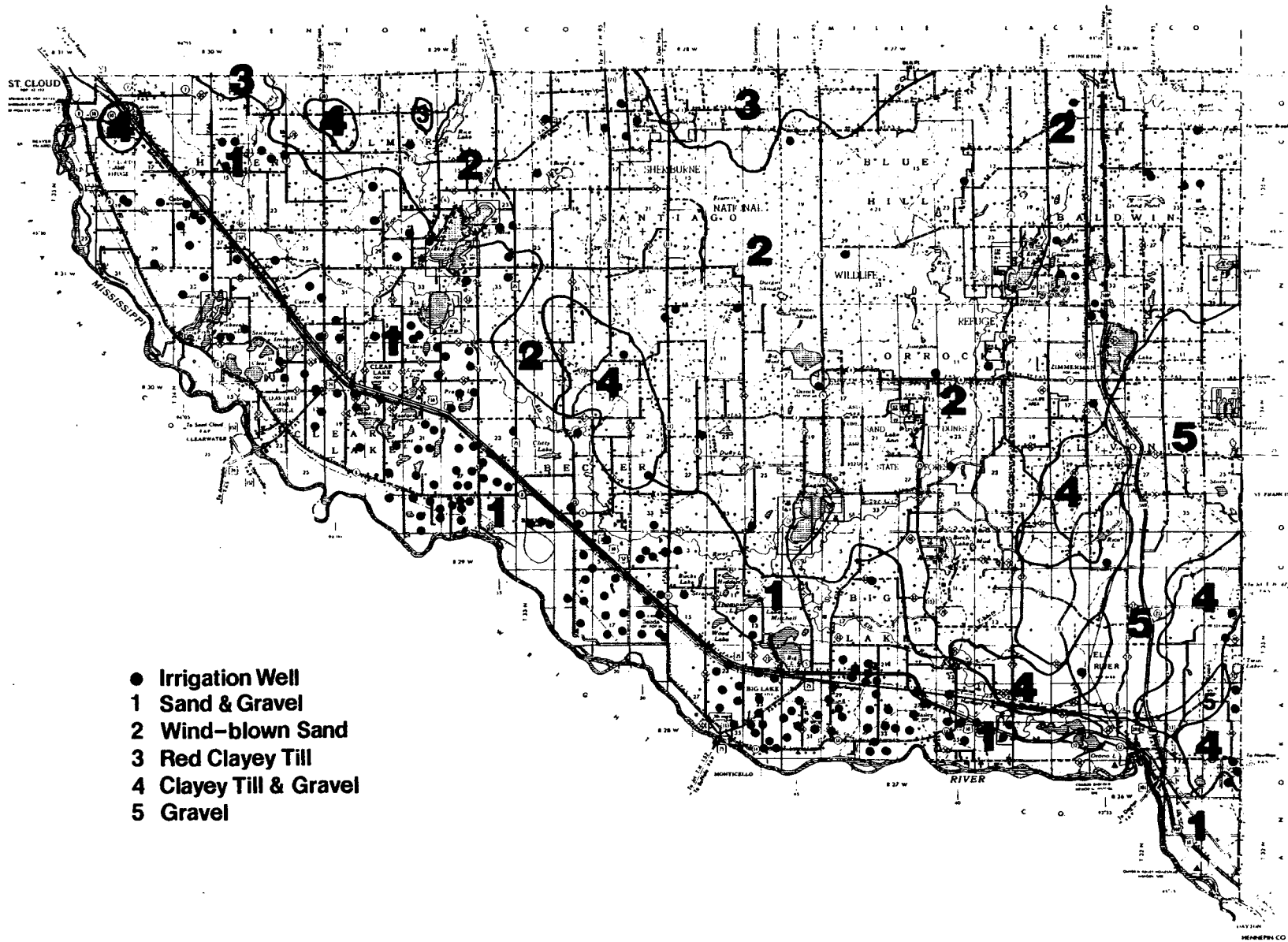4 Clayey Till & Gravel
5 Gravel

Figure 1. Irrigation well locations and soil parent material,
Sherburne County, Minnesota.

band 7 imagery. However, many fields are irrigated with traveling guns, laterals, booms, or cornering systems which either result in angular field patterns or obscure the circular patterns normally visible on the imagery. For demonstration and training purposes, the IDIMS system at Goddard was used to develop a Landsat digital classification of the Sherburne County area, which located irrigated fields regardless of shape, and was not dependent on visual interpretation.

The primary purpose of the project was to locate irrigation wells for which we had no record. Our objective with IDIMS was to contrast irrigated fields from nonirrigated fields and other terrain units. The locations of the irrigated fields were then correlated with known locations of irrigation wells. The "residual" fields not correlated with known wells could then be investigated further to determine the water source used. The result of this process, aside from the additional water use data, would be a considerable savings in personnel time and money needed to update our water use data base.

VARIABLES CONSIDERED AND GROUND TRUTH COLLECTION

As in any classification attempt using Landsat MSS data, there are many variables affecting the reflectance values recorded for each pixel. Climatic conditions, crop type, soil type, soil moisture conditions (irrigated versus nonirrigated), land use (plowed versus undisturbed land), topography, and general terrain units were all considered in ground truth collection and analysis of the reflectance data.

Climatic data, primarily rainfall distribution, were obtained from the State Climatologist's office. Isohyetal maps were produced for accumulated rainfall between the chosen Landsat image dates for 1978. Topography and soil types (Figure 1) were acquired from USGS 7-1/2 minute topographic maps and an SCS soil survey of Sherburne County (Grimes, 1968), respectively. Land use and crop type data were obtained from a Minnesota Department of Agriculture windshield survey and local ASCS crop set-aside program files. General terrain units were determined from the topographic maps and airphoto interpretation. Irrigated fields were located by field inspection and determined from the ASCS files and the hydrology data base of the Division of Waters.

The ground truth and field data were recorded on 7-1/2 minute topographic maps and 1:24,000 scale air photos and then were also tabulated by township, range, and section.

CLASSIFICATION ATTEMPTS

The first classification attempt was made with the ORSER system. The attempt was not successful, primarily due to inadequate ground truth.

A single-date (August 10, 1978) combination supervised-unsupervised classification was tried next, with moderate success, using the IDIMS system at ERRSAC. Irrigated corn was identified along with other mixed crops, but the map produced was not complete enough to help determine well locations. Analysis showed that available crop type, land use, and moisture condition ground data were not adequate for training area selection. A decision was made to collect additional ground truth before any more computer time was used.

65

After more ground truth was compiled, a multitemporal, unsupervised classification using the program Isoclass was run on IDIMS using May 21 and August 10, 1978 Landsat data. Using the available ground truth, the 16 Isoclasses produced were combined into land cover categories, and the resultant photo products were compared to the ground truth maps. The final classification derived from this analysis is shown in Figure 2. The Isoclass combinations and identifiers for this classification are listed below.

Isoclass	Land Cover Category	Color
3, 11, 15	Irrigated Corn	Red
1	Irrigated Alfalfa	Purple
14	Irrigated Potatoes	Light Green
2, 5, 6, 9	Small Grain/Grass	Peach
7	Other Agriculture	Green
10, 13	Trees/Brush	Dark Green
4, 8, 12, 16	Water/Marsh	Light Blue

The highest reliability of the classification appears to be in the glacial outwash sand and gravel shown in Figure 1 as soil parent material 1. This area has little topographic relief and is covered by well-drained (droughty) soils, which accentuate the reflectance contrast between irrigated and nonirrigated fields.

The May 21, 1978 Landsat data provided a contrast between plowed and nonplowed fields, while the August 10, 1978 data exhibited soil moisture (due to irrigation/nonirrigation) and vegetative cover differences. The overall effect of the two-date data set was a greater contrast in reflectance values (which improved the separability over the one-date classification) for selected irrigated crops and other nonirrigated fields and terrain units.

WELL LOCATION IDENTIFICATION

As of 1978, there were 195 known irrigation wells in Sherburne County. Visual interpretation of the two-date classification (Figure 2) revealed about 50 irrigated fields covering an area of about 10 square miles which could not be readily matched with well locations. It is likely that not all of this irrigated acreage is supplied by a ground water source and that some of the fields are misclassified. In addition, crops other than corn, potatoes, and alfalfa could not be separated based on soil moisture conditions (irrigation versus nonirrigation). However, field inspection of these 10 square miles, although scattered throughout the county, will take about one-third the time that inspection of the whole county would take. The classification effort was worth undertaking for this result alone.
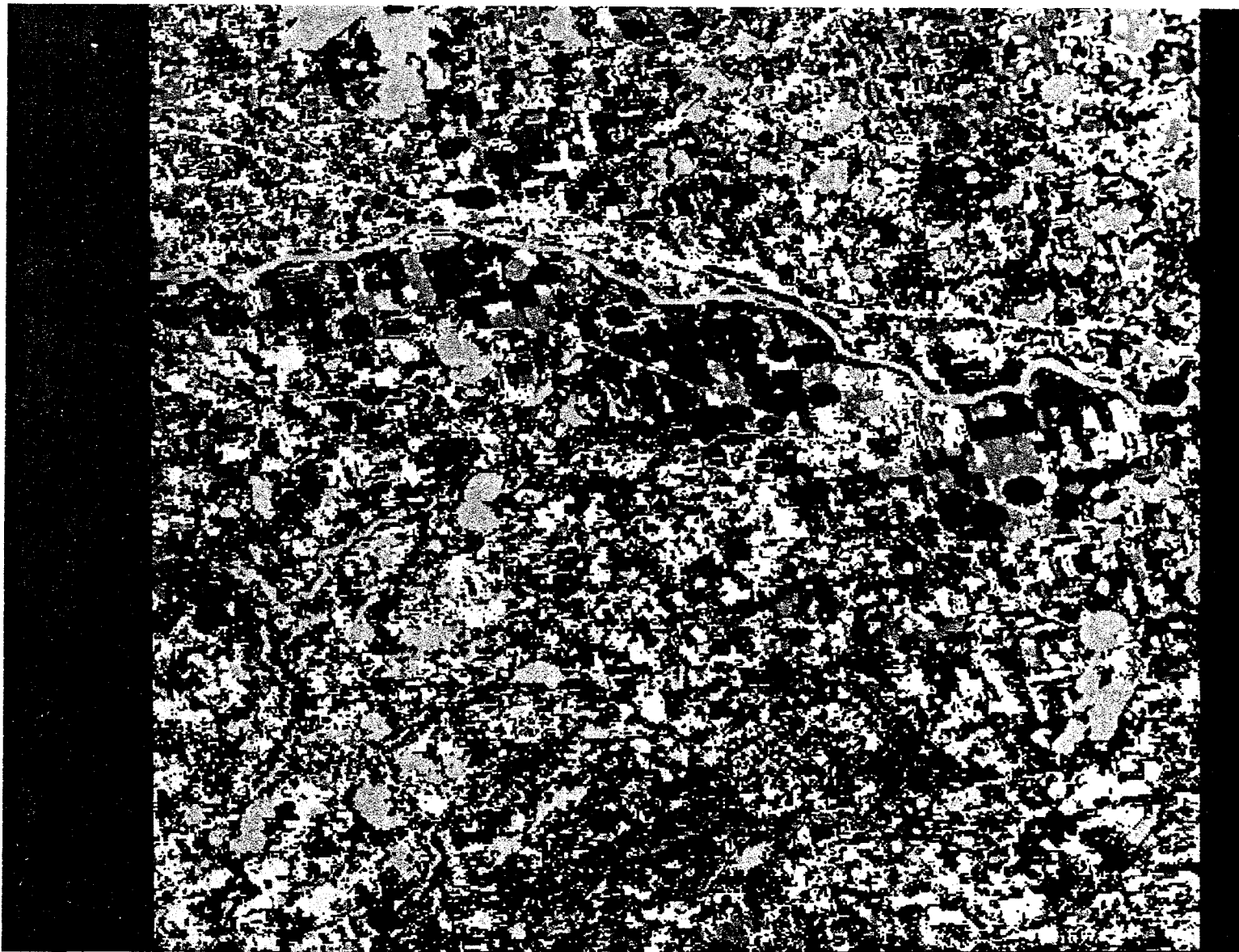
Figure 2. Irrigation Survey in Sherburne County.
Original in color (contact author).

CONCLUSIONS

The multitemporal unsupervised classification did provide a reliable delineation of specific crop types and irrigation conditions in Sherburne County. A supervised classification procedure could have been used if more ground truth was available prior to training area selection. Single date image classification should not be discounted for use in mapping irrigated fields in Minnesota as a result of this project. More ground truth, and care in training area selection, would have improved the classification attempt. The use of Landsat imagery for irrigation inventories in Minnesota should be investigated further including a cost/benefit analysis. The availability of Landsat analysis hardware/software in the state may make operational use of this technology feasible.

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CORRELATION OF LANDSAT LINEAMENTS
WITH DEVONIAN GAS FIELDS
IN LAWRENCE COUNTY, OHIO

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INTRODUCTION

More than one-half of the State of Ohio is underlaid by the Black Devonian Shale that has been proven to be rich in natural gas. An estimated 1.6 cubic feet of gas is contained in every cubic foot of this shale series. With a maximum thickness of 3,700 feet, this resource may contain trillions of cubic feet of natural gas. However, the shale is nearly impermeable with flow in the microdarcy range. This lithologic feature effectively locks up the gas in the interstices of the shale. Fractures in the shale bedrock are zones of higher porosity and potential gas development.

Vertical rock fractures or joints are zones of weakness in the structure of the bedrock. Water and its erosive forces follow this zone of weakness along the path of least resistance. With time, these fractures become clefts in the surface as the erosion of the landform follows geomorphologic evolution. Eventually the stream and river valleys form in these fracture lines and follow linear courses on the landform. These surface linears or lineaments are thought to represent zones of fracture that extend into the subsurface and down to the Devonian Shales. If this correlation could be corroborated by systematic study, a useful tool for natural gas development could unlock the resources of the shale. This would open the door to new reserves for Ohio's energy setting.

THE STUDY

The Appalachian Regional Commission supplied a grant to study lineaments and their relationship to Devonian Gas shale production in Lawrence County, Ohio. The study plan was performed first as an inductive logic test of the lineament thesis and secondly as a deductive logic application of the lineament analysis.

The first analysis of the lineaments entailed the measurement and delineation of real and remotely sensed fractures. The measurement of the fractures and lineaments was performed in three separate and independent studies: (1) field mapping of joints, joint swarms, and fractures; (2) stereo photo-interpretation of geomorphic lineaments with precise photoquads; (3) interpretation of linear features on the Landsat images supplied by NASA/Goddard Space Flight Center.

All of these studies were compiled and graphically represented on 1:250,000 scale maps. The geologic setting of Lawrence County was defined by maps at that scale showing surficial geology, structure on the Pittsburgh Coal, residual structure on the same member, as well as producing oil and gas fields. A field fracture map was generated from the joint study and plotted as rose patterns at the exposure site. The interpretation of geomorphic lineaments delineated every physical declivity in the Lawrence County area that was longer than 2,000 feet. The Landsat interpretation defined and delineated regional linear features, circular patterns, and a "mahogany" color tone. The mahogany tone was thought to correlate with gas-producing fields.

All of these maps were compared, contrasted, and correlated by superimposing each map over the other as a transparency. The analog was judged on the similarity and "lay on" correlation of the various geologic features. The most significant correlation was the geologic coincidence of the Landsat lineaments and the boundary and extension of several gas or oil fields. The correlation also demonstrated the directional coincidence of the field fractures, to the geomorphic lineaments and their Landsat counterparts. These correlations were considered significant and warranted further investigation for application.

The second study focused on using deductive logic to apply the Landsat interpretations to the landform surface and beneath. This application utilized precisely scaled 1:250,000 Landsat imagery of various seasons and filter passes to enhance the linear features.

Four color enhancements of imagery from three seasons were used for a total of twelve images. The seasons selected were spring (May 12, 1976), autumn (October 15, 1974), and winter (February 12, 1976). The four filter passes produced images with pale to rich hue, value, and chromas. The stretch enhancement produced positive contrast of the various linear features including shadows and cultivated alluvial plains. The images were interpreted as a composite for linear features. Four hundred and thirty-three unique features were delineated within the 440 square miles of Lawrence County, Ohio (see Figure 1).

The ground truth investigations of the interpreted Landsat lineaments were performed by several methods. Oblique stereo color photographs were taken from aerial overflights using a fixed wing aircraft. Ground surveys were performed at strip mines, road cuts, and natural exposures. An underground survey was also performed to verify the rock fractures origin of the lineaments.

Ektachrome and Ektachrome Infrared film was exposed with dual-single lens reflex cameras to produce simultaneous stereo oblique images. These images were acquired looking down the lineament as the aircraft flew perpendicular to the feature. The images produce a low altitude documentation of the physiographic representation of the geomorphic and Landsat lineaments. The infrared imagery displayed the magenta reflectance of the active chlorophyll in the conifers and grassy slopes. The time of the flight was early spring at a season when active chlorophyll in grass indicates surface warming by ground water springs. The magenta reflectance of the conifers correlated with the "mahogany" tone of the Landsat imagery. These oblique stereo images verified the ground expression of the lineaments.
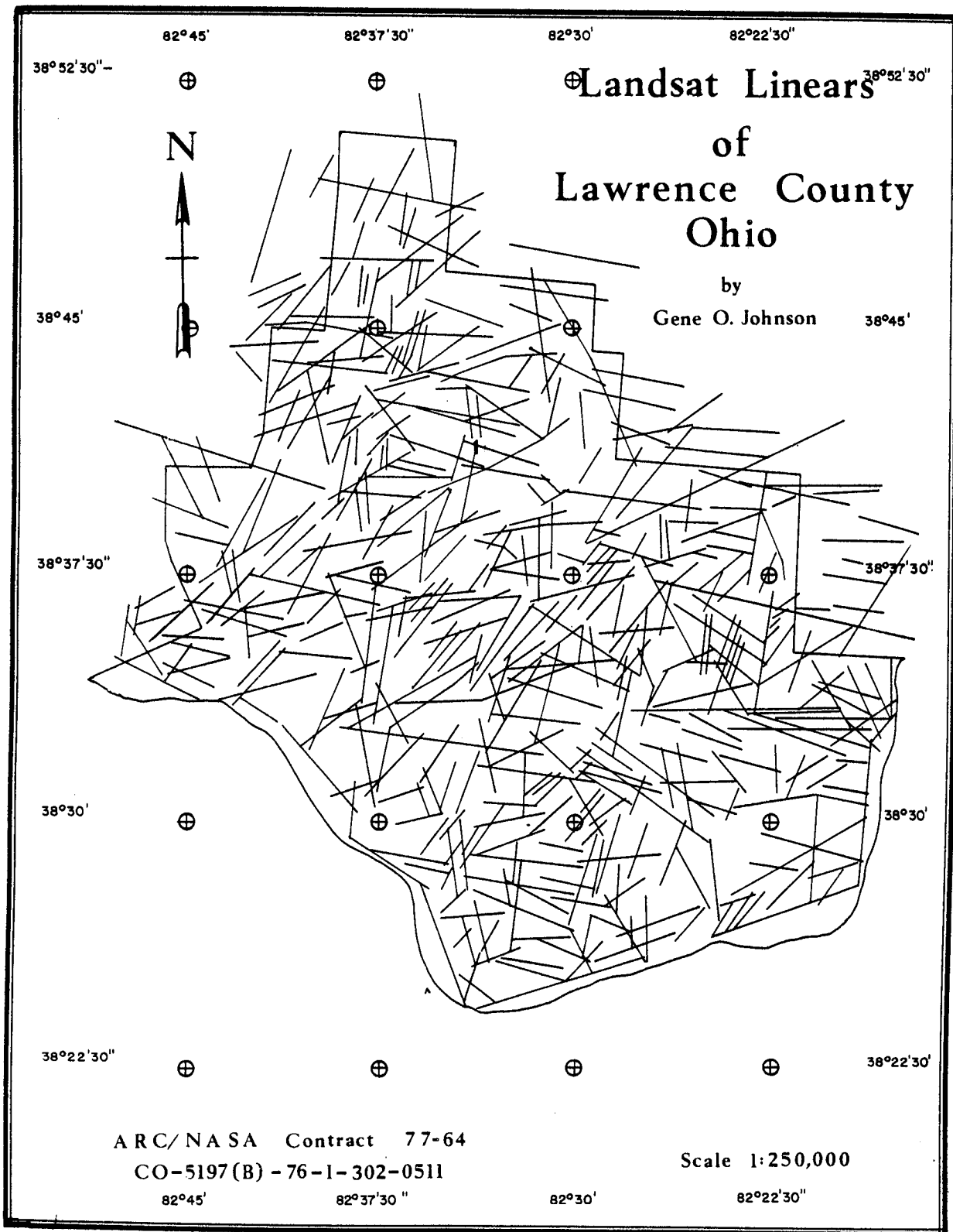
Figure 1. Landsat linear features of Lawrence County, Ohio.

The ground surveys were performed at exposures of the Allegheny, Conemaugh, and Monongahela formations of Pennsylvanian age. These formations are composed of lithified clastic deltaic deposits that are now represented by sandstone, siltstone, shale, and red clay shale. The joints were best displayed in the sandstone and siltstone bedrock units. Outcrops of those units were checked at strip mines, road cuts, stream banks, and cliff faces. Joints and fractures exposed at those sites were often contaminated by blasting cracks or exfoliation that lowered confidence in mapping. Oxidized as well as unoxidized joints were observed in both recent cracks and paleo joints. The surface expression of many joints left questions as to the origin and subsurface extent of the joints. Further ground truth was necessary to confidently project joints into lineaments and vice versa.

Located within the study area was an abandoned railroad tunnel (see Figure 2). This remnant of the Cincinnati, Hamilton, and Dayton Railroad built in 1916 was approximately 750 feet long and transected one of the interpreted Landsat lineaments. Field mapping of that tunnel and the joints exposed in the roof verified one of the lineament trends. That Landsat lineament trended on strike from the southwest to the northeast for nearly four miles at N 50 degrees E. Joints producing ground water and lined with clay films were measured striking at N 55 degrees E within the tunnel and along the roof. These joints were coincident with the lineament location. Several other joints in the tunnel were either producing seeping ground water or displayed clay films on the joint sides as evidence of ground water flow. Two travertine deposits were also noted associated with ground water flow from the joints. Four joint systems that were mapped in the tunnel had local or regional expression in the geomorphic or Landsat lineaments. These subsurface bedrock units and the physical evidence of their effect on permeability and geomorphology supported the original thesis.

The second study of the Landsat lineaments led to a deduction that bedrock joints were in evidence and associated with the lineament trends. The ground water movement and clay films in the joints of the tunnel demonstrated the permeability of the rock fractures. With these data, the Landsat lineaments were found to represent real rock fractures, as well as zones of increased permeability within the landform.

CONCLUSIONS

The Landsat lineaments had significant correlation with the limits of oil and gas producing fields. These limits included termination of fields production as well as extensions of other fields. The lineaments represent real rock fractures with zones of increased permeability in the near surface bedrock. These correlations support the thesis that Landsat lineaments are potential tools to enhance gas production by locating zones of higher permeability due to fracturing and joints. This tool could be applied to the development of natural gas production from the vast resource of the Devonian Shale in Ohio.
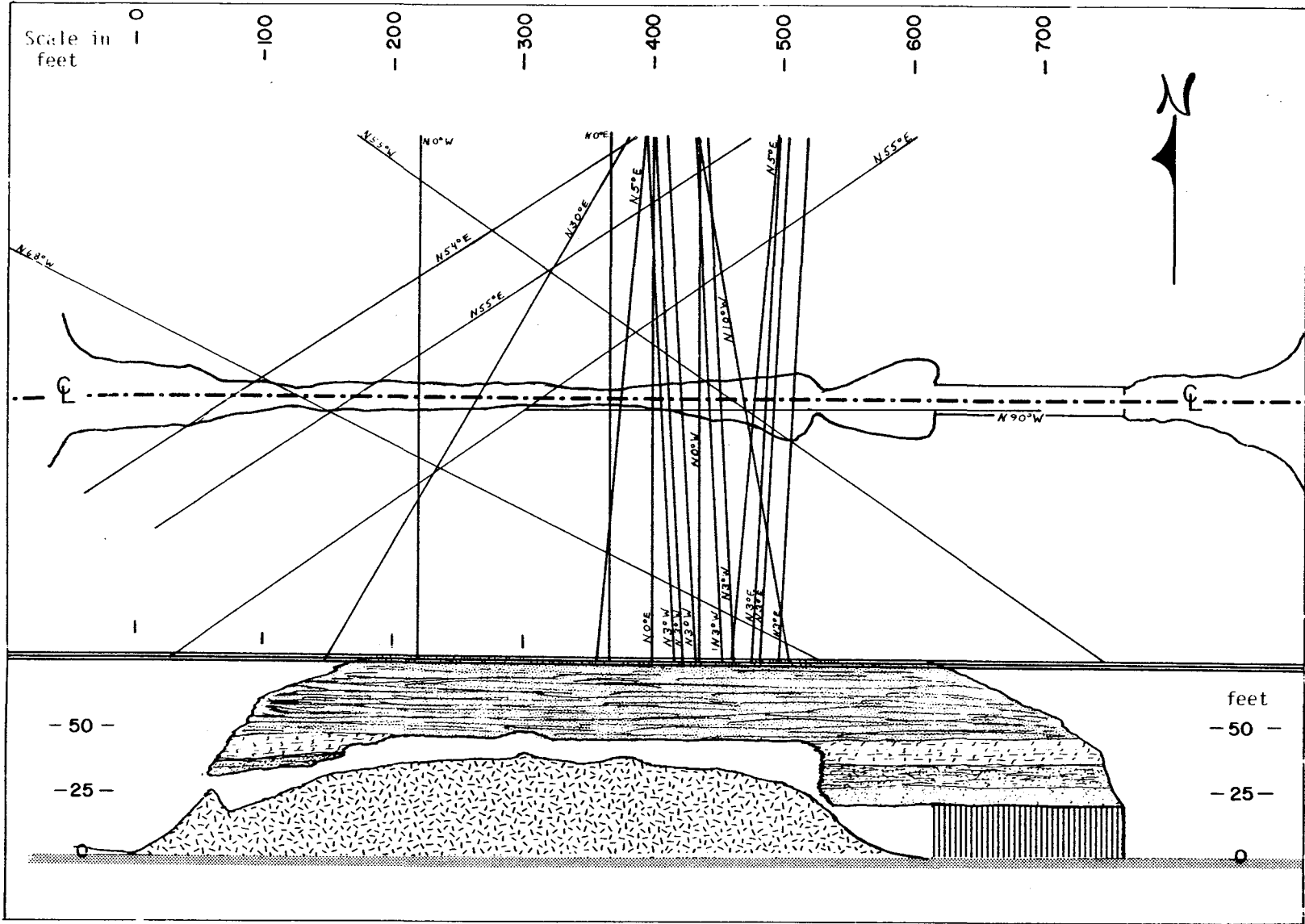
Figure 2. Plan and profile of the abandoned Cincinnati, Hamilton, and Dayton tunnel
(sec 25, Washington Township, Lawrence County, Ohio).

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LANDSAT DATA FOR COASTAL ZONE MANAGEMENT

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INTRODUCTION

The New Jersey Department of Environmental Protection (NJDEP) has been exploring the potential of Landsat information for state planning and management with the NASA Eastern Regional Remote Sensing Applications Center (ERRSAC) in three demonstration projects. The Office of Green Acres has been studying the applications of Landsat to State Heritage planning. The Division of Parks and Forestry has been experimenting with forest type mapping, and the Division of Coastal Resources has been testing Landsat data for inclusion in a number of coastal planning and management programs. The coastal project is the main subject of this presentation, although references are made to the other projects.

State coastal programs were initiated by the Federal Coastal Zone Management Act of 1972. This Act provided funds to states to encourage them to set up federally approved coastal management programs. The main goal of the Act was "to preserve, protect, develop, and, where possible to restore or enhance, the resources of the Nation's coastal zone for this and succeeding generations."* The National Oceanic and Atmospheric Administration (NOAA) administers the state programs. In many ways this was a pioneer program, calling for comprehensive regional planning. Few states had existing capacity to do this, and the coastal programs were forced to seek new techniques to gather, record, and analyze data, make rational evaluations, and formulate and implement defensible regional policy.

One of the key deficiencies in New Jersey, as in many other states, was the lack of accurate, up-to-date data on land and water surface conditions. The best surface information we had was on USGS quadrangle maps, New Jersey State Atlas maps, optical air photographs from a number of programs, and vegetation survey maps. The USGS maps were all below national map accuracy standards and up to 20 years out-of-date. The photo data were variable in date, scale, and resolution and were difficult and expensive to interpret. The vegetation information had been inaccurately interpreted 5 years before from 10-year-old photographs. The atlas maps were variable in date and accuracy. This

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*Section 305 of the Federal Coastal Zone Management Act (P.L. 92-583, as amended).

fragmented, aging, inaccurate, and cumbersome data base is quite typical of existing state geographical information. Clearly, a new survey was essential and better techniques of monitoring, updating, and managing information needed; but with limited funds and large regions, the traditional air photo/ground survey hand map techniques were impossible.

We had already concluded that Landsat information was a possible solution, and the coastal program had done some preliminary work with the Earth Satellite Program. We were about to contact NASA seeking help when the ERRSAC program contacted us seeking state pilot tests. The first results of this happy coincidence are the subject of this presentation.

CLASSIFICATION

New Jersey's coastal program has been testing new techniques of data collection and analysis in a pilot area in Cape May County, the southern peninsula of the state. We wished to continue with the same study area. NASA provided us with four-channel multispectral data of the county that had been collected in June 1978, and with access to the Office for Remote Sensing of Earth Resources (ORSER) computer interpretation system at Penn State. Our first goal was to test the spectral resolution of the data and produce a surface cover map. We prepared the map by going through the steps of supervised classification. We worked first on the ORSER system with a terminal in our own office connected to the Penn State University computer and then on the color-interactive Interactive Digital Image Manipulation System (IDIMS) at NASA-Goddard.

We duplicated all the steps of IDIMS classification on the ORSER system. This hands-on experience was essential to our understanding of the analysis procedure and of the potentials and limitations of Landsat data. We arrayed three channels of our June tape on a colored cathode ray tube, displaying MSS 4, 2 and 1 as red, green and blue respectively. This created colors similar to false color infrared film. We then explored some of the manipulations of raw data possible on IDIMS to clarify selected features. Our first analytic step was to select candidate areas for type classification. We used a combination of our best ground truth information and the local knowledge of Bob Myers, a Cape May County planner who lives in the study area and who is collaborating with us on this project. We outlined areas on the surface which we knew to be of a certain class, selecting areas reasonably homogeneous in color. We then analyzed the enclosed pixels in each class, producing a spectral signature and a multichannel decision boundary. If the histograms were poor, we selected new areas.

The coastal ecozone presents special problems for candidate area selection because so many features are narrow and linear. Beaches, dunes, tidal guts, streams, floodplains, and many vegetation types all tend to approach the limits of Landsat multispectral resolution. In some cases we were obliged to select single pixels for candidate areas with considerable care, avoiding the averaging effect of edges, and we still did not have a good beach signature. When the statistics of our candidate areas were computed, we were pleasantly surprised by the extent of spectral resolution. We were able to identify the high and low vigor forms of *Spartina alterniflora,* the critical wetland species of estuarine primary productivity. *Spartina patens, Phragmites communis,* and other wetland species also had clearly distinct signatures. The resolution of swamp and upland forests, including the

highly valued Atlantic white cedar and the federally protected oak-pine and pine-oak forests of the New Jersey Pine Barrens, was equally impressive. Agricultural signatures showed such bewildering variety that we set these aside for further work on crop inventory with better ground truth from the Cape May farmers. The weakest resolutions were the varying signatures of different urban densities. The heterogeneous reflectivity of these surfaces gave diffuse signatures which tended to overlap with several other types, and the pixel size of multispectral data contributed to this problem.

We did not attempt sophisticated classification in water areas in this first phase, recognizing the difficulty of interpreting the several variables that alter reflectance and the rapid and complicated variations in tidal systems. We plan to test Landsat capacity to monitor water systems and our own capacity to manage Landsat in the next phase. The map that we generated has 30 classes, a level of detail better than any we have, and is quite adequate for regional coastal planning on the land and water's edge. Because of hardware and software problems with the IDIMS system, we could not photograph our class map. Nor have we been able to ground truth our class map and make an accuracy assessment, but when we do I anticipate that we will already have more accurate and up-to-date surface information than any now in our data base at a resolution suitable for regional planning, but not local or site planning.

Celeste Tracy worked on the Green Acres project in the Great Egg Harbor Watershed to the north of our coastal study area. She ran both a supervised and an unsupervised classification, and used the spectral clusters of the unsupervised classification to check the signatures of the candidate areas and compared the unsupervised class map with the air photo ground truth data. This provided a double checking technique which improved the accuracy of the signatures. She considers her map adequate as a data source for State Heritage natural area selection.

Tom Taylor of the Division of Parks and Forestry ran a supervised classification of forest types in the Appalachian Ridge and Valley and Piedmont regions of northern New Jersey. He knew that remote species identification in mixed deciduous forests was uncertain but, like us, he was surprised at the spectral resolution. Moisture variations were a factor in the distinction of elm-ash-maple from oak-hickory forest, and the north-facing hemlock forests were distinct. He was working in hilly country and needed to correct for the shadowing effect of topography, exploring parts of IDIMS that we did not have to do in the flat coastal plain. Parks and Forestry is now planning extensive ground survey and air photo interpretation, and the inclusion of Landsat data will improve both the state program and Landsat accuracy. Very precise ground truth can be available in selected areas, and the Landsat class map can provide a double check for photointerpretation even while its accuracy is being assessed.

CHANGE DETECTION AND IMPROVEMENT OF SPECTRAL AND SPATIAL RESOLUTION

When we had completed the supervised classification of the coastal June image, we took tapes from two other dates, April and November, and set up mensuration points on each image. These were markings of clearly visible static surface points such as road intersections or jetties. We marked the same network of points on each image and overlaid and corrected the fit of each network. Then, using the June image as a target, we registered the three images. The computer adjusts each image

by "rubber sheeting" between fitted mensuration points. This created a registered 12-channel multitemporal image of the three dates showing spectral variations throughout the growing season. We created some false color curiosities from these data by taking a channel from each date and displaying April on the red gun, June on the green gun, and November on the blue gun. These displays immediately showed that the multitemporal image greatly increased spectral resolution. There was a noticeable color difference, for example, between coastal and inland wetlands. These differences come from different plant growth patterns and can be used to refine and correct the classification map.

We ran a principal components analysis to reduce the volume of multitemporal data from twelve to six channels. In the next phase, we will enter the coordinates of our candidate areas and compare the resultant class map with an unsupervised classification of the multitemporal tape and with high quality air photographs at the same scale. We anticipate that this will greatly improve both the detail and accuracy of the class map. Another use of the multitemporal data that we are planning to study is the capacity to detect the location, extent, and nature of change from one date to another. If we can establish that the surface classes in our candidate areas have not changed in the time period covered by the multitemporal tape, then the set of candidate areas established for the June image can be used to create class maps from the April and November images. By overlaying these class maps, we should be able to detect pixels where a change of class has occurred and sort these into classes of change. Change types that we are particularly concerned with are the removal of forest vegetation, filling of wetlands, and paving of soils. Accurate and timely knowledge of these changes is critical for a number of the planning, monitoring, and management applications discussed later.

All the analyses discussed thus far are based on multispectral data. These data have a 1.1 acre resolution and a pixel size of 79 X 56 meters. This resolution has various deficiencies for planning applications. Away from water bodies in New Jersey, the pattern of road networks is an important location aid. Since roads show only intermittently on the multispectral image, it is often difficult to determine the exact location of a pixel on the ground, and this limits the precision of candidate area boundary delineation and class accuracy assessment. The averaging of reflectance over 1.1 acre area is too gross for certain classes. Narrow linear features such as roads and streams and heterogeneous types such as suburban areas tend to disappear into false edge classes of diffuse overlapping signatures, and thus limit the spatial and spectral resolution of the class map.

We have been following with considerable interest the work of Scott Cox in overlaying the panchromatic Return Beam Vidicon (RBV) data with its 24-meter pixel on the multispectral data. This work is to be discussed in another presentation, but it is worth noting the visual comparison of multispectral image and RBV-multispectral combination. The six-fold increase of spatial resolution produces important improvements: roads appear, and class edges such as stream banks and field and woodlot boundaries become much crisper. Large structures are visible and pavement boundaries can be seen. Very precise location is possible with this increase of landmarks, and this should greatly improve the range and accuracy of spectral classes. Classification of heterogeneous areas such as urban areas becomes much simpler, and linear features will appear on the class map. We look forward to testing these RBV overlays in the classification of both single and multitemporal images and we

believe that these data will satisfy more than half of our planning needs at an acceptable resolution for all but site planning. Landsat-D data, with both multispectral and RBV data at the smaller pixel size, will further improve quality. We anticipate that the overlay of data from other sensors such as synthetic aperture radar, altimeters, and laser scanners may in the future provide extremely sophisticated data mixes which could be classified with great precision to answer many specific planning questions.

MERGING LANDSAT AND MAP DATA

Impressive though the products of computer-interpreted Landsat data are, there are limits to their application when they are the sole information source in isolation, since they show only two-dimensional patterns of surface reflectance. Other variables vital to planning, such as substate factors, topography, and socio-economic factors are beyond the reach of Landsat sensors and must be collected with other remote sensing or ground truth survey techniques. If these data can be stored in a way that can be combined easily and flexibly with Landsat data, then the applications of all the data greatly increase. The whole becomes greater than the sum of the parts.

For several years we have been developing a map overlay planning method which can take geographic data from many different sources and combine them in a controlled way to produce synthesis maps. These interpret raw data for particular planning applications. The manual process is done by mapping at a constant scale all the geographic variables relevant to a particular analysis. Matrices are formed that describe relationships between the data categories of different factor maps. The matrix connections are designed to answer particular planning questions. By applying the completed matrices to overlays of factor maps, the synthesis maps can be produced. Figures 1 and 2 illustrate two analyses that are well developed. Figure 1 identifies which environmental factors affect the sensitivity of a location to the impacts of a use, in this case housing. Sensitivity varies with the value placed on particular resources, the way new uses change these areas, and with the capacity of a location to transmit degrading impacts to valued resources, usually by water transmission. The distribution of each valued resource and the variations of impact transmission factors such as depth to water table and soil texture must be mapped. Combinations of these factors are then arranged along a gradient of sensitivity from high to low. From this matrix, a map can be prepared which shows the distribution of varying degrees of restriction that must be placed on the location of housing, if stated environmental objectives are to be realized.

The second analysis, shown in Figure 2, studies the natural or cultural features sought by use-developers when selecting optimum sites. Housing developers seek sites near roads, sewers, surface water bodies, shops, and schools (Figure 2). We have completed a study, with extensive input from developers, which identifies the siting factors required, or desired, for each coastal use and makes estimates of the variations of cost associated with the variation of each factor. By overlaying each of the costed factor maps and summing the costs, a quantitative map can be prepared showing the distribution of development potential for a use. If this development potential map is overlaid on the environmental sensitivity map, some planning conflicts become immediately apparent. Housing developers, for example, desire waterfront locations but these are usually highly valued for ecological reasons and sensitive to housing impacts. The coastal program with its objectives to preserve, and

81

STATE OF NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF MARINE SERVICES
OFFICE OF COASTAL ZONE MANAGEMENT

Figure 1. Location acceptability for residential development.

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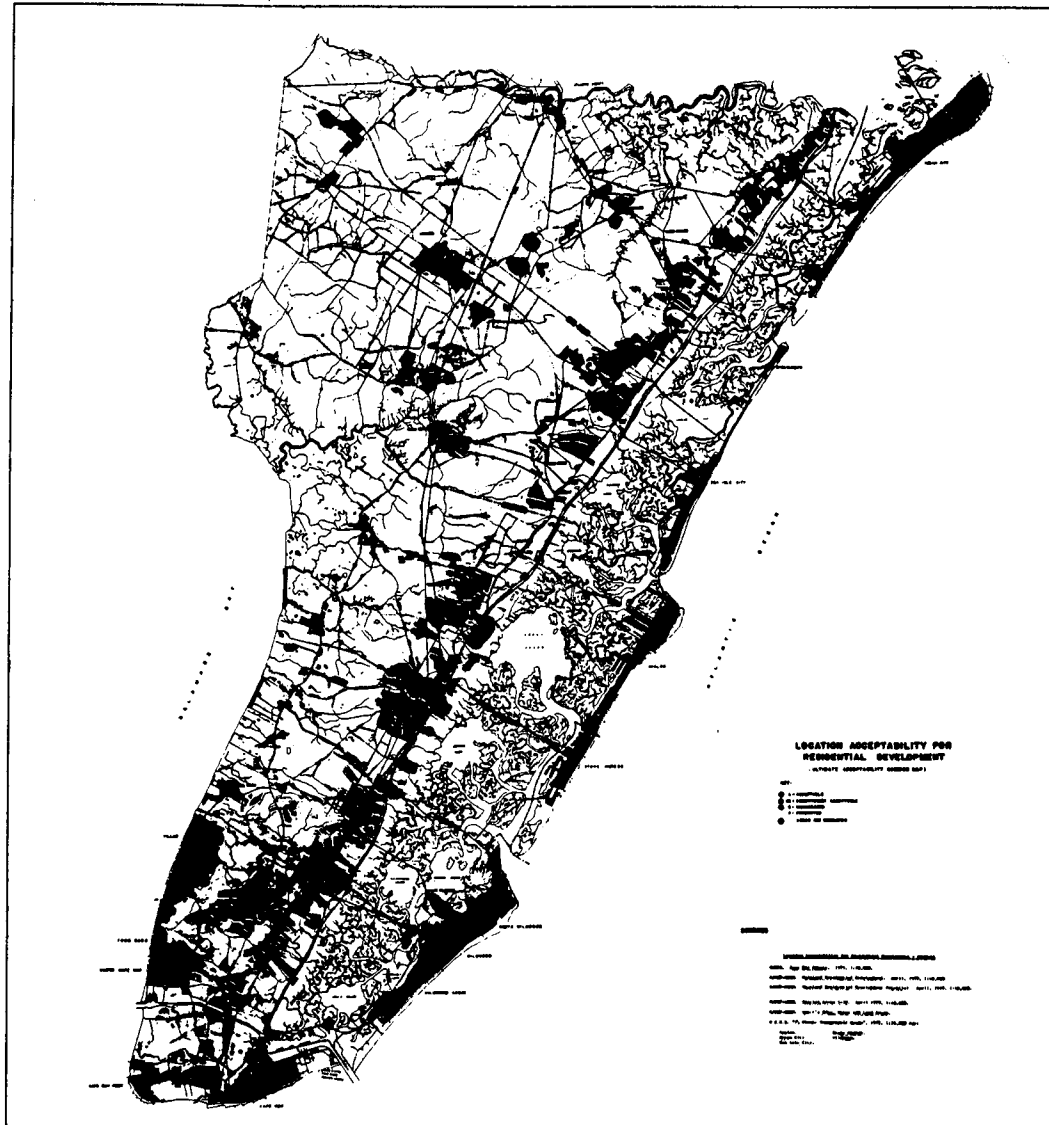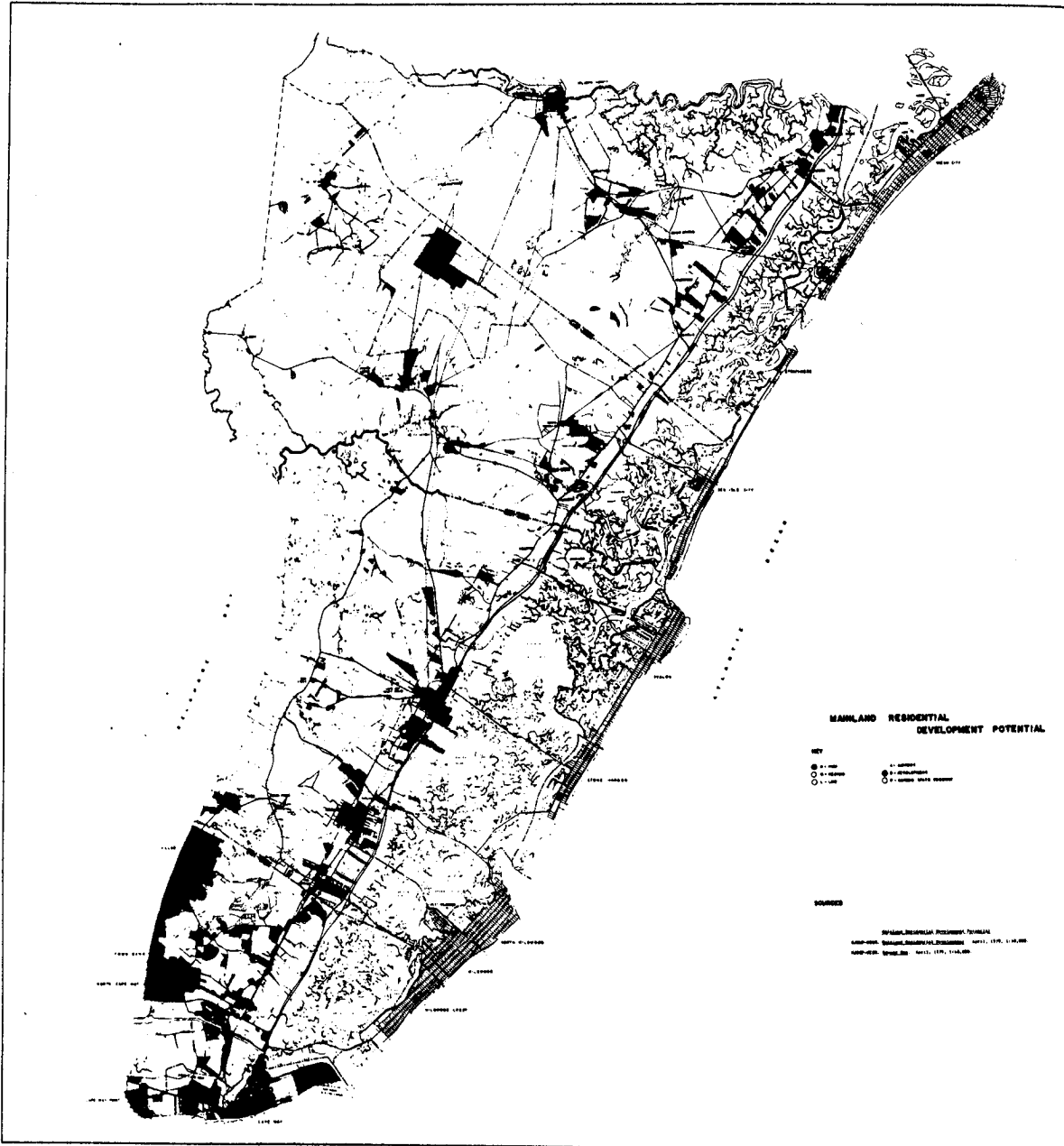Figure 2. Mainland residential development potential.

protect, as well as develop, must find resolutions to these conflicts. Overlay maps help to focus debate, explore alternatives, and seek consensus for policy. Policy can be recorded on the matrices and the overlay process used to produce policy maps. We are planning to add a third analysis to these two which will identify the distribution of socio-economic impacts associated with the introduction of new uses, whether adverse or beneficial. Policy will then be made on a debated compromise between environmental, developmental, and socio-economic objectives.

Because of the indifferent quality of source data and the extreme difficulty of doing these complicated map overlays by hand, the application of this method is at present limited far below its potential. We have established that it invites informed debate and produces reasonable land use distributions with sophisticated justifications. We are now using a simplified version in three coastal permit programs, and the method is standing up to appeal. However, we recognize that the next steps must be computerized. We are presently digitizing a number of maps of Cape May County including soils, topography, transport systems, and property boundaries. We are making a joint proposal with the Council of Environmental Quality to the National Science Foundation for the development of relational data base management and graphics software which will allow user-interactive map overlay analysis with grid or polygon data. If this system can be created, the inclusion of the data interpreted from Landsat is comparatively simple and we can then draw information from diverse survey sources, merging for example the Landsat class information with soils and topography. Landsat, we believe, can provide up-to-date data on all our remotely visible surface factors. If we can design this data overlay process to be flexible and interactively responsive to English language commands, then the high spatial, spectral, and temporal quality of Landsat data may be linked to a technique that allows rapid and sophisticated map analysis to answer questions not foreseen when the system was designed. This combination has revolutionary implications for planning, public debate, litigation, management, regulation, and even quality of life in the real world.

POTENTIAL APPLICATIONS

Predicting the applications of this powerful survey tool when linked to a computer map overlay program at this early state is rather like standing in the surf and trying to see over the horizon of an ocean. The proposed inclusion of Landsat data into the coastal map overlay process has already been described, and there are a number of other pilot applications in New Jersey that are now proposed and being prepared. An integrated land and water monitoring program is being discussed which would integrate data in a computer from Landsat, airborne sensors (both optical and digital), ground sensors, and surveys. These would be combined into a coordinated survey and monitoring program. Policy thresholds of acceptability in monitored variables would be recorded in the system. When a monitored trend approaches, relevant intensive survey and enforcement agencies would be notified. This would help with the difficult task of managing cumulative impacts. We have asked NASA/Johnson to fly a 10-channel low level multispectral survey with a 5-meter pixel to test the capacity of ORSER and IDIMS to assist intensive survey efforts.

The analysis and management of point and nonpoint source water pollution is a national concern. The containment of carcinogenic pollutants is a serious concern in New Jersey. We believe that Landsat may aid in monitoring water quality and provide data for such water computations as runoff and soil erosion equations and estuarine and aquifer flow models. The Department of Environmental Planning (DEP) will be testing Landsat in the Shore Protection and Dune Management Programs, Energy Facility, Solid Waste Siting studies, Estuarine Sanctuary Delineation, State Heritage Planning, Wild and Scenic River Planning, Water and Flood Planning, and the Cancer and Toxic Substance study. The potential of Landsat for coordinating DEP planning will also be studied. Other programs such as Pinelands and Cape May County Planning will explore our data and techniques.

I find it hard to imagine any geographic planning or management program not benefiting from a good remote sensor-computer system, and I anticipate that, as the results of the first pilots are released, the technique will spread rapidly to all relevant programs. There are some improvements which we believe could expedite this process, such as automating repetitive procedures, simplifying the user-machine connection, and speeding computation and display. The classification procedure could be largely automated. If a set of state candidate areas were selected representing the full range of types, the coordinates could be stored in the data base. Periodic ground truth or notification by owners of changes could guarantee accuracy of class and many could be on state land. When a new tape arrives, the candidate areas could be registered and the class map automatically produced, geo-corrected and registered as a batch job. Automation of the initial registration process is also very desirable, and greater use of light pens, tracking balls, and menu cards for often repeated sequences would increase the speed and fluency of manipulation. The planned zoom and linear tracking capability on IDIMS is an example of the kind of improvement that we are looking for.

I would like to thank the ERRSAC program in general, and Philip Cressy and Scott Cox in particular, for this opportunity to work with NASA. I realize that NASA was not entirely a disinterested philanthropist in the business of technology transfer; the vacuum cleaners must be sold. I hope that our energetic promotion of Landsat for New Jersey State planning will help to establish an operational program, but the enthusiasm and kindness that greeted our projects went well beyond the job description.

WILDLIFE HABITAT EVALUATION DEMONSTRATION PROJECT

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INTRODUCTION

The Michigan Landsat Technology Transfer Program is being carried out through the cooperation of the Eastern Regional Remote Sensing Applications Center (ERRSAC) of the National Aeronautics and Space Administration (NASA), the Environmental Research Institute of Michigan (ERIM), the Michigan Department of Natural Resources (MDNR), and the Michigan Department of Transportation (MDOT). While ERRSAC/NASA must be credited with being the primary motivator in this technology transfer effort, the availability of Landsat expertise and image processing capabilities at ERIM within the state of Michigan made the project feasible without numerous trips to the Goddard facility of ERRSAC/NASA. Only one of the Landsat projects worked on by MDNR personnel will be reported here.

PROBLEM

The State of Michigan is faced with managing a large, economically important, heavily exploited herd of whitetail deer. Wildlife management principles suggest that a large portion of the management of a free-living species consists of management of its habitat.

While habitat management for deer has been carried out in Michigan for many years, most of the fundamental concepts were formalized in 1971 as the Deer Range Improvement Program (DRIP). This program consists of an extensive program of subsidized habitat alteration on state-owned lands to improve deer habitat, coordinated with the regular commercial harvest of wood. The concept of this plan is supported by the policy for managing state forest lands adopted by the Department of Natural Resources Commission in June 1970 and further by Michigan Act 286 as amended in 1971, which allocates $1.50 of each deer license sold in Michigan to pay for deer habitat improvement.

The goal of the Deer Range Improvement Program is to maintain sufficient area and quality of habitat to support a spring deer population that will produce a population of 1,000,000 animals on October 1 of each year. The manager's job is to plan improvements to the deer habitat to meet the goal of deer numbers and to accomplish this within the available funds. This task involves

assessing deer habitat in terms of areas and mixes of species and age classes of vegetation to evaluate its present value as deer habitat and to identify its potential for improvement. Obviously, deer do not recognize land ownership, hence, the manager must include private, federal, and state-owned lands when evaluating present habitat condition, even though the deer habitat improvement funds can only be expended for alterations on state-owned lands in most cases. In addition, other factors including anticipated weather, geophysical data, and the up-to-date vegetation information are important to the manager when evaluating deer habitat and planning for its improvement.

The value of an area for deer is also affected by the manner in which the vegetative cover types are arranged on each area. This evaluation must be accomplished by the manager with whatever spatial distribution information is available to him. Usually this information is sketchy and inconsistent. Even if this information were complete and up-to-date, it is not likely that his evaluation would be consistent over time and space.

At present, much of the vegetative cover data is acquired either through on-the-ground observations or from cover maps derived from aerial photography. The cover maps are both dated and limited in areal coverage since the cover types were only prepared for state-owned lands. In most cases, only the on-the-ground observations can attempt to keep up with annual changes in the vegetative cover. This activity is limited, however, by other demands on the manager's time and restrictions on travel.

OBJECTIVES

Our Landsat demonstration project was designed to examine the use of Landsat data in two roles. First, could the information from Landsat be used as a primary source of vegetation cover type data, with sufficient accuracy to substitute for the traditional cover type information sources? Second, could Landsat data be used to supplement and improve the information normally used for making deer habitat management decisions, either by providing vegetative cover for private land or by providing information about the interspersion and juxtaposition of valuable vegetative cover types?

PROCEDURE

Lake County, in western lower Michigan, was selected to take advantage of recently completed full coverage forest type maps and an experienced field staff. The information traditionally used to make deer habitat management decisions has been compiled for this project area. In addition, local deer population information has been gathered to serve as a basis for judging the accuracy of the habitat evaluations. Presumably, the best deer populations should be associated with the best habitat. Meanwhile, a Landsat image has been chosen for vegetation mapping and has undergone preliminary processing and classification at the ERIM facility in Ann Arbor.

In the first part of the evaluation stage of the project, each area of the county will be scored using a mathematical formulation of the present deer range improvement program guidelines. These scores will be compared with the information about deer populations to provide a baseline of accuracy against which the information from Landsat can be compared.

The same areas will then be scored using the cover type information from Landsat to substitute for the traditional data sources. In addition, the supplementary information such as vegetation interspersion and juxtaposition computed from the Landsat data will be examined to determine if these increase the ability to describe and identify good deer habitat. The information, such as vegetative interspersion and juxtaposition, will be extracted from the classified Landsat data through the Wildlife Habitat Analysis and Modeling System (WHAMS) developed by Norm Roller at ERIM.

By comparing these evaluations with the previous evaluations based only on traditional data and then comparing both sets with the independent deer population information, it should be possible to identify the contributions of Landsat-derived information, both to replace and to supplement traditional information sources. Any of several of the following beneficial outcomes could result:

- The cost of gathering cover type information might be reduced, thereby reducing the overall cost of gathering information for management decisions.

- The time necessary to gather cover type data might be reduced, thereby making it possible to update cover type information more often.

- The Landsat data might provide a reliable and consistent means of getting vegetative interspersion and juxtaposition to supplement that from traditional sources and thus improve habitat management decisions at a reasonable cost.

Any of these alternatives would provide an improvement in the ratio of input to output in the deer program either by reducing the cost of gathering information or by increasing the value of the available information toward making correct management decisions.

LAND COVER ANALYSIS OF JAMES CITY COUNTY, VIRGINIA

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INTRODUCTION

The Division of Forestry, a branch of the State Department of Conservation and Economic Development, was one of several Virginia agencies selected to conduct a Landsat demonstration project in a cooperative ERRSAC program.

The acquisition and updating of resource data on a county-by-county basis is a major problem continually encountered by the Division of Forestry. At present, forest resource data for Virginia and most other states is obtained primarily through a comprehensive "Forest Survey" conducted by the U.S. Forest Service. This survey provides essential statistical information on a state and regional basis. The survey, while accurate on a regional basis, performs less well on an individual county basis and does not provide information on the spatial distribution of forest land within a county.

James City County, a small 116,000-acre county in the tidewater region of eastern Virginia, was chosen for the study. This county is bordered by the James, York, and Chickahominy Rivers and has a relatively flat terrain. The forest land is characterized by three major forest types: loblolly pine, oak/pine, and oak/hickory. Agriculture is a major land use; however, substantial development is occurring in the county, especially near the adjacent city of Williamsburg. This project is an attempt to obtain reliable countywide forest resource data, including statistics and a forest cover distribution map from Landsat data.

PROJECT DESCRIPTION

Objectives

The objectives of this project were to:

- Produce a Level II (Anderson, 1976) forest cover classification from Landsat data. This classification would also include statistics and a forest cover map for the three major forest types: conifer (loblolly pine), mixed (oak/pine), and hardwood (oak/hickory);

- Produce a Level I (Anderson, 1976) land cover classification from Landsat data. This classification would include statistics and a land cover map for a Virginia county; and

- Establish procedures for future Division of Forestry studies using Landsat to obtain and update forest resource data on a county basis.

Approach

Analysis of Landsat digital data from June 1978 was accomplished on two separate computer systems. The bulk of the analysis was done on the ERRSAC Hewlett Packard 3000 minicomputer using the IDIMS and GES software packages. The remainder of the data required for analysis were processed on the IBM 370/168 computer at the Pennsylvania State University Computer Facility, via remote access terminal in Charlottesville, Virginia.

James City County, along with the surrounding area, was located and extracted from the IDIMS file containing the whole Landsat scene. This extracted data set was geometrically corrected, map-registered, copied to tape in ORSER compatible format, and shipped to the Penn State computer facility. There it was later accessed and processed remotely using the ORSER Landsat analysis software package.

The signature development phase was undertaken in two parallel efforts: the unsupervised classification for general land cover was accomplished on IDIMS; the supervised classification for forestry on the ORSER system. The classification statistics achieved at each stage were compared with the high altitude photography, the raw Landsat enhancements, and the quadrangle maps. A final classification was achieved after all the classification conflicts were resolved by merging the classes obtained from the supervised forestry and unsupervised general land cover analyses.

The digitized county boundary was registered to and superimposed on the final land cover classification. Pixel counts for each class within the boundary were computed, converted to acreage and tabulated separately for Level I land cover and Level II forestry. These statistics were compared with the county comprehensive planning and the U.S. Forestry statistics, respectively.

RESULTS

Comparison of the 1978 Landsat analysis and the 1976 U.S. Forestry Survey data, the most recent comparable forest resource statistics available, are presented in Table 1. Pine, oak/pine, and oak/hickory accounted for 22.3 percent, 32.6 percent, and 45.2 percent respectively of the total forest area in the Landsat analysis, compared to 22.8 percent, 30.1 percent, and 47.1 percent in the Forest Survey. The corresponding figures for each forest type differ at most by 2.5 percent for the mixed forest. The total county area in forest land measured using Landsat was underestimated by 1,409 acres, a 2.2 percent error based on the Forest Survey statistics. However, the estimate of 61,242 acres fell well within the known 4 percent uncertainty of the estimate for the forest survey figures (62,651 acres ± 2,544 acres).

Table 1
Comparison of Forest Types of James City County, Virginia

	1978 Landsat Analysis		1976 Forest Survey		Survey Discrepancy
Forest Type	Acres	% Total Forest	Acres	% Total Forest	Acres
Pine	13,629	22.3	14,266	22.8	- 637
Oak/Pine	· 19,939	32.6	18,837	30.1	+1,102
Oak/Hickory	27,674	45.2	29,548	47.1	-1,874
Total	61,242		62,651		-1,409
			(±2,544)		

The Level I land cover statistics for the county and the land use categories derived from the 1974 James City County Comprehensive Plan are tabulated in Table 2. The two data sources have been regrouped to obtain a logical category correspondence. Overall, the statistics were in agreement to within approximately 4 percent for all land cover categories and for the total county acreage estimates. Landsat data provided good estimates of land designation in each cover type. For the actual acreage estimates, Landsat overestimated the county total by 2.6 percent, 3,070 acres. The largest acreage discrepancy occurred in the comparison of forest/open land, where Landsat underestimated this category by more than 4 percent or 2,936 acres.

Two color-coded classification maps with the county boundary superimposed in white were produced: a Level II forestry inventory map and a general county land cover map (see Figure 1).

DISCUSSION

Previous applications research has demonstrated the feasibility of forest land management by satellite, and the interpretation of Landsat data has proved particularly useful for this purpose (Williams and Haver, 1976). This feasibility has prompted forest resource managers to examine the utility of Landsat data both as a primary data source and a means for updating traditional surveys. A comparison of the 1978 Landsat with the Forest Survey data provided by the Division of Forestry, the best means of assessing the accuracy of Landsat, fared well. The total forest acreage estimates from Landsat fell well within the acceptable accuracy range of the Forest Survey estimate.

The comparison made between the general land cover statistics derived from the 1978 Landsat data and the statistics from the 1974 Comprehensive Plan for James City County were also satisfactory. In order to make the two sets of statistics as comparable as possible, the county planning "land use" categories were grouped into four units roughly comparable to the land cover unit measured by Landsat. Several Landsat-derived land cover categories were also combined to accomplish this, resulting in overlap between some categories and the inability to make precise distinctions between others. Due to this factor and the 4-year gap between surveys, discrepancies in the acreage estimates were inevitable. Estimates for percent county land cover per category were good, whereas the actual acreage estimates were not as satisfactory.

CONCLUSIONS

The utility of Landsat data for mapping three major forest types has been successfully demonstrated in this project. Landsat-derived estimates of the proportions of each of the three forest types which comprise the total forested lands in James City County, Virginia were more than satisfactory. The estimates for the actual acreage were also quite good. We conclude that the demonstration of Landsat as a test for forestry resources management has been a success.

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Figure 1. Land cover thematic map—James City County, Virginia.

The color assignments are as follows: Forest in shades of green (pine—dark green, oak/pine—medium green, oak—light green); field of any type (agriculture, pasture, grasslands, etc.) in tan; wetlands in purple; urban/developed in red; grass/developed in black; and marsh/tidal flat in aqua. Original in color (contact author).

Table 2
James City County, Virginia
Landsat vs. Traditionally Derived Land Use

| | 1978 Landsat Data | | | 1974 Comprehensive County Planning Data | | | Survey Discrepancy |
| | | Grouped Classes | | | Grouped Classes | | |
Land Cover	Acreage	Acreage	% County Estimate	Land Use Class	Acreage	% County Total	Acreage
Developed	7,201	7,201	6.0	Utility/ Transportation Industrial Commercial Residential	5,683	4.9	+1,518
Fields	15,228			Agriculture Recreation Public/ Semipublic			
Grasslands	8,202	23,430	19.6		21,070	18.1	+2,360
Forest	61,242						
Wetland	5,326	66,568	55.7	Forest/Open	69,504	59.7	−2,936
Tidal Flat	1,117		18.7	Water	20,220	17.4	+2,131
Water	21,234	22,351					
Total	119,550			Total	116,480		+3,070

96

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REMOTE SENSING IN WEST VIRGINIA

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Remote sensing has been a part of geological investigations in West Virginia for over 40 years, primarily using low-altitude black and white photographs. With the advent of Landsat, Skylab, side-looking airborne radar (SLAR), and high-altitude color infrared photography (CIR), newer dimensions have been added, but low-altitude black-and-white photography is still the major remote-sensing tool of the West Virginia geologist. This paper highlights several projects that have used various types of remote sensing with varying degrees of success. However, all of these projects have relied heavily on the field investigations mandatory for geological interpretations.

In cooperation with the U.S. Geological Survey's LUDA program, the State has produced a land use/land cover map at 1:250,000. The primary data source was 1:130,000 color infrared photography flown in December 1973. This map is the first land-use map of West Virginia. The map is presently being digitized to provide land use statistics needed for State and Federal programs involving planning and development (W. Va. Geological Survey, 1979).

Landsat linear features in Cabell and Wayne Counties were evaluated to test the possible correlation with rock fractures and gas production from Devonian shales (Fonner and others, 1978). Landsat images were enhanced by NASA/Goddard, and linear features were delineated by four geologists. Twenty man-days were spent in the field measuring systematic fracture orientations. The systematic fractures were consistently oriented N 50° W and showed a very poor correlation (0.21) with Landsat linear features. Data concerning subsurface Devonian shale fractures and Devonian gas production were not adequate to evaluate their correlation with systematic fractures and Landsat linear features.

As a continuation of this study, a Landsat linear features map (1:250,000) was prepared for the entire State of West Virginia (Reynolds, 1979). This map (Figure 1) is a preliminary effort and we anticipate revisions as future data become available. Linear features will assist in identifying potential locations of coal mine roof falls, water-well locations, coal degasification projects, oil-and-gas drilling, rock fracture studies, locations of faults, and tectonic and seismotectonic evaluations.

Karst subsidence is a problem in Greenbrier and Monroe Counties. There is a direct correlation among (1) the development of sink holes, (2) linear features on Landsat, color infrared, and black-and-white photographs, and (3) systematic fractures (Lessing, 1979; Dean and others, 1976). Sink holes are aligned along preferred orientations that match the orientations of linear features (Figure 2). This indicates that sink-hole development takes place along preferred pathways in limestone. Systematic fractures measured in limestone also show this preferred direction, as do subsurface cave systems. Present investigations are designed to further understand this limestone "plumbing system" and to predict areas that should not be used for development.

Figure 1. A part of the Landsat linear features map of
West Virginia (from Reynolds, 1979).

Figure 2. Sink holes and linear features in Monroe County, W. Va.
(from Lessing, 1979).

A 22-mile-long linear feature in McDowell County that was later named the Bishop-Bradshaw Creek fault (Elder et al., 1974; Johnston et al., 1975; Lessing, 1979b) was first revealed by SLAR. Field investigations have shown that the only displacement (40 feet of vertical movement) along this fault, that so far can be verified, has been noted at a coal mine exposure. But structural contour maps of major coal seams, and several subsurface formations (Ravenscliff, Greenbrier, and Berea) surprisingly show no displacement along this very conspicuous linear feature. Had field work not been performed, the Bishop-Bradshaw Creek fault might easily have been classified as a major structural element in the Appalachians, based only on remote sensing.

Landslides are a major hazard in the Appalachians, causing damage in the millions of dollars annually (Figure 3). To assess the significance, areal distribution, and causes, and to identify potential slide areas, a combination of aerial-photo interpretation and field mapping was initiated (Lessing et al., 1976). The total project has involved 36 7.5-minute quadrangles covering the major urban areas of the state. Each quadrangle required approximately one week of air-photo interpretation (low-altitude black-and-white) and two weeks of field mapping. The details required at 1:24,000 precluded the use of any photography with a scale smaller than 1:30,000. The use of remote sensing in this project was extremely valuable, both prior to and during field work. Most landslides can be detected on large-scale photography; this permitted field work to proceed rapidly. Photo work also revealed many large old slides that were not apparent at ground level.

The data gathered from remote-sensing projects like those briefly discussed above are being combined with other remote-sensing material (aeromagnetic and gravity surveys) to better understand geologic conditions (Kulander and Dean, 1978). Much of this effort is also aimed at providing direct benefit for West Virginians. Landslide maps can be immediately applied to planning-and-development programs. Linear features and fractures already improve the probability of finding high-yield water wells. Karst information has assisted with building decisions involving $4 million of HUD funds. And land use maps and inventories can be produced rapidly at minimum expense to provide critical information to state and local government. However, oil and gas production has yet to be linked to natural surface fractures and Landsat linear features.

Remote sensing is a tool that geologists should use in combination with field and laboratory work. Its value can be demonstrated time and time again.

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RECENT LANDSLIDES
Areas where landslides have been historically re-corded or characterized by fresh scars and obvious recent movement.

OLDER LANDSLIDES
Areas lacking evidence of recent movement, but characterized by hummocky ground, slump blocks, flow structures, water seeps, or evidence from aerial photographs. Presently stable but can be reactivated easily.

ROCKFALLS
Areas where rocks have fallen or are highly likely to fall. Normally confined to very steep, natural or man-made slopes and cliffs.

SLIDE-PRONE AREAS
Areas judged to be unstable due to the occurrence of landslides, incompetent rock and soil, steep slope, or other evidence of instability.

RELATIVELY STABLE GROUND
Areas judged to have very low susceptibility to landslides and contain no known evidence of in-stability.
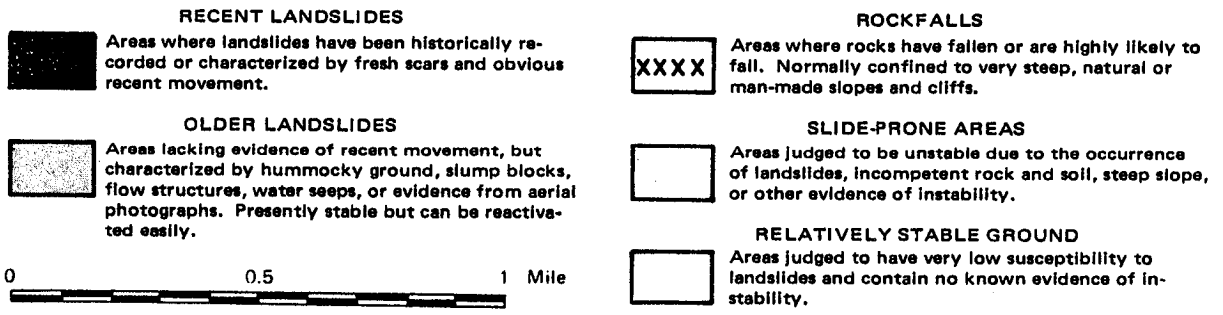
Figure 3. Landslide map from part of the Clarksburg quadrangle
(from Lessing and others, 1976).
Original in color (contact author).

103

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A PROPOSED MODEL FOR APPLIED REMOTE SENSING IN INDIANA

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INTRODUCTION

Landsat data, particularly that analyzed through implementing machine-assisted techniques, are slowly being accepted by user communities. Regional planners, environmental analysts, foresters, and resources managers are among the users who have accepted information derived from Landsat and other remotely sensed sources.

The widespread acceptance of remote sensing methods to acquire data which are applicable to a great variety of user needs at local, regional, and state levels requires effective interaction of several groups. Basically, these groups can be divided into those who are most concerned with remote sensing and data development and those who are users of remotely sensed data. Within the remote sensing group are federal facilities such as ERRSAC of NASA/Goddard and university affiliated remote sensing laboratories such as LARS/Purdue University and ISURSL/Indiana State University. Examples in the user group are regional and state planning agencies and state departments of natural resources. Other participants are consultants who may have either remote sensing or applications expertise, but are neither affiliated with the remote sensing community nor the user community. Thus, in total, four groups are involved in interactions which focus on effective development and use of remotely sensed data for analysis of earth resources. The manner in which these groups interact will determine the effectiveness and speed of incorporating contemporary remote sensing into applied research conducted by local, regional, and state agencies.

THE ROLE OF THE REMOTE SENSING COMMUNITY IN TECHNOLOGY TRANSFER

The forms of remote sensing which are often most useful may appear esoteric to a user; thus an emphasis on technology transfer of state-of-the-art remote sensing techniques applicable to users' needs is valid. Technology transfer of basic and advanced remote sensing techniques designed for both the research scientist and those responsible for local/state resources applications activities has been in operation for nearly a decade at large university affiliated remote sensing laboratories. These laboratories pioneered many contemporary advances in analytic remote sensing techniques and applications. For example, the Laboratory for Applications of Remote Sensing (LARS) at Purdue University has had a series of remote sensing short courses as well as more extensive training within a visiting scientist program. The Indiana State University Remote Sensing Laboratory (ISURSL) has

had an NSF-sponsored series of short courses which, like LARS, emphasizes machine-assisted processing of spectral data within the total framework of remote sensing. The university affiliated remote sensing laboratories are in an excellent position for technology transfer because of expertise in basic and applied research as well as in teaching.

Recently, federal facilities that have remote sensing expertise (e.g. EROS Data Center and ERRSAC at NASA/Goddard) have developed technology transfer programs which in various ways and to various degrees benefit and assist the user community in applying remotely sensed data (particularly Landsat). However, collectively there are still too few of these groups in existence that are capable of assisting the current user community, much less the increasing needs of an expanding user community in the near future.

The manner in which these technology transfer resources can be used to best advantage of the user community can be subject to debate. At this time, as new remote sensing technology is in a transitional stage between experimental and operational, there is perhaps no single correct method of technology transfer to the user community. Each remote sensing facility which actively participates in technology transfer has its own philosophy that in its own way will promote advances in applied remote sensing.

The role of the short course (1 to 10 days) and more extended visiting scientist programs (several weeks duration) designed for remote sensing students from the user community with no or limited remote sensing background should focus on providing insight into the sources and uses of remotely sensed data. Information relating to the physical principles of remote sensing needs to be introduced to the extent that this data acquisition tool is founded on sound scientific principles, but rarely is there time, even in the longer short courses, to allow a student to adequately comprehend and utilize such things as the significance of energy-matter interactions in applied research application.

It may be feasible to train a novice in remote sensing to analyze spectral data and derive information of value to county, regional, or state agencies. This approach can be successful if a person with minimal remote sensing expertise is strongly supported by experienced analysts and has access to sophisticated user-oriented equipment to analyze spectral data. Frequently this type of individual, in order to be effective in developing and analyzing data, must use a narrow spectrum of techniques which only can be applied to very specific applications and which may not be available for future analysis. The need for continued support from an experienced remote sensing analyst will remain, yet access to such an analyst cannot be assured. Undoubtedly a short course or a summer internship, used in conjunction with on-the-job experience in a specific applied remote sensing project, will be one step in the development of a remote sensing analyst within the user community. Nevertheless there is a danger that an analyst even with this degree of expertise can unintentionally develop poor quality or inappropriate information because of limited knowledge of remote sensing.

For the reasons stated above ISURSL views short courses and relatively short-term internships as vehicles which are best used to introduce the user community to the diverse possibilities that remote sensing has to offer within a designated field of interest. Basic principles of remote sensing, introduction to a wide variety of analytical techniques and remote sensing products, and insight into how to evaluate the potential applicability of a remote sensing product or approach to data

acquisition should be the foci of technology transfer to the user community under consideration. Short-term remote sensing instruction can prepare this user community to communicate effectively with the experienced analysts. This need for communications is much more important than creating an army of partially trained analysts within the user community who have limited ability to develop information from remotely sensed data for a variety of problems. It has been ISURSL's experience that user agencies which have no one knowledgeable in remote sensing have a difficult time in acquiring the data they really need from remote sensing laboratories because of communication gaps. Undoubtedly good short-term technology transfer programs can eliminate most of this communications problem, but these same programs can only superficially develop remote sensing analysts.

An individual in the user community interested in becoming an analyst for his or her agency should not be discouraged from doing so, since the future need for this activity is great. However, it should be made evident to the prospective analyst that there is no short route to becoming a remote sensing expert and that years rather than weeks of study and research is the norm.
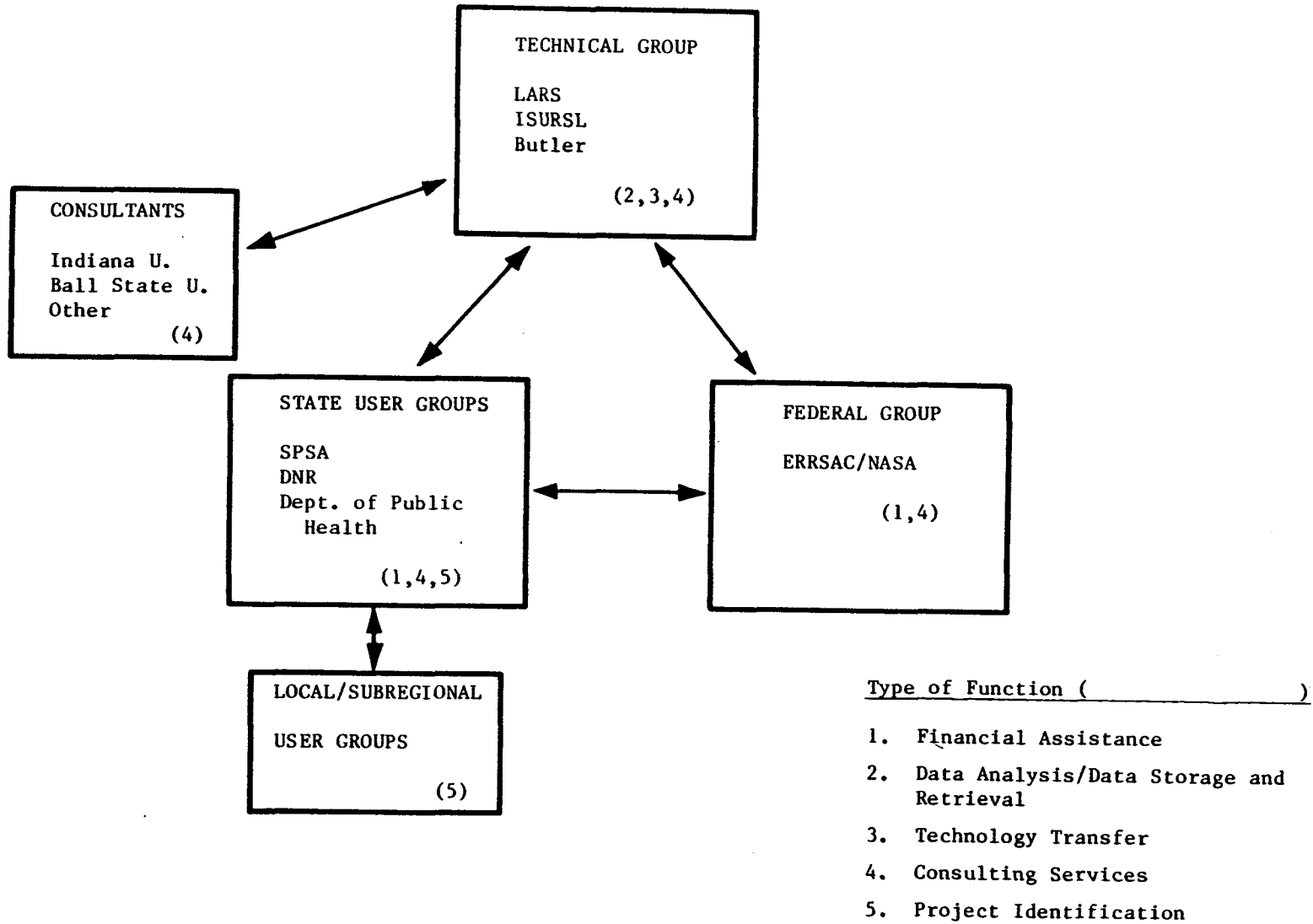
AN APPLIED REMOTE SENSING MODEL FOR INDIANA

Indiana is fortunate in having two large laboratories (LARS and ISURSL) which have state-of-the-art remote sensing capabilities and which have had extensive experience in applications of remote sensing and technology transfer. In addition, an operational geobased information system exists at Holcomb Research Institute (Butler University). These three facilities provide a complete resource for developing, analyzing, and transferring remotely sensed data for any user's needs.

There are many potential users in Indiana, but the state level agencies which are most interested in the services that the three university laboratories can offer are the State Planning Services Agency (SPSA), the Department of Natural Resources (DNR), and the State Board of Health (SBH). Preferably the more local users of remotely sensed data can get their needs fulfilled by working through the appropriate agency, or they can contact the LARS/ISURSL/Butler group directly.

Thus, the remote sensing/geobased information system group and user groups are well defined in Indiana, but how can these groups work together most effectively? Figure 1 suggests interactions among the various groups which are being considered for the state of Indiana. LARS, ISURSL, and Butler are striving to coordinate their activities in a manner which will provide the remote sensing data analysis and data storage/retrieval capabilities needed by users in the state. These three facilities will serve jointly as the focus on consultation, evaluation of projects, data development and data storage/retrieval as applied to remote sensing problems. Consultants to this group will be acquired from other universities and the private sector where needed.

Initially, this technical group will primarily serve the three state agencies that have the greatest need for remote sensing (SPSA, DNR, and SBH). These three agencies will identify remote sensing needs at the state and substate levels. The university-based technical group may assist in helping this user group identify needs, but the final identification of problems which the technical group is to consider and work on is designated by the user community. It is assumed that the users are responsible for financially supporting the applied research activities of the technical group. Consultation, proposed project evaluation, and many aspects of technology transfer will be subsidized largely by the technical group.

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                        ┌─────────────────────────┐
                        │  TECHNICAL GROUP        │
                        │                         │
                        │  LARS                   │
                        │  ISURSL                 │
                        │  Butler                 │
                        │                         │
                        │             (2,3,4)     │
                        └─────────────────────────┘
┌───────────────────┐
│  CONSULTANTS      │
│                   │
│  Indiana U.       │
│  Ball State U.    │
│  Other            │
│            (4)    │
└───────────────────┘

        ┌─────────────────────────┐        ┌─────────────────────────┐
        │  STATE USER GROUPS      │        │  FEDERAL GROUP          │
        │                         │        │                         │
        │  SPSA                   │        │  ERRSAC/NASA            │
        │  DNR                    │        │                         │
        │  Dept. of Public        │        │             (1,4)       │
        │    Health               │        │                         │
        │                         │        │                         │
        │            (1,4,5)      │        └─────────────────────────┘
        └─────────────────────────┘

        ┌─────────────────────────┐
        │  LOCAL/SUBREGIONAL      │
        │                         │
        │  USER GROUPS            │
        │                         │
        │                (5)      │
        └─────────────────────────┘
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Type of Function (   )

1. Financial Assistance
2. Data Analysis/Data Storage and
    Retrieval
3. Technology Transfer
4. Consulting Services
5. Project Identification

Figure 1. Interactions between remote sensing and user communities in proposed
Indiana applied remote-sensing model.

ERRSAC or some other federal facility with comparable expertise is needed to assist in consultation both with the state technical group and the state user group. There is no need for ERRSAC to participate in technology transfer and data analysis/data storage-retrieval in Indiana, because that expertise is locally available. There is a major need for ERRSAC to assist the state in developing funding sources for problems it identifies. The state has responsibility for funding a large share of its applied remote sensing activities, but the need is great for ERRSAC to assist in acquiring funding for selected projects, particularly during the early stages of implementation of this model.

CONCLUSIONS

Mobilization of remote sensing and geobased information systems expertise within each state should be the primary concern of state and federal agencies responsible for applied earth resources analysis. Ideally, the interaction between a user and a technical group should be at the local/state level rather than at the national level. In Indiana the designated technical group can work daily with state users and have a much better understanding of regional problems than if research were being conducted from a federal facility several hundred miles distant. Also, it would be better for states near Indiana that lack the appropriate remote sensing and geobased information facilities to use the Indiana technical group until their capabilities can be developed and applied to their state problems. For example, Illinois has no established technical group to satisfy their major remote sensing needs. Why shouldn't Illinois work with the Indiana technical group until its facilities are capable of satisfying the needs of its state users?

Hopefully, the decade of the eighties will see the establishment of strong remote sensing facilities in every state. Until that time it is ISURSL's opinion that the role of federal facilities such as ERRSAC should be one of assistance in the establishment of these state facilities along the lines of the proposed Indiana model or in some other effective organizational context. ERRSAC's assistance to the the remote sensing community by supporting pilot projects in various states may be useful temporarily, because of the limited facilities currently available to states. However, an increased focus is needed on helping individual states develop and organize their own remote sensing capabilities in order that applied research needs can be conducted and with greater effectiveness at the state and substate level. In the ERRSAC region are the nonfederal facilities such as LARS, ERIM, Penn State, ISURSL, and Butler being used effectively to serve their own state or neighboring states? These established laboratories need to approach their state and neighboring states, to offer their expertise. ERRSAC could greatly facilitate the development of these proposed regional and state centers for remote sensing application if this became one of its major priorities.

LANDSAT, A DATA SUPPLEMENT TO FOREST SURVEY

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Michigan Department of Natural Resources
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The Forest Management Division of the Michigan Department of Natural Resources (MDNR) has considerable interest in the changing forest land base of the State. Presently such statistics are gathered periodically through the cooperative effort of the MDNR, the U.S. Forest Service, and forest industry in Michigan. The Michigan Forest Survey has been conducted every 10 to 15 years and gives statistically reliable data on a multi-county basis. The Forest Management Division has received frequent requests for more up-to-date information and also for information on a county basis. Recognizing that Landsat could provide an opportunity to update certain portions of the Forest Survey and to provide some information on a county basis, we developed a project which would investigate such uses of Landsat and would also provide potential users with training and experience in its use.

The initial part of the project was an accuracy assessment of forest/nonforest cover with an eventual level II classification (hardwood, conifer, and mixed stands) if time and resources permitted. If accurate, these data could be coordinated with Forest Survey data to give reliable up-to-date forest statistics. Other potential users, such as an industry and regional planning commission representatives, were included in the training and assessment. Training and Landsat data display methodologies were provided by the Environmental Research Institute of Michigan (ERIM).

Dickinson County, in Michigan's Upper Peninsula, was selected for this pilot project (see Figure 1). This county was selected for several reasons. It is largely a forested county, but one which is being subjected to various pressures which are now or will result in sizable changes. Second home activity is increasing, resulting in decreases in available timber supplies. Mining and population expansion pose an additional threat to forest lands. The building of a large pulp and paper mill in the area will result in further developmental pressures while adding to the demand for timber resources. Thus, the county provides ample opportunity to view various land uses which are likely to change and enable us to assess Landsat as a tool for monitoring such change.

Interpretation was done from a color-combined image which was photographically enlarged and printed at 1:125,000 scale. Frames covering Dickinson County were geometrically corrected to a map base and restored to improve the geometric and radiometric properties of the data. Spatial resolution was improved to 50 meters, and data were contrast-stretched. This image format rather than a computer classification was used because it tended to be more instructive and since this probably will be the methodology used by the MDNR in the near future.

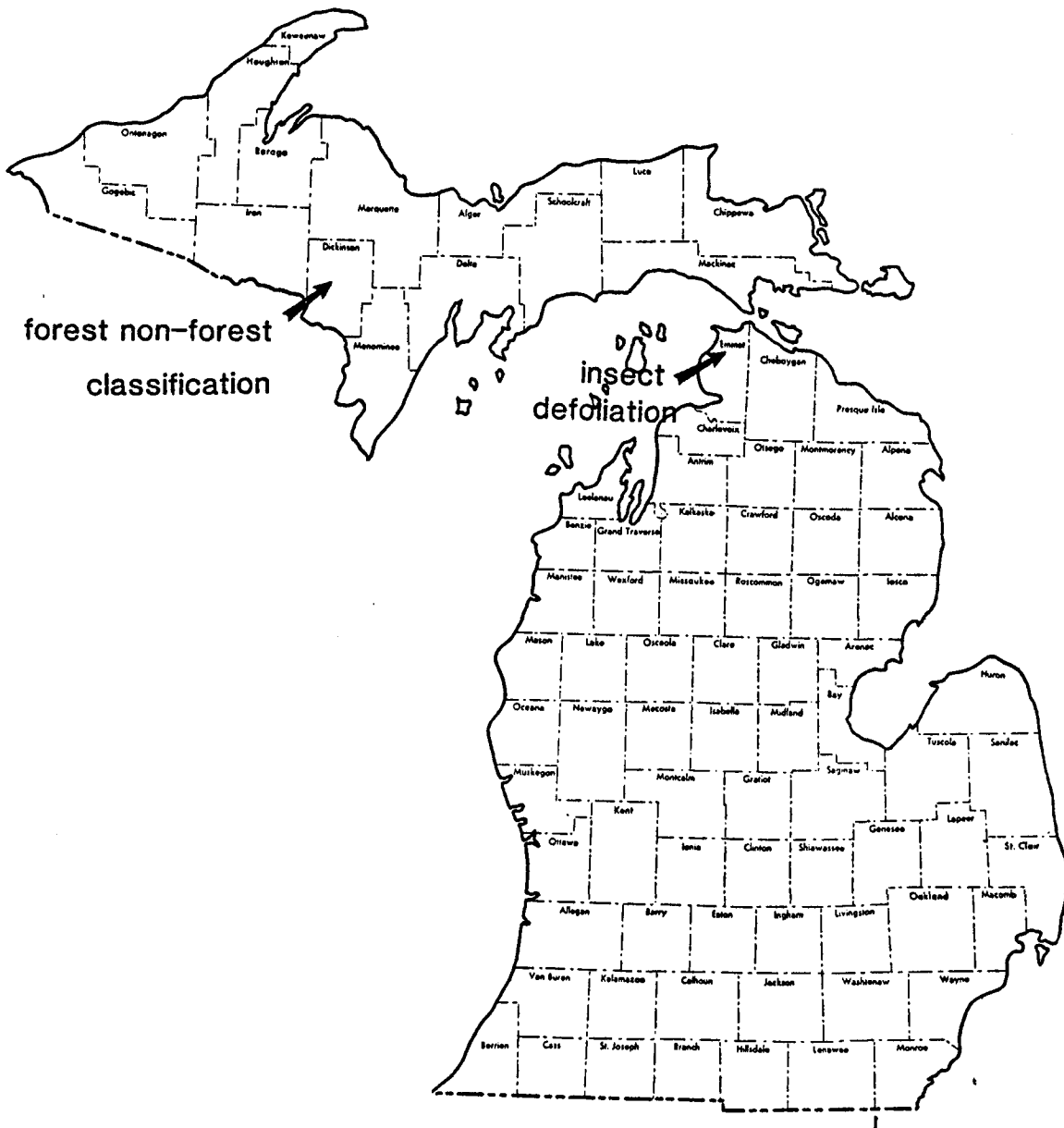forest non–forest

classification

insect
defoliation

Figure 1. Map of Michigan showing forest management division
project counties.

112

Much of the photo image interpretation was done by the industry representative, Mr. Richard Sirken of Champion Timberlands, because of his knowledge of the area. He is particularly interested in this area because of the eventual location of a large company facility in Dickinson County. His knowledge of and interest in the area contributed significantly to the accuracy of the classification.

For both the forest, nonforest, and level II classification, one hundred points were tested for accuracy. The points were equally divided between classification categories and randomly located within each category. Color infrared aerial photos, scale 1:24,000, flown at nearly the same time as the Landsat scenes, were used for ground truth. The forest/nonforest classification had only one point incorrectly classified, a nonforest area classified as forest. The level II classification had 4 of the 100 points incorrectly classified. In each case, the mixed forest category was involved in the misclassification, pointing out the difficulty in working with that category.

The level of error was considered quite low in both cases and convinced us of the usefulness of Landsat as a source of information. As a result of this project, the MDNR has entered into a cooperative research agreement with the Remote Sensing Unit at Michigan State University to do an evaluation of increased coordination possibilities between Landsat and Forest Survey information. Champion Timberlands has also instituted additional uses of Landsat data sources since taking part in the project.

As a sidelight to the major project, a serious forest tent caterpillar outbreak in Michigan in 1978 enabled the MDNR to evaluate Landsat as a tool in detecting and delineating the defoliation (see Figure 1). July and August Landsat color-combined images were photographically enlarged and printed at a 1:250,000 scale by ERIM for use in this project. It was assumed that the change which would occur as the trees refoliated would enhance detection. The defoliated area was easily and equally detectable for both scenes. However, there was little change between scenes indicating that, even though refoliation was well along in August, Landsat was capable of detecting the stressed condition of the trees. The photo images were definitely usable for delineating the extent of the tent caterpillar defoliation.

The help of NASA in instituting and completing this project is gratefully acknowledged. The Forest Management Division of the MDNR is convinced that Landsat can be an important source of information.

CLEARCUT MAPPING AND FOREST TYPE MAPPING
IN EASTERN FORESTS WITH LANDSAT DATA

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The State of New Hampshire is 87 percent forested, ranking second only to Maine in this regard. For this reason it is of major importance to the management of this resource to be able to make up-to-date type maps and to monitor clearcut areas in the approximately 5 million acres of forest in New Hampshire. This information is needed by the forester on the ground to assist him in actually managing the forests under his control.

Landsat data can provide this kind of information, and it is the job of the Cooperative Extension Service to produce it in a manner that is useful to the field forester. The GISS computer is used, through a remote terminal at Dartmouth College. The remote terminal consists of a decwriter, card reader, and high speed lineprinter. Currently, our output products are all done on the lineprinter, which hampers our ability to produce the most useable materials. Though we are basically a research unit, we are oriented toward providing the connecting link between pure research and pure application by producing a product requested by a user forester in a format he can use.

Recently we have been producing signature packages which provide a forest type map and which identify clearcut areas. This type map divides the forest land into three categories: softwood, mixed wood, and hardwood. The user defines each of these categories and adjusts the signature package to fit his needs. Clearcuts in New Hampshire typically range in size from 5 to 100 acres with between 30 and 40 acres being the most common. We have had success in identifying clearcuts and their stage of regrowth.

The following maps illustrate how forest mapping from Landsat digital data can be used to map forest types, areas where clearcuts have been accomplished, and the stage of regrowth of older clearcuts. Figure 1 is a portion of a USGS topographic map, with forest types overlaid from maps done by Colin Sutherland in 1973. Figure 2 is a computer-generated forest type map from Landsat data acquired in the summer of 1975. This map has been mechanically reduced to the same scale as the USGS sheet. The numbered items on the right identify clearcut areas. Those cuts completed by the date of the data are identified as to the year they were cut. Numbers 4, 6, and 7 are cuts which were to be done subsequent to 1975. Figure 3 shows the condition of the cuts identified in Figure 2 as they were when the data were acquired in the summer of 1978. You will note that there is a progression from open, new clearcuts to the reforested old one. The data acquisition and processing methods have allowed us to pick up reforestation of these clearcut areas as it progresses from year to year. Similarity in the shapes of the softwood areas in the Landsat maps to those on the
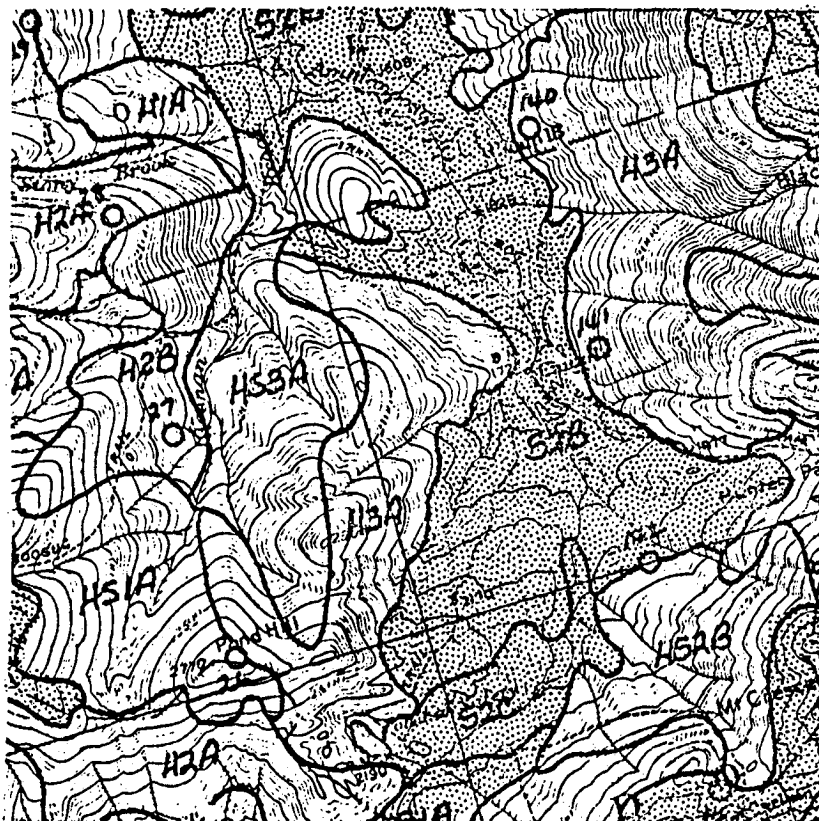
Scale 1:62,500 1″ = .986 miles

KEY   Produced by:

⸭⸭ S = Softwood   Emily Bryant
                                       Dartmouth College and
⸭⸭ H = Hardwood &Mixed Wood   Goddard Institutde for
                                       Space Studies
     Open nonvegetated

⸭⸭ Open vegetated

⸭⸭ Early regrowth

⸭⸭ Advanced regrowth   Arthur G. Dodge and
                                       Ken Sutherland
⸭⸭ Water   University of New
                                       Hampshire Cooperative
⸭⸭ Unclassified   Extension Service

Figure 1. Pond of safety area.

1. 1971±

2. 1972 / 70

3. 1975

4.

5. 1973

6.

7.

Pond of Safety
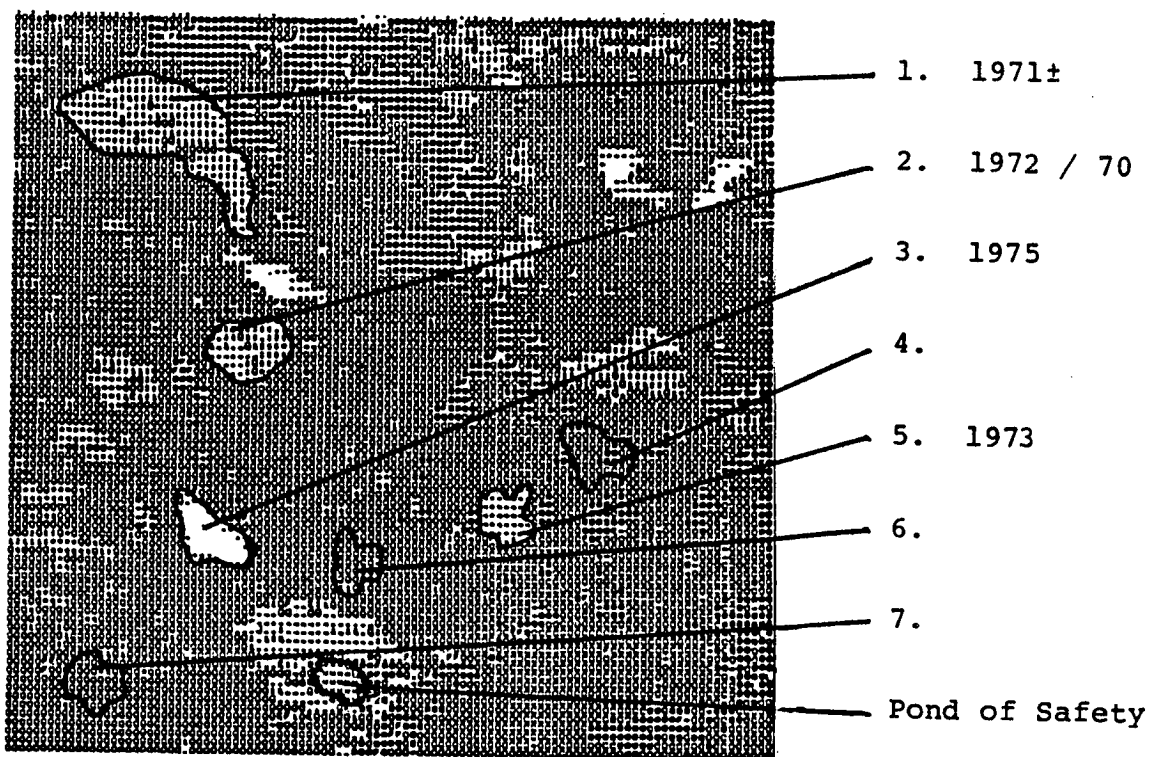
Figure 2. Computer-generated forest type map from
Landsat data acquired in 1975.

1.

2.

3.

4. 1978

5.

6. 1977
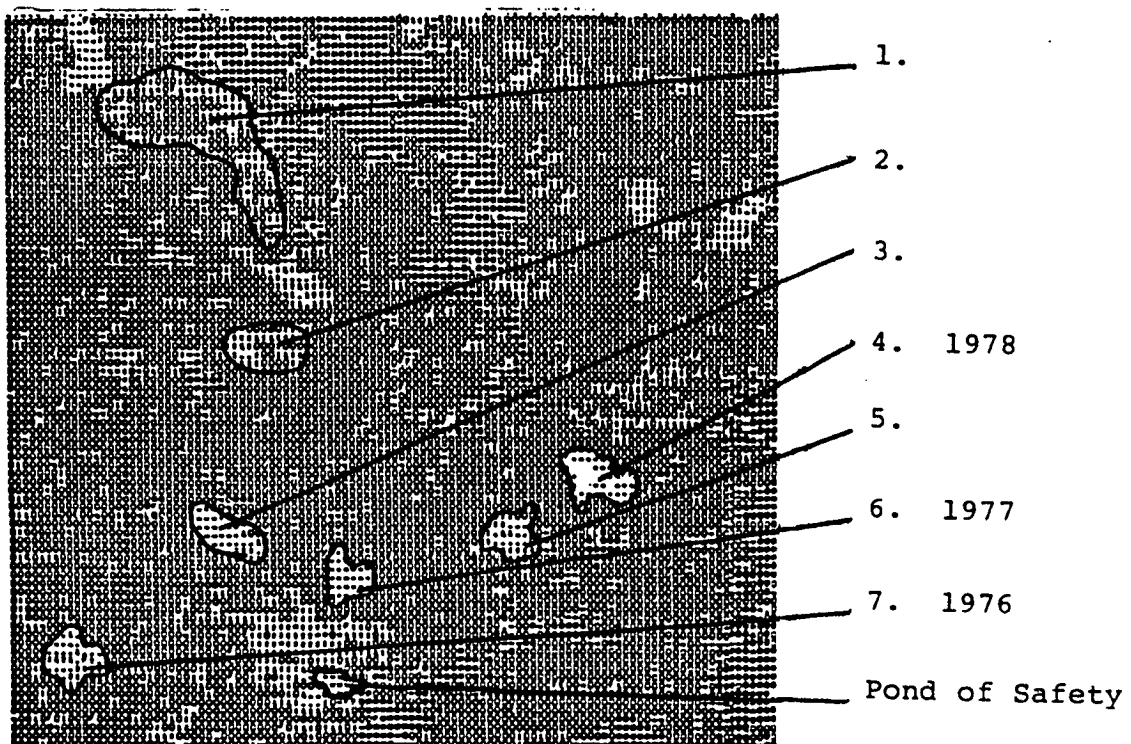
7. 1976

Pond of Safety

Figure 3. Computer-generated forest type map
from Landsat data acquired in 1978.

USGS sheet is also noticeable. In this particular example, the hardwood and mixed wood are combined on the Landsat maps, but the technology exists to separate them and to calibrate them quite closely to the USGS type map. You may wish to look at the other clearcut areas on both Landsat maps which have not been identified as part of this illustration.

We recently worked with a paper company on a 30,000-acre piece of land using the previously mentioned technique of adjusting signature packages. After showing the field forester the preliminary data, he suggested that he needed to be able to navigate from the Landsat printout and that it would be necessary to have such things as roads and boundaries, both property and compartment, overlaid on the Landsat data. This presented a problem for the programmers in New York, but eventually we were able to provide this type of product and will soon take it to the field forester for evaluation.

It is becoming increasingly apparent in our work with the field foresters that much more work needs to be done on multistage sampling techniques and the integration of Landsat with other forms of remote sensing. Our goal should be to produce data of equal or higher quality than is available with other methods currently used, and to do so in a more timely and less costly manner.

In the long run, we must aim to please field personnel who are the users of the data; we must give them information that they need and can use.

FORESTRY APPLICATIONS OF LANDSAT DATA IN NEW HAMPSHIRE

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Dartmouth College
Hanover, New Hampshire

Ken Sutherland
University of New Hampshire
Cooperative Extension Service
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Over the past several years, the Goddard Institute for Space Studies in New York, Dartmouth College in Hanover, New Hampshire, and the University of New Hampshire Cooperative Extension Service have been cooperating in a research effort to produce useful forest type maps by computer classification of Landsat data. Forest types have been mapped with some success (Dodge and Bryant, 1976; Bryant, Dodge, and Warren, 1978). Our efforts recently turned toward mapping forest harvests. We started with clearcuts rather than partial cuts because they are easier to distinguish.

There are several reasons for mapping clearcuts. First, forest managers need to know how large and where harvests are on their lands in order to make plans which balance the demand for wood with the rate of forest growth. Information on the stage of regrowth helps determine timber stand improvement practices as well. In addition, the location of clearcuts is useful in planning for forest fire control because clearcuts become a fire hazard one to two years after they are completed. Third, it is possible to map wildlife habitat indirectly by mapping clearcuts. Regrowth in clearcuts can be browse for deer and cover for grouse and woodcock.

We have found that it is possible to identify clearcuts using computer classification of Landsat data. In northern New England, regrowth in clearcuts is natural and relatively rapid. We have differentiated four stages of clearcut regrowth using Landsat data:

Clearcut Regrowth Stage	Age	Symbol on Printout
A	0-1 year	blank and ·
B	1-2 years	·
C	2-4 years	· and :
D	4 + years	: and *

The Landsat classification in Figure 1 includes clearcuts in stages A through D. Figures 2 and 3 are ground views of stages A and D, respectively. Regrowth, as shown in Figure 3, is natural and relatively rapid in this region. In the figure, note the forester's hat which is held about 8 feet above the ground.

If we are to use Landsat data to follow the progress of clearcuts, or any changing land cover feature, techniques must be developed for creating classification categories which are consistent from one pass to another. These must compensate for changes in atmosphere, differences in instrument response, and any other discrepancies from pass to pass which are not related to changes on the ground. Figure 1b illustrates an attempt to create forest and clearcut categories for a 1978 Landsat pass which are consistent with those from 1975 (Figure 1a). Areas which have not changed, for instance softwood (darkest symbol on the printout), remain more or less the same size and shape. The clearcuts have changed, however, in this 3-year interval, and the changes are evident on the printout. Regrowth stages have advanced and new cuts appear. Investigation into such "temporal signature extension" is a part of our ongoing research.

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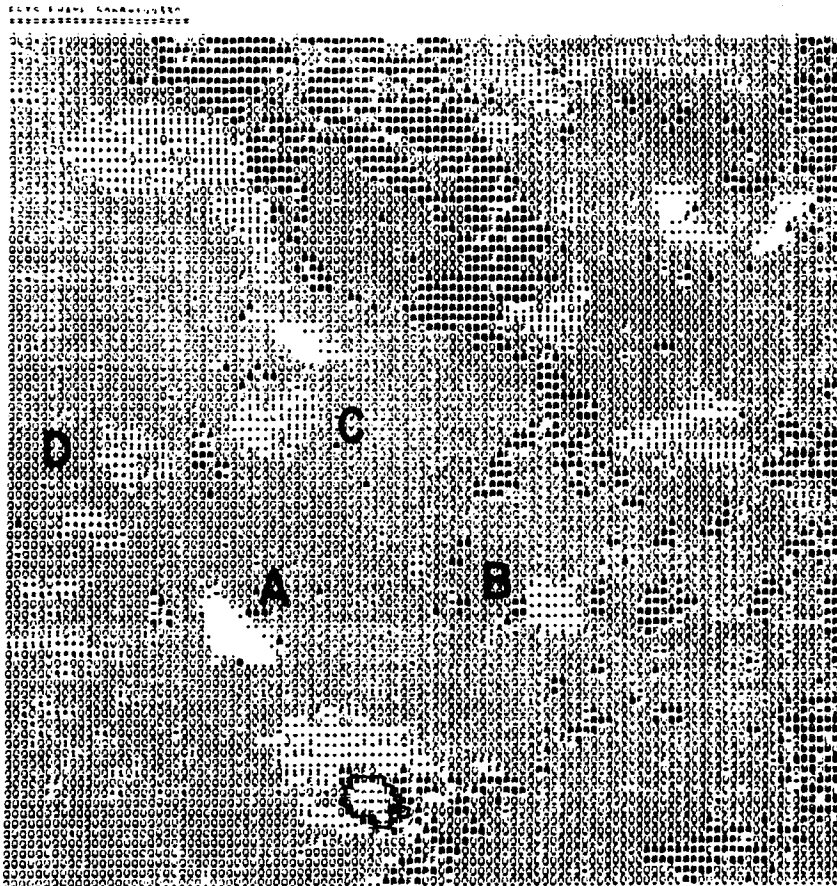
121

1975   Pond of Safety   1978

dark = forest, light = open

Figure 1. Computer classification of Landsat data.

Figure 2. Clearcut in regrowth stage A (10-1 year's growth).

Figure 3. Clearcut in regrowth Stage D (4 or more years' growth).

LAKE TROPHIC APPLICATIONS: WISCONSIN

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The Department of Natural Resources (DNR) in Wisconsin is working on a project to classify the lakes in the state of Wisconsin. Wisconsin, like Minnesota and Michigan, has numerous inland lakes, with estimates of the number ranging from five to one thousand, depending on how the word "lake" is defined.

As many of you no doubt know from looking at Landsat information, water values are fairly simple to define, mainly because of their relatively low reflectance in bands six and seven. We have used this idea to locate the lakes, and then, using the other chunks of information in the green, red, and the near IR (band six), have attempted to classify the water quality. It is not at all clear, of course, when looking at a Landsat image, what exactly you are seeing, especially with water-related types of problems. We have spent a fair amount of time trying to sort out the volume effects from the surface effects, and there seems to be a reasonable relationship between factors like turbidity and other types of water quality parameters and information that can be derived from Landsat-type of data.

The DNR has been interested in Landsat for some time, as a result of the Environmental Protection Agency's (EPA) 1972 mandate to classify all lakes in the state. The interest is not just in doing a color-coded thematic representation on maps, but also in actually getting some numbers representing the relative water quality in particular lakes. The DNR is also interested in efficiency; we are striving for a system which does not require an unreasonable amount of man-hours and one that operates fairly independently.

There are between 13 and 15 different Landsat scenes in Wisconsin. We used lakes all around the state for our first effort, trying to do a ground calibration of Landsat imagery and then ultimately putting together a system that classified all those other lakes in the state. In order to classify lakes quasi-automatically, the Landsat scene must first be navigated. Landsat data do not arrive in a format that gives longitude, latitude, and picture elements; we do this ourselves. Among the control points we used were road intersections, peninsulas, and other lakes. We chose a few control points around the state, and found the latitude and longitude of these points, and from there we were able to navigate all the Landsat scenes.

We now have a system in place which takes the tape and navigates each one-quarter scene separately, extracting data from the tape. The data are then inserted in the file, and a unique polygon is drawn around each lake. We take all the data within the polygon and separate the data which correspond to the lake by using a band seven level slice and extract the water information, and store it in the appropriate lake file. Files were developed, essentially of all lakes within the boundaries of the state's outline.

We have found, of course, that occasionally the location of these polygons is incorrect, usually when something less than a full lake is extracted. As a result of this, we had to develop an output that would ensure the reliability of the program. This was accomplished by printing a binary representation of land and water with zeros and pluses. We inspect these to see that the program is working sufficiently well. We found that when we extracted data from different dates, the water quality would vary, on a seasonal basis, at least for the lakes DNR was interested in. As a result of this, we decided to figure a classification based on a multidate type of analysis, early or late spring, midsummer, and early fall. Three of every scene in Wisconsin were acquired and navigated. We did some relatively simple atmospheric corrections, normalizing all the scenes to a spring date. (Many of these were not absolutely normalized; we are still in the process of working on this as a research project.)

After the data were normalized, they were put into an algorithm developed on the DNR's concept of what lakes should look like. The output of this analysis was a trophic class number from one to seven, since the DNR felt they would be satisfied with such a lake classification scheme. For these same lakes, the DNR assigned a trophic rank class number from one to seven based on their own water samples for all usual water sampling parameters. A comparison was made between the trophic class predicted by the Landsat analysis and the corresponding rank assignment according to field measurements.

The results we came up with were very encouraging. We looked at several different years, especially 1976 and 1975. For a set of 75 to 100 lakes we came to within one trophic class, using Landsat, of the DNR assessment of the lakes. For a number of different lakes, for different days, we predicted the trophic class "correctly," according to the DNR standards, to within one trophic class.

The output that was desired was a list rather than a thematic representation, so the trophic class was listed by an arbitrary lake number assigned within each county. The information listed for each lake in a county included the lake name and number, the trophic class from one to seven, the types of water quality problems associated with the lake—whether it was an algae, macrophyte, silt, or tannin problem, or if the lake was clear. We also printed the number of days used in the computation. As you know, Landsat sometimes has problems and you can't really count on acquiring three days all the time. The algorithm worked with one date but we were more confident of the results when several dates were used. Because of this we printed the number of dates used to answer the question: "Is this something we could actually believe or at least have more confidence in?" At the same time, we did do some thematic type of classification on selected lakes in the southern part of the state, with a range of trophic statuses. We did not do this for the whole state since there was not much interest in this type of data.

124

We did work with the Tennessee Valley Reservoir with the same algorithms, to see if it made any difference if we used reservoirs, which are man-made types of water bodies, as opposed to inland lakes which have more natural succession types of problems. There did not seem to be much difference. The algorithms worked equally well on the inland lake, or the reservoir type of water body.

In the case of the Tennessee Valley data, what is clearly being measured is Secchi depth, an indication of water turbidity. Landsat or other types of remote sensors do a very good job in examining water clarity or turbidity, an important component in trophic status. The other factors in the trophic status index are conductivity and bottom temperature, based on field measurements. These factors are indirectly related to turbidity, and some relationship can be developed between them. Trophic state is some conglomerate of water clarity and these other types of parameters.

This has been, I believe, a good application of Landsat data. We chose a problem which has the right resolution for this type of sensor, and used lakes which were at least five to ten acres in size. The application is reasonable, operational, and fairly cost-effective. The project should be completed by December 1979. In January 1980, we will begin work on 1979 data. We are trying to update the state on a three-year basis, providing our funding continues.

Since the current research is really based on a geobased-information system, we are also trying to implement land cover information from Landsat to work on a number of related problems involved with land cover, especially nonpoint source pollution types of problems. We are using this data base for lakes as a first step in a comprehensive program. With the addition of Landsat-derived land cover data, we plan to look at some of the nonpoint sources pollution problems and how land cover affects the lake water quality.

SESSION 4

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MINNESOTA LAND MANAGEMENT INFORMATION CENTER

Earl Nordstrand
Minnesota State Planning Agency
St. Paul, Minnesota

INTRODUCTION

What I would like to do is give you a little background on the Minnesota situation. From what I have heard, a lot of people are talking about the geographic information system concept and the Landsat analysis concept in concert. I think Minnesota has been afforded the opportunity to do a lot of things with that concept because we have been active with a geographic information system for about ten years.

I would like to give you a little bit of a feel for what we have been doing, and how we are planning and working on the process of making Landsat part of our operation in Minnesota. And I think that we do intend to make Landsat an operational part. I hope NASA follows through with making Landsat operational so that we will be able to use that data in the future.

But our intent right now is to make Landsat data available to anyone in the state to use in conjunction with the geographic information system that we do have.

The development of the Minnesota system dates back approximately ten years to the late 1960's, with the passage of state environmental legislation. During this time, a great deal of concern was expressed by the legislature and by interest groups in the natural resources that are such a big part of the state. Concern was expressed about the development that was occurring on the lakes in the state. You began to see a very heavy second home development on lakeshore property. You began to see intensive pressure from the metropolitan area to use those resources, somewhat randomly perhaps, and without any real methodology. There was also a lot of concern about the changing land use, the changing pattern of resources in the state, and as a result, a lot of environmental legislation was passed in the late 1960's.

One important aspect of that time period was the formation of the Legislative Commission on Minnesota Resources (LCMR), which was established as a joint committee of the legislature of Minnesota, between both Houses, and which was set up to provide monies obtained through a cigarette tax, to accelerate resource management and provide money for resource types of programs. It initially put a lot of money into purchasing land for preserving resources that we have in the state, and also for data collection so that we could do a more effective management job on the resources that Minnesota had. So it became a job of collecting data for the policy assessment phase.

This research project housed at the University of Minnesota was called the Land Management Information System (LMIS). It was organized as strictly a university research project to begin to collect data of different types.

One of the first things we did was to organize a data collection system for the land around the largest lakes in Minnesota, so that some information about that resource could be captured. From there it moved to a statewide land use map.

Some of you may have seen this map. It was published at a scale of 1:500,000. It was manually put into a grid for the entire state based on public land surveys. A forty-acre parcel was the basis for that photo interpretation. It was a manual grid system which captured that data. There are about 1.3-1.4 million forty-acre parcels in the state of Minnesota, so it was quite an ambitious photo interpretation and data-capturing task.

This task was concluded in 1970 and the map was published shortly thereafter. The staff of the project was an interdisciplinary staff housed at the university. We used people from a variety of different programs—foresters, geographers, landscape architects, computer science personnel. All of these people were brought together for their expertise to help mold what we think is a fairly successful state information system.

During the early 1970's, the data base was expanded by capturing a variety of different kinds of information; information on statewide soils was provided by a cooperative project with the Soils Sciences Department at the University and the Soil Conservation Service in the state. It is a generalized soils survey but it does give a lot of information statewide that would not be available if you had to wade through detailed soil surveys.

There were a number of other collection programs. At that time we began talking about collecting data in a manner that would facilitate putting it into a centralized data bank for a national information system. There were initial discussions and they were very difficult because we had people who were used to doing things on their own and didn't really care whether the data were used by someone else. It was a slow process, getting people to cooperate and join together and talk about how their data could be useful to other programs.

Throughout the 1970's and in our function as a university research project, it became apparent that this research project was now at a stage where it could become an operational part of the state program. As a result, the 1977 legislative session moved the project from the University into the State Planning Agency, which is a coordination unit for state government organized under the Chief Executive—the Governor's Office. The Land Management Information Center (LMIC) was set up as a division within the State Planning Agency to act as a service bureau to provide geographic information system capabilities to anyone who wanted to use it. This includes all levels of government, from the federal and state agencies that are housed in the metropolitan area and are concerned with the resources of Minnesota, down to private consultants and local units of government.

We have been a service bureau now for about three years. We are there to provide resource information and geographic information system capabilities. We still use the university computer system but we are moving away from that and will be developing our own increased capabilities.

Another important point occurred in that 1977 legislative session along with the institutionalization of the Land Management Information System. Many of the data collection programs in the other agencies of this state were mandated by legislative funding and, through LCMR, (Legislative Commission on Minnesota Resources), data could be collected in a manner that was consistent and compatible with the Minnesota Land Management Information System. Data compatibility with LMIS appear in the line item funding of many data collection programs in the state of Minnesota. It gives us the ability to go out to these agencies and talk about what their data collection programs are and actually work with them and develop their data in such a way that can be used in a state-wide information system. That really insures cooperation among the different agencies. I can't stress what a key that has been. Minnesota is somewhat unique in that we have a focus in St. Paul. There is not a lot of competition between different universities and departments spread out in different locations in the state. And the focus has allowed us to work in concert, with all these different agencies.

About a year ago or so, we began to think about other data sources and other development means that we had in Minnesota—the other kinds of data that might be possibilities. We got to talking with ERRSAC about the possibilities of using Landsat data and began to get some programs going in that direction. One area that we thought we could improve upon was our 40-acre data base by using Landsat, and we wanted to get in before Landsat became operational so that we could handle a variety of more detailed data becoming available from different federal sources.

We are updating our system capabilities through a request to LCMR for special funding. We asked for, in the last biennial appropriation phase in the spring of 1979, a funding of about $430,000 to enhance our capabilities as a geographic information system as well as provide for Landsat analysis and integration. This includes purchase of hardware to develop our in-house capabilities, plus software development that would allow us to expand into all the different areas that we think are important. This includes being able to digitize polygons which we haven't done at this point. It means capturing data from other digitized data sources, and integrating data by doing geometric corrections and converting data sources that do not particularly mesh with our present data base system.

We talked about getting state agency personnel involved in using Landsat with ERRSAC and decided that the best way to approach this was to get a number of different departments (Department of Natural Resources, State Planning Agency, and Pollution Control Agency) started processing Landsat, and at the same time, within our own group, devise a way to obtain digital handling capabilities for Landsat data for the state of Minnesota. We initiated three different projects. One which was presented yesterday was an irrigation study, another project is a land cover classification of Wright County shown in a poster display and a third in initial discussion stage, is a water clarity analysis for the state of Minnesota.

We have also been talking about cooperative projects with other people. We act as a coordination group within the state and we try to provide them with a focus for asking questions and provide them with information about Landsat technology. One of the things that we were funded to do specifically by LCMR was to provide the technology and the technical expertise to help people who are not familiar with Landsat data in the development of projects that could utilize it.

I would like to say just a couple of things about what our present situation is and how we are approaching these problems of getting our own hardware, getting a suitable software package, and what our funding is.

We are funded through a state appropriation—line item appropriation—through the State Planning Agency. We operate as a separate division. We had a staff the last fiscal year of seven professionals and an approximately equal number of student assistants. And through this year's appropriation we're expanding to eleven full-time staff with an appropriation of approximately $300,000 per year. In addition to that funding which we use to operate the service bureau, we have a revolving account that we use to charge back to clients the out-of-pocket cost that we incur in the process of providing services. These include computer charges that are billed to us by the University, and any student or technician time does involve additional dollars.

The amount of that revolving fund was $60,000 last fiscal year and will be $80,000 for this next fiscal year. So that will give us about $380,000 operating budget for this fiscal year. In addition, we did get an additional $30,000 for expansion costs which includes hiring temporary people as part of this program, and installing the hardware and software.

We looked at a variety of hardware and software configurations that we thought might do the job for us. We had to have this complete emphasis on geographic information systems. We wanted to expand in a lot of different areas, and we considered a lot of different options to accomplish this. We tentatively decided to purchase a minicomputer system, a 32-bit size minicomputer with all of the graphic peripherals, image processing system, dot matrix impact plotter, electrostatic plotter, and pen plotter so we'll have a full range of graphic capabilities. That's a very key part of our service operation. We have to be able to produce a plot, and if we can't produce it in a form that's understandable, it is very difficult to sell our capabilities. And that's what we ended up doing, selling our capabilities.

We decided to expand our software capabilities in two ways. We are going to work with the Earth Resources Lab of the Southern Region and will obtain their software package and adapt the classification and the data base management system that they have. Secondly, we are going to rewrite some of our own software that we developed over the ten-year period so that it will work on the new minicomputer system.

At this point we have developed our system on a Control Data Cyber 74 which caused some unique problems in trying to convert, and we are very anxious to see how that is going to turn out. We have also obtained the polygon handling software of Environment Systems Research Institute (ESRI) of Redlands, California.

We hope to integrate all of these software packages together into something that is going to provide a whole range of capabilities for us. In the meantime, we will continue to be operational on the university's computer system and we will go through a painful development stage in the near future of trying to get hold of things that are available to us.

We are optimistic about what is going to happen. We think we have a unique opportunity to obtain new capabilities for Minnesota and to expand the potentials of our information system.

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THE VERMONT OPERATIONAL LANDSAT DATA ANALYSIS SYSTEM

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In June 1978, the School of Natural Resources at the University of Vermont was awarded NASA Grant NSG-7453 for a three-year project entitled "The Development of a Remote Sensing Applications Program for Vermont." The purpose of this program is to encourage investigation and technology transfer of practical applications of remote sensing technology to solve earth resource problems.

During the first year of the project, particular emphasis was placed on upgrading and acquiring various types of equipment able to handle both photographic and digital data. One of the biggest decisions facing the staff was the selection of a Landsat digital image software package. The decision was made to acquire the Office of Remote Sensing of Earth Resources (ORSER) software from Pennsylvania State University. The selection of ORSER was based primarily on its compatibility with the IBM computer at Vermont, its dollar cost and the fact that Vermont could draw on the expertise of the resident staff at ERRSAC in the use of ORSER.

After a local examination of the ORSER source code, and considering our short timetable, the decision was made to seek outside help in the installation of the software. In February of 1979, George Baumer of the Office of Remote Sensing of Earth Resources at the Pennsylvania State University came to Vermont to install ORSER on the University of Vermont's IBM model 3031 computer. George spent four days in Vermont, at which time the system was about 75% operational. By the end of February the local staff had the system about 98% operational and functioning smoothly.

The principal advantages to Vermont in installing ORSER locally have been: 1) a much faster operating environment, particularly in terms of output; 2) a much greater availability of disk space, eliminating the need for BAT files and decreasing the necessity for utilizing tape drives; and 3) the ability to modify the software to meet specific user needs or to take advantage of local capabilities.

The Remote Sensing Applications Program at Vermont has been very satisfied with the ORSER image processing package. At the present time Vermont maintains one of the most complete, if not the most complete, installations of ORSER outside of Penn State. We have found that our version of ORSER, running under IBM's CMS operating system, to be much more user-friendly than remote access to the Penn State ORSER package.

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MASSACHUSETTS: THE ESTABLISHMENT OF A REMOTE SENSING CENTER

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INTRODUCTION

I have often heard stories, mythical or otherwise, to the effect that NASA is a very "political" agency. Well, don't any of you believe these stories, because I would like to offer the following "ground truth" that dispels such a rumor. I come to this conference representing the home state of the Speaker of the House of Representatives, the Chairman of NASA's Appropriations Subcommittee in the House, and the ranking Republican member of the full House Appropriations Committee. And yet, ERRSAC does not have a single project in the Commonwealth of Massachusetts. In any case, we at the University of Massachusetts appreciate the invitation to this conference and the time to describe briefly our remote sensing program. The Remote Sensing Center at the University of Massachusetts, probably the newest of the centers represented here at the ERRSAC Conference, was established in September 1979. Robert L. Huguenin was appointed Center Director at that time. The Center consists of 12 faculty members from 8 university departments, ranging from the natural science areas of physics, astronomy, and geology through the complete range of computer and information sciences to the more applied areas of forestry, wildlife management, landscape architecture, and regional planning. The Remote Sensing Center has received the strong endorsement of the University administration, and the Graduate Dean has made a commitment to the success of the Center.

Members of the University of Massachusetts Remote Sensing Center have identified five objectives that mark the remote sensing effort. I would like to describe each very briefly for you now.

RESEARCH

We at the University of Massachusetts feel that the most unique aspect of our remote sensing effort is our strong research capability, both basic and applied. All members of the Remote Sensing Center are active researchers with proven track records. In addition to the more traditional remote sensing research efforts in geology, forestry, etc., the Center includes a strong planetary and astronomy remote sensing research effort, especially in instrument development. Members of the Center hope to transfer the advanced technology that characterizes the planetary and astronomy remote sensing programs to terrestrial applications. The sophisticated instruments developed to study planetary surfaces and astronomical bodies have to be precise and incredibly accurate since, for example, there is no such thing as "ground truth" on Jupiter. Researchers developing and employing these instruments in the planetary and astronomy programs are interested in utilizing them to study the earth.

DEVELOPING FACILITIES

A key objective at the University of Massachusetts is the development of the most up-to-date research facilities that will assist in this remote sensing research program. The strong computer capabilities on campus provide an excellent backdrop for the development of an image processing software capability. Other state-of-the-art image processing equipment will be sought, and a Reflectance Spectroscopy Lab has been established to study the optical properties of materials, especially vegetation, with the aim of improving ways of recognizing specific plant and soil signatures.

APPLICATIONS

A key element in the success of any remote sensing center is its applications effort, especially as it relates to state and local governments. As part of a land grant institution, the University of Massachusetts Remote Sensing Center has a very strong incentive to develop interactions with state and local agencies. By assisting in the transfer of remote sensing technologies to governmental users, the center will not only be serving the state, but also will be gaining valuable experience in the use of remote sensing data, experience that will come in handy as the research effort to improve the technology expands. Already, members of the Center have made major contributions to state agencies. Professor Bill MacConnell's forest and wetland resource inventories are in great demand as planning tools. Steve Leatherman's work on coastal mapping, especially the mapping of barrier islands, has had a major impact on the protection of the Cape Cod beaches and the natural vegetation of the area. And Jack Finn's modeling techniques for wildlife in the Quabbin Reservoir will have implications, I am sure, for the management of the area by the appropriate state organizations.

EDUCATION

As a university center, the University of Massachusetts' effort is not ignoring the educational aspects either. This fall, for the first time, the members of the Center have joined forces to offer an interdepartmental, multidisciplinary seminar on the principles of remote sensing. Team-taught by all 12 faculty members, the aim of the seminar is to give graduate students in a variety of fields a familiarity with remote sensing techniques and to show the potential applications of remote sensing to the various disciplines. The course has been enthusiastically received. The Center would like to expand this educational function to include training programs for state and local government officials in the use of remote sensing data.

REGIONAL COOPERATION

The Remote Sensing Center at the University of Massachusetts is very interested in exploring the possibility of joint or cooperative projects with other remote sensing centers, especially those in New England. Such cooperative ventures, which will take advantage of the various and unique capabilities that NASA and ERRSAC have helped develop, will permit everyone in the region to make maximum use of remote sensing technologies for the betterment of all.

REMOTE SENSING OF COASTAL PROCESSES AND RESOURCES

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SUMMARY

Remote sensors on satellites and aircraft are being applied by the University of Delaware to accomplish the following in coastal and estuarine areas:

- Mapping wetland boundaries and plant species diversity and productivity;

- Comparing training site and spectral signature techniques for mapping coastal vegetation and its productivity;

- Monitoring man-made and natural changes in the coastal zone, including the impact of land use change on the environment;

- Predicting on-shore impact of Outer Continental Shelf development along the Delaware coast by comparing to similar development along the Louisiana and Alaska coasts;

- Charting current circulation and other dynamic properties related to coastal erosion and storm damage assessment;

- Mapping suspended sediment concentrations in coastal waters;

- Verifying and improving oil drift/dispersion prediction models for the Delaware Bay, including the effects of estuarine fronts on oil slick behavior;

- Determining the movement and dispersion of ocean-dumped waste plumes and correlating with ship and drogue data; and

- Mapping chlorophyll and nutrient-rich regions important to fisheries resources management.

These applications of remote sensing require a wide assortment of data analysis techniques ranging from visual photo-interpretation of color infrared film for wetland plant type mapping to standard digital techniques for thermal mapping, to multispectral analysis methods for marsh biomass mapping to sophisticated principal component analysis approaches for quantitative analysis of pollutant concentration in water. This paper illustrates, by specific examples, how various remote sensors and

multispectral analysis techniques can be employed to solve environmental and resource management problems in the coastal zone.

MULTISPECTRAL ANALYSIS OF COASTAL VEGETATION AND PRODUCTIVITY

Studies of land cover distribution along Delaware's coast, especially in tidal wetlands, have been made by utilizing automated analysis of Landsat multispectral scanner (MSS) digital data. Cover maps with 11 vegetation and other cover categories have been produced with accuracy of identification above 85 percent in all categories. More recent studies have tested new techniques for training such as automated analysis which use *in situ* measurements of target radiance and an atmospheric correction procedure to derive reflectance signatures for land cover categories in preference to the relative radiance signatures traditionally derived from training samples within the satellite data itself. A Bendix Radiant Power Measuring Instrument (RPMI) was used to measure upwelling and downwelling irradiance in the field, allowing computation of target reflectance in the four Landsat MSS spectral bands.

Land cover categorization of data from the same overpass in four test wetland areas was carried out using a wetland category classification system. The tests indicate that training data based on *in situ* reflectance measurements and atmospheric correction of Landsat data can produce comparable accuracy of categorization to that achieved using more conventional relative radiance training. The analysis of the four wetlands cover categories (salt marsh cordgrass, salt hay, unvegetated tidal flat, and water) produced overall classification accuracies of 85 percent by conventional relative radiance training, and 81 percent by use of *in situ* measurements. Overall mapping accuracies were 76 and 72 percent respectively. Further refinement of the atmospheric correction and ground measurement procedures should produce better accuracies in a more operational mode. (Bartlett and Klemas, 1979).

In addition, field measurements showed that variability in spectral reflectance was, as expected, symptomatic of significant physical characteristics of the test cover types such as time elapsed since tidal inundation of mud, plant height, and growth form. Significant correlations were found between single band reflectances and tidal inundation and plant morphologic characteristics. Optimization of seasonal sampling procedures for detection of plant morphologic parameters is suggested.

Modeling and other techniques applied to quantitative assessment of wetland energy and nutrient flux depend, in part, upon accurate data on vegetative species composition and primary production. As shown in Figure 1, recent research in the tidal wetlands of Delaware has demonstrated that spectral canopy reflectance properties can be used to measure the emergent green and total biomass of *Spartina alterniflora* (Salt Marsh Cord Grass) periodically throughout the peak growing season (April through September in Delaware). Such measurements have been applied to calculations of net areal primary productivity for large areas of *S. alterniflora* marsh in which conventional harvest techniques are prohibitively time consuming. The method is species specific and therefore requires accurate discrimination of *S. alterniflora* from other cover types. Exploitation of seasonal changes in species spectral signatures has also helped improve multispectral categorization of wetland cover types in Delaware.
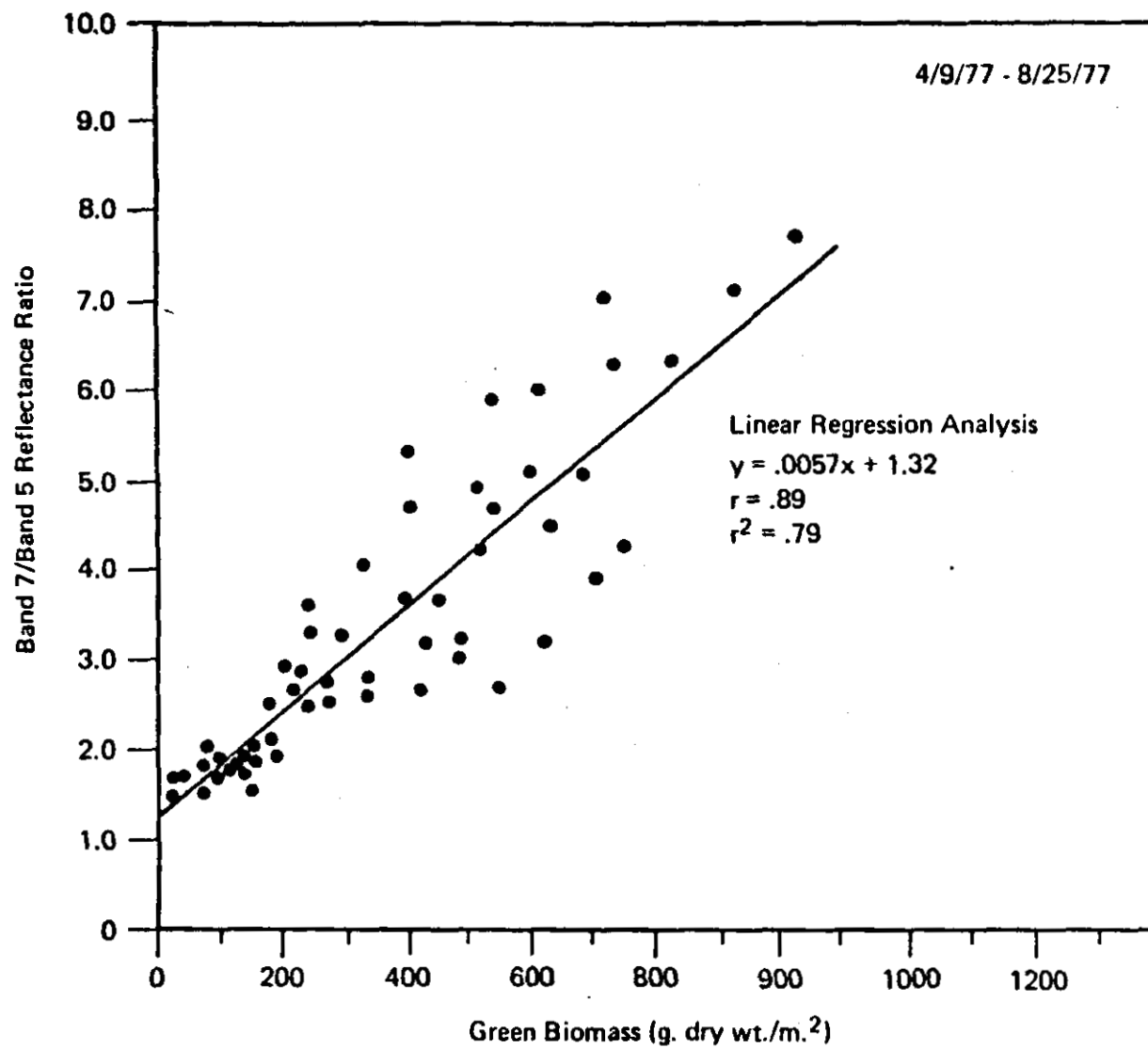
Figure 1. Plot of measured Landsat/MSS band 7/band 5 reflectance ratio as function of green biomass in grams of dry weight per square meter of *Spartina Alterniflora*.

The study was conducted using multispectral reflectance measurements in the four Landsat MSS wavebands (4: 0.5-0.6 μm; 5: 0.6-0.7 μm; 6: 0.7-0.8 μm; and 7: 0.8-1.1 μm) but has implications for other remote platforms or use of hand-held instruments in the field.

REMOTE SENSING OF ESTUARINE FRONTS AND THEIR EFFECTS ON OIL DISPERSION

Landsat, aircraft, and boats were used successfully to study coastal/estuarine circulation and fronts. Fronts (regions of high horizontal density gradient with associated horizontal convergence) are a major hydrographic feature in most estuaries and coastal waters. The water masses separated by a front frequently differ in turbidity and spectral properties, both of which can be observed remotely. Other surface features of fronts which can be imaged remotely include water temperature; wave refraction; foam or debris indicative of convergence; displacement of foam line indicative of lateral shear; displacement of ship wakes or dye lines indicative of longitudinal shear; and capture, movement, and dispersion of dyes, drogues, or other tracers. Remote sensors mounted on aircraft or satellites are capable of providing a synoptic view of frontal systems in real time over large coastal areas.

As shown in Table 1, horizontal salinity gradients of 4 percent in one meter and convergence velocities of the order of 0.4 m/sec. have been observed. Secchi depths changed from one meter to two meters as certain fronts were crossed. Fronts near the mouth of Delaware Bay are associated with the tidal exchange with shelf water. The formation of fronts in the interior of the Bay appears to be associated with velocity shears induced by differences in bottom topography and with horizontal density difference in the deep water portion of the estuary (see Figure 2). Surface slicks and foam collected at frontal convergence zones near boundaries were found to contain concentrations of Cr, Cu, Fe, Hg, Pb, and Zn higher by two to four orders of magnitude than concentrations in mean ocean water.

A computer simulation model has been developed for tracing oil spills in the Delaware Bay (Wang et al., 1976). The model takes into account two aspects of transport, drifting and spreading. The modeling of drift is based on the fact that oil on water drifts under the combined influence of water current, wind effects, and the earth's rotation. The physical processes governing the spreading of the slick are divided into three stages. In the initial stage, the spreading is predominantly governed by the balance of the forces of gravity and inertia. In the second stage, the spreading involves the balance of viscous and inertial forces. In the third and final stage of the spreading, a turbulent diffusion model is employed. The input requirements include the boundary conditions (the geometry and bottom topography), tidal current, wind conditions, and the nature of the oil spill: viz., the size of the spill, location of the initial spill, and the nature of the oil. Historical tidal current information and present wind conditions in the Delaware Bay region are now being used as input. The interactive nature of the model allows for information transfer between the computer and users, who may or may not be familiar with computer programming. The details of oil spill tracking are displayed on a television-type screen.

Table 1
Observed Features of Three Front Types

Feature	Estuarine Tide & Bottom Related	Estuarine Tidal-Wedge	Coastal Wind & Current Induced
Location	Upper & Lower Bay	Lower Bay	Coast & Shelf
Frontal Alignment	Parallel to River Flow Axis	Perpendicular to River Flow Axis	Any Direction
Transverse Velocity (cm/sec)	5-20	10-60	5-40
Transverse Movement (km)	± 0.3	> 10	> 10
Convergence Velocity (cm/sec) .	5-40	2-20	2-20
Shear Velocity (cm/sec)	5-20	1-5	1-15
Secchi Depth ($m_1 \rightarrow m_2$)	0.4→1.6	1.0→2.2	Sometimes
Color Change	Strong	Moderate	Moderate/None
Foam & Oil Capture	Strong	Moderate	Moderate/Weak
Detritus & Dye Capture	Strong	Moderate	Moderate/Weak
Wave, Refraction & Damping	Strong	Moderate	Moderate
Temperature Change (°C)	0-3	0-2	0-2
Salinity Change (‰ S)	0.5-2	1-4	1-2

*Changes in water properties across fronts were measured from boats or estimated from remotely sensed data along transects across the fronts. Changes indicated were measured over a distance of 10 meters on either side of the front.

**Some coastal fronts exhibit changes in temperature, salinity, turbidity and color as one crosses them, others may have gradients in only one of these parameters or none. Turbidity and color changes become less distinct as one moves out of the bay and onto the shelf.

FOAM
LINE   DETRITUS
LINE   COLOR
LINE

BOUNDARY
LAYER

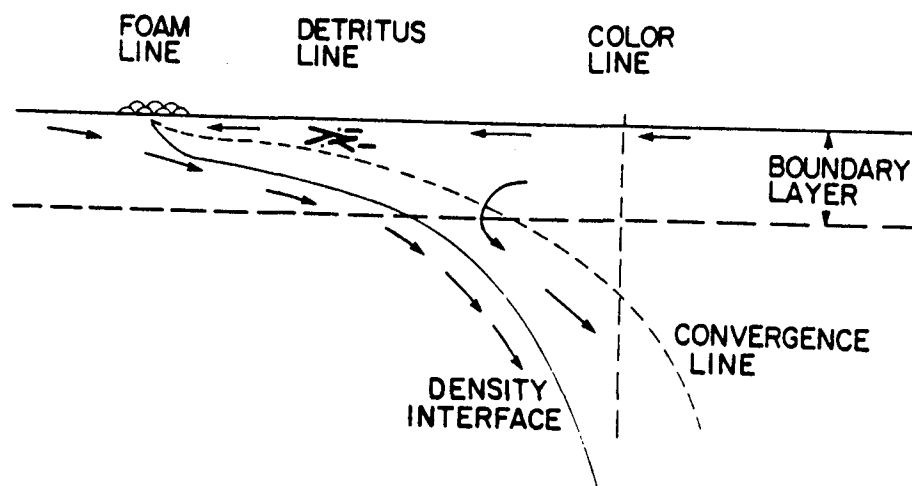CONVERGENCE
LINE

DENSITY
INTERFACE

Figure 2. Schematic diagram of a vertical section perpendicular
to a frontal convergence zone. Note displacement of surface,
near-surface and main zones of convergence as marked by foam,
detritus, and color lines respectively.

By capturing and holding oil slicks, frontal systems significantly influence the movement and dispersion of oil slicks in Delaware Bay. Oil slick tracking experiments conducted to verify a predictive oil dispersion and movement model have shown that during certain parts of the tidal cycle the oil slicks tend to line up along fronts. Thus, unexpected oil slick distribution patterns result which even for a known oil type cannot be predicted on the basis of wind and tidal current information alone.

In order to modify the predictive model to include the effect of boundaries on oil slick movement, one must determine where in the Bay boundaries form repeatedly and prevail over major portions of the tidal cycle. Aircraft have been most useful in locating fronts, photographing them, and guiding boats to collect data in frontal zones. However, for tracking the extent and repeatability of fronts over the entire bay under different tidal conditions, satellite imagery is more effective. Imagery and digital tapes from 36 Landsat scenes were used in our work. The tidal conditions in each satellite image were matched to one of the twelve National Ocean Survey tidal current charts, where each chart represents current conditions in Delaware Bay during a one-hour segment of the tidal cycle. Thus an average of three satellite images was associated with each of the twelve current charts. The fronts discerned in each image were superimposed on the appropriate tidal current chart.

144

The identification of fronts was based primarily on strong turbidity gradients or discontinuities. Some of the fronts also have foam lines, temperature gradients, and salinity gradients associated with them. The twelve Landsat charts containing current velocities and fronts have been used to establish locations where boundaries tend to prevail. A computer subroutine is being developed for the oil slick drift model in order to handle oil slicks that enter these front-infested areas. The subroutine will include dynamic effects such as shear currents at a finer scale.

DRIFT AND DISPERSION OF OCEAN-DUMPED WASTES

Landsat offers an effective means of assessing the drift and dispersion of certain industrial wastes dumped on the continental shelf. This is particularly true for acid waste disposal about 64 km off the Delaware coast, since this waste forms a sparse but optically persistent ferric floc which can be observed by Landsat's multispectral scanner band 4 up to 2 days after dump. The twice-a-week frequency of the dumping made it possible for Landsat satellites and aircraft to observe the waste plumes in various stages of degradation, ranging from minutes to days after dump completion. Spectrometric measurements indicate that upon combining with seawater, the waste develops a strong reflectance peak in the 0.55 to 0.60 micron region, resulting in a stronger contrast in the Landsat band 4 than the other bands. This spectral appearance seems to be caused by the formation of a sparse but optically persistent suspended ferric floc.

Using 16 Landsat images, vector drift diagrams were constructed showing the drift speed and direction of the acid waste plumes. As shown in Figure 3, most of the 16 waste plumes imaged by Landsat were found to be drifting at average rates of 0.59 km hr^{-1} (0.28 knot) to 3.39 km hr^{-1} (1.83 knots) into the southwest quadrant. The plumes seemed to remain above the thermocline which was observed to form from June through August at depths ranging from 13 m to 24 m. During the remainder of the year, the ocean at the test site was not stratified, permitting wastes to mix throughout the water column to the bottom.

The magnitudes of plume drift velocities were compatible with the drift velocities of current drogues released during the same 12-month period at the surface, at mid-depth and near the bottom. However, during the stratified warm months, more drogues tended to move in the north-northeast direction, while during the nonstratified winter months a southwest direction was preferred. Rapid movement toward shore occurs primarily during storms, particularly northeasters. During such storms, however, the plume is rapidly dispersed and diluted.

The spatial and temporal resolution of the satellite imagery was not sufficient to provide precise data on waste plume dispersion. However, a visual estimate of plume width was obtained from satellite imagery and plotted as a function of time after dump in Figure 4. As shown in Figure 4, the plume width spreading rates range from about 0.5 cm sec^{-1} to about 6 cm sec^{-1}. During calm seas, the plume width increased at an average rate of about 1.5 cm sec^{-1}. During wind-dominated, rough sea conditions, spreading rates in excess of 4 cm sec^{-1} were attained. On days when wind velocities exceeded 15 km hr^{-1} rapid formation of regular patches (Langmuir cells) was evident. These results are in agreement with Falk's (1974) estimate of plume dilution shown in Figure 5, which indicates that by the time a waste plume moves 28 km from the dump site, dilution is at least about one million to one.
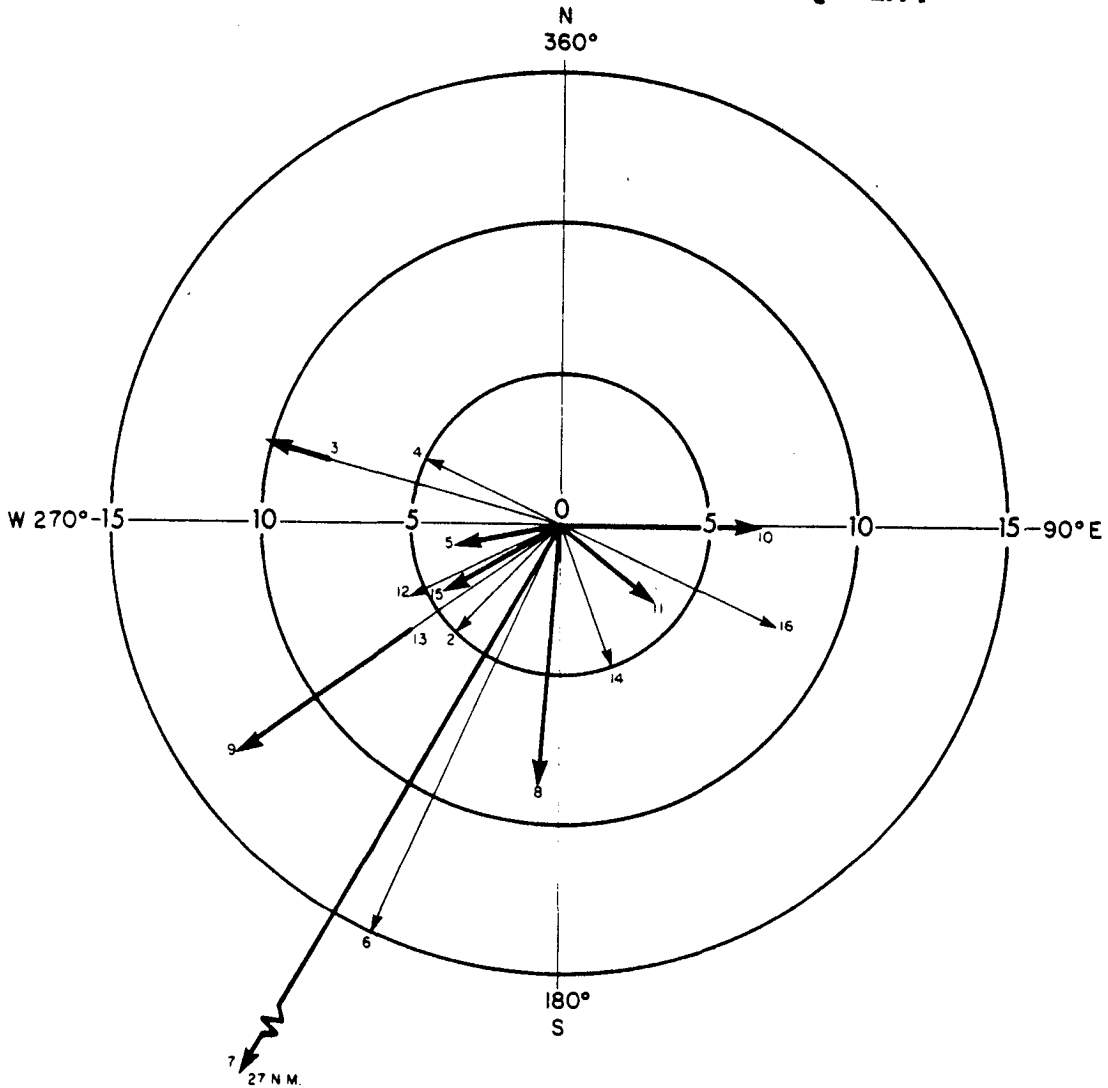
Figure 3. Distance from center of dump site to estimated centroid of imaged plume.

MULTISPECTRAL ANALYSIS OF WATER POLLUTANTS AND SUSPENDED SEDIMENT CONCENTRATIONS

Much of what is unique about our approach is an indirect result of the use of Landsat MSS digital data. Landsat was not designed for observations in water. The gain is low, making the dynamic range of the sensor very limited. The four spectral channels were selected for land use applications and are hardly ideal for water observations. Yet, there is a surprising amount of information in the Landsat
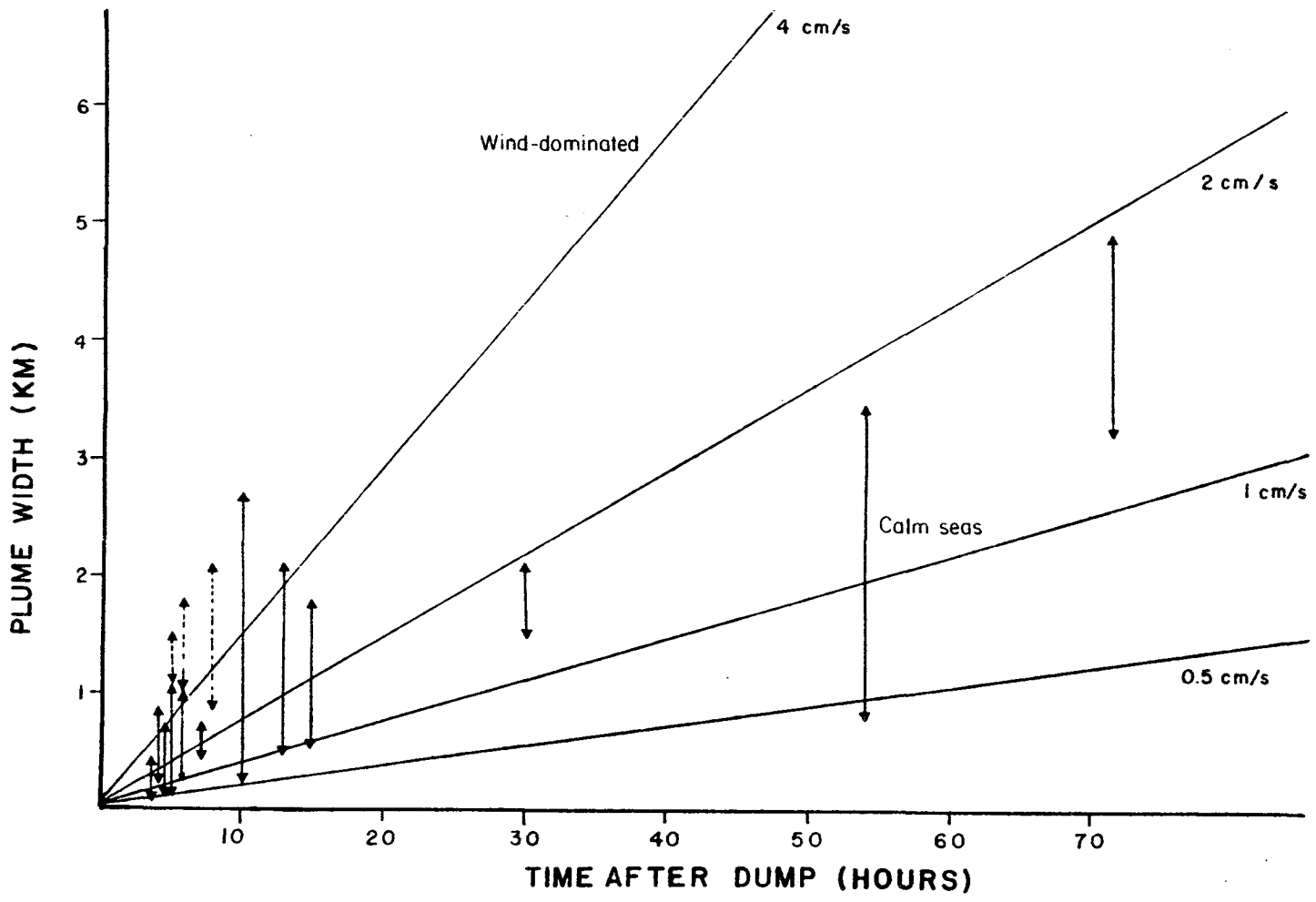
Figure 4. Dispersion of acid waste plume.
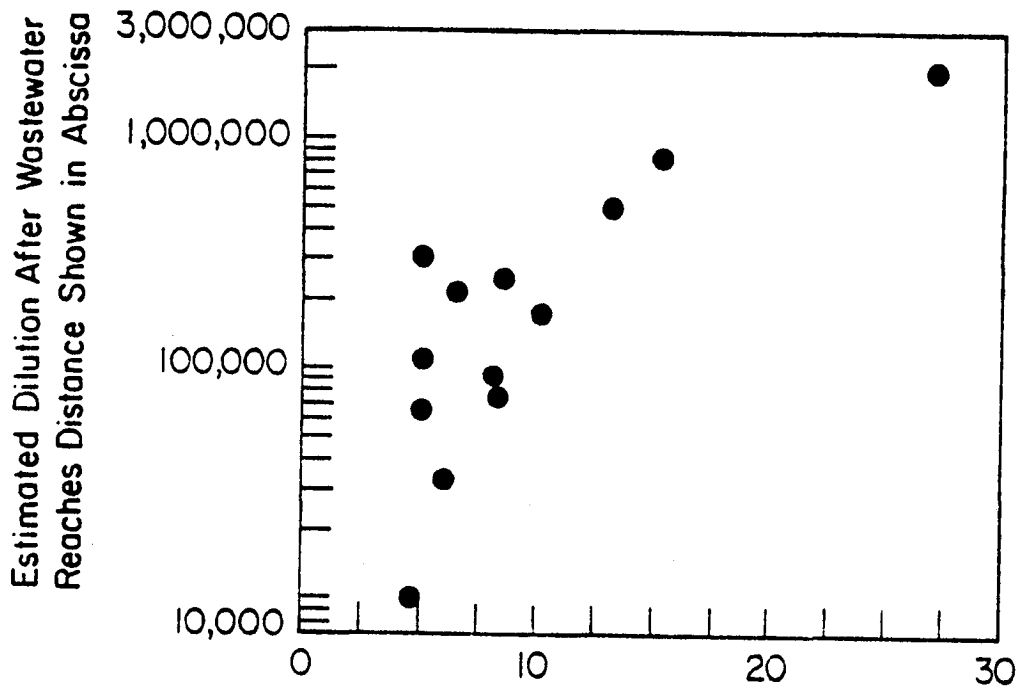
Figure 5. Maximum distance of satellite image from center of DuPont disposal site, nautical miles.

imagery. Landsat data have been used to map sediment distribution patterns (Klemas, et al., 1977), to observe the occurrence of estuarine fronts (Klemas and Polis, 1977), and to observe the occurrence of internal waves (Apel, 1974), to cite only a few of the many papers in which Landsat imagery has been used in sensing of water.

The use of spectral reflectance characteristics to identify substances in the water has attracted considerable attention in the past several years. Our approach is most similar to that suggested by Mueller (1976)—eigenvector (principal component) analysis. Eigenvector analysis has been described by a number of investigators including Mueller (1976) and Simonds (1962).

One major reason for using eigenvector analysis is that it allows the reduction of significant variates with minimal loss of information. With Landsat MSS data, there are only four spectral bands and therefore only four variables to begin with, and the analysis will rarely reduce this number by more than one. However, the eigenvectors can also provide an efficient representation of variations in water color which can be readily adapted to an automatic classification process. (Philpot and Klemas, 1979).

To illustrate the technique one can imagine a body of water, part of which is clear, part of which is heavily sediment-laden, and part of which contains pollution of some sort. A Landsat image of the area would show the clear water as relatively dark, while both the sediment and pollutant would appear relatively bright. The sediment might show up brighter than the pollutant in band 5, and the reverse might be true in band 4. If one were to plot the radiances observed in both bands for each picture element (pixel) the result would appear as in Figure 6. The origin represents the clear water pixels and the two lobes represent sediment pixels ($\overline{B}$) and pollutant pixels ($\overline{A}$). Clear water has a particular spectral signature and addition of any material to the water will cause that signature to deviate from the clear water signature—the more material added, the greater the deviation. If the deviation is in different directions for two materials, then they will be distinguishable to some extent. Vectors $\overline{A}$ and $\overline{B}$ represent the first eigenvectors associated with each material. The simplest measure of the spectral separability of the two materials is the angular separation of these two vectors. The eigenvector analysis also provides measures of the dispersion of the data about the axis of the first eigenvectors. The whole procedure is covered in considerable detail by Klemas, et al., 1978.
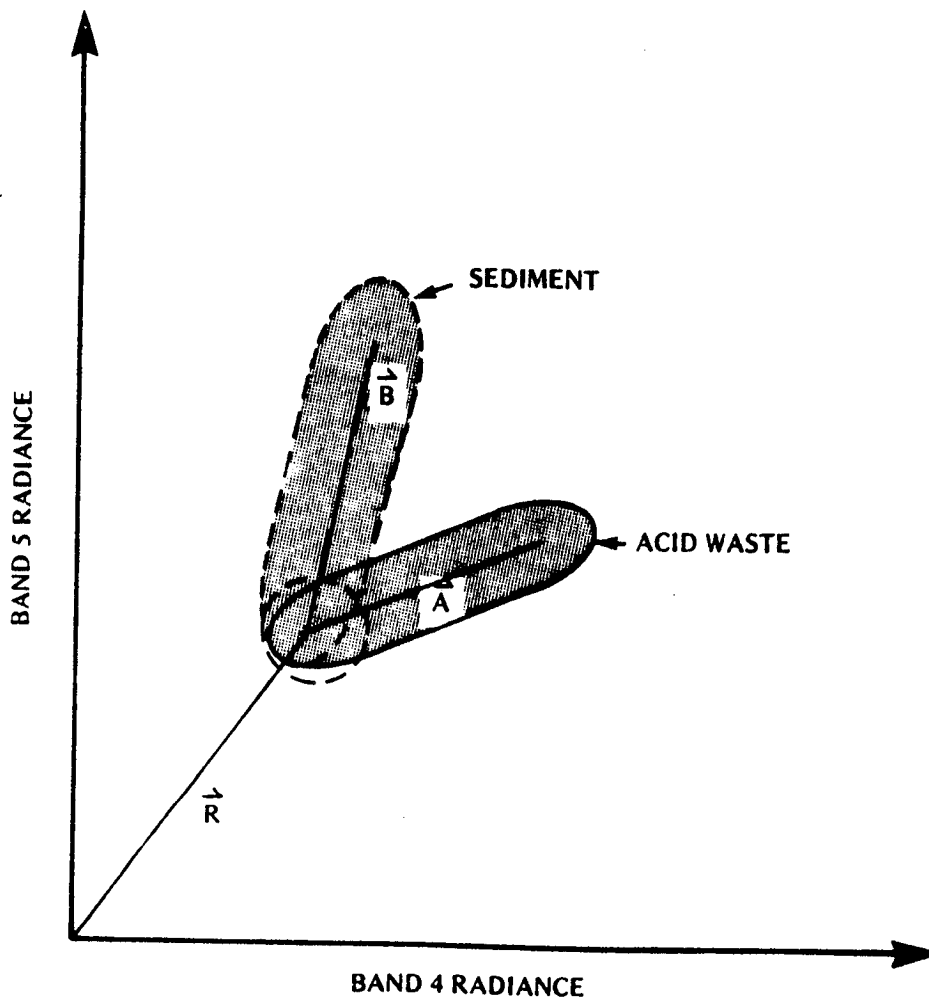

Figure 6. Diagram of the geometry of the eigenvector analysis. The origin has been placed at the position of the "clear" water standard.

For our present purposes, we will limit ourselves to the angular separation of the eigenvectors as a measure of spectral separability. Table 2 shows the results of analyzing six different coastal Delaware Landsat scenes for sediment, ice, clouds, and an acid-iron industrial waste. There is some dispersion among vectors identifying each material resulting solely from the use of data acquired on different days. This dispersion amounts to $\sim 6°$ for sediment, $\sim 10°$ for the acid waste and $\sim 10°$ for clouds. The angular separation between different substances is always significantly higher, however—between acid and sediment it is about 35°, between acid and clouds it is about 40°.

To demonstrate what this means in terms of classification, two of these scenes were chosen in which there was some uncertainty as to what was cloud and what was acid. The eigenvector analysis was used to classify each pixel in both scenes as either acid, sediment, clouds or clear water. The results are shown in Figure 7. In Figure 7A the clouds and acid are both plotted as dark points. The light areas correspond to clear water. (Less than 20 points out of tens of thousands were classified as sediment in both cases. These points were treated as clear water.) In Figure 7B only those pixels actually classified as acid-iron were plotted. The pattern that is seen is the course followed by the acid-iron barge while dumping. There is some noise in the background and there are some gaps in the pattern caused by clouds directly over the dump track, but generally the distinction is quite good.

It is likely that this approach can be extended with the Landsat data to include several other substances, and that considerably better results could be achieved using spectral channels more appropriate for analysis of water, such as those on the Coastal Zone Color Scanner (Hovis, 1977). Landsat image radiance data also were correlated with suspended sediment concentration and Secchi depth data obtained from boats and helicopters during the selected satellite overpasses. A suspended sediment concentration map based on Landsat image radiance correlation with water sample analyses is shown in Figure 8.

Table 2
Angular Separation (in degrees) Between Primary Eigenvectors

| | | IRON-ACID WASTE | | | | | | | SEDIMENT | | | | CLOUDS | | | | ICE |
		24 FEB 76	19 JAN 76	21 OCT 75	19 AUG 75	17 NOV 75	15 MAR 74	AVERAGE	24 FEB 76 (NORTH)	24 FEB 76 (SOUTH)	19 JAN 76	AVERAGE	19 JAN 76	19 AUG 76	15 MAR 74	AVERAGE	19 JAN 76
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
24 FEB 76	1	--															
19 JAN 76	2	14.4	--														
21 OCT 75	3	3.9	13.7	--													
19 AUG 75	4	12.7	6.2	10.5	--												
17 NOV 75	5	4.4	13.6	7.8	13.8	--											
15 MAR 74	6	6.3	10.7	8.6	11.6	3.3	--										
AVERAGE	7	8.5	11.1	8.6	10.3	8.8	7.9	--									
24 FEB 76	8	36.1	22.9	33.9	23.7	36.4	33.5	31.5	--								
24 FEB 76	9	37.9	24.8	35.7	25.4	38.3	35.4	33.3	2.0	--							
19 JAN 76	10	34.2	22.6	31.4	21.8	35.2	32.7	30.1	6.1	6.5	--						
AVERAGE	11	36.1	23.5	33.7	23.6	36.6	33.8	31.8	3.6	3.9	5.1	--					
19 JAN 76	12	47.2	33.8	45.9	35.7	46.1	42.9	42.2	19.8	18.9	24.1	21.0	--				
19 AUG 76	13	31.6	18.5	30.8	21.3	30.2	26.9	27.0	16.9	17.8	20.2	18.3	16.2	--			
15 MAR 74	14	39.4	25.7	38.1	27.8	38.4	35.2	34.5	13.5	13.4	18.0	15.1	8.3	9.2	--		
AVERAGE	15	39.8	26.7	38.7	28.8	38.7	35.5	35.0	16.9	16.9	20.9	18.3	10.5	10.8	7.2	--	
19 JAN 76 AVERAGE	16	42.6	28.6	41.1	30.6	41.9	38.7	37.6	11.2	10.5	16.5	13.0	9.4	14.3	5.9	10.4	--

Row groups: ACID (rows 1–7), SEDIMENT (rows 8–11), CLOUDS (rows 12–15), ICE (row 16).
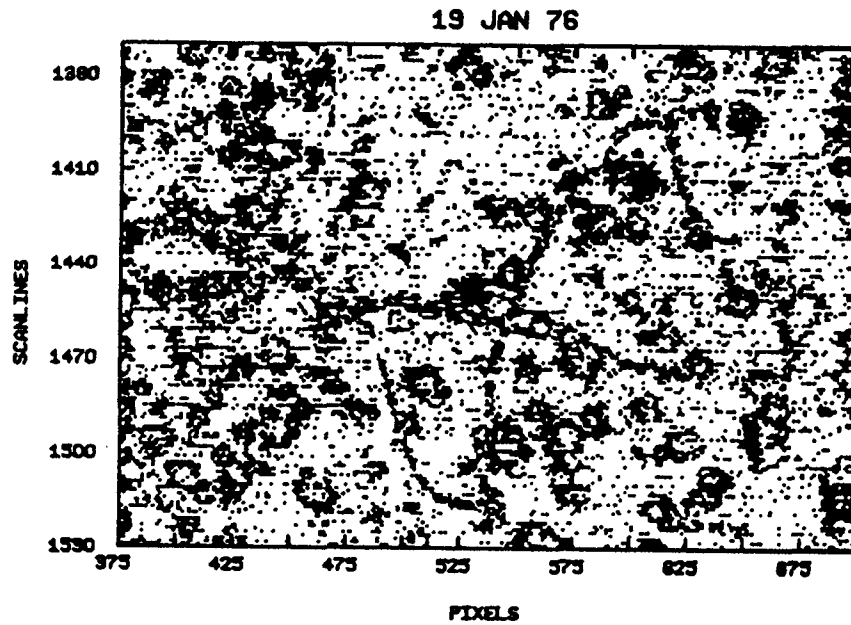
19 JAN 76

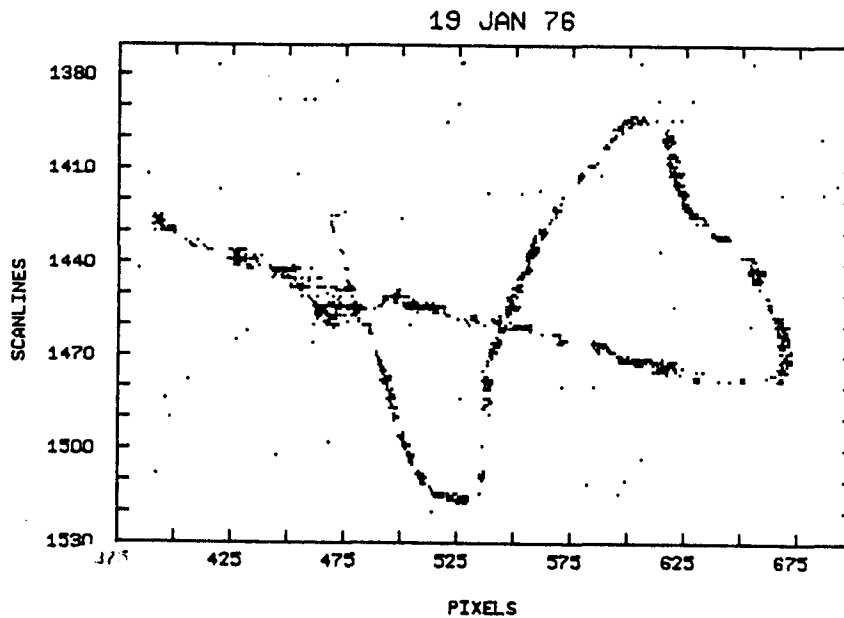Figure 7A. Iron-acid waste plume imaged by Landsat on January 19, 1976 with
with cloud background.

19 JAN 76

Figure 7B. Enhancement of the iron-acid waste plume of January 19, 1976,
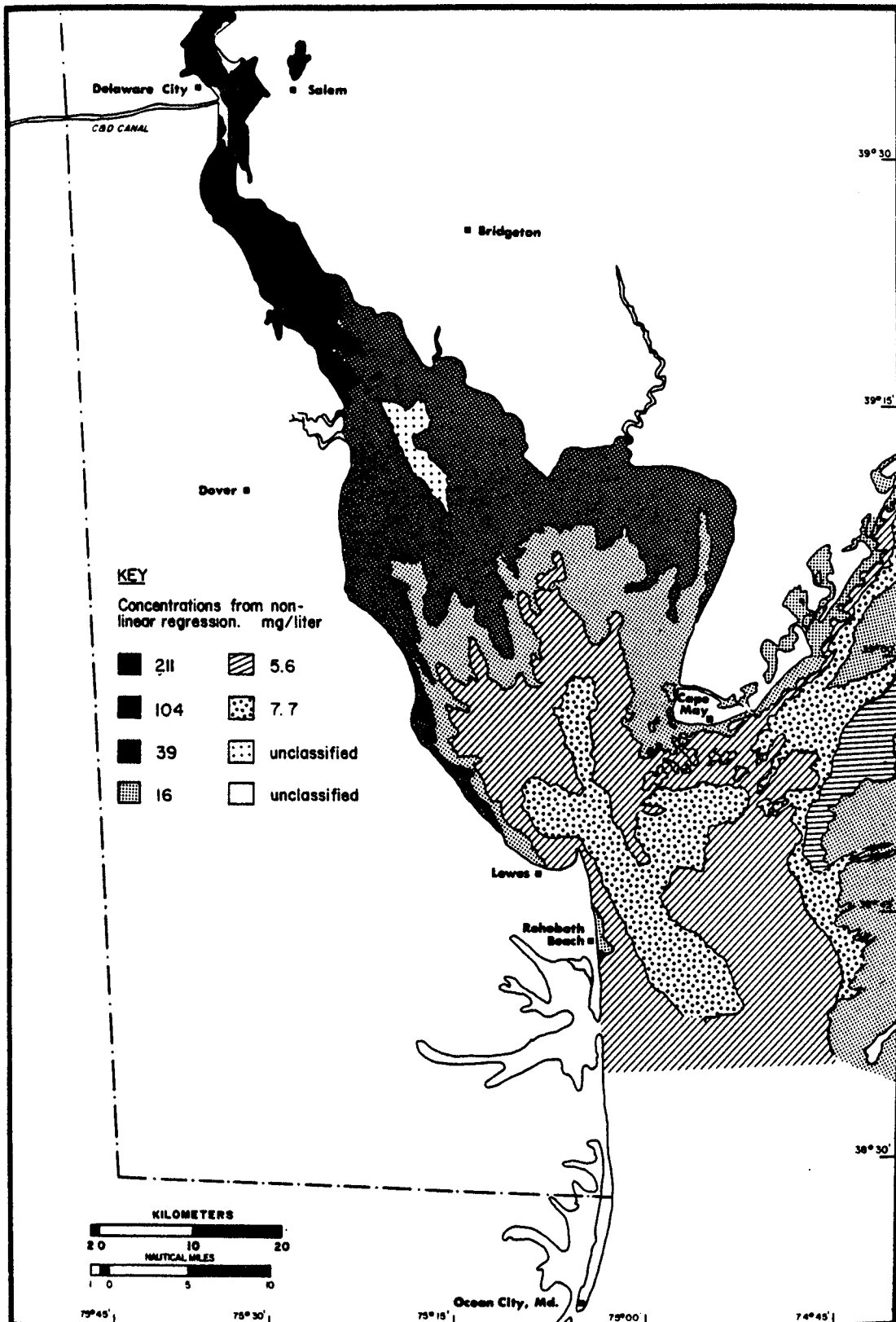against a cloud background.

152

Figure 8. Sediment distribution map.

153

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MODELING A BEAVER POPULATION ON THE PRESCOTT PENINSULA, MASSACHUSETTS: FEASIBILITY OF LANDSAT AS AN INPUT

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INTRODUCTION

The Prescott Peninsula in central Massachusetts was formed when the Quabbin reservoir was filled between 1939 and 1945. The size of the peninsula is 23 square miles. Beaver were not known to occur there until 1950. Since about 1968, the beaver population on the Prescott Peninsula has been studied by faculty and students at the University of Massachusetts (Hodgdon and Larson 1973, Brooks 1977, Hodgdon 1978, Lancia 1979, Lyons 1979). This population is of particular interest because it has never been exploited. Beaver construct two distinctly different kinds of colonies. Shore colonies build lodges on the shore of the large Quabbin reservoir, and inland colonies dam streams and build lodges in the resulting small ponds.

A preliminary dynamic model of beaver spatial distribution and population growth was developed in the fall of 1978. This paper describes the feasibility of locating beaver ponds on Landsat digital tapes, and using this information to provide initial conditions of beaver spatial distribution for the model, and to validate model predictions. The techniques used to identify beaver ponds on Landsat are described first, followed by a brief description of the model.

IDENTIFICATION OF BEAVER PONDS USING LANDSAT

Inland beaver ponds begin as small widenings of a stream. As a beaver colony ages, trees are cut down, dams are enlarged and new dams constructed, trees are drowned out, and canals dug. In a few years a beaver pond can become very large, some complexes covering 10-20 acres (see Figure 1). Beaver may eventually exhaust their food supply and abandon a colony site. The abandoned dams often remain for several years, and the pond slowly turns into a beaver meadow.

A beaver pond on Landsat imagery would appear as either open water or water mixed with vegetation. This signature could not be differentiated from other pond and marsh signatures, except by comparing successive years. Significant changes in pond size and shape could be attributed to beaver activity.

Figure 1. A large beaver pond on the Prescott Peninsula.
Original in color (contact author).

To test the feasibility of this identification scheme a Landsat scene taken on May 6, 1976 (see Figure 2) was classified by the ORSER unsupervised classification program CLUS using all channels and "SAMPLE" = 400 (Turner et al., 1978). Signatures of the 17 spectral classes were input into programs CLASS and DISPGM to produce a geometrically corrected printer map. This map was overlaid on land use maps (MacConnell, 1975) to associate the 17 spectral classes with 6 land cover classes (Table 1). Three mixed pixel categories were found around the shore of Quabbin reservoir, and in spots within Prescott Peninsula.

A beaver survey was done in 1976 and sites of active and inactive beaver ponds recorded on maps. The classified Landsat map was overlaid on the map of beaver colony locations. Colony sites not overlain by one of the mixed pixel classes were considered errors of omission. Commission error could not be estimated. Success rate is shown in Table 2. Over 90 percent of active beaver ponds older than 4 years were visible on the classified Landsat image. Young ponds and inactive ponds could not be identified consistently. No consistent relation between beaver ponds and surrounding cover class could be determined.

Thus, Landsat can be used to identify beaver ponds, although multidate, multiyear analysis will be required.

Figure 2. A subscene from the May 6, 1976 Landsat scene for path 14, row 30 (ID #2470-14495). This figure contains the smaller subscene (lines 2123-2294 and elements 2196-2314) analyzed on ORSER. This is a contrast stretched enhancement made on the IDIMS system. Original in color (contact author).

Table 1
Cover Classes for Map of the Prescott Peninsula, Massachusetts

W = WATER

P = PLANTED PINE

− = HARDWOODS

+ = MIXED WOODS

S = SOFTWOODS

/)
!) = MIXED PIXELS, SWAMP, MARSH,
:)　　ETC.

Table 2
Beaver Pond Identification Success Rate

<u>Number of Sites</u>

	Year Class	Shore	Inland	Inland on LANDSAT	% Inland Found
	1,2 yr	8	5	1	20
ACTIVE	3, 4 yr	2	4	1	25
	OLDER	2	16	15	94
TOTAL		12	25	17	65
	1,2 yr	13	7	4	57
INACTIVE	3, 4 yr	2	2	0	0
	OLDER	2	3	1	33
TOTAL		17	12	5	42

PRELIMINARY BEAVER MODEL

During the Fall 1978 semester, a preliminary model of beaver population dynamics and spatial distribution was developed by the Systems Ecology class at the University of Massachusetts. The model was constructed as a cell-space model (Ziegler, 1976), i.e., spatial distribution was represented on a grid network. The behavior of each grid cell in this model is dependent only on the states of the cell itself and its immediate neighbors. State variables are 1) vegetation divided into classes: hardwoods - H, softwoods - S, planted pine - P, mixed woods - M, open field - blank, and water - W; 2) streams; 3) number of beaver pair colonizing a cell, broken down by age and sex; and 4) colony age. Natural plant community succession was represented as a random Markov process (Shugart et al., 1973) with probabilities of transition from one vegetation class to another proportional to the length of time the transition takes in nature. The beaver's effect on vegetation is represented by an altered set of transition probabilities, basically increasing the chances that a cell next to a beaver colony will become open. Beaver reproduction is a function of the "quality" of the site, quality being determined by vegetation classes surrounding a site. Mortality in the model is set high for kits, and low for adults, both being functions of "quality." Beaver disperse at two years of age. The process of dispersal and colonization of new sites is poorly understood. It was represented here as a random search with the probability of settling down a function of site quality and nearby colonies. Most parameters for this model are best guesses. A good deal of field work remains to be done before the model is operational.

Results of a 30-year simulation are presented in Figures 3 and 4. The vegetation at year 0 and the initial location of beaver is shown in Figure 3. Vegetation classes are as given above. Streams are represented as "+" symbols and numerals along a stream represent the number of beaver pairs in that cell. The vegetation and beaver population at year 30 are presented in Figure 4. Along streams open unforested area has increased greatly, while away from the streams little or nothing has changed.

Expansion of the model to the Prescott Peninsula will require either a large effort to either manually transcribe or digitize existing land use maps, or a moderate effort to classify Landsat images for the Quabbin. This project has demonstrated the feasibility of obtaining not only land cover information, but also information about beaver ponds from Landsat images for use in a spatial model of beaver distribution.

ACKNOWLEDGEMENTS

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LAND COVER MATRIX AT TIME   0

```
W  W  W  W  W  W  W  W  W  W
W  P  P  H  H  H  P  H  H  W
W  P  P  S  M  M  H  H  H  W
W  M  M  M  H  H  H  H  H  W
W  M  M  M  H  H  H  H  H  W
W  H  H  H  H  H  H  H  H  W
W  H  H  H  H  P  P  H  H  W
W  H  H  H  H  P  P  H  H  W
W  H  H  H        H  H  H  W
W  W  W  W  W  W  W  W  W  W
```

MAP OF POPULATION AND STREAMS AT TIME   0

```
                3
                1
           +  +
           +        +
      +              +
      +                    +
           +
           +              +
```

Figure 3. Vegetation map, and stream population map at time = 0 for a hypothetical run of the beaver model. H - Hardwoods, S - Softwoods, P - planted pine, M - mixed woods, blank - open field or meadow, W - water. Plus signs and numerals indicate presence of a stream, and numerals also indicate the number of beaver pair on a particular cell.

LAND COVER MATRIX AT TIME   30

```
W  W  W  W  W  W  W  W  W  W
W  P  H  H     H     H  H  W
W  S  H  H           H  H  W
W  H  H  M     M  H  H  H  W
W  H  M  H  H  H  S  H  H  W
W  S  M  H  H  H           W
W  H           P  P        W
W  H           P           W
W  H           M  H  H  H  W
W  W  W  W  W  W  W  W  W  W
```

MAP OF POPULATION AND STREAMS AT TIME   30

```
            3
            +
        +  4
        +     +
    +           +
    +         4
      4            +
      +         3
```

Figure 4. Vegetation map, and stream and population map at time = 30 for a hypothetical run of the beaver model.

161

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LAND COVER CLASSIFICATION IN SOUTHERN RHODE ISLAND USING MULTIDATE LANDSAT MSS DATA

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The objective of this project was to make use of Landsat multispectral scanner (MSS) data from several different dates to classify ground cover in southern Rhode Island. The advantage of using several dates as compared to a single pass is that seasonal data can be incorporated in the classification. The disadvantage is that the volume of data to be manipulated by the classifier increases linearly with the number of scenes used, and the execution time of the classifier increases at an even greater rate. In order to circumvent this problem (i.e., time spent on the computer) the dimensionality of the Landsat data in general can be reduced by the principal components method.

The principal components technique makes use of the fact that for a single Landsat scene there is a great deal of redundancy (for example, between bands 6 and 7). In addition, there may be redundancy between the same bands on different dates, e.g., band 7 in June with band 7 in August. Because this redundancy does not carry any additional information for the classifier, the objective in this project was to eliminate redundant data. The principal components method defines a rotation of the n-dimensional coordinate system such that the data are arranged along axes (consisting of linear combinations of the original data axes) of decreasing variance. The linear combination of the radiances from the various bands is selected such that the variance of the transformed data is a maximum along the first principal axis. The next axis is selected in the same way from the remaining dimensions. This procedure is continued until all axes, i.e., the entire n-dimensional space of the data has been rotated to a set of axes of decreasing variance. The last several dimensions can then generally be rejected with no loss of significant information. Indeed, it has been found in geological studies that by eliminating the last several dimensions the noise in the data is often reduced, resulting in better classification. It was necessary to make one modification to the principal components method for this project: elimination of water from the statistics used in generating the rotation. This was necessary because, in the coastal area studied, the first dimension was one of brightness, determined primarily from land/water differences. This separation is trivial, hence this dimension was wasted inasmuch as a cut can readily be performed on brightness prior to the classification.

In order to meet the objectives of this project, it was necessary to perform a number of tasks. These were:

1. **Registration**—The various Landsat scenes had to be registered one to another prior to performing the principal components rotation or classification. Three scenes of the Rhode Island region were used for the project: October 8, 1972, May 22, 1978, and October 13, 1978 (chosen because of their availability). The last two were registered to the first to within ± .5 pixels.

2. **Reduction of Dimensionality**—This was done as described above where the first five components of the twelve components available were selected. These five components accounted for over 93 percent of the variance in the data. Note: The reason there are 12 dimensions in the original data is that there are 3 images each of 4 spectral bands.

3. **Classification**—Because of the lack of accurate ground truth an unsupervised classification was performed using the output of a cluster analysis on the data. In the clustering of the data, 16 groups were requested. This took approximately 2 hours of computer time. These 16 groups were observed by visual inspection and a familiarity with the area to define 8 ground cover classes: deciduous forest, coniferous forest, forested wetlands and mixed forest, shallow water, medium residential, industrial, transportation, and agricultural. Following the cluster analysis, the image was classified into the eight groups identified. The results are shown in Figure 1.

4. **Verification**—The result of the classification was compared in a qualitative fashion to existing data bases. The qualitative rather than the quantitative comparison was undertaken for two reasons. First, more than one land use/land cover data base already exists for the region but these are not consistent with one another, making it difficult, without a detailed analysis of these data bases, to select the more accurate one. Second, the Landsat imagery selected for this project does not consist of an optimum set for land cover classification. The selection was dictated primarily by what imagery was available on short notice at the time. Were the project repeated or performed for another area, a more appropriate set consisting of an image from each of the seasons with an extra image in the spring or summer months would be selected. Qualitatively the agreement was good between this classification and one performed on a 10-acre grid size by Professor W. P. MacConnel of the University of Massachusetts for the State of Rhode Island, using aircraft imagery. The fact that the images were properly registered is indicated by features such as highways that appear in Figure 1. The major disagreement with Professor MacConnel's classification appears to be in the confusion between medium residential and deciduous forest cover in the northwestern corner of the study area. This confusion is understandable when one considers that medium residential districts often have significant tree cover. A definite improvement would have resulted had a winter scene with no foliage been included. Indeed the ability to distinguish coniferous from deciduous would have also been enhanced.

In summary, the methodology used in this project offers a convenient mechanism to incorporate seasonal information in land cover classification, thus improving the overall classification accuracy. It is important to note that this improvement is made at little extra cost in computational time over conventional Landsat classifications. In addition, the increase in analyst effort is primarily in the registration of one scene to the next. This effort will, for all practical purposes, be eliminated with the registration of imagery to take place at the EROS data center.
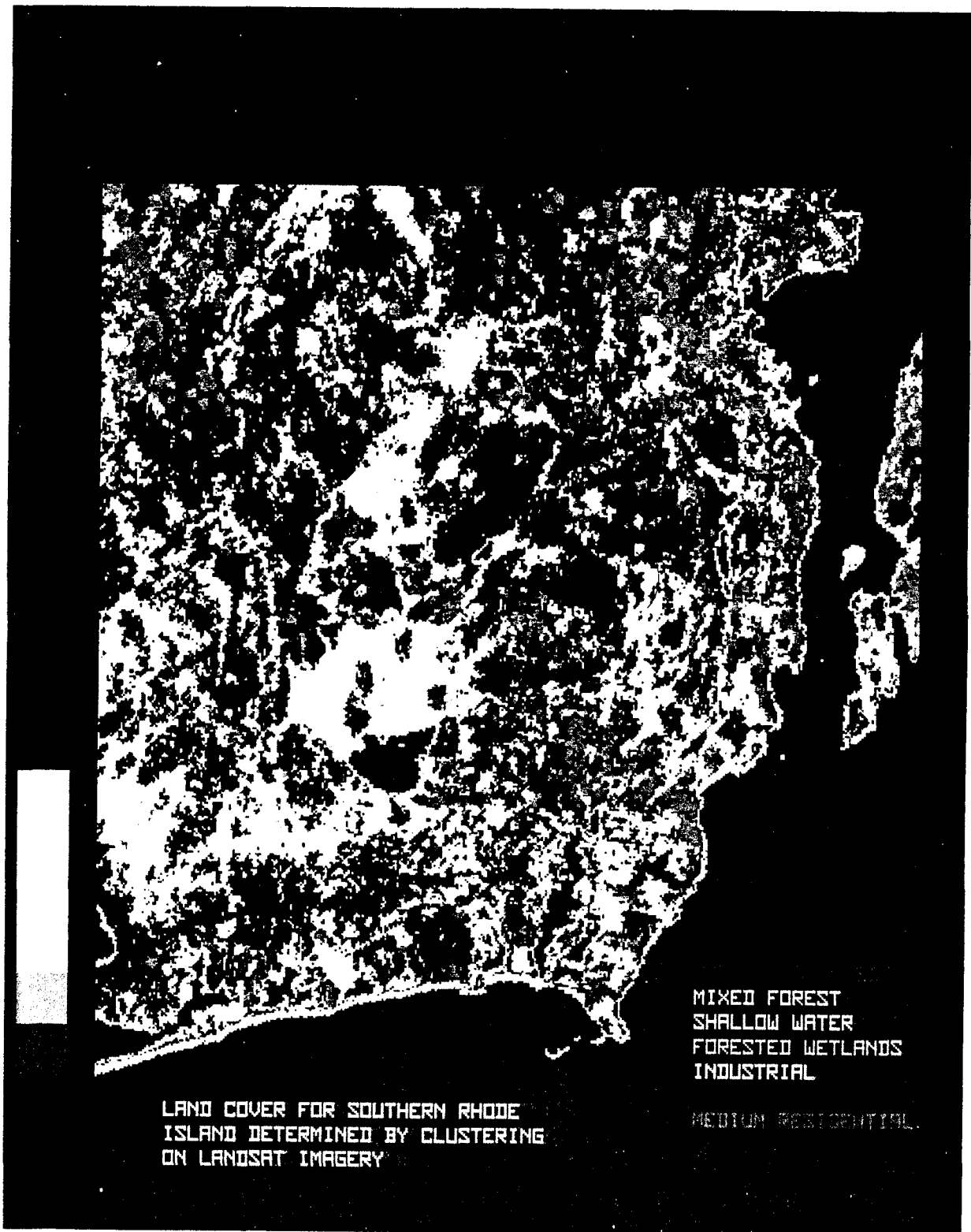
Figure 1. Land cover classification of southern Rhode Island using multitemporal Landsat data.
Original in color (contact author).

FORESTRY
FORUM SUMMARY

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By immediate consensus, the scope of the Forestry Applications Forum was expanded to include forestry and vegetation analysis, since many of those participating in the forum were concerned not only with forestry, but also with total vegetation analysis. And by the time that the session was completed, it had probably expanded into the whole area of land cover.

The forum provided all of those present with an opportunity to briefly tell what experience they had had or were currently having with vegetation applications of Landsat data. Broad inventory studies, clear-cut monitoring, and insect and disease detection were among the subject areas discussed and were the major uses that had been made or were currently being made of Landsat data.

Field foresters, the foresters who spend their time in the field rather than in the office, have very practical and down-to-earth problems. People at this end of forestry, who make up the majority of the practice, voiced a number of concerns. One of the problems expressed in relation to Landsat data was the time element in obtaining the required data. Many of the situations that occur in the forest areas, in various ecosystems and with associated land uses, are very dynamic. Changes that field foresters are interested in monitoring occur in short periods of time, and there was considerable concern relative to delays in obtaining the data necessary for the various applications.

Another problem that was stated had to do with cloud cover. This can be a serious problem, because the fixed orbital cycle provides only one chance every 18 days to see the surface. In order to get the answers needed on a timely basis, conventional photography might have to be relied upon for many of the applications which might otherwise be compromised.

Resolution and classification accuracy constituted another area of concern. Suitable accuracy which would enable the forester to classify to the necessary levels is a critical factor. This area provoked many questions and reservations on the part of those present.

In the area of output products, the color classification maps that have been produced thus far may not be a complete answer to people who are working in the field. It was generally agreed that overlays showing roads, political boundaries, topographic data, as well as other data that cannot currently be discerned would have to be provided in order to supply a more satisfactory Landsat product.

To summarize the views expressed, it was agreed that there is a very definite and important role for Landsat to play in forestry, especially in serving as a broad-brush tool. Landsat can also play a major role as a preliminary tool, or first step, in any multistaged application which proceeds from the macros down to the micros, as data from other sources is added.

LAND COVER/USE
FORUM SUMMARY

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The land cover/land use forum began with a discussion of the distinction between land cover and land use. It is important to realize, in dealing with land use and land cover, that there is a difference between these two categories. There is much confusion, even on the part of those who are involved in state land programs, in distinguishing between these two concepts.

A variety of complicated interrelationships involving resolution were also discussed. As resolution increases, down to the types of data expected from Landsat D or the RBV, individual rooftops will be seen against the background of surrounding areas. Because of this, the surrounding green vegetation will have to be taken into account, which is going to exacerbate an unfamiliar problem. Looking at the facilities in, say, 400 acres to determine the land use there, and considering it from the land cover standpoint, of course, there is very little developed area. It amounts to a few buildings in the middle of a grassy area. It was suggested that the landcover concept developed on Landsat data could be used, adding land use data to that. A number of private firms have been doing this, including detailed GIS data in our urbanized areas where we have different kinds of resolution problems.

The necessity of obtaining experience in managing more complex data bases was also discussed. The entire subject of geographic data base management is one that needs to be very carefully considered along with the large volumes of Landsat data in statewide and regional areas. One possibility would be to combine that type of data with our cartographic data bases, in order to be able to answer questions for decision makers. The decision maker ordinarily is not interested in finely tuned technical details; he may not understand what they mean. He might, however, be interested in specific facts, such as the number of acres in a township that are devoted to a specific type of land use, and how many acres are going to change if a certain Planned Unit Development (PUD) application is accepted. The capability to obtain such information as acreage counts, by jurisdiction, extracted automatically from the classifications is vital. A number of states are currently doing work like this.

Despite the importance of an extension of Landsat products, as an input to decision makers' models, everybody's been spending so much time pumping out the basic, classified image in the past that we hear them say: "Phew! We've got this done." And then the stuff never gets taken any further. These should be an input to a model. Either a classification output can be input to the model, or a

reflectance value can be input to some sort of predictive model. This requires a data base of raw reflectance data in some cases, rather than jumping directly to the classification process. We have to start looking at what was the answer we were looking for, and wanted to get out of it, before we started the process, rather than focusing on this intermediate problem of classification.

Also, while many programmatic needs have been satisfied already with Landsat data, a lot of state people have also been forced into using Landsat data by other Federal programs, such as Section 208 of Public Law 92-500. Many states have a problem with 208 because of a U.S. District Court decision which forced them to do an awful lot of planning for a huge area, after all the money had already disappeared into a very small part of the region. Other needs are developing in this way in land management. Minnesota was mentioned as an example, with something like 13,000 lakes to inventory. We also have coastal energy impact planning programs, grants by NOAA to state departments of energy and other types of organizations at the state level. So there are going to be continuing programmatic needs for land cover data. We will have to try to anticipate them somehow in order to deal with them.

Another area of research is on the commonality of needs, particularly with respect to pilot projects. New Jersey is involved in a number of different mapping programs which have had differing needs, to some extent, but also a lot of support for sharing. To what extent are they independent and to what extent can they use common data? They are separate to the extent that the applications are different, but similar in that they can share resources, information, and goals.

Finally the issue of anticipating projects which combine land cover data generated from Landsat with geographic information systems, using Landsat as a data base for a planning and geographic information system was discussed. An information storage and retrieval system for a classified landcover map will be needed in order to edit, update, and correct it interactively; a number of systems do this. The black box, "untouched by human hands" approach, in which data are inserted and an end product pops out, must be avoided. Since the "grunt" work of this remote sensing business has been eliminated, using computers to classify the images, brainpower must now be used on the analysis, where it's needed, using human spatial pattern recognition on the outputs before using them in a model.

WATER
FORUM SUMMARY

John C. Munday, Jr.
Virginia Institute of Marine Science
Gloucester Point, Virginia

The participants in the Water Forum recognized that they did not represent the full spectrum of existing Landsat activities with respect to water resources. Nevertheless, these general conclusions emerged concerning topics of interest.

There is a great amount of interest in lacustrine trophic state classification on the part of a number of states (for example, Wisconsin, Michigan, Minnesota, and Illinois), mainly dealing with satisfaction of the 208 program requirements. The second topic of major interest is land cover input to hydrologic and nonpoint pollution models, and to watershed and drainage basin analysis. The level of interest in this topic was surprising. It was discussed in the Land Cover Forum as well as in the Water Forum. There is also interest in ground water problems.

Generally, participants wanted to know whether any states or state agencies are using remote sensing data, primarily Landsat, as parts of regulatory programs, that is, on-line operational regulatory programs. In our small sample of water resource people, there were none who are involved in or knew of operational regulatory programs using Landsat data. However, there are agencies that are carrying out water quality/trophic state classification programs, and presumably those will, in time, evolve into periodical monitoring programs involving satellite and surface data, and thence into regulatory programs.

Some discussion centered on the desirability of having new satellites with very narrow wavelength bands, since planetary observation programs utilize such sensors and do very well without surface information in gathering accurate and quantitative data. The technology exists. Perhaps such satellites for earth observation could be fruitfully addressed by NASA in the future. This idea was strongly endorsed.

In the meantime, state legislatures may be hesitant to commit funds for existing Landsat operational possibilities, because the Landsat's potential for highly accurate and detailed water quality measurements is limited. State legislatures may wish to wait until other satellites are available that provide much more specific capability than Landsat for water resource measurements.

In closing, much deeper inquiry should be made into the specific needs of water resource agencies. This inquiry should focus on the exact mechanism for incorporating Landsat and other satellite remote sensing data into the water resource monitoring and regulatory process.

ENVIRONMENTAL ASSESSMENT
FORUM SUMMARY

Herbert Blodget
Goddard Space Flight Center
Greenbelt, Maryland

To some extent, the Environmental Quality forum was a "catch-all," considering a wide variety of topics that were not included in the agenda of other discussion groups.

The topic which raised greatest interest was that of wildlife habitat evaluation. In addition to the study formally presented by panel co-chairman Burgoyne, there are a number of other wildlife management investigations being conducted. For example, duck breeding areas are being evaluated in the Great Plains states. In this study, Landsat information is especially suitable for mapping small ponds and their immediate environs during breeding and brooding periods. Significant changes or drying-up of ponds over these critical periods can greatly influence the wild duck population.

Several states have programs to protect endangered species within their boundaries. One approach that is being used is to relocate a part of the population into optimum environmental areas. Landsat data can be used to identify such areas by providing land cover data base information required for habitat models.

In all wildlife habitat studies it was concluded that Landsat data could provide very significant information concerning the real extent and spatial distribution of the various land cover classes, and their degree of interspersion—all of which are important factors in wildlife habitat assessment models.

Identification and monitoring of point and nonpoint pollution sources is a major objective of many local and regional water management agencies. Runoff models, similar to that in use and described earlier by the Washington Area Council of Governments, have been developed to relate nonpoint pollution to land cover. It was concluded that a minimum resolution of 10 meters is required for location of pollution sources or in providing an adequate land cover assessment in urban areas, where these data are most important. Thus, the anticipated resolution of Landsat-D will not be adequate to provide the currently required information.

Digital Landsat data have been used successfully to monitor strip mining and restoration practices where open-cut areas are over 100 acres. The anticipated thematic mapper resolution will reduce the size of areas that can be effectively monitored, but will still be inadequate to monitor the small, and in some cases unpermitted, mining operations that cause the greatest environmental problems.

The spectral characteristics of the currently operational Landsat and those anticipated on Landsat-D are adequate for the type of projects that were considered.

RESOURCE INFORMATION SYSTEMS
FORUM SUMMARY

Vern Svatos
Delaware Water Resources Agency
New Castle City, Delaware

A rather diverse group participated in the Resource Information Systems Forum. The discussion touched on several diverse subject areas, and will be briefly summarized below.

Some of the discussion focused on land cover. It was mentioned that Landsat data may be more representative of the real world than data that we currently use. Perhaps we should think in terms of devising new land cover classifications such as urban cluster, ecocenter analysis, or ecocenter classification instead of relying on the more traditional classifications.

Another point made was that of registration of data. It was suggested that there may be more concern with registering data than with what to do with that data once it has been obtained.

Another issue raised was that when analyzing urban areas, the resolution of Landsat data is inadequate. This comment was countered by one of the panel members who stated that if the urban data tend to be homogeneous, it is possible to delineate about three levels of classification. Where it does fall apart is in areas which are more diverse.

The problem of resolution was also addressed. Apparently, there is disagreement as to what resolution is optimum, some members suggesting ten meters as the optimum resolution, others fifteen meters. It was suggested that the users initiate action toward determining a standard resolution for future satellites.

Further comment indicated that users should start thinking of applications of Landsat data other than mere land cover classification. For instance, can Landsat data be used to develop a data file containing flood plain information or ecosystem data which could then become part of an input to an existing information sytem? Some innovative thinking in this area is needed.

The final point made was that although much modeling with information systems is being undertaken nationally, there is a dire need for a central exchange information agency so that the actual users of the data do not needlessly duplicate work done by others.

INSTITUTIONAL CONSIDERATIONS
FORUM SUMMARY

Jimmie Weber
Space Applications Branch
NASA Headquarters
Washington, D.C.

Many of the people who attended the Institutional Considerations forum were politicians, and probably because of this it was not difficult to provoke conversation. However, I am not sure that we actually came to an agreement on what recommendations should come out of the forum. One thing that we did settle on, and that no one debated, was the definition of "institutional considerations." We agreed that these consisted of everything not covered in the technical forums. This gave us a wide base to work from, and since there was no disagreement, we used this definition to specify our topics.

The discussion fairly quickly centered upon what NASA's involvement in the states' activities ought to be, once the demonstration projects were completed. How do you encourage the states, following successful demonstration projects, to adopt the technology?

We also discussed whether or not the states would tend to use their own personnel to do the Landsat processing analysis, or would, instead, contract with the private sector (including universities) to do the data processing and analysis. There was a good deal of debate as to whether or not the universities should be involved in a significant way, most of the university attendees agreeing that this was, indeed, a proper role for them.

To summarize the forum, I believe we tried to solicit recommendations from the panel members as to how NASA, in general, and the regional programs, in particular, might improve the "technology adoption" phase. The panel, in general, approved NASA's present approach of conducting training and demonstration projects, followed by technical assistance and adoption measures. There was a recommendation that NASA clarify precisely what kind of services it would provide the states, following successful completion of the demonstration projects. In fact, it was recommended that this be addressed even before a demonstration project begins.

Another thing that came through loud and clear was that there is no "standard state." Each state must be considered on an individual basis, and the regional program must take care to invest in the institutional structure of each state rather than setting uniform values for all states.

BANQUET ADDRESS

Dr. Anthony Calio
NASA Associate Administrator
for Space and Terrestrial Applications
NASA Headquarters
Washington, D.C.

I am really pleased to be here tonight, for several reasons. One is that this marks my second anniversary with the NASA Applications Program. It is fitting to share that anniversary with you people tonight, because one of the things that we have been trying to do within the Applications Program is to get our technology transfer capabilities into the hands of users. An added pleasure is being among people who will be making this program grow, not just as a NASA program, but as a national program. I truly believe that remote sensing has a lot to offer to this country and can capture peoples' interest as well as being useful. State governments are an important part of the program because, in aggregate, you probably represent the largest user community for remotely sensed data.

I was delighted to see not only some old friends, but also to make some new ones. I don't know how Bob Regan gets around so much! Bob is also an advisor to NASA for the development of our Renewable Resources Program, and works with us very diligently and effectively. At the same time, he teaches school, chairs several other committees, and participates in such things as providing support for this symposium. It's good to see him here. And, I was also pleasantly surprised to find one of our state legislators (MD Delegate Judith Toth) here, especially since she represents the district in which I live. I think you're going to be seeing a lot of her in the future.

I would like to avoid subjecting you to a formal after-dinner speech (which I don't like to listen to or give), but I would like to talk a bit about some of the things we've been doing over the past couple of years. I would like to be informal, so as I go through some of these things, if you have questions, break in and ask me, and we'll see if we can get a little dialogue going. I understand you've been meeting for a couple of days. You've gotten all the barriers down; you're communicating with each other, so I'd like you to do that with me as well.

I'm not going to talk about the technical elements of the program, because you have the experts here, and I don't know very much about those since I come from Headquarters. I'll leave that area aside and tell you about some of the functional aspects of our program endeavors.

We started out about two years ago to change the direction of the Space Applications Program at NASA. We felt that there were a few basic things that had to be put into the program. We were not now trying to build a better mousetrap, and we were not trying to sell technology. Rather, we

were really trying to see if we could focus our attention, through the use of space devices and from the vantage point of space, to help solve national and global problems. To achieve this goal, we completely shifted the tactical approach of the applications program and tried to make it problem-oriented. As soon as we became involved in that approach we recognized that it really was very important to understand the physics and chemistry involved in the phenomena that we were trying to observe. What's really happening? How does it work? I feel there is no sense trying to build a better device unless we can understand how those physical and chemical mechanisms work. First you develop a predictive capability to describe what you think is really happening, and then you measure the indicators to get some insight as to what's really going on. We've spent considerable time in the past few years trying to build a very sound scientific base for our whole program and to remove any perception that applications is a "dirty word."

The third thing we've tried to do, and we've talked very openly about it, is to make it clear that we're not jamming anything down anybody's throat. NASA is not interested in becoming an operator of any satellite system. We think our role is in the research and development activities that will help us to learn to use remotely acquired data in very practical and beneficial ways. We are a research organization, not an operations organization. Our job is to develop technology along the lines of basic principles, and to get that technology into the hands of the people who can make the most use out of it in the fastest possible way.

That brings us to our fourth area of emphasis, which is transferring this technology. When I speak of transferring technology, I'm talking about doing the basic research as well as getting it into the hands of the users. Users—everybody talks about "users"—but determining real user needs is a different job, particularly because there are so many different user groups wanting to be heard.

In addressing users, we did not want to have them involved just to spell out a list of requirements which we could hide behind in justifying our research program. What we really wanted was to develop a symbiotic group of participants and partners with whom we could work. Thus, when our job of basic research had moved far enough, or our job in technology development had moved to the point where we had practical results, those people could pick up what we had developed and go on to use it in an operational way to solve their own problems.

We've been very interested in trying to develop these relationships between ourselves and the "Users." Dick Weinstein and his group have been working very hard during the past two years to develop those relationships. That is why I am so delighted to be here tonight with the ERRSAC group at the first of the three conferences sponsored by our Technology Transfer Division. I am also delighted that so many people from what I call the participating community—our partners in this business—are here at this particular workshop.

There will be another conference on the West Coast in two weeks and then in mid-November there will be a third one, in Mississippi, for the Southern Region. It is very gratifying to see this kind of activity taking place. I've found out that a by-product of the Conference is that it looks as if Landsat has become a vehicle for those of you from different states to talk to one another about your common problems in resources management and to share common solutions to those problems. This is a feature of the transfer program we hadn't anticipated.

Those are the things that we've tried to do for these past two years. We're just getting started, and we have a long way to go. We have become very heavily involved in the "user" area with many other federal agencies—the Department of Agriculture and the Department of the Interior, to name just two. But, as expansive as their requirements may be, I don't believe that they represent a majority of the users. They do not represent the people who really have to get out and solve the problems on a daily basis in the state and local areas. We are finally getting down to the people at the grass roots level, who are making use of the data and these techniques. That these kinds of interactive programs are being developed is most rewarding.

I would like to shift a bit now, get away from what we've been doing and try to get some questions that you have been asking us at NASA. First, let's discuss where we are going relative to Landsat. That is a question I am asked constantly. Future direction of our Metsat (Weather Satellite) Program is less a question because there is a federal agent for those activities, the National Oceanic and Atmospheric Administration. But who is running the show as far as Landsat is concerned? Who is in charge? In another new area, what is going to happen in the ocean satellite program and how will that relate to our other satellite programs? During the past two years we've tried not to let that bother us. What we have tried very hard to do is bring to focus the need for a responsible agent for Landsat and other satellite systems within the Federal Government. We tried to work on that problem last year through a series of summer studies and by writing special papers that we sent to the White House. We did not actually get what we were after which was the designation of a single federal agency which would be responsible for Landsat. However, we did get a commitment to continuity of Landsat data, at least through the 80's.

One result of our efforts was rather disconcerting. We somehow got into a "chicken and egg" type situation. By that I mean that the Federal Government said that it won't invest in operational systems until there is an adequate group of "users" out there who can make use of the data. On the other hand, the users said that they would not invest in using the data until they were assured of an operational system. I've sometimes felt like a ping-pong ball during the last year, trying to get those two viewpoints straightened out.

Unfortunately, Landsat has not lent itself to as easy a set of solutions as have the meteorological or communications fields. You know the reason why. It is because Landsat has such diverse and widespread uses. There is not one single user group that can say that it is "the customer" for Landsat data. We also have territorial disputes within the Federal Government as to who should be the agent. For instance, the Department of the Interior can wax eloquent on why they should be the agent, and they can tell of all the marvelous things they could do. The Department of Commerce's ideas concerning operation of the system also have interesting aspects. Meanwhile, NASA backs away from the situation and says that we don't want to operate these systems. I'm sure, from your vantage point outside of the Federal Government, that it looks as if we're playing another bureaucratic game. But we really aren't.

This past summer I was fortunate enough to chair an interagency task force to try, one more time, to help get some decisions made by the Administration and within the Executive Department of the Federal Government. It is very clear that we have a great deal of support from the legislative

side—the congressional people have pushed, and probed and pulled trying to get us to commit to operational Landsat activities.

It looks as if our work this past summer may have paid off. We wrote position papers concerning remote sensing of the atmosphere, the ocean, and the land. We also developed a composite system paper. We submitted our papers to the White House, and today (October 4, 1979) they had a meeting of the Policy Review Committee on Space. I understand there have been some agreements reached. A paper will be finalized, and recommendations will shortly be transmitted to the President for action. I cannot really say too much about what these recommendations were, because I don't know what the President is going to do. Being a perennial optimist, I feel that some of the clouds are going to move away as far as Landsat and the federal position on remote sensing is concerned. I am therefore looking forward to a very positive decision coming out of the Administration within the next two or three months.

We continue to say that we don't care who is running the show. We really do not care. We think that what is truly important is that this technology and these research efforts and the results from these efforts get into the hands of the people who need them and, that we insure that there will be continuity. As I stated earlier, we think that the President will soon make a statement that gets us moving down that road (a very bumpy road at the outset).*

We also think that earth resources will continue to develop and grow over the years. We think it is quite probable that the way in which we are approaching the use of the data today will probably be outstripped within 5 or 10 years.

Our next step will be to provide the continuity that is the critical first step in the process. We are continuing the development of Landsat-D, which will carry a multispectral scanner just like Landsat-3; however, Landsat D will also carry a Thematic Mapper which has an improved spatial resolution (from 80 to 30 meters). The Thematic Mapper also has additional spectral channels so that it will be able to look at the 1.6 and 2.2 micrometer regions thus allowing us to segregate different crop types and hopefully, someday, with better resolution in the thermal channels and the near-infrared channels, to help us in geological rock type identification. We are beginning the development of such solid state devices as the push broom scanner, from which we expect high reliability and performance. The nice part about the solid state devices is their high reliability—we don't expect to suffer from such problems as the line dropout we're now experiencing with the Landsat MSS. Solid state devices will also provide us with the capability to obtain better coverage at 8- and 9-day intervals with a pointable electronic system. Hopefully we'll eventually be able to get down to coverage every 3, 4 or 5 days.

So, we are making some strides in providing continuity. We have been trying to untangle the Federal morass of segregating what each of the federal agencies should be doing and who should be in

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*On November 20, 1979, Presidential Directive 54 reaffirmed the national commitment to an operational land remote sensing satellite system, and assigned responsibility for all operational civilian remote sensing from space—land, ocean and atmosphere—to the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce (DOC).

charge. I think that the U.S. Government is finally in a position to begin to step forth and see that these programs are implemented in a positive way.

As this process begins to take place, there are several issues which come to mind with respect to reaching out to the state and local governments and involving the private sector. As I see these programs growing, I am a little concerned as to whether you folks in the state governments will be facing the same problems that we in the Federal Government have. I wonder why the state governments are setting up remote sensing centers and making capital investments as opposed to using private sector services, which would ease the fight for funds because of lower requirements. Financing and people are two of the most difficult things to get out of any government, federal, state or local. Frequently, people are even more difficult to get than an appropriation of funds. I am curious about this and would like to learn more from you about your rationale and objectives. I do realize that you first have to get involved in order to understand the business. But, why not count more on the private sector to meet your near-term needs instead of building your own capabilities in house?

The second thing I am curious about is that from your perspective, as you start to get involved in the use of these data do you think that there is a further market with local governments? Do you believe that local governments could actually make use of these data in a profitable way?

Next, as we in the Federal Government work with the operational system agent (whoever it might be), how do we get that agent to recognize your requirements? How do we get that agent to work with you as a partner? To me, this is a very difficult problem to solve. Where do we come together? Where is the focus? Is it in the NCSL (National Conference of State Legislatures)? Is it in the NGA (National Governors' Association)? We've worked very well with Len Slosky who is the assistant to Governor Lamm, Chairman of the Natural Resources Task Force of ISETAP, the Intergovernmental Science, Engineering and Technology Advisory Panel and I hope he is the voice for the states. He is a bright and energetic man, and provides a lot of insight to us at the federal level. But does he represent you? And is the ISETAP Report your report?

A final consideration is that as we proceed to select an agent for the operational Landsat system, is it unreasonable to ask that the operational costs of that system be paid by the user, or should this be provided as a public service? I think these are some of the more important questions we should be addressing in the next year or two.

I don't know whether you are going to lynch me after this talk, or if you are going to have a dialogue with me, but there are many difficult questions like this that I think must be addressed openly.

I hope that what I have said gives you an overview of what our philosophy has been and where we are going with respect to continuity. I think we can look forward to some kind of decision out of the White House within the next two to four months. But, there are still numerous questions in our minds in NASA. We will never back away from an applications program; our administration is committed to it. If an agent (for the system) is named, we will stay with that agent and provide the necessary R&D support until that agent is able to operate the system independently. Only then will we be able to go back to our research and development activities and begin to take on new challenges.

But what should be the relationship with state governments? We must find the best way to work with you as partners, not just with respect to financial requirements, but really getting you involved in and understanding how we can build better systems, what basic research has to be done, what problems we have to solve, what knowledge we have to sell, and how are we going to pay for it.

I welcome any questions you may have . . . . .

QUESTION:

This is probably a three-part question. The first question has to do with what the bottom line is—what is NASA's position in terms of operational systems? You are faced with at least one state (Minnesota) investing a great deal of money in establishing remote sensing analysis centers. Other states that we have interacted with are talking about possibly getting into that area, and there has to be apprehension on their part. We (Minnesota) are already into it—committed. I think that the apprehension on the part of other states might be somewhat put to rest if they could at least hear what NASA's bottom line is, with respect to operational systems, looking down the road. That is going to be a crucial part of any state's interaction with the Federal Government, if they are not sure that the system is going to be on somewhat of an even keel with the state's program.

ANSWER (Calio):

The Administration has made a positive statement on the operational system. First of all, there will be continuity of remote sensing data for the 1980's. That much is certain. What form it will take is what we tried to work out this summer. What is really required to provide that continuity? We took the position that there are many possible technical approaches to remote sensing systems. The important question, at least in the position we took, was an institutional one which centered around getting an agent named, someone who will be an operator of the system and stand out front and make sure things happen. First we must try to solve the institutional problems, and within that framework we could then work out some of the technical solutions to those problems. That has been the position that we have taken over the last two years; to try to define the institutional framework in which data continuity could be provided. We know, technically, as I described to you, what is underway with Landsat-D. We are trying to take the next step beyond Landsat-D.

With respect to NASA, we feel that our job is to continue on with the program until such time as an operational system agent is determined. When that agent is determined we will assist in establishing the appropriate organization to provide data. We cannot do this alone. We are on the technology and science end. You folks at the state and local levels have to participate, also. There has to be representation from the states so that the agent knows how to operate that system and put requirements on that system in a very positive and useful way.

A lot of people ask why NASA shies away from that job (of acting as the system's agent). My boss, Dr. Frosch says, "we'll do it if asked." We say that because our expertise is in research and development, not in operating systems. We don't think that we're best at operating systems on a continuing basis.

QUESTION:

I don't want to put you on the spot, but have you taken a position, or has the committee or task force taken a position as to who to recommend to be the agent to operate the system?

It is understandable that you (at NASA) do not want to deal with operating the system, in light of the fact that you are in an R&D organization. I think the point is that there is going to be a lot of apprehension on the part of the states who become involved, if there is a transition to an operating agency that is slow, sluggish, or cumbersome, and if we're stuck with the process of getting a program underway that suffers in the transitional stage.

ANSWER (Calio):

That's right. And that is why I've said to you that we would never back away from the situation. We would stand next to whoever that agent is until it is capable of operating the system independently.

Yes, we have made recommendations during the course of these studies. We have listed a series of advantages and disadvantages for NOAA, the USGS, or EROS Data Center and Interior as the operating agent. We also noted advantages and disadvantages raised by the U.S. Department of Agriculture as a possible system agent.

Now, for those of you who would like this system to be operated as a public service, you have an advocate. NOAA looks at Landsat as a public service venture, and they would argue very strongly for that position to be maintained.

You have my personal opinion; I don't know what is going to come out of all this. In preparing and writing the reports we felt that it was important that all of the considerations be aired and the issues be brought to a focus, rather than NASA simply presenting its own viewpoint. To us, the important thing is getting those issues on the table and making sure that the President is addressing the right questions, and not being confused as to what one particular system looks like, or what another system looks like. The technicians can take care of that. The important thing is to get the policy issues settled first. Are we going to have a Landsat? If so, will an operating agent be named, and will we have a follow-on operational capability? That's what we have spent our time considering.

QUESTION:

The last part of my question is, how can we feed back to you our feelings about this system? We realize that this is a critical point. Is it best for the states to give feedback to NASA through our Congressman, or would it be more appropriate to go through the various agencies that we represent? I can only speak on behalf of the delegates from Minnesota, but we are very pleased that NASA is doing this. I would suspect that other states feel the same way. How can we best help you?

ANSWER (Calio):

NASA is not doing it; the White House is doing it. We happen to be the vehicle they're using to do it. We were commissioned by the President to carry out these studies over the past year. All of the studies have been done and our recommendations have been transmitted to the White House through the Office of Science and Technology Policy.

QUESTION:

In this country, we have a long tradition of several sectors of the economy not providing a direct return on investments. I am thinking, especially, of the military and some of your (NASA's) programs. Nobody is expecting Voyager II to bring a lot of money back to earth, although we are all very interested in the progress of some of these programs. I am very curious as to why there is so much emphasis—in the resource inventory applications of your program—on the service agency having to provide a return on investment, and therefore causing us to become involved with the private sector. It has been some of our experience in dealing with the private sector on Landsat-related issues that they (the private sector) have not provided adequate service.

ANSWER (Calio):

Let me answer your question backwards. In the government, we have a tendency to be suspicious of contractors in the private sector. I am not sure that contractors give us a dollar's worth of service for every dollar we invest. But I doubt if we do much better in the government. I think we have to continue to consider whether we can get good service out of a contractor. I think that it is a question of building a sound and meaningful relationship with the contractor. In doing this (investing money in the private sector), you are adding to the Gross National Product rather than building an increase in the tax base. And if I learned my basic economics, that is the way to move it—not to increase the tax burden. This is one of the reasons why we try to keep our programming costs down and, get away from operating projects at the proper time. We want to keep that tax base down and keep the segment of the tax dollar we ask for at NASA down to a relatively small percentage.

The other portion of your question concerned the return on investment principle. The Department of Defense job is the national security of this country, and that is the sole return on investment. Some believe that is as it should be and some don't. There is a lot of debate as to exactly what constitutes that return, since there is no return on investment in an actual dollar value. In the space science segment of NASA (the Voyager II Program, for instance), the return on investment is knowledge, a new institutional base, and new concepts for education and training. In the Applications Program we are trying to benefit those of us who live on the Earth, without increasing the tax burden. There is intrinsic value in the (Landsat) data that we collect. We would like you to extract that data, but the information also has a value sitting on the shelf. And this value benefits more people than the researcher who uses the METSAT data for a full five days after it has been sitting on the shelf. The question is, of what value is this data to the users in the state and local governments, or to the private geological petroleum exploration companies? Is this information more than just a public service? If so, why shouldn't the government reduce the tax base, reduce the tax burden, and contribute to the GNP by establishing this information as a product—a product that has an intrinsic value and that is paid for.

186

The other side argues that since we already pay our taxes, we should get this data as a part of our tax return (as a public service). Perhaps I should turn this debate over to a legislator to determine whether we should have it as a commodity or as a public service. I took a stand to try to promote these kinds of debates, and to air the differing opinions within the federal bureaucracy. I'm sure there is similar debate at the state level.

While running the studies this summer I became dismayed by what was happening. As you know, the President took a position in his space policy statement. In addition to saying that we will do applications, he also said that we will continue to maintain leadership in space, that there will be continuity of remotely-acquired data for the next decade, that we will define what that data looks like, that we will commission studies to be done, and that we will focus our attention on the serious problems. Another thing he said was that we should try to involve more of the private sector, in order to contribute to the GNP, and to diminish the tax base. We were commissioned to look into how we could better involve the private sector in a cooperative way in the remote sensing business.

What is my opinion on the state of this important decision? To me, it was a disaster! Why? Because we bureaucrats did not want that solution. Some of the recommendations that were brought to the interagency task force, in my opinion, were disgusting. Nobody on that task force wanted to talk about how to get the private sector more involved on a representative basis. I was shocked! It seems to me that there are ways (without losing what it is that we want to do), that we could get industry more involved in our program than just being a buyer of components, parts, software, and the like. I think that if we can get some capital investments up front, ultimately it will probably pay off. We may have to pay some money, but in the long haul it would probably cost us a lot less than building a large capability on our own.

I was very surprised to see the bureaucracy doing the same old thing, just walking away from this concept of greater involvement by the private sector.

QUESTION:

I'm probably one of the few people here who represent local and regional planning commissions—totally separate from the state. I have been a local user of Landsat data for about three years now. If you want to attract more of us, you ought to pay more attention to us. Fortunately, through my working relationship with two agencies within the State of Illinois we have come up with a very workable program and have accomplished quite a bit. I have to congratulate those agencies that have worked so well with us. But there are about 500 other agencies throughout the United States, similar to mine, that are primary users of Landsat data. But you have to recognize us first of all.

ANSWER (Calio):

As I said earlier, I think, that in the final analysis, folks like you are probably going to represent the biggest single user of Landsat data. How do we listen to you? Where is the link? Is it through the NCSL or the NGA?

COMMENT:

There is the National Association of Regional Councils (NARC) for one. Although I am not a member of that association, we do receive their information. There are a couple of other organizations that also represent regional and local governments. Each of them is willing to give their opinion on how users can best be helped.

ANSWER (Calio):

Yes, and we have to hear it too. As a matter of fact, that is what ERRSAC is all about. In addition to exposing you to remote sensing technology, it also serves as a contact point to help you communicate with us. But we can't listen to each individual user. That is why these people are working in this program. We've got to hear from you as to exactly where the focal points are. We need to know where we can get an aggregation of concepts that we can listen to. We do not want a shopping list of diverse views, but need a way to focus on what we can do best in these programs.

QUESTION:

I believe that that is what the NCSL did, and fortunately I had the opportunity to participate in the task forces. A link has been established with regional and state governments which I think probably is the result of the efforts of the people you see here tonight. I think that a number of people in this room can all pat themselves on the back and say that it is through their efforts over the past four years, and through the help of ERRSAC and NASA that this body of people is assembled here tonight. I think that the local governments should be approached in the same manner.

ANSWER (Calio):

Let me ask you a question. Is the state the best place to get that advice concerning the local element?

COMMENT:

Sorry folks, but no. The states do not necessarily communicate with the lower forms of life. (The "Feds" don't like to communicate with the states, and the states don't like to communicate with the local governments.) This is an unfortunate occurrence. Of course, I'm not going to say that as an absolute statement, but generally that is the way it happens.

ANSWER (Calio):

Do you think that a governing board, set up for an operational Landsat system, with state and local representation on it is a good way to move? In this case it would be known throughout the state and local governments that this (governing board) is the rallying point to go to, to get your input in. Is that the right way to go?

COMMENT:

I would think so.

One other point, I certainly feel that Landsat should be a public service. It should be provided as a public service in the same way as the USGS, the Forest Service, and the Parks Departments are.

ANSWER (Calio):

Even if the result is an increase in the tax base?

QUESTION:

You have to understand that most of the studies requiring us to come up with this data are federally-mandated anyway. (Applause) If they (the "Feds") would back off on their requirements, then we'd back off on our request. But a service is still a service, and other people may find applications for Landsat that currently have not been exploited.

ANSWER (Calio):

I know what you're talking about because at NASA we've added 15 staff offices without increasing personnel because we've had to be responsive to other Federal regulators.

QUESTION:

And one more part to my question is: when will the EROS Data Center-Goddard connection be resolved? (Laughter) I'm referring to the current (Data Delay) problem. We had problems getting data before, but it appears that the system has improved so much that now we can't even find the data.

ANSWER (Calio):

This is an unfortunate cross we bear. Strangely enough, as you know, we did try to improve the system, and we got ourselves into other difficulties. We have commissioned a group to try to find out where the problems are and to remedy them as quickly as possible. We know what a hardship it is on those of you who are using the data. This hasn't helped us to make the program move any better, especially when we ask for new techniques and we can't even work the old ones. I hate to give you a date because since last August I've been saying next month, next month, next month. The only thing I can say to you is that we've put a task team together to try to find out where the problem is and how to correct it.

I hope that we correct it before Landsat-D flies, and I also hope that we not only avoid this problem with Landsat-D, but also have the ground data systems up and operating before the satellite ever flies. One thing we learned from this last episode was to make sure that the ground network is in place and operating before the satellite is launched.

C - 3

189

I can't give you an exact answer, and I am embarrassed that I can't. I can just say that we are working on the problem.

QUESTION:

I would like to address the question of whether or not the user should pay part of (Landsat's) operational costs. In my opinion, there are a number of good reasons why we should not have to do so.

One reason is the money (it already costs us) to process the present generation of Landsat data. The amount of data increases fourfold with Landsat-D, so the (data processing) costs will be that much greater. If we also have to pay part of the cost of launching that satellite, it may be the straw that breaks the camel's back.

Second, a very large portion of the American economy is subsidized by the Federal Government (the vessels that carry cargo, for example). So why can't the average American taxpayer be subsidized too?

Third, I think if we are forced to pay part of the cost of keeping the satellite up and launching it, a basic result might be an embarrassment to this country's foreign policy (it might also be discriminatory). I really cannot see the Russians and the Chinese paying their share for launching the satellite. I also think it would be very bad public relations if a country like Bangladesh had to pay a great sum of money for this data.

ANSWER (Calio):

Okay. I'll try not to take too long. Yes, there is a lot of subsidizing that goes on, in the highways as well as in just about everything else that we use. Sure, we could also subsidize Landsat. But the tax base would grow.

I don't think that this could happen anytime soon, but we do have a product that may be able (if put in the correct framework at the outset) to pay for itself. It's just a question of whether you put it in there anyway, so why not have those who use it pay for it, at a reasonable rate.

I don't think we should establish a price tomorrow, or next week, or next year. But I think that we should try to develop some kind of formula that is set on an equitable basis, and get enough lead time to allow the states to legislate funding before the levies are imposed. If we established a policy today we would not expect it to take effect for at least two to three years. Before that time, people won't have the money to pay for it. I think that the entire group that is looking into this understands that. We have had the same problem with the Department of Agriculture—our biggest user. Agriculture doesn't object to paying for it ultimately; they just need enough time to budget for it. And of course, that's not going to happen on the first time around, so we're going to have to miss one, and build a better case for it in the future. I believe that this can be done.

As far as paying for the entire system is concerned, maybe that is not an appropriate solution, because the numbers might be so large as to be prohibitive. But there is no reason to say that the costs can't be broken down into segments, where maybe the subsidy is for the states' share of development costs and where the operation and the handling of the data on the ground might be some of the costs that could be covered through the sale of data.

Now I'll get to the last part of your question. I am a nationalist, and as far as I'm concerned we ought to worry about establishing national remote sensing programs and get that really settled in this country before we go international. If you read the Washington Post last week you probably saw Senator Stevenson's article on the internationalization of remote sensing. I think we're giving away the leadership of the U.S. capability and that we ought to use it in this country and have the system worked out with the state and local governments; then we can figure out how to operate with foreign nations.

Yes, we can make the Chinese pay for it. I was the leader of a delegation that went to China for space technology discussions, and I don't think that it is out of the realm of reason to charge them a fair share of the cost of collection of that data. You know we're not going to get the Soviets to pay for it because they have their own systems. And as far as Bangladesh and the other less-developed countries are concerned, I think that they should pay for the system also—through AID (Agency for International Development). If we're going to have an aid capability within the Federal Government, let the aid capability buy the training and then give it to these developing countries instead of the United States establishing a policy in which different countries are treated unequally.

The data-access charges that are in effect today—$200,000 a year for a Landsat ground station—are a mockery. Foreign nations ought to be paying their fair share of the U.S. investment. The U.S. taxpayers have paid for that capability, and we ought to try to recover some of those costs. You just hit my red button! This is one of the things that I feel very strongly about and would like to see the United States do something about. We have been "nip'n tuck" and "toe to toe" with the State Department on this entire issue, because it seems that some people want to give it away. If we can establish a value for it in this country, in a very profitable way, then we can turn around and charge those outside of this country for the data.

I'll give you a beautiful example of this issue, and then I'll shut up on the subject. SEASAT is my nemesis. We took every penny that we had out of data acquisition, and out of scientific data analysis, all planned for the analysis of SEASAT data, to build that satellite and to launch it. And when it was finally flying, we did not have one penny left to analyze one piece of data coming down from that. In the meantime, the Europeans had put up a receiving station (for $5 million) and had $10 million to analyze the data. They were skimming the cream off of our whole program. And not one U.S. scientist, not one U.S. agency could analyze that data unless they had money of their own. And thank God we had NOAA who helped bail some of us out, and thank God there were other people around who were willing to help. I don't want to get caught in that situation again, because I don't think that we treated the taxpayer fairly. Enough said.

QUESTION:

I don't think the issue should be whether a public sector party or a private sector party should be the chief operator (of Landsat). The issue should be who can operate the system in the most efficient manner and (who can) provide the products to the users or benefactors most efficiently and therefore, hopefully, most cheaply. But don't you see that regardless of whether it's a public or a private party, the taxpayer is going to pay. The tax base is not going to be reduced, necessarily, by putting the system into the private sector. The states (or regional users) can't provide a product to satisfy either a state or a federal requirement without raising the money out of state or local taxes. The total burden on the taxpayer is not going to be reduced a bit. The question is who can do the job most efficiently—that is where a reduction in the tax base is going to occur.

ANSWER (Calio):

Well said; I agree with you. The question is, now, how do we determine how and where the job can be done most efficiently. How do we determine that? It isn't a priori in the State or Federal Government because we are not that efficient. I'm not saying that the private sector is either. But how do you get an efficient investment?

QUESTION:

Let me follow that by in part responding to some of your initial questions. You asked how you (NASA and Federal Government in general) can deal with the states most efficiently. I think you're doing that through a couple of mechanisms. One is the Regional Applications Program and the kind of meeting we're having here today. The second mechanism is through NCSL and NGA committees set up to deal directly with remote sensing technology, which provides a forum through which all states can participate. We've discussed the ISETAP report contents. I think that this report spells out the kind of criteria that the states would like to see in an operational system. If those criteria are used as guidelines to determine who gets the system, I think we'd be on the road to getting the most efficient system in place.

ANSWER (Calio):

That's good input. I would like to read through those criteria again.

QUESTION:

That report does represent us to the extent that the 10 states in the NGA committees are now representing all the states, and we have initiated a drive to create a network of communications with the other 40 states. I think that once this is done we'll have a really effective mechanism for keeping the states' policymakers and program managers in pace with what is happening at NASA, and using them as a sounding board in decisions that have to be made on those positions.

ANSWER (Calio):

Thank you. That was well put.

QUESTION:

I think that if you turn responsibility for the operational program over to USGS you could probably solve it, because they have a project that is already useful. But you don't get support unless you share the costs. You've got to cooperate, with money. And you have to back certain funds, unless the DOD wants it.

ANSWER (Calio):

I won't touch that one, unless you want a response.

Anything else? I thank you for having me down with you tonight. It is really very gratifying to me to see this turnout and to hear about new interactions among users. I welcome your participation. Thank you all very much.

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SESSION 5

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NASA'S EARTH RESOURCES PROGRAM: FUTURE OUTLOOK

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The next decade in remote sensing will see a shift in emphasis away from the development and demonstration of applications of earth resources satellite data to the routine use of satellite-acquired data in operational management information systems. Other nations also recognize the immense potential of satellite remote sensing, as evidenced by the number of existing foreign Landsat ground stations and the interest shown by other nations in acquiring such stations or requesting Landsat data acquisition over their country, and by the number of feasibility studies of remote sensing systems being conducted.

Foreign governments also realize the technological and economic benefits of developing their own satellite systems. In the coming decade, we can expect France, India, Japan, and perhaps the European Space Agency (ESA) to launch earth resources type satellites. In addition, West Germany, France, and ESA have been studying the potential application of imaging radars on earth resources satellites. It is quite probable that one of the three will develop such a system.

Within the next 10 years, initial elements of a global information system will probably be in place and operating, probably reaching maturity in the 1990's. This mature global information system will contain satellites from several countries in orbit with similar data outputs, all of which can be received by the same ground station. In the 1990's we believe that the United States will have an earth resources satellite system in operation that could either stand alone or be a part of an international global information system. The future U.S. system (Figure 1) could consist of several appropriately instrumented spacecraft in orbit transmitting data through a data relay satellite to a centralized data processing center where the data would be geometrically and radiometrically corrected. The processed data would then be transmitted via a communications satellite to several localized information centers where the preprocessed data would be disseminated to users for analysis and subsequent incorporation in their management information systems.

A major task for NASA will be to ensure that the research and development necessary to implement such a system is accomplished in a timely fashion and that the required technology is available when needed. In the next few years the major technological advances in the spacecraft systems are anticipated to be in the new multilinear array (MLA) sensor technology. In the ground processing system the throughput must be significantly improved in order to be able to handle the immense quantities of data capable of being produced by MLA's. Research is needed to strengthen the scientific base for the application of remote sensing techniques in monitoring the earth's resources as well as significant improvements in techniques for extracting information from remotely sensed data.
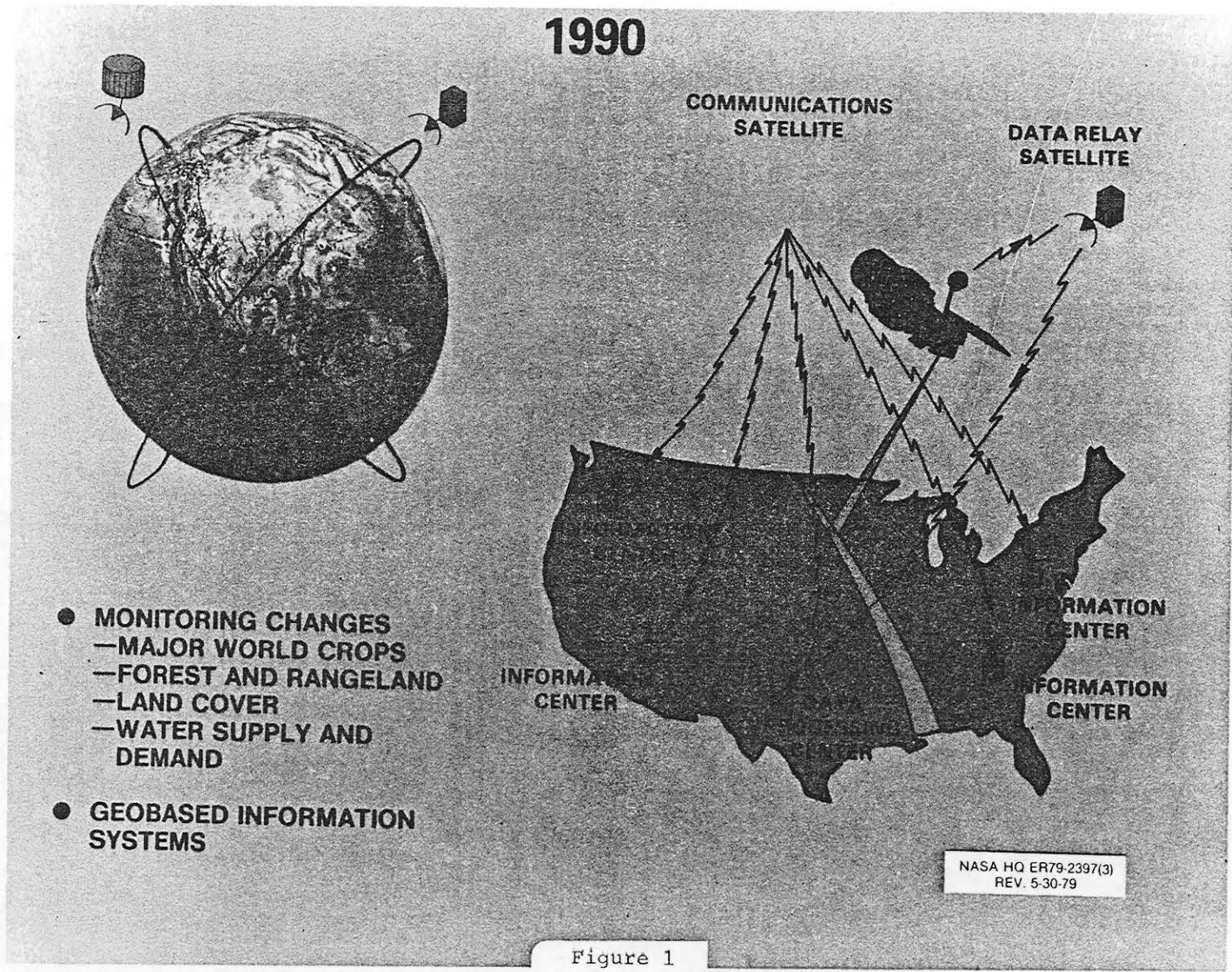
Figure 1. Future United States system.
Original in color (contact author).

As a result of the administration's decision in November 1979 to assign management responsibility for the satellite-based operational land observing system to the Department of Commerce/National Oceanic and Atmospheric Administration (NOAA), an ad hoc planning group, composed of representatives from NOAA, USDI, USDA, and NASA, has been working to identify the tasks to be undertaken as we move toward the operational era. Although the specific details of the institutional responsibilities have not been defined, NASA will continue to be responsible for the space and related ground segment research and development activities, for development of the protoflight system, and may act as NOAA's agent for the procurement of subsequent space operational elements. The operational system, including the initial data processing activities and dissemination of the data to the users, will be managed by NOAA. Over the next few years, NASA will be working with NOAA to effect a smooth transition from the ongoing research-oriented NASA Landsat system to the NOAA operational system.

Based on the anticipated system technological advances and on the strongly expressed user needs for Landsat data continuity, our research and development strategy for earth resources systems in the 1980's is:

- Continue to fly the Multispectral Scanner through the mid-1980's to provide the requisite Landsat data continuity.

- Fly the Thematic Mapper in the 1982-1985 time frame in order to acquire the data needed to assess the utility of:

  — different spectral bands and extended spectral range;

  — potential for intercomparison and merging of the various bands;

  — higher radiometric sensitivities; and

  — improved resolution in inventory mode.

- Initiate development of solid state sensors for flights in mid-1980's to assess impact of:

  — improved spectral resolution;

  — improved radiometric sensitivities;

  — improved spatial resolution;

  — calibration techniques;

  — atmospheric and view angle effects; and

  — inventory versus sampling mode studies.

- Establish all solid state sensor technology for the visible and infrared regions by 1990.

- Provide for Landsat data continuity and the implementation of the operational system.

In addition to working with NOAA to effect a smooth transition to the operational system, NASA will support NOAA in the definition of the Operational Earth Resources System (OERS). One of the concepts studied previously is shown in Figure 2; this concept would build on the Landsat-D/ Landsat-D' system and would stress shuttle retrieval of the replaced spacecraft, refurbishment, and subsequent reuse. The scope of the OERS definition study to be performed in 1980 and 1981 is shown in Table 1; an FY 1982 new start is anticipated for the OERS, with the launch of the first flight element in 1987. Since the launch of Landsat-D is planned for late 1981 with Landsat-D, launched six months later, and since these spacecraft have a 3-year design life, we are keeping the option open to procure an additional spacecraft (Landsat-D") to ensure data continuity until the operational system is functioning.

Another system, Stereosat, which is somewhat more specialized than Landsat, has been under study over the past three years. Our studies indicate a need for worldwide stereo data by both the mineral and petroleum exploration industries as well as by a wide segment of the specific community, particularly for regional geomorphological studies (Table 2). In addition, such data are required for highway and pipeline routing, by soil conservationists, hydrologists, etc. Currently, stereoscopic imagery is lacking for many areas of the world, and existing data are in a variety of formats and scales. Stereosat would provide a worldwide, uniform, and consistent set of stereoscopic imagery under the same illumination conditions.

The Stereosat concept (Figure 3) includes a spacecraft with a three-camera instrument system. One camera would be pointed at the nadir, one fore, and one aft to obtain panchromatic stereoscopic imagery with base-to-height ratios of 1.0 and 0.5. Each camera would utilize MLA technology with an IFOV of 15m and a swath width of 60 km. The spacecraft orbit would be similar to Landsat-D, but with a 48-day repeat cycle. The stereo data would be mergeable with MSS and Landsat-D TM data. Approximately three years would be required to obtain cloud-free imagery of 85 percent of the world's land mass between 80°N and S latitudes.

In addition to sensors in the visible and near-to-mid infrared spectral regime, the application of imaging radars to earth resources studies is being actively pursued. In the spring of 1981, on the second shuttle flight, the Shuttle Imaging Radar (SIR-A) will be flown (Figure 4). SIR-A, a modified Seasat L-Band Synthetic Aperture Radar, will have the antenna look angle fixed to maximize the data return for geological studies. A multiple look angle capability will be incorporated into the antenna for subsequent flights in 1983 and 1984, in order to expand the scope of potential applications to other areas, particularly land use, hydrological, and agricultural studies. A multifrequency/ multipolarization Synthetic Aperture Radar will be developed for flight in the mid-1980s for a wide range of earth resources investigations.

OPERATIONAL EARTH RESOURCES SYSTEM

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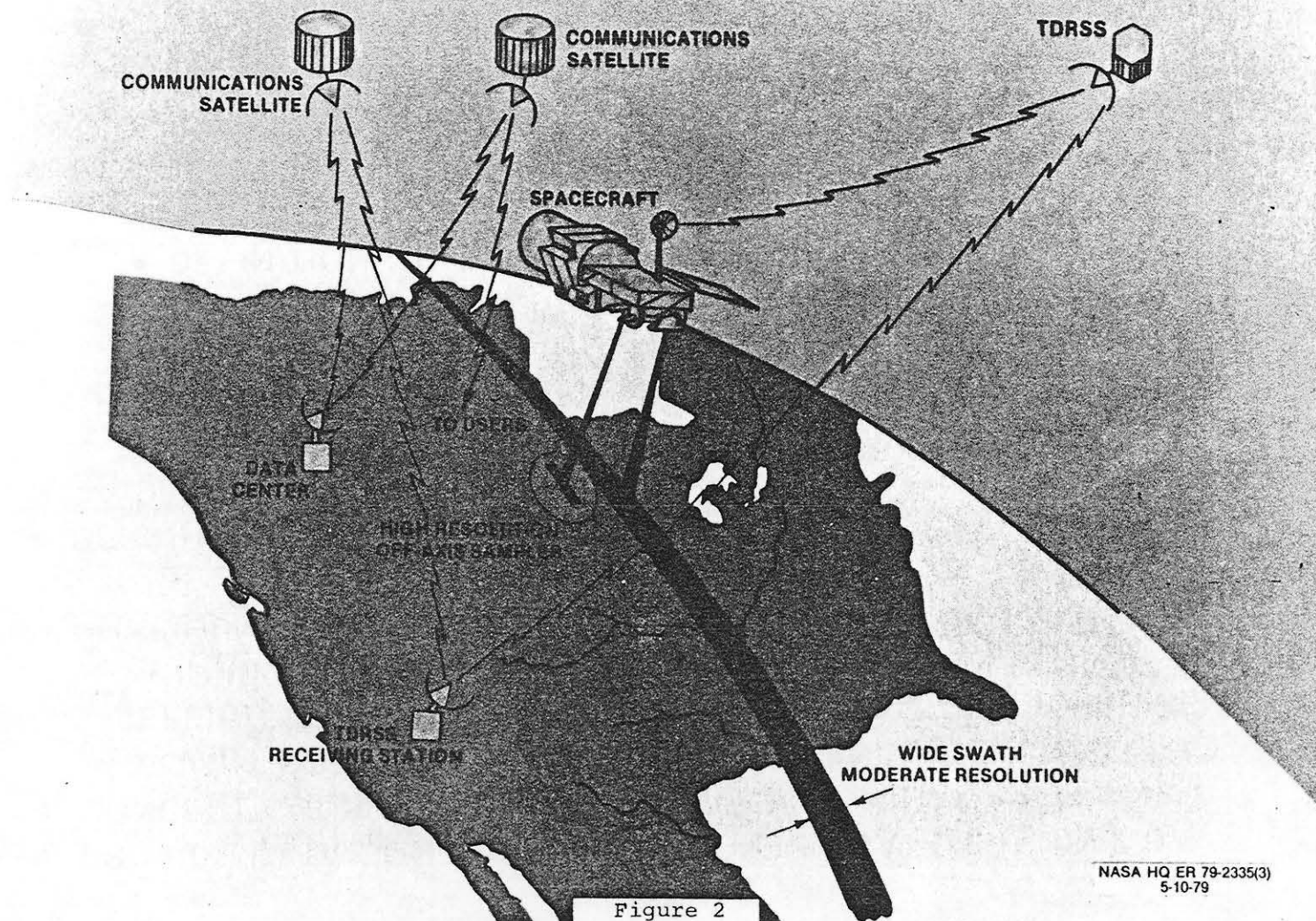
Figure 2

Figure 2. Operational earth resources system.
Original in color (contact author).

201

Table 1
Operational Earth Resource System

- PROVIDE DATA CONTINUITY BEYOND LANDSAT-D/LANDSAT-D'
- CONCEPT CONSIDERED
  - FLIGHT SEGMENT WOULD BUILD ON LANDSAT-D & D'
  - DESIGN FOR SHUTTLE LAUNCH, RETRIEVAL, REFURBISHMENT, AND REUSE
  - GROUND DATA MANAGEMENT SYSTEM BUILT ON LANDSAT-D SYSTEM

- DEFINITION STUDY IN FY 80-81
  - DEFINITION STUDY TO INCLUDE:
    - USER REQUIREMENTS
    - MARKET ASSESSMENT
    - INSTITUTIONAL ARRANGEMENTS
    - DATA POLICY
    - DEFINITION OF FLIGHT SYSTEM AND GROUND SYSTEM

- FY 1982 NEW INITIATIVE

Table 2
Why Stereosat?

APPLICATIONS OF STEREOSCOPIC IMAGER

- FUNDAMENTAL REQUIREMENT FOR MINERAL AND PETROLEUM EXPLORATION SURVEYS

- PROVIDES CRITICAL INFORMATION ON LANDFORMS, FAULTS, FRACTURES, AND DRAINAGE PATTERNS REQUIRED FOR MAJOR ENGINEERING PROJECTS

- GREATLY IMPROVES THE USEFULNESS OF MONOSCOPIC IMAGERY

SCIENCE UTILIZATION

- PERMITS QUANTITATIVE GLOBAL GEOMORPHOLOGICAL STUDIES OF SURFACE LANDFORMS

- CAN BE USED WITH ANCILLARY DATA (E.G. MAGNETIC AND GRAVITY SURVEYS)

NEED

- NO UNIFORM SET OF GLOBAL STEREOSCOPIC IMAGERY AVAILABLE

- STEREOSCOPIC IMAGERY LACKING FOR MANY REGIONS OF THE WORLD

- NO OTHER PROGRAM CURRENTLY PLANNED TO OBTAIN AN ORGANIZED SET OF GLOBAL STEREOSCOPIC DATA

- BROAD SEGMENT OF THE GLOBAL GEOSCIENCE USER COMMUNITY WILL UTILIZE GLOBAL STEREOSCOPIC DATA
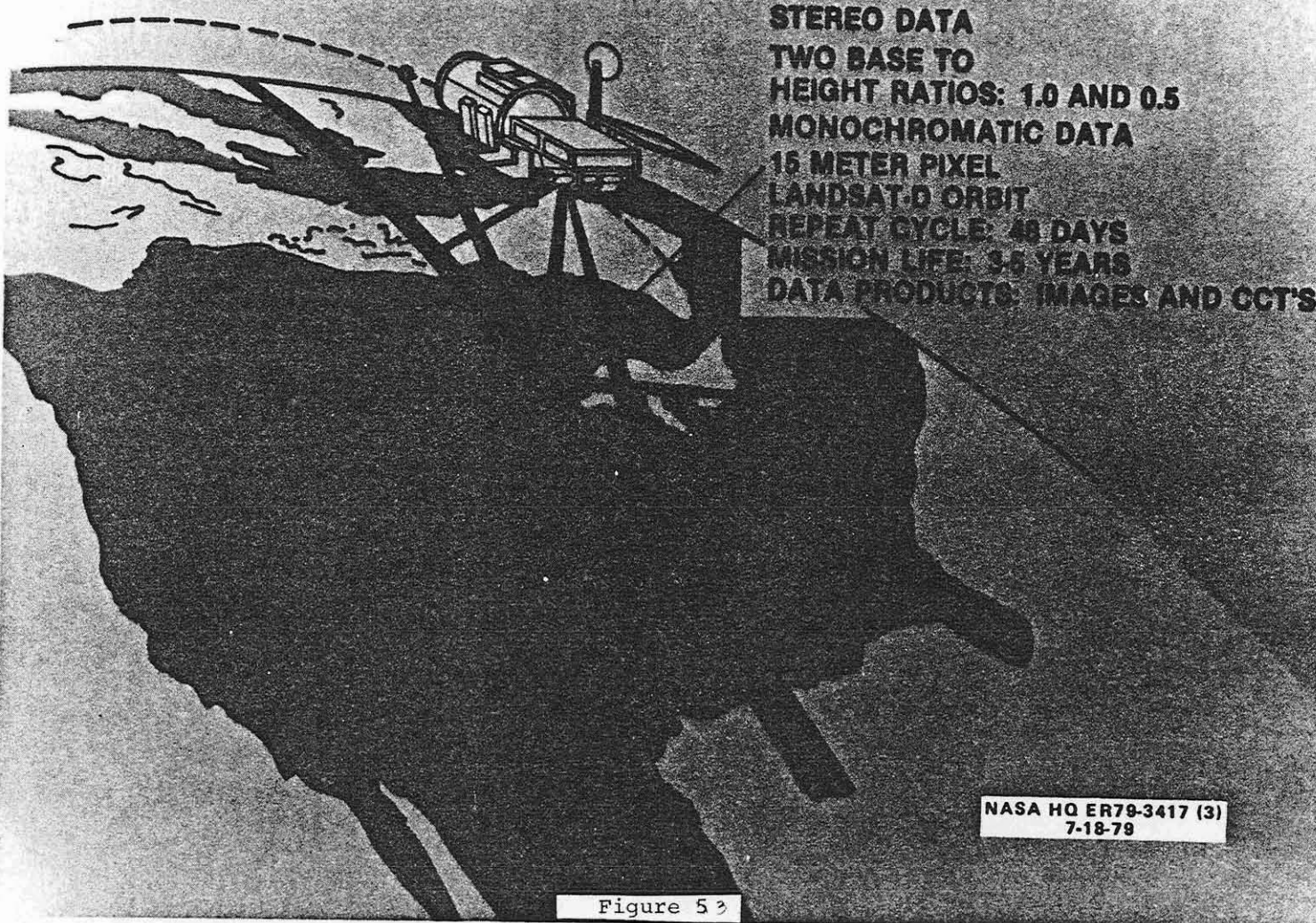
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Figure 3. Stereosat.
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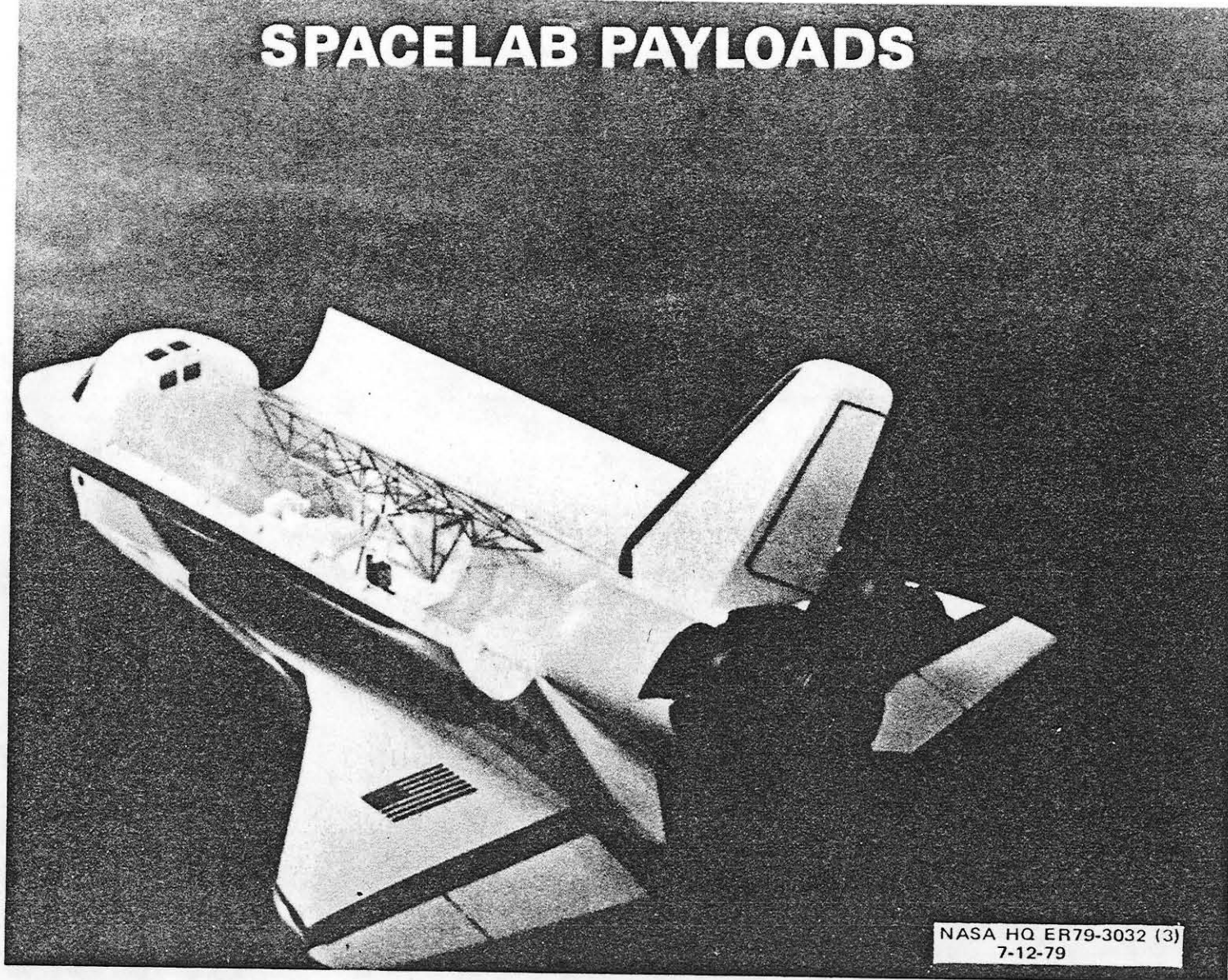
Figure 4. Spacelab payloads.
Original in color (contact author).

In the area of new sensors, the multilinear array technology will be the basis for the next generation of earth resources sensors. In the multilinear array, several thousand minute detectors would be positioned in a line in the focal plane of the sensor telescope. The projection of this line of detectors on the ground defines the swath width, obviating the need for mirrors to scan the detectors across the swath (Figure 5). The motion of the spacecraft essentially moves the ground trace along, similar to a broom sweeping out a path, hence the name "push-broom scanning." With the MLA technology, spectral bandwidths as low as 20 nm are feasible for earth resources investigations (vs 60 nm for the TM and 100 nm for the MSS) while still improving on the radiometric sensitivity.

Initiation of a multilinear array sensor development is planned for FY 1982 for flights in the mid-1980's. Other planned future systems with potential earth resources applications are indicated in Table 3.
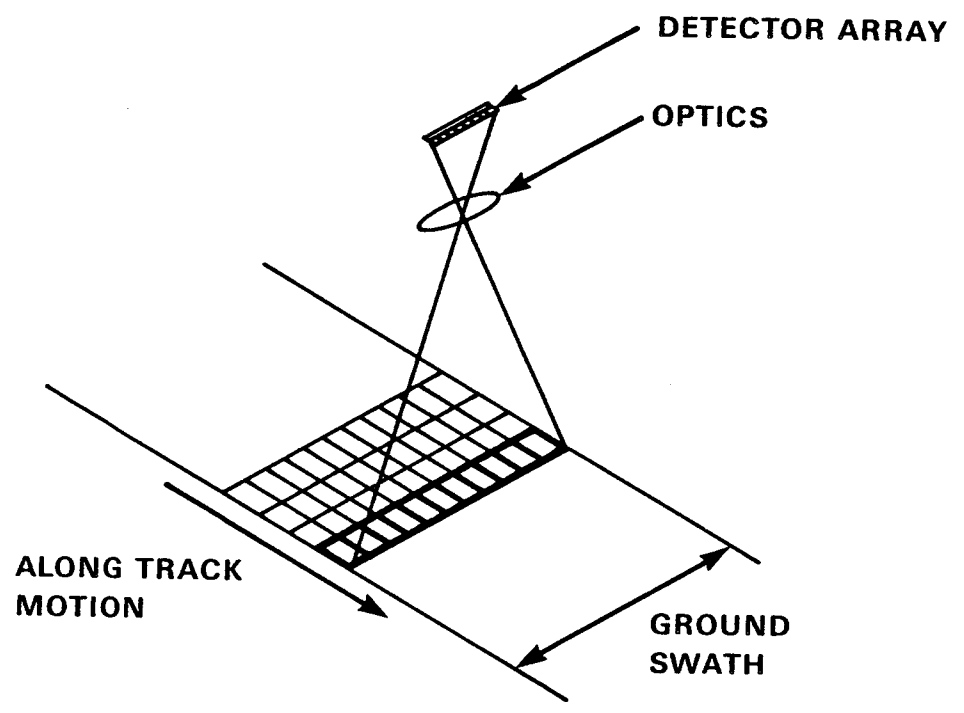
Figure 5. Multispectral linear arrays (push-broom scan mode).

Table 3
Planned Earth Resources Missions

New Initiative	Initiation of Development 1982	1983	1984	1985	Launch Date
Multispectral Multilinear Array (MMLA)	X				1985
Landsat-D"/D"'	X				1984/1985
Operational Land Observing System Protoflight	X				1987
Soil Moisture Research and Assessment Mission		X			1986
Magsat-B			X		1986
Tethered Magnetometer			X		1987
Advanced Thermal Mapping Applications Satellite			X		1988
Earth Resources Synthetic Aperture Radar				X	1989
Spacelab Payloads					
Broadband Reflectance Imager		X			1985
Multiband Thermal Imager	X				1984
Variable Depression Angle Antenna (SIR-A)	X				1983
Dual Frequency/Multipolarization SAR		X			1984

SEASAT SYNTHETIC APERTURE RADAR DATA

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Most remote sensing devices are passive systems. That is, the sensor records or measures electromagnetic energy reflected or emitted naturally by objects in the environment. Radar (an acronym for RAdio Detection And Ranging) is unique among sensors in that it is an active sensor. Radar systems send out pulses of electromagnetic energy in the radio and microwave regions of the electromagnetic spectrum and record variations in the signal that is returned or bounced back to the radar antenna from environmental features.

As an active sensor operating at relatively long wavelengths, radar offers several advantages for land resource investigations. Radar systems can be operated during the day or night and are virtually weather independent. Sunlight or cloud-free weather conditions are not required to acquire acceptable imagery, nor is radar subject to the atmospheric scattering and absorption problems that passive sensors (e.g., photography or multispectral scanners) are. Since a radar system transmits and receives its own signal, the look direction and look angle of the antenna can be directionally oriented to enhance selected terrain features and relative relief.

To explore the advantages and potential of radar imagery from space altitudes, the National Aeronautics and Space Administration (NASA) launched the Seasat satellite on June 28, 1978 (Figure 1). This was the first satellite dedicated to establishing the usefulness of microwave sensors for analysis of oceans and marine phenomena. Among the five sensors onboard was an L-band (22-cm wavelength) synthetic aperture radar (SAR) system with 25-meter spatial resolution. As the spacecraft passed over the earth, the SAR, looking to the starboard side of the satellite, imaged a 100-km wide swath centered 20° off nadir. Unfortunately, after some three months of operation a massive power outage forced the permanent shutdown of the system on October 10, 1978. However, during its operational life the satellite did make 22 passes over North America, providing much useful data for scientific examination and as input into the design and expected results of the upcoming Space Shuttle SAR systems.

Although the examination of land resource phenomena was of secondary importance to that of the earth's oceans, several such investigations are being conducted. While it is too soon to report on completed studies, a description of some of the work and possible areas of land resource applications provides insight as to what information can be expected from similar SAR systems in the near future.
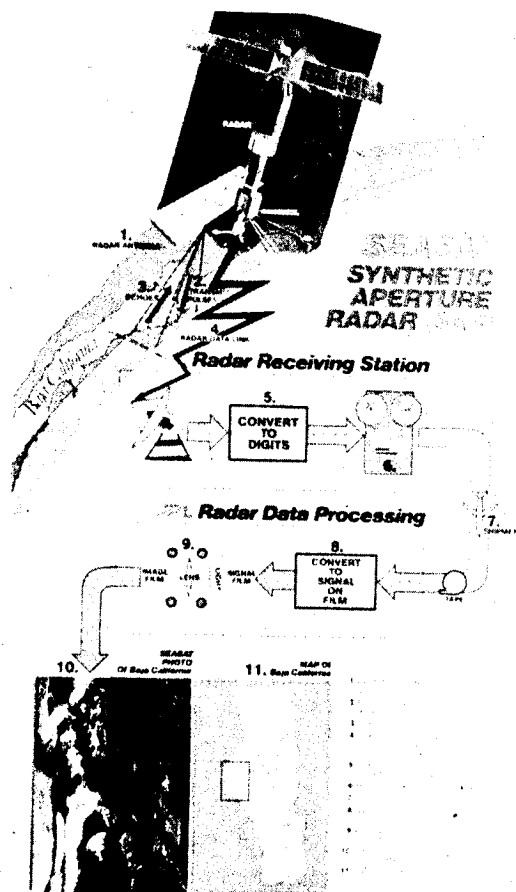
Figure I. Data recording procedures for the Seasat
SAR system.

In the coastal zone, measurement of wave refraction is being studied as an aid in measuring water depth and in mapping the existence and position of shoals. Investigations on wave patterns should prove useful in determining possible coastal locations for power generation sites, deep water ports, harbors, and breakwaters. Using information on wave heights during normal and storm conditions, models can be generated to aid in the construction and design of offshore oil platforms.

210

The utility of SAR for detecting and monitoring oil spills is also being investigated, as is its role in assessing the areal extent and damage caused by storms, hurricanes, and flooding (Figure 2). The real time all-weather capability of SAR would do much to expedite disaster relief measures in such cases.

Other areas receiving attention include snow and ice reconnaissance. Of interest is the possibility of using SAR to measure the areal extent and depth of snow, and melt-off rates. These data would be used in forecasting impacts on reservoir storage capacity, the probability of spring flooding conditions, and expected available water for irrigation. Detecting from SAR the location, distribution, type, and the freeze/thaw movements of sea and lake ice would provide valuable navigation information, particularly during adverse winter weather conditions. Portions of the Gulf of Alaska, the Northwest Passage, Lake Erie, and the St. Lawrence River are serving as North American study sites for ice studies.
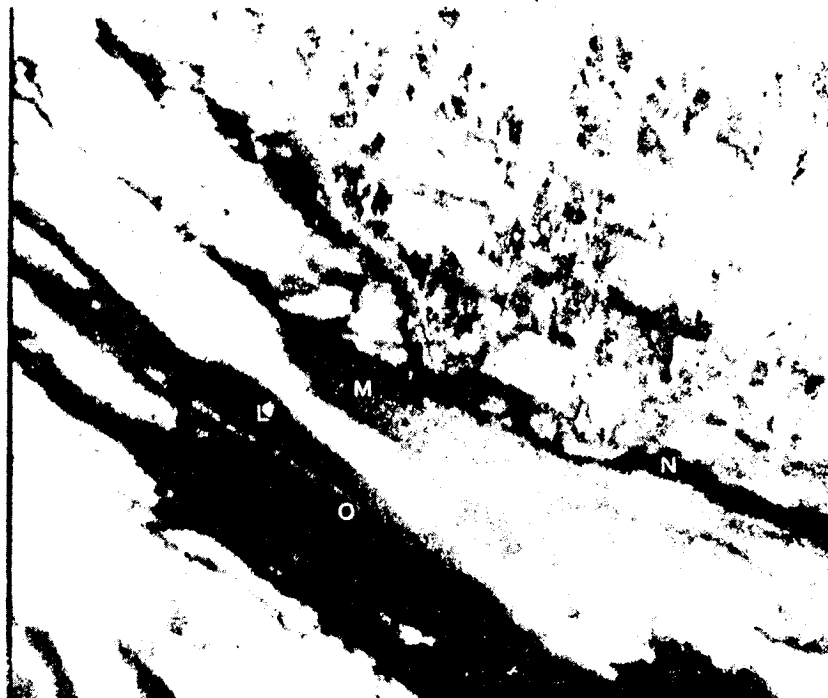
Figure 2. Seasat SAR image enlargement of the Santa Barbara Channel, California. M is probably oil, O is definitely oil, N is a kelp bed, and L is an offshore drilling platform.

Airborne radar systems have shown great promise and applications for geologic reconnaissance studies. Seasat SAR provides further opportunity to explore the utility of radar for mineral exploration, lineament detection, and geomorphic studies such as drainage basin delineation (Figure 3).

Most of the work centered on forestry and agricultural applications is very exploratory in nature due to the numerous variables involved. Correlating SAR sensor response to specific forest and crop conditions is an extremely challenging and complex task. Research is being conducted to determine the capability of SAR to monitor soil moisture conditions, soil salinity, and as input in developing models for optimum crop irrigation programs. Attempts are also being made in forestry and agricultural studies with regard to measuring plant growth, plant stress, and drought conditions. The possibility of measuring forest area and tree density appears to be one of the more immediately promising forestry applications.

The contribution of space platform SAR imagery to detecting and monitoring phenomena in the urban environment is another avenue of research being pursued. The high return from most built-up areas indicates SAR can be used to delimit the rural-urban fringe (Figure 4), denote areas and direction of urban expansion, and, possibly, to detect the presence of small settlements in remote areas.

Also of concern is the sensor's value in providing data for census studies and geographic information systems. Although single-family residential areas and open space can be fairly readily identified, the complex interaction among urban structures, vegetation, and a feature's orientation relative to the antenna tends to produce convoluted SAR signature responses (Figures 5 and 6). Current efforts are concentrating on procedures to overcome this problem and delimit more detailed urban land cover classifications.

It is apparent that regardless of the area of interest the most immediate value of satellite SAR imagery is for reconnaissance studies. The synoptic view provided is ideal for small scale thematic mapping efforts, particularly land cover inventories. Although there is much interest and potential use for such data in the industrial nations of the world, it is in the developing nations, perpetually cloud-covered tropical environments, and/or low-light northern latitudes, where the operation of a space imaging radar system will have the most instant impact. The value of an all-weather, day or night sensor to areas of the world where land resource information is dated or absent due to environmental conditions cannot be underestimated.

One final comment is in order. Every remote sensing system possesses unique capabilities and provides information not available by any other sensor. However, no one sensor is a panacea for all problems (Figure 7). The synergistic effect and benefits of merging data from two or more sensor systems has already been demonstrated in preliminary work. SAR imagery has been and will continue to play an important role in such efforts and subsequent applications.

In the future, the use of radar imagery for land resource analysis should become more widespread among the scientific user community as the quantity and availability of such data increase with the operational status of the shuttle space imaging radar systems.
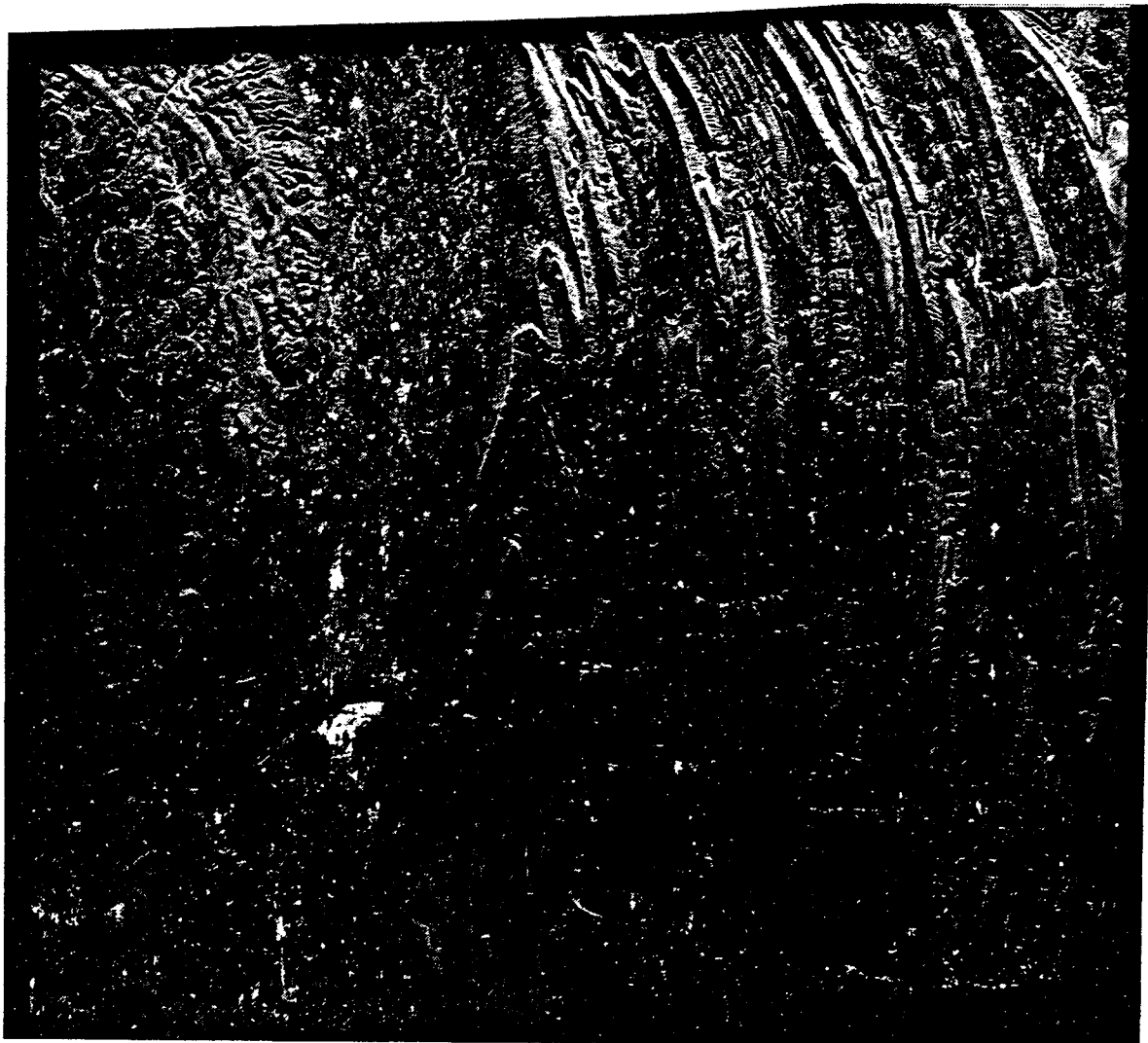
Figure 3. This image of central Pennsylvania suggests applications of SAR for land
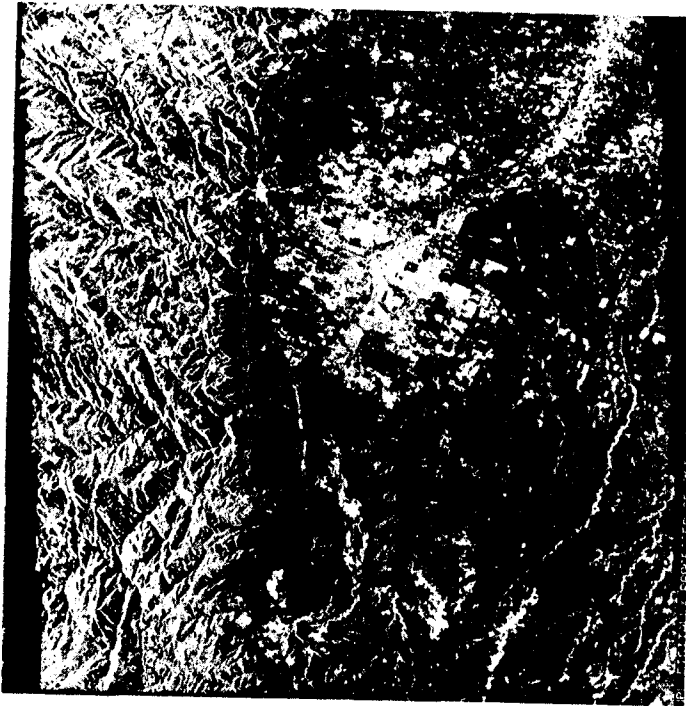cover inventory, drainage basin analysis, and surface geology studies.

Figure 4. Seasat SAR image enlargement of the Denver, Colorado metropolitan area. North is at the top. The rural-urban fringe is quite distinct and easily delineated.
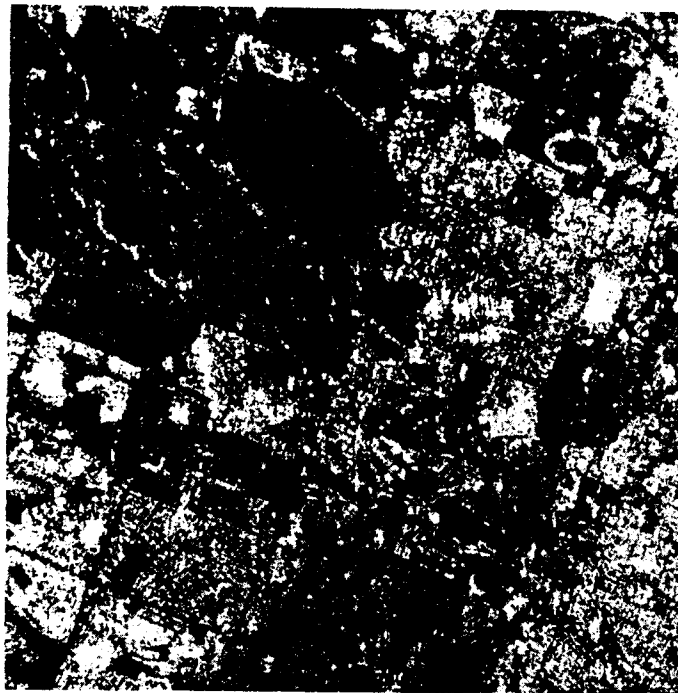

Figure 5. In this enlargement of a portion of the Denver Seasat scene (Figure 4), the southwest corner of the city is depicted. Some of the detailed features of the urban area (e.g., the residential reservoirs, and open space) are visible.

NEWPORT BEACH/SANTA ANA REGION

36 km

32 km
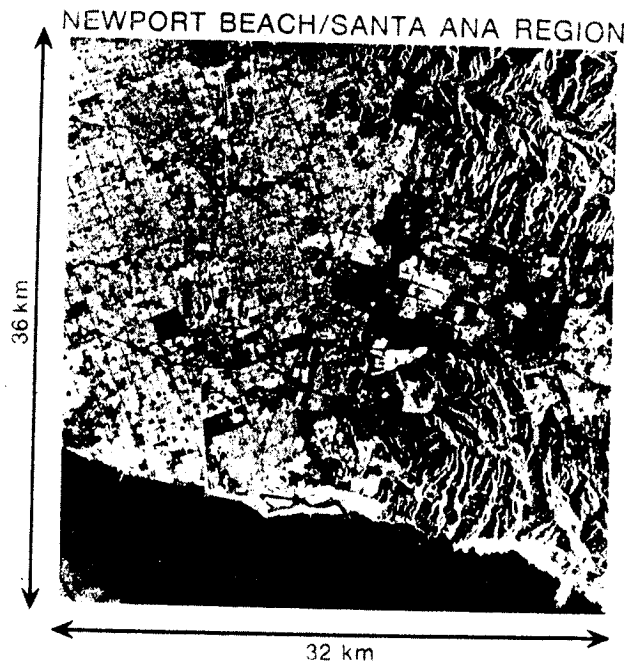
Figure 6. Seasat SAR image subscene of Newport
Beach/Santa Ana, California. Note the visibility of
major transportation arteries, port facilities, and
urban built-up areas.

Figure 7. Landsat color composite of the Denver area.
North at top. By comparison with Figure 4 some of the
unique and complimentary qualities of each sensor can
be observed.

DATA ACQUISITION AND PROJECTED APPLICATIONS OF
THE OBSERVATIONS FROM LANDSAT-D

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INTRODUCTION

Since the launch of the Landsat series of satellites in the early 1970's, a considerable amount of research has been directed toward extracting useful information from satellite remotely sensed data for monitoring the Earth's resources. The utility of the observations provided from space by the MSS on Landsats-1, -2, and -3 has been fairly well determined, yet the operational use of the data has gained rather slow acceptance because it is found to be unsatisfactory in several respects. Three characteristics of Landsat MSS data often identified as limiting factors are spatial resolution, spectral resolution, and timely availability of data. The need for improved sensor capabilities over those of the MSS was envisioned prior to the launch of Landsat-1, and the characteristics of a new sensor system have been under study since about 1970. The new, experimental Earth resources monitoring system which has evolved through a series of study efforts and with the guidance of several advisory groups representing all facets of the remote sensing community is called Landsat-D, and is presently scheduled for launch in the third quarter of 1981. The Landsat-D system is designed to be a complete, highly automated data gathering and processing system that should substantially contribute to more effective remote sensing of Earth resources and to the management of these resources on a local, regional, continental, and global basis.

The Landsat-D Mission consists of an orbiting observatory termed the flight segment and a ground segment which includes the necessary data processing and support systems. The principal instrument on the Landsat-D spacecraft will be the TM, which is designed to provide spatial, spectral, and radiometric capabilities significantly advanced over those of the MSS. Another major advance associated with the Landsat-D system is the use of the Tracking and Data Relay Satellite (TDRS) system to permit TM and MSS sensor observations to be relayed in near-real time to data processing centers on the ground. The Landsat-D system also includes several other technological advances over the previous Landsat missions, and these have been described in detail during the past year in several publications (Salomonson 1978; Salomonson and Park, 1979). It is the intent of this paper to briefly summarize the overall Landsat-D system, placing emphasis on: (a) the more timely acquisition of sensor observations using the TDRS system, (b) the improved sensor capabilities of the TM versus the MSS, and (c) the projected applications of the data by the remote sensing community.

LANDSAT-D FLIGHT SEGMENT

The flight segment of Landsat-D (see Figure 1) is being configured for compatibility with the operations of the Shuttle Transportation System (STS). A backup spacecraft, including sensors, that is called Landsat-D' (D-prime) is being planned. It is to be available for launch within six months after the launch of Landsat-D. The launch vehicle for Landsat-D will be a Delta 3910 rocket. It will carry the Landsat-D payload to an orbital altitude slightly above 700 km. This altitude is compatible with the retrieval and replacement capabilities planned in conjunction with the STS during the Landsat-D project time frame.
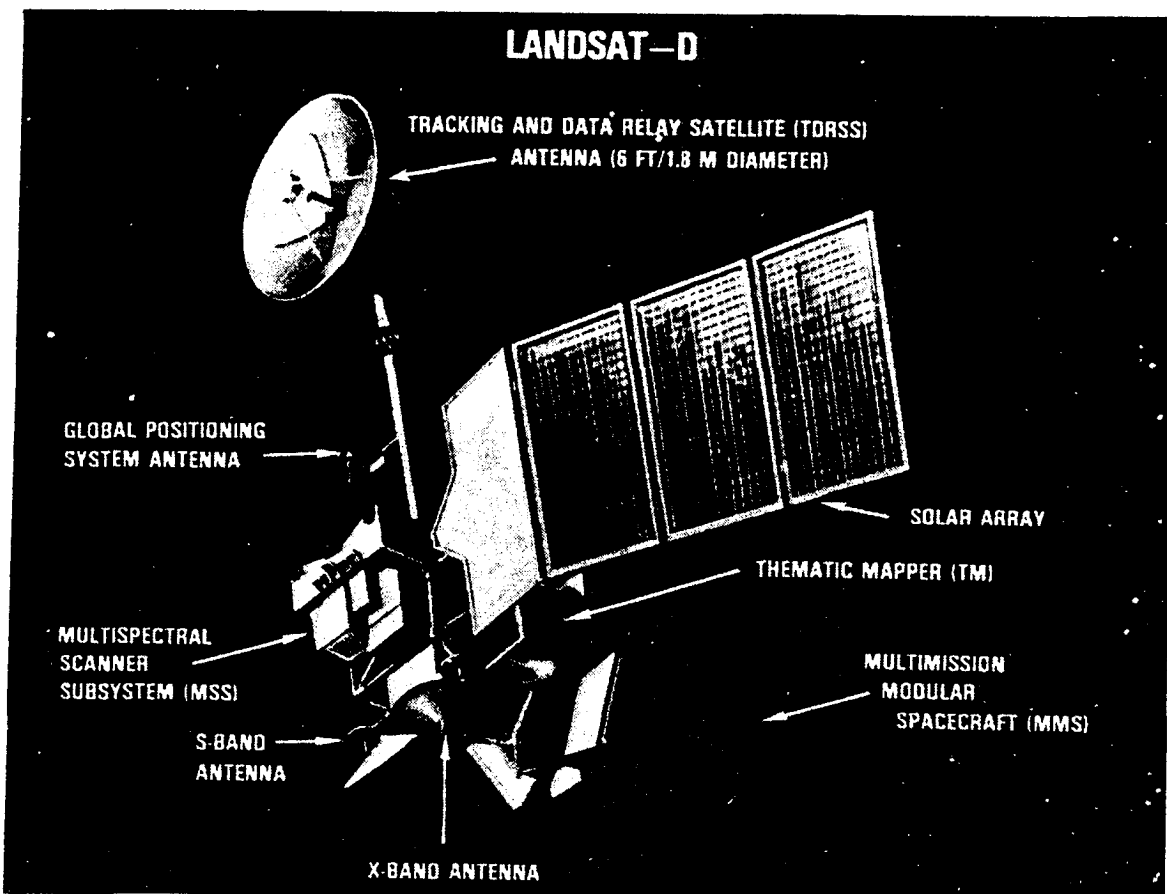
Figure 1. Landsat-D flight segment.

It is expected that the Landsat-D flight segment will be placed into a Sun-synchronous orbit at an altitude of 708 km, with an equatorial crossing on the descending node of approximately 9:30 a.m. Figure 2a shows the coverage pattern of this orbit, which has been described as a "skipping or sampling" orbit in comparison to the "minimum-drift/inventory" type of orbit associated with Landsats-1 through -3. This "sampling" orbit permits acquisition of observations (i.e., scenes) over

218

very large areas in a minimum amount of time. The advantages of the orbit are most realized in the higher latitudes (above 45 degrees) because of the orbit sidelap coverage. Barring cloud cover, observations would be available at least every 9 to 11 days at latitudes higher than 45 degrees. This attribute makes the orbit attractive for monitoring short-term, dynamic phenomenon such as critical stages of growth in crops or the rate of change in snowcover and related run-off. Another feature of this orbit is that an inventory type of coverage could be achieved if Landsat-D' were concurrently placed into an identical orbit, with a temporal offset of one-half the cyclic period of Landsat-D. For example, for the 20-day repeat cycle associated with the 708 km orbital altitude, the second satellite could cover the same orbital path 10 days later. The coverage pattern for two satellites at this orbital altitude is shown in Figure 2b. It should be noted, however, that there is no authorization or funding at this point in time to support the concurrent operation of two satellites, and the final decision on orbital coverage has not been made at the time of this writing.

The spacecraft component of the flight segment will be the Multimission Modular Spacecraft (MMS). This spacecraft will perform the basic functions of providing power, altitude and attitude control, and the command and data-handling systems. The MMS has improved attitude-control capability over previous Landsat systems. The pointing accuracy is specified to be 0.01 degrees (1-sigma value), and the stability is 10^{-6} degrees/second (1-sigma value). To appreciate the advantages afforded by the MMS in this area, one can compare these performance values to the 0.7-degree pointing accuracy and 0.01-degree/second stability values associated with Landsats-1 through -3.

Data Acquisition

As mentioned previously, one of the major advances in the Landsat-D system is the use of a series of communication satellites to gather all data in near-real time. The two communication satellite systems involved are the Tracking and Data Relay Satellite (TDRS) system and the Domestic Communications Satellite (DOMSAT) system. The use of the TDRS system will eliminate the need to rely upon onboard tape recorders, which is certainly an advance in concept, because tape recorders have failed on previous Landsat missions. The DOMSAT system will be used to greatly reduce time delays previously encountered in shipping sensor data from the Landsat ground receiving stations to the data processing facility at the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, and subsequently to the EROS Data Center (EDC) in Sioux Falls, South Dakota. The present plan would allow no longer than eight hours delay from time of Landsat sensor acquisition to delivery of raw data to the Landsat-D data processing facility at GSFC. Figures 3 and 4 give an overall view of the communications process and flow of data through the Landsat-D system.

The TDRS antenna, located on the Landsat-D spacecraft as shown in Figure 1, will permit command signals, telemetry signals, and TM and MSS sensor observations to be relayed to a single ground receiving station located at White Sands, New Mexico through one of the two satellites in the TDRS system. The TDRS satellites will be placed in geosynchronous orbits at 41°W and 171°W longitudes respectively. This configuration will permit the acquisition of TM and MSS sensor data of nearly all of the Earth's surface. A small area of land between 67°E and 82°E longitudes and between 50°N and 50°S latitudes will be excluded from coverage by the geometry of the system. This "zone of exclusion" is shown in Figure 5.

HEIGHT – 708 KM
REPEAT PERIOD – 20 DAYS
ORBITS/CYCLE – 291
TRACE SPACING – 136.3 KM
SCAN WIDTH – 185.2 KM

INCLINATION – 98.22°
SCAN ANGLE – 14.9°
OVERLAP – 35 PERCENT (AT EQUATOR)
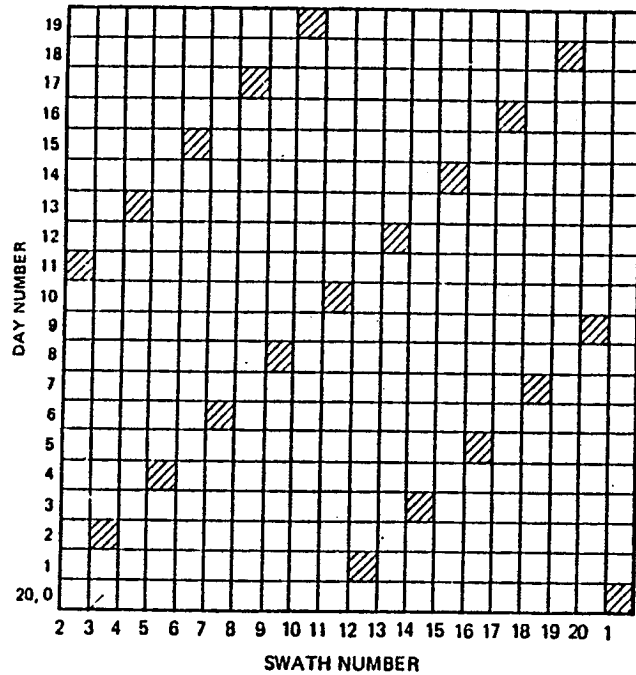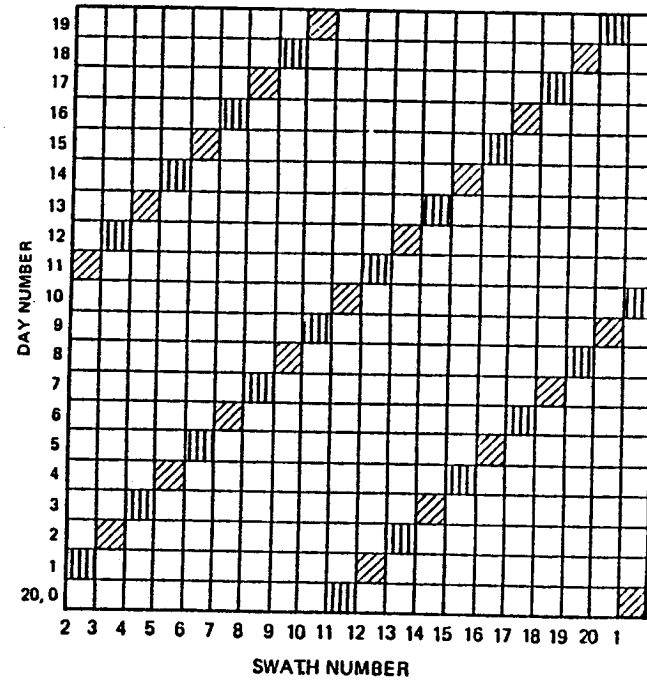RESOLUTION – 30 METERS

LANDSAT-D

LANDSAT-D'

FIGURE 2a

FIGURE 2b

Figure 2. (a) Coverage pattern and characteristics of the expected 708 km orbital-altitude for Landsat-D. (b) Coverage provided by two satellites operating concurrently at 708 km, where adjacent swaths would be covered on consecutive days, but any given scene would be "sampled" every tenth day.
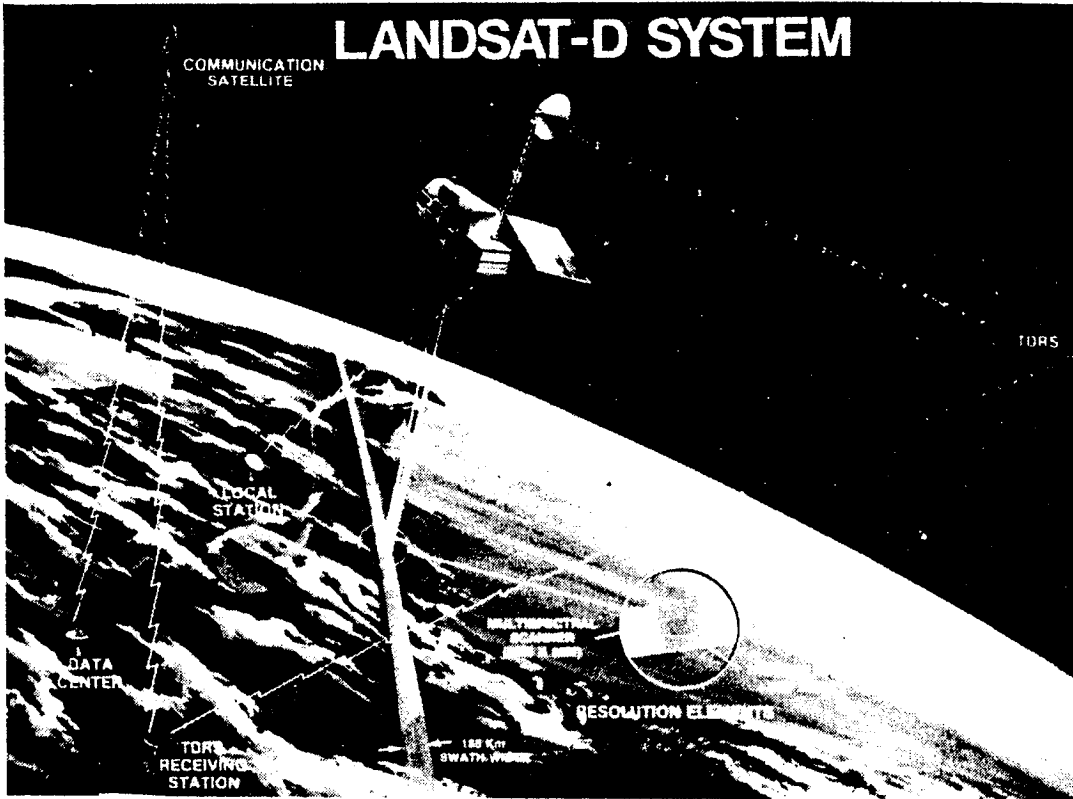
Figure 3. An illustration depicting the overall communications
and data-gathering process for Landsat-D.
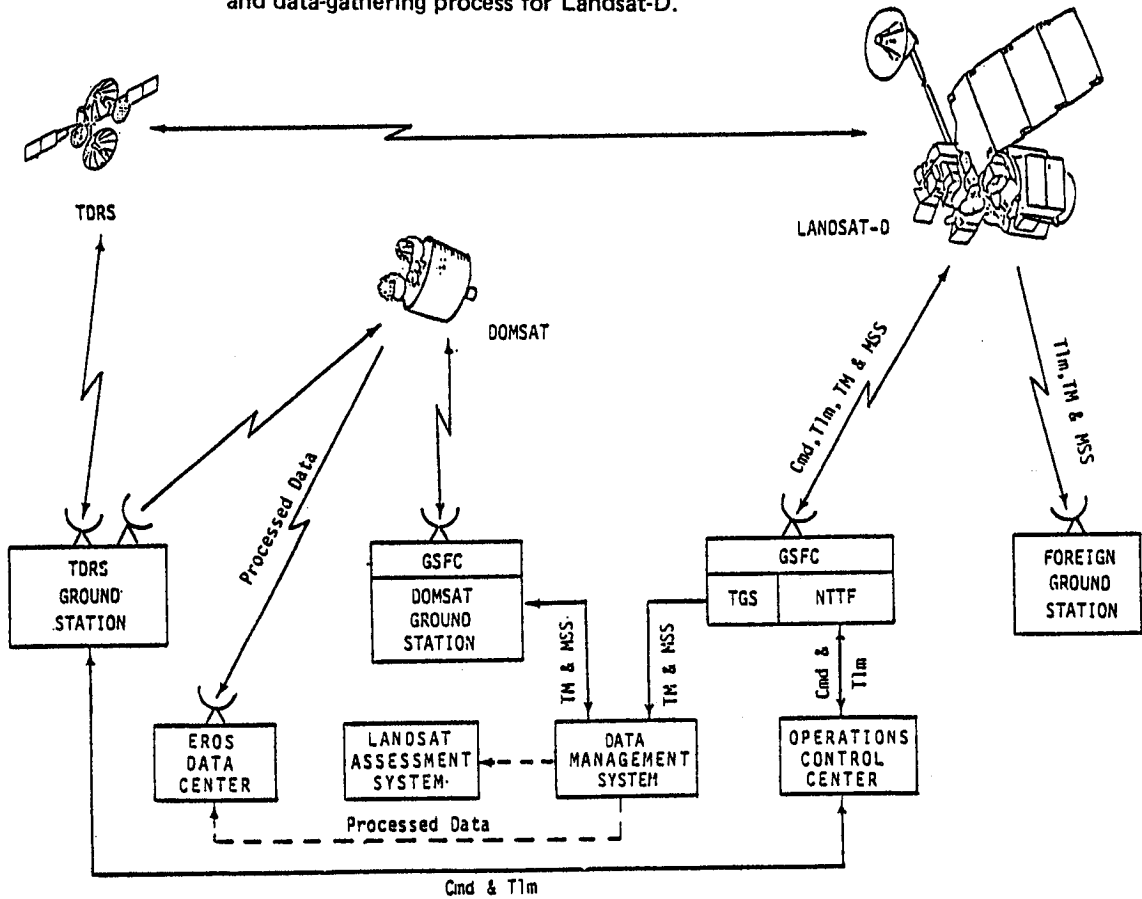

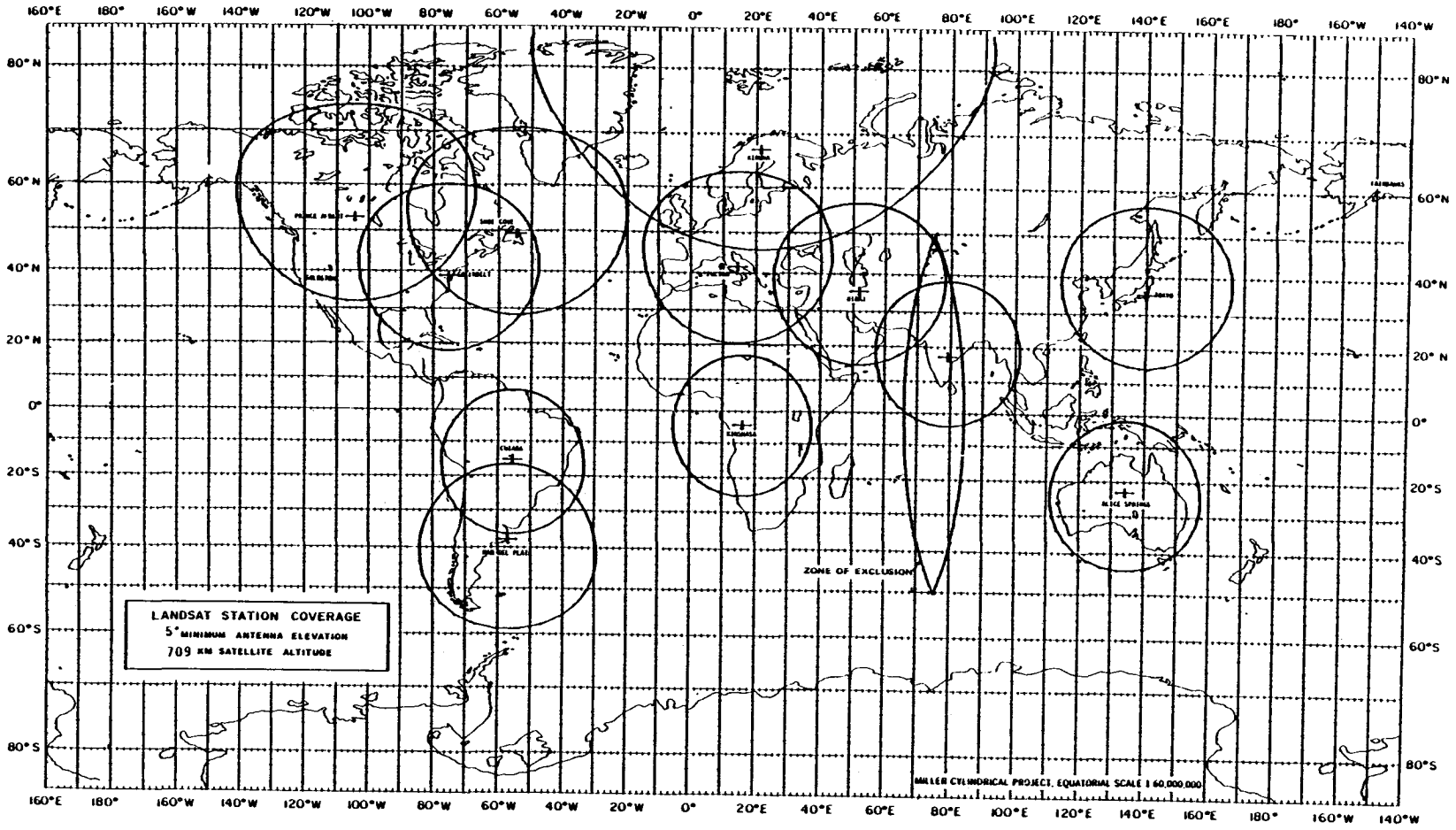Figure 4. Schematic diagram of the total Landsat-D system.

Figure 5. Landsat ground receiving station coverage expected to be in effect in the Landsat-D time frame, and the "zone of exclusion" in direct readout capabilities due to the geometry of the TDRS system.

To handle the high data rates associated with Landsat-D and other space missions, the TDRS system uses a Ku-band ($\approx$15 GHz) frequency for communications. The Ku-band frequency will support the simultaneous transmission of both TM and MSS data. Because this frequency is somewhat more affected by atmospheric conditions than previously applied communications links, a relatively cloud-free location (White Sands, New Mexico) was chosen as the point for receiving TDRS information. Sensor data received at the White Sands facility will be demodulated, separated, and recorded on separate wide-band digital data recorders. Once each eight-hour shift, compacted raw data tapes will be replayed from White Sands to the GSFC processing facility via the DOMSAT system. The 50 megabits per second DOMSAT capabilities will support the serial transfer of TM data at one-half real time and MSS at two times real time. Under normal circumstances this data off-loading scheme will ensure a data delay of no more than eight hours from sensor observation to availability for processing at the GSFC facility. In the event of a DOMSAT support failure of a duration longer than two days, data tapes will be mailed directly to GSFC to prevent unmanageable backlogs.

Landsat-D will also be able to directly communicate with and send data to Landsat ground receiving stations. For this purpose, X-band (8.025 to 8.4 GHz) and S-band (2206 to 2300 MHz) frequencies will be used. Although S-band has been used for previous Landsat missions, the high-frequency X-band link is required for handling the TM data streams. As a result, stations that intend to receive TM data must add X-band capabilities that were not previously required. Landsat-D MSS data will still be transmitted using the S-band. Representative Landsat ground receiving station coverage, based upon a nominal satellite altitude of 709 km, is shown in Figure 5.

Sensor Payload

The Landsat-D instrument payload (Table 1) consists of the Thematic Mapper (TM), mentioned previously, and the familiar four-band MSS of Landsats 1 and 2. The TM provides seven narrower spectral bands which cover four major regions of the optical portion of the electromagnetic spectrum. The regions and TM bandwidths are: visible (0.45 - 0.52 μm, 0.52 - 0.60 μm, 0.63 - 0.69 μm); near infrared (0.76 - 0.90 μm); middle infrared (1.55 - 1.75 μm, 2.08 - 2.35 μm); and thermal infrared (10.4 12.5 μm). The resolution field-of-view (RFOV) of the visible, near, and middle infrared bands will be 30 meters, while the thermal infrared RFOV will be 120 meters. The radiometric performance requirements for the TM are outlined in Table 2.

In terms of basic design, there is at least one fundamental difference between the two instruments. The MSS scans and obtains data in one direction only. The TM, however, scans and obtains data in both directions. The bidirectional approach was employed in order to reduce the scan rate and provide the dwell time needed to produce improved radiometric accuracy. The scanning strategy of the TM is illustrated in Figure 6.

Table 1
Landsat-D Earth-Observing Instrumentation (March 1979)

	THEMATIC MAPPER (TM)		MULTISPECTRAL SCANNER SUBSYSTEM (MSS)	
	MICROMETERS	RADIOMETRIC SENSITIVITY (NEΔP)	MICROMETERS	RADIOMETRIC SENSITIVITY (NEΔP)
SPECTRAL BAND 1	0.45 0.52	0.8%	0.5 0.6	.57%
SPECTRAL BAND 2	0.52 0.60	0.5%	0.6 0.7	.57%
SPECTRAL BAND 3	0.63 0.69	0.5%	0.7 0.8	.65%
SPECTRAL BAND 4	0.76 0.90	0.5%	0.8 1.1	.70%
SPECTRAL BAND 5	1.55 1.75	1.0%		
SPECTRAL BAND 6	2.08 2.35	2.4%		
SPECTRAL BAND 7	10.40 12.50	0.5K (NEΔT)		
GROUND IFOV		30M (BANDS 1 6) 120M (BAND 7)	82M (BANDS 1 4)	
DATA RATE		85 MB/S	15 MB/S	
QUANTIZATION LEVELS		256	64	
WEIGHT		227 KG	68 KG	
SIZE		1.1 X 0.7 X 2.0M	0.35 X 0.4 X 0.9 M	
POWER		320 WATTS	50 WATTS	

Table 2
Radiometer Characteristics for the Thematic Mapper

BAND	SPECTRAL WIDTH (μM)	DYNAMIC RANGE (MW/CM² — STER)	LOW LEVEL INPUT (MW/CM² — STER)	SNR
1	0.45 — 0.52	0 — 1.00	0.28	32
2	0.52 — 0.60	0 — 2.33	0.24	35
3	0.63 — 0.69	0 — 1.35	0.13	26
4	0.76 — 0.90	0 — 3.00	0.16	32
5	1.55 — 1.75	0 — 0.60	0.08	13
6	2.08 — 2.35 M	0 — 0.43	0.05	5
7	10.40 — 12.50	260K — 320K	300K	0.5K (NET D)

- ABSOLUTE CHANNEL ACCURACY   < 10% OF FULL SCALE

- BAND TO BAND RELATIVE ACCURACY   < 2% OF FULL SCALE

- CHANNEL TO CHANNEL ACCURACY   < 0.25% RMS OF SPECIFIED NOISE LEVELS

ANGULAR SWEEP
6 BANDS SIMULTANEOUSLY

16 DETECTORS
PER ARRAY

42.5 μRAD IFOV (30M)

480 M

185 KM SWATH
(6320 PIXELS)

LANDSAT D PATH

PRIMARY OBJECTIVES

• RADIOMETRIC ACCURACY
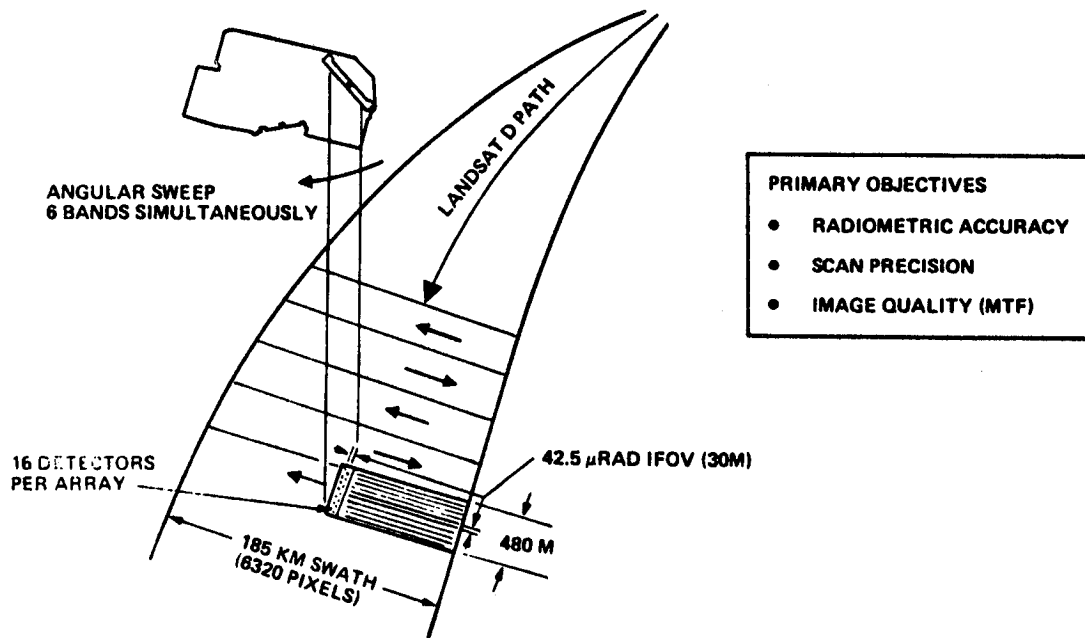
• SCAN PRECISION

• IMAGE QUALITY (MTF)

Figure 6. A sketch illustrating how the thematic mapper will
scan the Earth.

LANDSAT-D GROUND SEGMENT

The ground segment, a major part of the overall Landsat-D system, is being assembled for NASA by the General Electric Corporation. The ground system faces substantial challenges that are largely a function of the high data rate of the TM and MSS combined ($\approx$100 megabits/second). This vast amount of data must be rapidly processed in order to enhance its utility for resource observations. The ground segment of the Landsat-D system consists of three major subsystems: the Operations Control Center (OCC), the Data Management Systems (DMS), and the Landsat-D Assessment System (LAS). These subsystems are only briefly described here. Smith and Webb (1979) provide a more complete review of the total Landsat-D ground segment.

The OCC handles all communications with the flight segment, including the commanding and scheduling of the various subsystems of the flight segment and the monitoring of their performance.

The DMS, the major subsystem of the ground segment, processes all the data from the TM and MSS into final products. A key performance requirement for the DMS is to produce output products within 48 hours of data acquisition. Radiometrically corrected MSS digital data will be relayed to

225

the EROS Data Center in Sioux Falls, South Dakota using the DOMSAT system, while TM film products will be forwarded to EDC by air mail. Danaher and Inscoe (1979) have specifically addressed the performance activities and goals of the DMS.

The third major component of the ground segment is the LAS. The LAS will be a facility at GSFC housing an advanced minicomputer and a pipeline processor to analyze TM and MSS data in order to quantify the advantages of the improved sensor system for monitoring Earth resources. The design and applications of the LAS have been discussed in detail by Bracken et al., 1979.

PROJECTED APPLICATIONS OF LANDSAT-D DATA

As indicated by the comparison of TM and MSS sensor characteristics in Tables 1 and 2, the Thematic Mapper offers advantages over the MSS in terms of spatial resolution, spectral resolution and numbers of spectral bands, and radiometric resolution. These significant improvements in sensor capability are expected to provide improved information for Earth resources management, and one of the major objectives of the Landsat-D project is to assess the capability of the TM to provide improved information. To achieve this goal, data use investigations will be conducted in several major Earth resources disciplines such as agriculture, forest and rangeland, water resources, geology, and land use. The LAS facility at GSFC will be heavily utilized to quantify the incremental improvement afforded by the TM's improved resolution capabilities. The following discussion addresses some of the projected applications of the TM data due to improved spatial, spectral, and radiometric resolution. The actual utility of the TM data relative to these projected applications will have to be determined by postlaunch research.

Spatial Resolution

In quantitative terms, the TM resolution element ("pixel"/instantaneous field-of-view) covers 0.09 hectares on the ground. For mensuration and classification, several pixels must fall within a field or feature. If one assumes that at least 25 pixels are necessary for signature extraction and mensuration, then the field size involved is approximately 2.5 hectares. The corresponding figure for MSS is over 16 hectares. For example, in urban situations, the TM spatial resolution is roughly equal to the standard lot size of 30 by 30 meters or approximately 100 by 100 feet. The identification of urban features, therefore, should be markedly facilitated by the use of TM data. Similarly, the increased spatial resolution should permit smaller features or phenomenon such as small agricultural fields, strip mines, forest stand density and canopy texture, geologic structure and mineral deposits, and small water bodies and physiographic features of watersheds to be more easily and accurately identified.

The TM spatial resolution advantage and the attendant data processing for geodetic accuracy of pixel location should also produce map products from satellite imagery that are applicable at larger map scales than are possible with MSS data. Landsat-1, -2, and -3 MSS data can be used to compile a planimetric map that meets map accuracy standards at scales of 1:500,000 to 1:250,000. For Landsat-D, maps that meet national map accuracy standards at 1:100,000 scale should be possible. In cases where thematic maps of major land cover themes are being extracted from MSS data, it

appears that increasingly useful thematic maps may be constructed using Landsat-D TM observations, particularly by including an existing map for control at larger scales, such as 1:62,500 or 1:25,000.

Spectral Resolution

The familiar spectral bands of the MSS cover two major regions of the optical portion of the electromagnetic spectrum; that is, the visible and near infrared regions. Thus, the spectral dimensionality and information content of Landsat MSS data are often considered to be two. In comparison, the seven narrower spectral bands of the TM cover four major regions of the spectrum; the visible, near infrared, middle infrared, and thermal infrared regions. The TM data are, therefore, expected to provide a basic dimensionality of four in information content. This increased dimensionality, coupled with the narrower bandwidths, is expected to result in significant improvements in classification accuracy (i.e., separability of classes). C. J. Tucker has recently reviewed the TM bands in terms of monitoring vegetation, and Table 3 summarizes the utility of each band relative to this application (1978; 1979). Tucker concluded that "significant improvements are expected for most vegetational analyses from Landsat-D Thematic Mapper . . . imagery over MSS and RBV imagery," and that "the 1.55 - 1.75 μm region is the best . . . wavelength interval for satellite-platform remote sensing of plant canopy water status . . . ." The spectral and radiometric capability of the TM relative to some typical spectral reflectivity curves is shown in Figure 7.

In addition to these expected improvements in monitoring vegetation, the water resources community expects the blue band (TM 1 - 0.45 to 0.52 μm) to be useful in bathymetric studies. This same band, in combination with the other bands in the visible region, should enable hydrologic investigators to do improved water-quality studies relative to the MSS, particularly when considered in combination with the increased spatial resolution of the TM. It is also expected that the TM bands will facilitate the discrimination of snow versus clouds, as well as snow versus bare rock and soil.

The geologic remote sensing community is expected to have improved capabilities to delineate energy sources, mineral deposits, and geobotanical and geothermal areas, as well as the ability to produce or revise structural maps by using TM data in conjunction with existing information. For example, the TM band covering the 2.08 to 2.35 μm region may allow the delineation of increased clay content in sandstone units, which generally is a manifestation of alteration often associated with uranium mineralization. For geobotanical exploration, the applicability of the TM bands for monitoring vegetation stress, as previously discussed, may facilitate the delineation of mineral-induced stress in the plant canopy. Finally, the increased resolution and more extensive middle and thermal infrared channel placement of the TM should allow a definitive improvement in the detection, evaluation, and modeling of known, and as yet unknown, geothermal areas.

Radiometric Resolution

The increased radiometric resolution afforded by the Thematic Mapper (256 quantizing levels versus 64) should permit finer differences to be delineated between or within land cover classes. For example, the subtle difference in reflectance characteristics between two similar, yet importantly

Table 3
Thematic Mapper Spectral and Radiometric Characteristics

| Band	Wavelength (µm)	NEΔρ	Basic Primary Rationale for Vegetation
TM 1	0.45-0.52	0.008	Sensitivity to chlorophyll, and carotinoid concentrations
TM 2	0.52-0.60	0.005	Slight sensitivity to chlorophyll, plus green region characteristics
TM 3	0.63-0.69	0.005	Sensitivity to chlorophyll
TM 4	0.76-0.90	0.005	Sensitivity to vegetational density or biomass
TM 5	1.55-1.75	0.01	Sensitivity to water in plant leaves
TM 6	2.08-2.35	0.024	Sensitivity to water in plant leaves
TM 7	10.4-12.5	0.5 K	Thermal properties
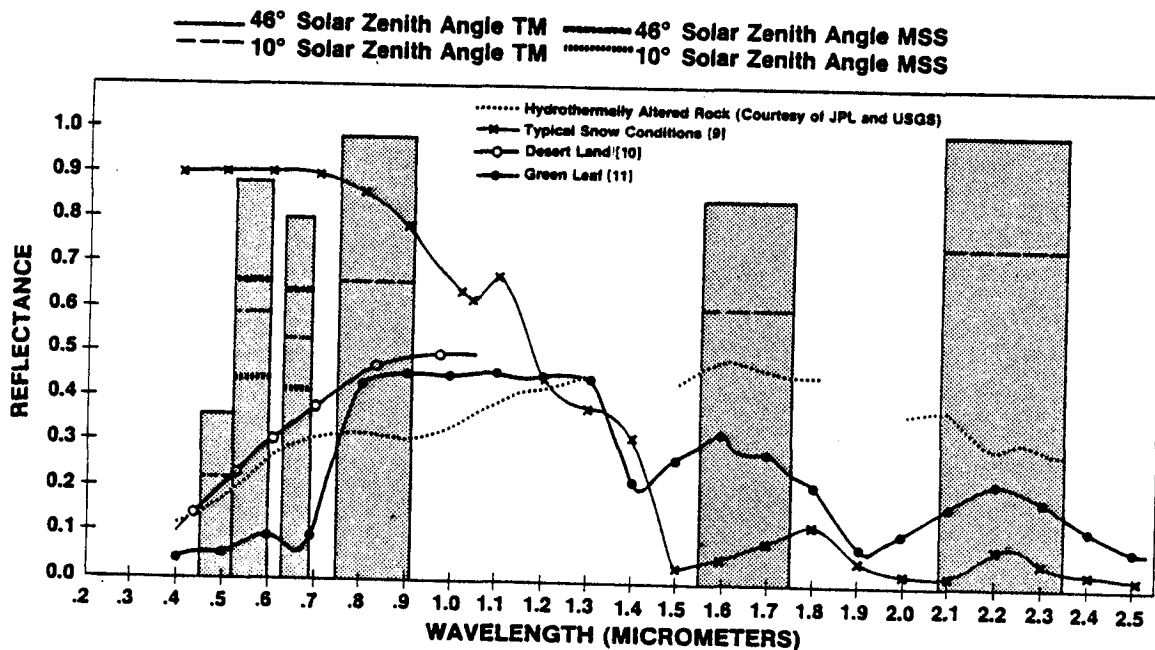
Figure 7. Typical spectral reflectance curve for hydrothermally altered rock, snow, desert land and a green leaf showing saturation levels for the visible, near and middle infrared bands of the thematic mapper (saturation of bands).

228

different tree species such as loblolly pine and slash pine, may be discernible with 256 quantizing levels, but obscured if only 64 levels are available. Tucker has recently completed a simulation of the radiometric resolution needed for monitoring vegetation and concluded that 256 quantizing levels gave only a 2 to 3 percent improvement per channel over 64 quantizing levels (1979). This improvement is certainly less than previously expected, but it is not insignificant, particularly if added over all channels. Postlaunch research with actual TM data may also yield different results.

Interaction of Resolution Parameters

The above discussion of projected applications of TM sensor data has dwelled upon expected improvements which may be realized due to the individual contribution of increased spatial, spectral, and radiometric resolution. However, the problem of quantifying the TM versus MSS improvements associated with each resolution parameter is not simple, because the three improvement parameters will have strong interaction terms in addition to their individual attributes. In many scene situations, the radiometric-spectral interaction term may be much more important than either of these parameters by themselves. The decoupling and quantification of the individual contributions of each TM resolution parameter presents an interesting and important challenge to the remote sensing community.

SUMMARY

Studies initiated in the early 1970's have led to the design of a new and highly automated data gathering and processing system called Landsat-D. The Landsat-D system, and the principal observing instrument, the TM, offer many exciting technological advances over the familiar Landsat MSS satellite systems. The improved spatial, spectral, and radiometric resolution of the TM, coupled with the more timely availability of data, should greatly enhance the utility of remotely sensed observations from space for monitoring Earth resources. The remote sensing community will be faced with the challenge of determining the information content and applicability of these data.

ACKNOWLEDGEMENTS

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WRAP-UP PANEL

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I'm here to represent the legislative point of view. I'm not a state legislator. I would not be, even if I chose to try, which I will not.

I don't know whether Delegate Toth is still here or not, but I certainly applaud her for her perseverance. She spent a lot of time here and she is one of the notable examples of what state legislators can do in this area.

If you ask me what a state legislator's perspective of remote sensing is, I would tell you that it is very remote and not very sensible. I say that with a certain amount of so-called insider's knowledge; this technology is not perceived at the state legislative level as being something that is going to rescue us from our myriad problems. As a matter of fact, I would daresay that under 50 percent of the Virginia General Assembly has never heard of it. They will, of course, but have not at this point. I don't mean to put any onus on anybody, and I hate to sound that note at the end of this obviously very successful conference, but nevertheless it's a note that I feel must be sounded.

We used to have a definition on the personal property tax form in Virginia that said: "what value would you place on this property if you, as a seller, did not want to sell it to a buyer who does not want to buy." That is roughly where remote sensing stands in a lot of areas, and it's an attitude we've been fighting in Virginia for some time. I think we've made some real progress. The Virginia experience has been a good one, by and large, in spite of these institutional obstacles. And I agree that the highest priority, at least from my perspective and from the state legislative perspective in general, is to raise the awareness of how to break down these institutional barriers.

Within Virginia, our experience has been quite good. We have had tremendous cooperation from a great number of states, and we have seen some mighty fine programs in a lot of states. I hope we have enough sense in the Old Dominion to use what we know, and not go out on our own and try to reinvent what Minnesota, North Carolina, Georgia, and Louisiana and some of the other states here have already done. I suspect that we will do this in some cases, but we have had great help from these folks and we are trying to capitalize on their experience by learning mainly from their mistakes, not their successes.

Let me just, as a point of interest, call your attention to some things about states that maybe you don't realize. For example, in Minnesota the driving force—and this has been the success of their remote sensing capability—has been land management. I think that is true in a great many midwestern and western states. If you walk into the Virginia General Assembly and say anything about land management you're going to find yourself covered with a black, gooey substance and looking like a chicken. You just don't mention that word down there. This just points out the problems that one has to face when dealing with this kind of technology and the approaches to it.

We, in Virginia, have met with some success. There has been a legislative initiative that was helped a great deal by the NCSL. We've had just great cooperation from that project, and I really feel that we probably would not be nearly so far along had it not been for that.

I personally believe that the best way you can transfer technology is to transfer people. And I think that NASA has done that in our case. They gave us a person. NASA-Langley gave us a person, Warren Hypes, to help us out with our project. I really feel without the transfer we would not have been successful. We're not there yet. But, without this person, we just never would have made it.

We're very close to an implementation scheme in Virginia, because of the cooperation between the legislature and the executive branch, with the help of NASA and with the help of the NCSL. And I think that we are developing a scheme that will work. It will not be an elaborate one, but it will work.

As far as the local front is concerned, there appears to be one point that needs to be made. I rather get the impression that the pitch being made to the local governments is: "here is a solution, all you have to do is find a problem which can be solved by the solution." In order to convince the localities of the worth of remote sensing to their particular concerns, you are going to have to become thoroughly familiar with the concerns. Each locality has its own particular view, even though the problem may be much more broadly defined. This, in essence, means that each application requires a tailored approach. My guess is that for any fruitful interaction at the substate level, particular projects will have to be chosen and these used as models. Even then, transfer to other localities will be difficult because of the provincialities mentioned above. There really aren't any clear-cut answers to information transfer into the local applications. It would appear that the process of diffusion from the state level, assuming success there, may be all that can be expected.

WRAP-UP PANEL

Robert Nelson
Pennsylvania Bureau of Information
Harrisburg, Pennsylvania

Dick Weinstein's initial charge was that we take two or three minutes during which we would introduce ourselves and then give some overview regarding what our state was doing in using this type of technology. Well, Dick chose to change things a little bit. He introduced me, leaving me 2½ minutes with nothing to say, because that is where Pennsylvania is. Many of you will have noticed, in the early presentation, that large white area in the middle of the eastern seaboard where nothing was going on with the satellite technology. That was Pennsylvania.

Pennsylvania probably epitomizes the institutional problem. It started in a most unfortunate manner. Our first formal introduction to NASA was in 1972. NASA released a request for proposals to have people offer suggestions and bid for their money to support demonstration projects. The person within the Commonwealth who knew that NASA wanted to work with Pennsylvania also knew that NASA had approximately 2 to 3 million dollars to work with. We put together a consortium, or a team consisting of representatives from Penn State University, several Commonwealth Agencies (the Department of Environmental Resources was the lead agency), General Electric with their Image 100 (there was a manufacturing plant in Valley Forge, Pennsylvania), and the Mitre Corporation.

We put together a rather substantial proposal, estimated to cost somewhere in the range of 1.5 to 2 million dollars. NASA reported to us that it was an excellent proposal. However, we'd misplaced a decimal point by about 2 places; and if we could find a way to take our 2 million dollar proposal and scale it down to about $20,000 and come up with the same thing, that would be wonderful. The net result was a very sour taste which developed within the Commonwealth because of this misadventure. In fact, the man who was then the Secretary of the Department of Environmental Resources was likely to turn livid if he heard anything that sounded like ERTS. That was the beginning of a lot of difficult problems in even discussing the idea of ERTS and Landsat.

The other institutional problem we've had is that whenever we tried to put together some representative persons from the Commonwealth, we've come up against the same problems that have been discussed in this room. The Department of Transportation wants to be able to see mileposts, and the Fish Commission wants to be able to see trout in the trout stream. Our Forestry people are very satisfied with 40-acre swatches of things and being able to see the difference between clear cutting and not clear cutting, because that's the mode they work in. Our Environmental Protection people,

when we spoke to them about this technology for 208 planning, said how nice it would be if, in fact, Landsat had greater resolution and were operational. The other objection concerns building a data base based on data collection technology, which is predicated on a research and demonstration type effort. What would happen if budgets were cut or if the budget cutters eliminated the Landsat program entirely? So, the operational nature of the satellite and its longevity, from our perspective, is extremely important.

I think I can be reasonably confident in saying that, based on what I have learned during the last few days, there is reason to push forward again, within Pennsylvania, to get something going. The states have demonstrated that there is a great value in this area, particularly for those agencies such as forestry, that are involved in the land management considerations. It would probably be wise to draw on those areas which have the predominate interest, probably the forestry area. Since Pennsylvania does contain large forest lands, this might be our best thrust. We can, I hope, talk to some of those persons who have been active in this area and thereby develop some expertise within that large white area in the middle of the eastern seaboard.

WRAP-UP PANEL

Robert L. Myers
County Planning Commission
Cape May, New Jersey

Cape May County has become involved in remote sensing through the New Jersey Coastal Management Program. Cape May County has been a pilot study area for the state Landsat project. I'll pause here to reflect on advice that grandmother once gave me when she advised me to scratch where it itches, not where it looks good. In contrast to the gentleman who suggested, last night, that some state agencies view county agencies as lower forms of life, I must praise the productivity of the relationship between Cape May County and the New Jersey Department of Environmental Protection. We have worked closely with them during the past two years and look forward to continued cooperation and collaboration. I think over the last few days it has been repeated often enough, but the bulk of the interest in Landsat data is driven by state and federal mandates that are, in turn, driving the need to improve the availability and quality of natural resource information and our understanding of natural processes to sophisticated resource management and planning decisions.

In the planning process at the local level, there is a great need to understand the casual links between man-induced perturbations in the environment and environmental change. Local planning decisions are often site-specific. Cumulatively, these incremental decisions have regional inpacts, and thus, the lower the level of government, the higher the need for detailed information and data. RBV data, with higher level of resolution, could certainly help to meet those needs.

The AUTO-CLAM proposal was thoroughly reviewed yesterday by Stewart McKenzie in the morning session. We are collaborating with him and with the Department of Environmental Protection in using Cape May County as a Landsat and AUTO-CLAM pilot study area. I don't want to plow through all of that again. The main point for Cape May County, and for New Jersey, is that Landsat is valuable to us as an element of a geographic data base management system. I think that it is important to point out and recognize the opportunities that Landsat offers, as well as its limitations. Landsat data is an element rather than a single, sole-source tool for planning and managing a coastal area within an automated system. Nevertheless, we are looking forward to getting into an operational mode. By happy coincidence, Cape May County is now surveying and analyzing its data processing needs, and we have been able to include our hardware and software requirements in that evolving process.

Just to wrap up, I agree that the institutional problem is the toughest nut to crack. That has been my perception throughout this conference and prior to that. Speaking for Cape May County, I can say that if it all goes to hell in a handbasket tomorrow (which I do not think will happen), there will have been some tremendous spinoff benefits in our understanding, at the county level, of how state

government works as a result of the collaboration with the state, under the auspices of ERRSAC. The direct and immediate benefits of up-to-date land cover/land use mapping from Landsat are even more important to our ongoing planning programs, such as coastal management, 208 planning, and the county's comprehensive planning program. I think that the state has gotten a better handle on what it is like down at the local level. In New Jersey, Landsat has been a vehicle to better understanding of intergovernmental relations, in addition to all its other considerable benefits.

WRAP-UP

Wim S. Schoonhoven
Pennsylvania Power and Light Company
Allentown, Pennsylvania

My name is Wim Schoonhoven, and I work for the Pennsylvania Power and Light Company. Although a private company, it is rather heavily regulated by the Pennsylvania Public Utility Commission. Prior to this Tuesday I knew nothing about digital data or Landsat, and I have been really impressed by what I have learned.

For any facility that the Pennsylvania Power and Light Company locates, whether it is a substation, power plant, or a transmission line, we do what we call a constraint factor analysis, and we believe that LANDSAT data may be of help to us in this area. For the past eight years, our company has employed eight planners to do this analysis work, and they have been wading through massive amounts of information. All of us have attended a number of public meetings during which someone usually suggests: "what would have happened if you'd tried this?" As a result, additional months must be spent re-examining the information, usually resulting in a different decision.

About two years ago my company decided to allow us to develop a geographic information system, and we now have this type of system on line. We like to think that it is a fifth generation ESRI (Environmental Systems Research Institute) system which can be operated both on a grid or polygon mode. We have approximately 40 data layers or data planes. We have the capability of mapping, of asking where things are, and of modeling.

The data in the data planes, which are subject to change, will have to be updated, perhaps costing $100,000 in the process. We are very interested in land use updates, for instance. And we see, as one way out, the use of digital data not only from Landsat 2 but from Landsat D. That is why I am here. I really would like to hear some solutions as to the updating from you, because we have one shortcoming. We may not have a problem convincing management to spend $300,000 for a data system that covers a 10,000 square mile area, since this comes to only $30.00 a square mile. However, as soon as that system is on line, management would expect products, from a transmission line location analysis to an environmental impact analysis. Because of this, there is little time for research or discovery of new ways to use the system.

And so, someone will have to be out there doing some research and turning out another product for me, which I can add to my data base in order to make sure that after five years, it does not fail because of a lack of up-to-date data.

WRAP-UP

Frank Scarpace
Institute for Environmental Studies
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The university's responsibility in remote sensing appears to be twofold: first, research, and second, adult education. Normally, the university is not expert in the area of operational applications. There are, of course, exceptions but, for the most part, this should not be the thrust of the university's attention since there are other more appropriate avenues of pursuit open to them.

The university may possibly embody an ideal intermediate solution to some of the problems of remote sensing. This means that NASA (or ERRSAC) might wish to assist the universities in developing expertise in remote sensing, especially in areas of the country lacking practical experience. This is being done successfully in several states at the present time. In this way, the state and local governments could eventually interact with the university groups, and the technology transfer would be taking place on a local level among people who really understand the problems. Even if disagreements arose between the parties, both groups would be close enough, physically at least, to discuss and solve the problems.

The university community has an important role to play in remote sensing research, but this research ought to proceed only up to the point at which the technology is most applicable. At that point, the research should be turned over to either a state agency (as Minnesota has done) or to a private consulting firm to apply the data. Whether the recipient is a state agency or a private sector party would probably depend upon the perception of which direction would be most efficient, and this is a rather subjective and debatable issue.

With regard to the university's second area of responsibility in remote sensing, adult education, the internship which NASA has initiated may be a start in the right direction, but only a small start. To really understand a highly technical subject, certainly a course lasting three months is preferable to one that is only two weeks long; but even two or three months may not be enough time. Possibly, rather than sending the university professors to NASA for one or two months, senior-level scientists from NASA ought to spend an entire year within the university community, maybe even conducting seminars during that time. An enormous bank of expertise has been developed by NASA over the years, especially in the areas of instrumentation and the physical sciences, and obviously this expertise cannot be absorbed in a month or two. The kind of program in which a NASA scientist would spend a year at a university could be costly, but it would be a commitment to a real technology transfer. The NASA scientist not only would be educating the faculty and student body, but would at the same time be developing a feeling for what the local problems are. This kind of effort takes time and money, but could ultimately be very successful.

To summarize the outcome of the conference, it has been a productive and useful meeting. We have learned about the significant progress that many of the states have already made in remote sensing. It appears that the technology is understood, and will proceed. The universities and government agencies must now find the most advantageous applications for remote sensing technology, and in many instances, it seems that this is already taking place.

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