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EARTH RESOURCES SURVEY SYSTEM

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HEARINGS

BEFORE THE

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON

SCIENCE AND ASTRONAUTICS

U.S. HOUSE OF REPRESENTATIVES

NINETY-THIRD CONGRESS

SECOND SESSION

ON

H.R. 14978—H.R. 15781

OCTOBER 3, 4, AND 9, 1974

[No. 46]

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EARTH RESOURCES SURVEY SYSTEM

THURSDAY, OCTOBER 3, 1974

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10 a.m. in room 2318, Rayburn House Office Building, Hon. James W. Symington [chairman of the subcommittee], presiding.

Mr. SYMINGTON. The subcommittee will be in order.

This morning, the Subcommittee on Space Science and Applications begins 3 days of hearings on H.R. 14978 and H.R. 15781, bills to establish offices in the Department of the Interior and NASA, respectively, to operate an Earth Resources Survey System. These hearings have been scheduled in order to explore the desirability of creating an operational satellite system for surveying the Earth's resources, and to attempt to determine the most appropriate institutional arrangements.

Perhaps even more to the point, these bills provide a vehicle for reviewing the accomplishments of NASA's ERTS program; assessing the technological state-of-the-art both in terms of the quality of the data as well as the methods of its acquisition, dissemination, and utilization; and evaluating future prospects for such remote sensing systems. We have invited a number of distinguished witnesses to give us their views on these and related matters.

I want to take this opportunity to note that, over the years, no part of the space program has received stronger and more enthusiastic support on Capitol Hill than the ERTS program. For almost a decade, our committee has received the persuasive testimony of many expert witnesses who have expressed the view that satellites would some day prove to be powerful new tools for assessing, monitoring, and managing the Earth's resources. Studies have been conducted by the National Academy of Sciences, by academic and industrial organizations, and by Government agencies. There appears to be virtual unanimity that a system for remotely sensing the Earth's resources using instrumented satellites has enormous economic potential. Some observers believe that the economic impact will some day be measured in billions of dollars annually. Whatever the future may hold in this regard, the National Academy of Sciences has noted that "other benefits, less measurable and longer range, could add even more to the welfare of our planet by contributing to a better understanding of its total resources and by encouraging international cooperation in the wise utilization of these resources."

Although ERTS has received the strongest and most enthusiastic support on Capitol Hill, no part of the space program has encountered so much resistance in the executive branch, particularly the Office of Management and Budget. As long ago as 1968, this subcommittee issued a report in which NASA was taken to task for the slow progress in the ERTS program, and the report urged NASA to concentrate a much larger portion of its efforts and resources on ERTS. Moreover, every year since 1968 the Science and Astronautics Committee report which accompanies the annual NASA authorization bill has reiterated the committee's desire to move forward with the ERTS program, and has encouraged the space agency to accelerate its development schedule.

Finally, in July 1972 the first ERTS satellite was launched. By all accounts, it has been an unqualified success. Because its design lifetime in orbit was 1 year, a second satellite was originally scheduled for launch in the fall of 1973. To the very great surprise of everyone on Capitol Hill, in the spring of 1973 NASA announced that the launch of ERTS-B would be delayed for more than 2 years—until early in 1976. Both houses of Congress insisted that the launch schedule be accelerated. The administration responded to the pressure, and ERTS-B is now scheduled to be launched early in 1975; not a moment too soon, I might add, since we received word from NASA only yesterday that ERTS-1 is failing.

This year, Congress also made clear its support for a follow-on to ERTS-B in the most unequivocal terms. The Authorization and Appropriations Committees of both Houses all urged NASA to include ERTS-C in the program as soon as possible, and additional funds were provided for this purpose. When four separate committees of Congress take the same position on a matter of national policy, one would hope that the administration would take heed.

In spite of this extraordinary unanimity on Capitol Hill, the Office of Management and Budget continues to reject any and all suggestions for a follow-on program. In point of fact, an OMB witness before the Senate Space Committee recently testified that "any additional launch, beyond ERTS-B, of a remote sensing satellite should be carried out only when such a launch can be shown to be the most cost-effective way to achieve a significant advance in the state-of-the-art." He went on to say that a hiatus in the data flow after the failure of ERTS-B would be acceptable.

While ERTS-B may exceed its 1-year design lifetime in orbit as ERTS-1 has done, we have no assurance that it will. And if work on ERTS-C does not begin soon, a substantial hiatus in the flow of satellite data seems inevitable.

At this point in the record we shall insert copies of the bills and executive reports.

93^D CONGRESS
2^D SESSION

H. R. 14978

IN THE HOUSE OF REPRESENTATIVES

MAY 23, 1974

Mr. SYMINGTON introduced the following bill; which was referred to the Committee on Science and Astronautics

A BILL

To establish an Earth Resources Observation Administration within the Department of the Interior, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*

3 That as used in this Act, the term—

4 (1) “earth resources satellite system” means a
5 combination of one or more earth orbital satellites and
6 associated ground equipment for satellite command, con-
7 trol, data reception, and data analysis and interpretation,
8 designed to provide information as to the quality and
9 quantity of earth resources, except that such term does
10 not include systems which have as their primary pur-
11 poses acquisition of meteorological information, or sys-

1 tems established primarily for purposes of national
2 defense; and

3 (2) "space segment" means that portion of an earth
4 resources satellite system which includes the satellites
5 and associated ground equipment for command and con-
6 trol of the satellites, and the transportation system for
7 satellite launch, recovery, repair, and refurbishment.

8 SEC. 2. (a) There is hereby established within the De-
9 partment of the Interior the Earth Resources Observation
10 Administration (hereinafter referred to as the "Administra-
11 tion"). The Administration shall be headed by an Admin-
12 istrator, who shall be appointed by the President of the
13 United States, by and with the advice and consent of the
14 Senate, and who shall be compensated at the rate provided
15 for level V of the Executive Schedule pay rates (5 U.S.C.
16 5314). Under the supervision and direction of the Secretary
17 of the Interior, the Administrator shall be responsible for
18 the exercise of all powers and the discharge of all duties of
19 the Administration, and shall have authority and control
20 over all personnel and activities thereof.

21 SEC. 3. (a) The Administration, in order to carry out
22 the purposes of this Act, shall establish and carry out a
23 program to develop more efficient and effective means to
24 acquire and interpret information on the quality and quantity

1 of earth resources in order to assist the United States in
2 earth resources management.

3 (b) The Administration shall be responsible for—

4 (1) consultation with all interested agencies of the
5 United States and other appropriate entities, including
6 State and local governments, to ascertain the needs for
7 information on the quality and quantity of earth re-
8 sources; and

9 (2) on its own, or at the request of other agencies
10 of the United States, planning, research, design, de-
11 velopment, and operation of earth resources satellite
12 systems, except that the planning, research, designing,
13 development, and operation of the space segment of the
14 earth resources satellite systems shall be carried out in
15 accordance with the provisions of section 4 of this Act.

16 SEC. 4. The Secretary of the Interior and the Adminis-
17 trator of the National Aeronautics and Space Administration
18 are authorized to enter into an agreement or other arrange-
19 ment pursuant to which the National Aeronautics and Space
20 Administration shall undertake the responsibility for the
21 planning, research, designing, development, and operation
22 of the space segment of the earth resources satellite systems
23 on a reimbursable basis.

24 SEC. 5. (a) The Administration, in order to carry out
25 the purposes of this Act, shall provide for the widest prac-

1 ticable and appropriate dissemination of information con-
2 cerning its activities and the results thereof.

3 (b) the performance of its functions, the Administra-
4 tion is authorized—

5 (1) to make, promulgate, issue, rescind, and amend
6 rules and regulations governing the manner of its opera-
7 tions and the exercise of the powers vested in it by
8 law;

9 (2) to appoint and fix the compensation of such
10 officers and employees as may be necessary to carry
11 out such functions, and, to the extent that it determines
12 such action necessary to the discharge of its responsi-
13 bilities, to appoint, without regard to the provisions of
14 title 5, United States Code, governing appointments in
15 the competitive service, scientific, engineering, and
16 administrative personnel and compensate such scientific,
17 engineering, and administrative personnel without regard
18 to the provisions of chapter 51 and subchapter III of
19 chapter 53 of such title relating to classification and
20 General Schedule pay rates, but in no event in excess
21 of the maximum rate for GS-18 of the General Sched-
22 ule under section 5332 of title 5, United States Code;

23 (3) to enter into and perform such contracts, leases,
24 cooperative agreements, or other transactions as may be
25 necessary in the conduct of its work and on such terms

1 as it may deem appropriate, with any agency or instru-
2 mentality of the United States, or with any State, ter-
3 ritory, or possession of the United States, or with any
4 political subdivision thereof, or with any person, firm,
5 association, corporation, or educational institution;

6 (4) to use, with their consent, the services, equip-
7 ment, personnel, and facilities of Federal and other
8 agencies with or without reimbursement, and on a
9 similar basis to cooperate with other public and private
10 agencies, institutions, and instrumentalities in the use of
11 services, equipment, and facilities. Each department and
12 agency of the Federal Government is authorized to co-
13 operate fully with the Administration in making its
14 services, equipment, personnel, and facilities available
15 to the Administration;

16 (5) to appoint, in accordance with the applicable
17 provisions of the Federal Advisory Committee Act, such
18 advisory committees as may be appropriate for pur-
19 poses of consultation and advice to the Administration in
20 the performance of its functions;

21 (6) to establish within the Administration such
22 offices and procedures as may be appropriate to provide
23 for the greatest possible coordination of its activities
24 under this Act with related scientific and other activities

1 being carried on by other public and private agencies,
2 institutions, and instrumentalities;

3 (7) to enter into agreements with foreign countries
4 for cooperative programs or reimbursable services when
5 these agreements are deemed in the best interest of the
6 United States and coordinated with the Department of
7 State and other appropriate agencies; and

8 (8) to obtain services of experts and consultants
9 in accordance with section 3109 of title 5, United States
10 Code.

11 SEC. 6. There are authorized to be appropriated such
12 sums as may be necessary to carry out the provisions of
13 this Act.

93^d CONGRESS
2^d SESSION

H. R. 15781

IN THE HOUSE OF REPRESENTATIVES

JULY 2, 1974

Mr. TEAGUE (for himself, Mr. MOSHER, Mr. SYMINGTON, and Mr. ESCH) introduced the following bill; which was referred to the Committee on Science and Astronautics

A BILL

To amend the National Aeronautics and Space Act of 1958 to provide for the coordinated application of technology to civilian needs in the area of earth resources survey systems, to establish within the National Aeronautics and Space Administration an Office of Earth Resources Survey Systems, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*

3 TITLE I—SHORT TITLE; DECLARATION OF
4 POLICY; AND FINDINGS

5 SEC. 101. This Act may be cited as the "Earth Re-
6 sources Survey Systems Act of 1973".

I—O

POLICY

1

2 SEC. 102. The Congress hereby declares that it is the
3 policy of the United States that the products, services, tools,
4 and knowledge offered by advanced technology shall be
5 directly and expeditiously applied to meet public needs for
6 information on the quality and quantity of the resources of
7 the earth.

8

FINDINGS

9

SEC. 103. The Congress finds that—

10

(a) Investment in National Aeronautics and Space
11 Administration programs has led to significant contribu-
12 tions in applying new technology to meet a broad
13 spectrum of public needs, including such areas as hous-
14 ing, health care, education, transportation, pollution con-
15 trol, and public safety. It is in the public interest to
16 insure that in appropriate areas this proven potential is
17 consolidated, preserved, and extended in the most effi-
18 cient manner.

19

(b) A critical factor in applying technology is the
20 institutional arrangement used to coordinate National
21 Aeronautics and Space Administration programs with
22 those of other Federal agencies with statutory operating
23 responsibilities.

24

(c) Earth resources management is one of the most
25 pressing areas of public need. A key to effective manage-

1 ment of these resources is more efficient and effective
2 means to acquire and interpret information of the quality
3 and quantity of such resources. New technological solu-
4 tions have already been developed and demonstrated by
5 the National Aeronautics and Space Administration in
6 cooperation with other agencies of the United States.
7 More effective utilization of new technology to meet
8 these needs is both desirable and feasible.

9 TITLE II—AMENDMENT TO THE NATIONAL
10 AERONAUTICS AND SPACE ACT OF 1958

11 SEC. 201. The National Aeronautics and Space Act of
12 1958 is amended by adding the following new title IV:

13 “TITLE IV

14 “EARTH RESOURCES SURVEY SYSTEMS OFFICE

15 “SEC. 401. The Administrator shall establish, within the
16 Administration, the Office of Earth Resources Survey Sys-
17 tems, hereinafter referred to as ‘the Office’.

18 “SEC. 402. The Office shall, on behalf of the Administra-
19 tion, be responsible for—

20 “(a) Consultation with all interested agencies of the
21 United States, and other appropriate entities, including
22 State and local governments, to ascertain the needs for
23 information on the quality and quantity of earth
24 resources.

25 “(b) On its own, or at the request of other agencies

1 of the United States, planning, research, design, and
2 development of earth resources satellite systems.

3 “(c) The planning, research, design, development,
4 and operation of the space segment of earth resources
5 satellite systems of the United States.

6 “SEC. 403. As used in this title—

7 “(a) ‘Earth resources satellite system’ means a
8 combination of one or more earth orbital satellites and
9 associated ground equipment for satellite command, con-
10 trol, data reception, and data analysis and interpretation,
11 designed to provide information as to the quality and
12 quantity of earth resources. It does not include systems
13 which have as their primary purpose acquisition of
14 meteorological information or systems established pri-
15 marily for purposes of national defense.

16 “(b) ‘Space segment’ means that portion of an
17 earth resources satellite system which includes the
18 satellites and associated ground equipment for command
19 and control of the satellites. It includes the transportation
20 system for satellite launch, recovery, repair, and re-
21 furbishment.”.

22 TITLE III—AUTHORIZATION

23 SEC. 301. There is hereby authorized to be appropriated
24 to the National Aeronautics and Space Administration for
25 use by the Office of Earth Resources Survey Systems for
26 research and development, \$50,000,000.



United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

AUG 15 1974

Dear Mr. Chairman:

Your Committee has requested the views of this Department on H.R. 14978, a bill "To establish an Earth Resources Observation Administration within the Department of the Interior, and for other purposes."

We recommend that the bill not be enacted.

H.R. 14978 would establish, within the Department of the Interior, the Earth Resources Observation Administration to carry out a program to develop more efficient and effective means to acquire and interpret information on the quality and quantity of earth resources in order to assist the United States in earth resources management. The Administration would be responsible for consulting with all interested agencies of the Government as well as State and local governments to ascertain the needs for information on the quality and quantity of earth resources. In addition, the Administration would also be responsible for working closely with the National Aeronautics and Space Administration (NASA) in planning, research, designing, development, and operation of the satellite systems associated with the program.

We agree with the underlying concept of the bill that earth resources management is one of the most pressing areas of public need. We believe that potential utilization of new technology in conjunction with on-the-ground and aircraft data collection to meet these needs should be fully evaluated. Indeed, this Department already sponsors programs which are designed to do just that.

Based on the potential application of new technology and in response to a critical need for greater knowledge of the earth's resources, this Department, in 1966, established the Earth Resources Observation Systems (EROS) Program as a Departmental effort under the management of the U.S. Geological Survey to gather and experimentally use remotely sensed data, collected by satellite and aircraft, on natural and manmade features on the earth's surface. An interagency agreement was reached in 1972 that this Department should take the lead in the earth's resources survey. The objective of the Departmental



Let's Clean Up America For Our 200th Birthday

Program is to analyze the costs and benefits of the resources utilization of all types of remotely sensed data, supported by satellite and aircraft data collection systems developed in collaboration with NASA and other resource agencies. The 1975 Budget funds a new activity called Land Use Data Analysis (LUDA) in the U.S. Geological Survey which uses advanced technology to provide products useful to decision-makers. The EROS Program assumed a major role in the first experimental satellite, ERTS-1, launched by NASA to determine potential applications for mapping, monitoring, and managing the earth's resources.

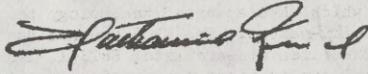
Earth resources inventory and management applications utilizing remote sensing technology are coordinated through the EROS and LUDA Programs with active participation by many Interior agencies. A \$5 million EROS Data Center was recently established in Sioux Falls, South Dakota, to provide ready access to spacecraft and aircraft data for the general public, domestic government agencies at all levels, and foreign government agencies at all levels. Facilities are available at the Center for data storage, retrieval, reproduction, and dissemination, and for user assistance and training.

In addition, the EROS and LUDA Programs are receiving cooperation of State and local agencies responsible for resources, planning, recreation, conservation, and environmental protection.

In view of the above, it appears that creation of the proposed Administration in this Department would duplicate many of the objectives and ongoing efforts of the EROS and LUDA Programs. The mechanism for accomplishing the purposes of the proposed legislation already exists within the Department of the Interior, which has primary responsibility for management of the Nation's resources. Further, remote sensing satellite programs are still in an experimental and developmental stage, with the role of satellite data versus other remotely sensed data and other conventionally acquired data not yet clearly defined. An organizational unit charged only with responsibility for earth resources sensing from space could not, it seems to us, adequately address the broad and complex question of how best to meet earth resources information needs considering all potential sources of such information.

The Office of Management and Budget has advised that there is no objection to the presentation of this report from the standpoint of the Administration's program.

Sincerely yours,



Assistant Secretary of the Interior

Honorable Olin E. Teague
Chairman, Committee on
Science and Astronautics
House of Representatives
Washington, D.C. 20515



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

AUG 13 1974

REPLY TO
ATTN OF:

Mr. John L. Swigert, Jr.
Executive Director
Committee on Science and Astronautics
House of Representatives
Washington, DC 20515

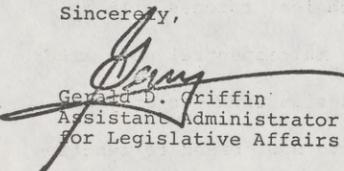
Dear Mr. Swigert:

This is in further reply to your request for the comments of the National Aeronautics and Space Administration on the bill H.R. 14978, "To establish an Earth Resources Observation Administration within the Department of the Interior, and for other purposes."

On August 6, 1974, Dr. Fletcher testified before the Senate Committee on Aeronautical and Space Sciences, addressing in his statement the bills S. 2350 and S. 3484. H.R. 14978 is essentially identical to S. 3484.

Pursuant to a discussion between you and Tom Thornburg of this office, a copy of Dr. Fletcher's statement, containing NASA's comments on S. 3484, but also pertinent to H.R. 14978, is hereby forwarded in lieu of a report.

Sincerely,



Gerald D. Griffin
Assistant Administrator
for Legislative Affairs

Enclosure

HOLD FOR RELEASE UNTIL
PRESENTED BY WITNESS

Statement of

AUG 6 1974

Dr. James C. Fletcher
Administrator

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Committee on Aeronautical and Space Sciences
United States Senate

Mr. Chairman and Members of the Committee:

I am pleased to appear before you today, as you requested, to give my views on the ERTS program and S.2350 and S.3484 relating to Earth Resources Survey activities. Appearing with me today are Mr. Willis H. Shapley, Associate Deputy Administrator, Mr. Charles W. Mathews, Associate Administrator for Applications, and other members of my staff.

As we have testified in detail on previous occasions, the ERTS-1 satellite has been a great technical success. It is still providing high quality, useful, multispectral data after two years in orbit, even though its design life was only one year. The tape recorders on board have now ceased to function, but real time reception of data by NASA's ground station in the US, and by the ground stations established and placed in operation by Canada and Brazil, is continuing without impediment.

We are preparing to launch ERTS-B early in 1975 and expect it to work well for at least two years, including its tape recorders, as a result of fixes that are being made to components that failed on ERTS-1.

Results of investigations with ERTS-1 by the more than 300 original investigators are continuing to flow in; another 93 investigators for follow-on work with data from ERTS-1 and ERTS-B have just been selected, with an emphasis on operational-type uses of ERTS data. The Departments of Interior and Agriculture, the National Oceanic and Atmospheric Administration, and the Corps of Engineers, among other agencies, are today using ERTS data. State and local agencies are also using ERTS data and learning how to apply it to their specific needs.

ERTS investigations are now increasingly oriented toward a new focus. In the first phase, the emphasis was on finding out what could be done with this new space tool. Now we are entering a second phase in which the users are learning how to apply ERTS-derived information to real problems of monitoring and managing our national resources on a significant scale.

NASA's technical assessment of what we have learned to date in the ERTS and related earth resources programs can briefly be summarized as follows:

- Repetitive, global, multispectral data in digital form has tremendous potential for providing economical and social benefits in the areas of agriculture, water resources, and land use, among others.
- The current ERTS-1/ERTS-B system is good and provides valuable, usable data in its present form. To realize the full potential of ERTS-type systems, future systems will probably need:
 - More spectral channels to increase the variety of phenomena that satellites can distinguish and measure with precision. The thermal infrared "fifth channel" is one high-priority example; we and the users also see important advantages in some increase in the number and narrowing in the width of bands in the visible range.
 - More rapid handling of data, from its acquisition by the satellite through the ground processing equipment and to its delivery to the user. For some time-dependent applications, processed digital data will have to be available in a matter of days, not weeks, after collection.

- More frequent repetitive coverage. For some applications, it may be desirable to have repetitive satellite data every 9 or 10 days instead of on the 18-day cycle currently determined by the ERTS orbit.
- Higher ground resolution, in the multispectral mode, will be desirable for some applications.
- ERTS-type earth sensing satellites can make their most effective contributions when used in proper conjunction with other available data sources and capabilities, including satellite relay of data collected on the ground, data collected by aircraft, and data available from conventional ground sources. The optimum mix of data acquisition and distribution systems has yet to be established for each particular application.
- The benefits from the use of earth resources satellite data will come in several forms. In some areas, there will be cost savings to the Federal Government and others in that existing operations can be carried out with less effort than before. In other areas, use of

ERTS data will provide wholly new services and benefits not before possible or otherwise available. The identification and assessment of the specific benefits ERS satellites can provide is a continuing task for all prospective users as their experimentation with ERTS-1 and -B data proceeds and they consider their plans for the potential use of such data in an operational mode.

This, in brief summary, is our current assessment of what we have learned to date in the experimental phase with respect to the utility of ERTS-type systems. The next questions are: What do we see for the future? What are the next logical steps in moving from the present investigative phase toward the eventual delivery of solid, measurable values on a continuing basis?

First, we see the need for a steady evolution from the early experimental phases with ERTS toward improved, more flexible hardware systems in space and on the ground. I have mentioned the need for additional spectral bands, more rapid through-put, more repetitive coverage, and higher resolution for some applications.

Second, we can now see some interesting possibilities of economies in future satellite systems by combining experimental and operational capabilities in a single satellite, which could provide data from proven sensors and also test and demonstrate experimental new capabilities. For example, a five-channel multispectral scanner could be used to provide operational users with the four-channel data they have learned to use from ERTS-1 and -B, and at the same time provide new experimental data from the fifth infrared channel for new potential uses and users. There is no reason for having two separate types of satellites.

The most important point that has become clear to us during the past year, however, is that there should not be, and in fact there is not, a clear-cut distinction between "experimental" and "operational" phases in the earth resources program. This distinction has been a premise on which most of our thinking in the past, as well as the two bills now under consideration, has been based. Our present thinking is pointing clearly to the conclusion that the actual dynamics of the transition from experimentation to operations and the most economical conduct of the entire ERS program require an evolutionary approach in which:

- Both experimental and operational needs are met with a single series of satellites, as discussed above, and
- Each operational use of ERS data moves from the experimental to the operational phase on its own timetable, depending on when its utility and cost effectiveness have been sufficiently established to support the necessary investment decisions.

The need for experimental work in earth resources is continuing in nature. There is no sharp cut-off point when a whole system or even any particular use of ERS data, stops being experimental and becomes purely operational in nature. The same data can be used, for example, for geophysical research and for water resources management. Continuity from experimentation into operations is essential in sensor development and other hardware

aspects of the program, and especially in the development of data utilization techniques and other aspects of user systems. On the one hand, experimental data can be used operationally, as we have already seen with ERTS-1; on the other hand operational uses of data will continue for some time to be partly experimental, as improved ways of utilizing data are conceived and tested.

In summary, then, we see the need for a continuous evolutionary approach, in which operationally useful data from space are provided to users for research, for experimental demonstrations, and for routine operations when they are ready, while at the same time and with the same satellites, necessary improvements to the system can be developed and tested. With this approach each of the prospective users will be able to make his investment and management decisions committing to the use of ERS data with the knowledge that data will be available to enable him to get the values he seeks from an operational system.

Let me now turn to the bills before the Committee, S.2350 and S.3484, both of which address the question of organizational arrangements for earth resources programs.

Under the approach I have suggested, it would seem premature to define ultimate institutional arrangements by legislation. If we can have continuity of ERTS-type data flow for experimentation and demonstration, the transition to operational uses can begin within the current legislative and organizational framework. Legislation could be considered at a later time when the needs

and problems to be addressed can be more precisely defined.

While legislation at this time could establish for potential users the promise that there would really be a permanent operational satellite system eventually and thereby give them a basis for making the necessary investments in learning how to use the data, the problem is that the Government is not yet ready to make these assurances. Such assurances must wait until more user oriented satellites have been flown and further analyses are made to determine optimal national investment in systems, systems mixes, uses, and modes of operation.

With respect to the details of the bills themselves, I must say that S.2350 as drafted would pose several problems for NASA. In establishing by statute a separate office within NASA, it unduly reduces NASA's flexibility to organize itself most effectively to carry out all of its functions. Specifically, the bill as drafted would artificially separate earth resources activities from similar and closely related satellite applications programs such as oceanography, pollution monitoring, environmental measurement, and meteorology. I believe NASA should retain the flexibility we now have under our basic legislation to revise NASA's internal organization when necessary to conduct our programs in the most effective and economical manner. In addition, I believe that to accomplish its intended purposes, S.2350 would have to define explicitly the necessary interfaces between the space segment, i.e., the data acquisition system, and the users and beneficiaries of the data, i.e., other agencies, the private

sector, and foreign and international entities. S.2350, as drafted, also does not adequately recognize, in my opinion, the large and complex functions involved in turning data collected by earth resources satellites into usable information for the users and beneficiaries.

S.3484 would appear to have drawbacks from the Department of the Interior's standpoint similar to those of S.2350 with respect to NASA which I have just discussed. As far as NASA is concerned, S.3484, as drafted, has another major flaw: it would appear to limit NASA's research and development in earth resources to activities supported and funded by the Department of the Interior. NASA opposes this as creating an artificial compartmentalization in the space program which would complicate the program and be contrary to the basic concept of the National Aeronautics and Space Act of 1958.

I should also note that some important national and international policy issues are not addressed in either bill. I have in mind matters such as the role of the private sector, safeguards against unfair exploitation of information, allocation of costs, and reimbursements for services. More experience and study is needed, in my view, before sound policies can be set in these areas.

Mr. Chairman, as I have indicated, continuation of the current ERTS program into a broadly based transition phase appears to be the most appropriate and beneficial next step. This course preserves all options for the future and gives both the Executive

Branch and the Congress the time to learn the lessons of the experimental phase, while at the same time continuing and increasing the flow of benefits from space to all users.

Thus, the considerations I have discussed suggest an approach that is somewhat different from that contemplated by either S.2350 or S.3484. However, I believe that further consideration by NASA, the user agencies, and OMB is required before we can present a specific alternative proposal and before the need and nature of additional legislation that may be required can be determined. For this reason, I suggest that the Committee defer action on the pending bills and request NASA, in concert with the other agencies, to come forward with a proposal in connection with the FY 1976 program:

Mr. Chairman, this concludes my statement.

#



COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-181426

August 7, 1974



The Honorable Olin E. Teague, Chairman
Committee on Science and Astronautics
House of Representatives

Dear Mr. Chairman:

Reference is made to the request from your Executive Director for our views and recommendations on H.R. 14978, 93d Congress, which would establish an Earth Resources Observation Administration within the Department of the Interior (Interior).

There are two related bills in the Senate, S. 3484 which is virtually identical to H.R. 14978, and S. 2350 which is similar in scope but gives primary authority to the National Aeronautics and Space Administration (NASA) rather than the Department of the Interior for carrying out the provisions of the bill. We prefer the provisions of H.R. 14978 and S. 3484 in that the program would be established in Interior where the existing arrangement for the on-going earth resources observation system (EROS) could be utilized. The EROS program, funded at about \$9 million in fiscal year 1974, is a function of Interior's Geological Survey with NASA furnishing both professional expertise and equipment. Through EROS the Geological Survey has demonstrated its ability to use space technology to solve earth resources and environmental problems and to disseminate earth resources information obtained from the satellite.

Another consideration in favor of placing the new agency in Interior is that the agency's function could involve what is intended to become a continuing routine operation, whereas NASA's mission has been essentially to conduct space and related research and development activities.

With regard to specific provisions of H.R. 14978, we offer the following comments:

The bill defines the term "earth resources satellite system" but does not define the term "earth resource" leaving open questions of agency jurisdiction. While the bill explicitly excludes from the new agency's jurisdiction the acquisition of information primarily for

meteorological and defense purposes (presumably because such information falls within the ambit of the Commerce Department's National Oceanographic and Atmospheric Agency (NOAA) and the Department of Defense), it makes no mention of oceanographic data. We suggest the bill make clear whether the new agency or NOAA will have jurisdiction over such oceanographic systems.

Also, the term "earth resources satellite system," in designating the principal responsibility of the new agency, may be too narrow because an earth observation program could include the use of airplanes and ground sensors as well as satellites. It may be desirable to extend the agency's responsibilities to include "earth observation systems using satellites and other devices of observation." Similarly, it may be desirable to recognize, in the definition of earth resources satellite systems, the use of "other observation platforms," in addition to "earth orbital satellites."

The definition of "space segment" in H.R. 14978 is not as broad as that stated in S. 3484, in that the latter also encompasses "payload." Specific mention of "payload" appears desirable in order to preclude possible jurisdictional disputes between Interior and NASA.

Section 3 states the general purpose of the program but does not define its scope. We believe that a statement as to whether coverage includes only the resources of the United States or those of other countries should be included.

Section 5(a) states that the Administrator of the new agency should provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof. Some of the information may be of a sensitive nature involving national security or the discovery of valuable resources having economic implications for certain organizations, enterprises, markets, or the Nation as a whole. We recommend, therefore, added language which would require adequate safeguards to prevent premature or unauthorized disclosure of sensitive information and to insure publication in a manner equitable to all interested parties.

Section 5(b)(2) authorizes the Administration to appoint and fix the compensation of officers and employees without regard to the provisions of title 5, United States Code, governing appointments in the competitive service and relating to classification and General Schedule pay rates (except for an overall pay ceiling at the maximum rate of GS-18 positions). We are not aware of a need for exempting the new agency from the classification and pay rates generally applicable to Civil Service employees. The new agency should be able to recruit qualified personnel within the structure of the General Schedule.

Section 5(b)(3) authorizes the Administration to enter into contracts, leases, cooperative agreements, or other transactions as may be necessary in the conduct of its work, and on such terms as it may deem appropriate, with, among others, any person, firm, association, corporation or educational institution. We are not aware of the need for the Administration to be exempt from the provisions of the Federal Property and Administrative Services Act. However, if such an exemption is determined to be needed, we recommend that the bill be amended to include language that would require recipients of Federal monies under contracts, or other arrangements entered into by the Administration by means other than formal advertising to keep such records as the Administrator shall prescribe and to permit access to such records by authorized representatives of the Secretary of the Interior and the Comptroller General for the purpose of audit and examination. This could be accomplished by adding to the bill a section reading as follows:

"Sec. (a) Each recipient of Federal assistance under this Act, pursuant to grants, subgrants, contracts, subcontracts, loans or other arrangements, entered into other than by formal advertising, and which are otherwise authorized by this Act, shall keep such records as the Administrator shall prescribe, including records which fully disclose the amount and disposition by such recipient of the proceeds of such assistance, the total cost of the project or undertaking in connection with which such assistance is given or used, the amount of that portion of the cost of the project or undertaking supplied by other sources, and such other records as will facilitate an effective audit.

"(b) The Administrator and the Comptroller General of the United States, or any of their duly authorized representatives, shall, until the expiration of three years after completion of the project or undertaking referred to in subsection (a) of this section, have access for the purpose of audit and examination to any books, documents, papers and records of such recipients which in the opinion of the Administrator or the Comptroller General may be related or pertinent to the grants, subgrants, contracts, subcontracts, loans, or other arrangements referred to in subsection (a)."

We note that the bill does not specifically provide for program evaluation by the Secretary. It is our view that program evaluation is

a fundamental part of effective program administration and that responsibility for evaluation should rest initially upon the agencies. In line with that concept we believe the Congress should attempt to specify the kinds of information and tests which will enable it to better assess how well programs are working and whether alternative approaches may offer greater promise. We will be happy to work with the Committee in developing specific language, if so desired.

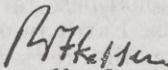
In addition to requiring general evaluations and reports thereon to the Congress by the executive agency, we believe specific reports to the Congress would be desirable in connection with the following two provisions of the bill:

(1) Section 4 provides for agreements between Interior and NASA for the planning, research, design, development, and operation of the space segment of the satellite system. We suggest that, upon completion of the research and development stage, Interior be required to report to the Congress on the estimated costs of the system before entering into the production phase.

(2) Section 5(b)(7) authorizes the Administration to enter into agreements with foreign countries. We suggest that the Administration be required to report to the Congress, from time to time, on any such agreements and anticipated and accrued benefits of those agreements.

The following editorial corrections are needed: on page 2, lines 15-16, the United States Code reference should be to 5 U.S.C. 5316, and on page 4, line 3, the word "in" should be added after "(b)" as the first word of the sentence.

Sincerely yours,


Deputy Comptroller General
of the United States

Mr. SYMINGTON. With this background, I would like to begin our hearings by welcoming our first witness, the distinguished Senator from Utah, the chairman of the Senate Committee on Aeronautical and Space Sciences, and an outstanding spokesman for the ERTS program, Senator Frank E. Moss.

STATEMENT BY SENATOR FRANK E. MOSS

Senator Moss. Thank you very much, Mr. Chairman.

I am pleased to appear this morning before you and to testify concerning the bills that are before this subcommittee, I also would like to give you a little view of some of the matters that have come before our Senate committee on this same subject.

I want to state at the beginning that I believe you are performing a great service in holding these important hearings on Earth resources satellites at this time. I want to thank you sincerely for allowing me to present a brief statement.

I understand that this weekend ERTS-1 began to develop some additional problems that are not fully defined yet. This indicates that it may be really coming to the end of its life. It is now long over the life projected for it when it was launched. Its recorders have been out for some time, but it has continued to perform many of its functions. It may soon fail; however, it has been a resounding success and will have extended far beyond its proposed life.

The bills that are pending before this subcommittee differ in detail. They have, it seems to me, a common and laudable purpose: Establishing a sound institutional base for the continued development of, and experimentation with, Earth resources satellite systems.

As you know, these bills are essentially identical to two bills, S. 2350 and S. 3484, on which the Senate Committee on Aeronautical and Space Sciences held hearings in August and September.

Many of the witnesses appearing before you during these hearings are far more knowledgeable than I about the details of the ERTS system and the techniques for translating ERTS data into resources information of great value to all mankind. Therefore, I thought my most useful contribution to your record today might be to summarize the record as it has been developed in the Senate and to outline for you the conclusions I draw from that record.

I think it is fair to say that no other project of the National Aeronautics and Space Administration has received such instant acclaim and widespread acceptance. ERTS has been a phenomenal success and the people know it. In preparation for the Senate hearings, I wrote to the 50 Governors asking for their views on the ERTS system in general and the pending bills in particular. I have now heard from the Governors or other senior State officials of over 30 States. In every case but one they give strong support to the ERTS program. I doubt if any other Federal program, except perhaps revenue sharing, is so near to universal popularity with the Governors.

Mr. Chairman, I have copies of the Governors' letters I have received to date and would be glad to leave them with you for the record.

As the chairman said, this has been a very popular program on the Hill, and this committee and others have for years been saying to the executive branch that we wanted its continuation and emphasis, which seems to have been ignored.

I would like to add for your record copies of the letters that I have received from the Governors of 30 of our States, of which, as I said, 29 endorse ERTS wholeheartedly. Only one did not give his full endorsement. I will leave these here and if you care to include them in your record, I will be pleased to have you do so.

Mr. SYMINGTON. Without objection, that will be done.

[Letters referred to follow:]



JACK WILLIAMS
GOVERNOR

OFFICE OF THE GOVERNOR
STATE HOUSE
PHOENIX, ARIZONA 85007

IN REPLY
REFER TO:

July 10, 1974

SEN. FRANK E. MOSS
RECEIVED
JUL 15 1974
RECEIVED
WASHINGTON, D. C.

Honorable Frank E. Moss
Chairman, Senate Committee on
Aeronautical and Space Sciences
United States Senate
Washington, D.C. 20510

Dear Senator Moss:

Thank you for your letter of June 24, 1974. The State of Arizona has derived much benefit from the Arizona Land Use Experiment and the outstanding working relationship with both the National Aeronautics and Space Administration and the Department of the Interior. Much has been accomplished in laying the foundation to utilize this technology for civilian purposes at the State level.

Arizona would like to see Earth Resources Technology Satellite (ERTS) become operational so as to assure that the data would be timely, regular and ongoing.

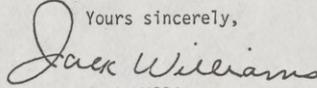
Arizona would benefit by the continuation of several applications already in progress. For example, Earth Resources Technology Satellite (ERTS) data is being used by the University of Arizona in many important research projects. Within Arizona State Government, the Arizona Resources Information System, in conjunction with the United States Geological Survey, is supporting significant projects such as the mapping of potential sources of geothermal energy by the State Land Department and the mapping of land developments and subdivisions in Arizona by the State Office of Economic Planning and Development. The base map for the latter study is a mosaic of Arizona produced by the U.S. Geological Survey using Earth Resources Technology Satellite (ERTS) imagery.

Earth Resources Technology Satellite (ERTS) imagery is very important to the Arizona Salt River Project in monitoring water

resources on its watershed. A copy of a news release from the Salt River Project detailing this application is attached.

Considering the vast amount of funds that have been spent on satellite systems and the new capabilities we have as a result, we believe an Office should be established for the purposes outlined in the proposed legislation.

Yours sincerely,



Jack Williams

JW:ct
Enclosure



DALE BUMPERS
GOVERNOR

STATE OF ARKANSAS
OFFICE OF THE GOVERNOR
LITTLE ROCK

July 12, 1974

Gu
4.5-7

The Honorable Frank E. Moss
Chairman, Committee on Aeronautical
and Space Science
United States Senate
Washington, D. C. 20510

SEN. FRANK E. MOSS
RECEIVED
JUL 26 1974
RECEIVED
WASHINGTON, D. C.

Dear Senator Moss:

Numerous agencies of State government in Arkansas have found Earth Resources Technology Satellite data useful in their planning and operational roles. We support the continuation of the system and consider the output as valuable to the State of Arkansas.

Kindest personal regards.

Sincerely,

Dale Bumpers
Dale Bumpers

RONALD REAGAN
GOVERNOR

State of California
GOVERNOR'S OFFICE
SACRAMENTO 95814



July 26, 1974

The Honorable Frank E. Moss
United States Senator
Senate Office Building
Washington, D.C. 20510

Dear Senator Moss:

In your recent letter you asked for my comments on the Earth Resources Technical Satellite (ERTS).

Without equivocating, we believe ERTS should be an operational system. No useful purpose is served by orbiting another satellite with the same equipment to duplicate what has been done before with similar expectations of results. Since ERTS has established its efficacy, all evidence suggests a satellite with improved systems fulfilling an operational role. Further, we believe the second generation ERTS should include side looking airborne radar and an infra red thermal scanner as part of the data surveillance and collection systems. These types of sensors are needed to provide new dimensions to acquisition of earth resources information.

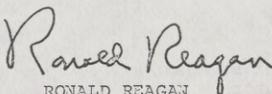
To date, ERTS imagery has been used in agriculture for crop inventory to identify range land, pasture, and other land use patterns. It also has been used in the broad categories of forest management, hydrology and water resources, coastal processes, geology, littoral drift and dune movement, watershed studies, and vegetation mapping. Additionally, various campuses of the University of California have extensive programs utilizing ERTS imagery in discipline areas such as agriculture, forestry, water resource management, and land use inventory.

Placed in perspective, our experience with ERTS imagery reveals that it has a potential yet to be exploited. ERTS data has progressed beyond the experimental stage and should

move to an applied, operational role. The need for an ERTS-type system is clearly manifested in ever increasing pressures to obtain timely and accurate information for efficient resources management.

Thank you for the opportunity to express some capsulated remarks on this subject.

Sincerely,



RONALD REAGAN
Governor



STATE OF DELAWARE
EXECUTIVE DEPARTMENT
DOVER

SHERMAN W. TRIBBITT
GOVERNOR

July 30, 1974

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1 - W
MC

The Honorable Frank E. Moss
Chairman, Committee on Aeronautical
and Space Sciences
United States Senate
Washington, D. C. 20510

SEN. FRANK E. MOSS
RECEIVED
AUG 7 1974
LEGISLATIVE
WASHINGTON, D. C.

Dear Senator Moss:

Thank you for your letter of June 24th enclosing copies of S. 2350 and S. 3484.

We have received copies of the maps of the Del-Mar-Va area and recently maps were purchased by the University of Delaware. We did not find the quality of the maps from the ERTS program sufficient to encourage us to make further purchases.

We have received some valuable information through the NASA programs and through the United States Coast and Geodetic Survey.

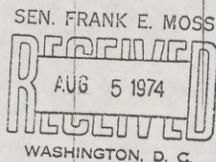
We could not encourage the expenditure of \$50,000,000 for this particular program in view of the shortage of funds to support environmental, health, education and basic research projects.

Thank you for the opportunity to review and comment on the proposed legislation.

Sincerely,

Sherman W. Tribbitt
Governor

STATE OF FLORIDA
OFFICE OF GOVERNOR REUBIN O'D. ASKEW



August 2, 1974

Honorable Frank E. Moss, Chairman
Committee on Aeronautical and
Space Sciences
Room 3121, Dirksen Building
Washington, D.C. 20510

Dear Senator Moss:

We have found the information received from the ERTS program to be very useful. Our Department of Transportation, which is a depository for the ERTS photography, has used it for a variety of projects. These include the mapping of the April 1972 Suwannee River flood, and identification of geological subsurface lines and general land use.

These are but a few of the applications that we have found for these materials. However, with improved quality of imagery and faster service from the EROS Center, their value would be increased tremendously. Unfortunately, the quality of imagery from EROS has always been fair to poor and delivery of the materials range from three to five months. Nevertheless, we feel the program has excellent potential and with improved techniques, better communication, and proper notice to state agencies, much more can be gained from satellite imagery.

With kind regards,

Sincerely,

Governor

ROA/epr

mk.



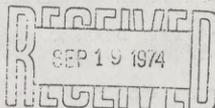
Executive Department
Atlanta 30334

Jimmy Carter
GOVERNOR

Frank Moore
EXECUTIVE SECRETARY

September 11, 1974

SEN. FRANK E. MOSS



WASHINGTON, D. C.

The Honorable Frank E. Moss, Chairman
Committee in Aeronautical and Space Sciences
United States Senate
3121 New Senate Office Building
Washington, D. C. 20510

Dear Senator Moss:

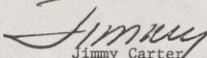
Georgia has long recognized the need for more and better information concerning the nature and distribution of our natural resources, as well as the extent of man's activities on the land and water. This need has resulted in a system of programs whose common objective is the collection, storage, and distribution of land use and resource information for use by planners, educators, and the general public in addressing the critical problems which now face us.

Over the past two years, ERTS has played an increasingly valuable role in this process. In Georgia, satellite data has been used in the preparation of statewide water resource, geologic, landform, and vegetation maps as well as in the investigation of regional mineral resources and in the charting of sediment transport on the Georgia coast. Land cover maps have been prepared utilizing ERTS imagery for the southwestern portion of the State and for the Atlanta area, using computer techniques developed at the Georgia Institute of Technology. Future applications will include the development of programs for monitoring short term land use and resource changes with a particular emphasis on the Coastal Region, and for monitoring strip mine development all over the State. An interpretative atlas has been prepared from ERTS imagery which presents geologic, landform, and land use information for the entire State.

The great interest which has developed in Georgia, and in a great many other States as well, concerning the application of satellite-obtained remote sensing is a clear indication of the need for the type of agency envisioned in S. 2350 and S. 3484. However, I feel that it is extremely important that this organization have a basic responsibility for all types of non-military

remote sensing operations which are currently conducted by the Federal Government. The difficulties, as well as the opportunities, which are inherent in the ERTS program equally apply to the high-altitude photographic programs conducted by NASA. ERTS must be seen as only one of a series of remote sensing platforms, all of which have varying degrees of applicability in our inventory effort and many of which are available only through Federal programs. If remote sensing is to continue to be a primary ingredient in land use planning, then increased coordination and cooperation will be essential.

Sincerely,



Jimmy Carter

JC:gds



EXECUTIVE CHAMBERS

HONOLULU

July 25, 1974

JOHN A. BURNS
GOVERNOR
 SEN. FRANK E. MOSS
 RECEIVED
 JUL 30 1974
 WASHINGTON, D. C.

The Honorable Frank E. Moss, Chairman
 Committee on Aeronautical and Space Sciences
 U.S. Senate
 Washington, D.C. 20510

Dear Senator Moss:

Thank you very much for your letter and enclosures of June 24, 1974, addressed to Governor Burns, informing us of the capabilities of the Earth Resources Technology Satellite (ERTS) and requesting our opinion regarding the merits of establishing an operational ERTS system.

We have been apprised of the many applications of this remarkable spacecraft by representatives of both NASA and the AMES Research Center. In addition, representatives from our Legislature as well as our Department of Planning and Economic Development have attended ERTS seminars on land use application and sensor imagery interpretation both at Moffett Field, California, and Sioux Falls, South Dakota.

Unfortunately, we have not been able to enjoy the full benefits of ERTS imagery, which reduces each of our eight islands to thumbnail proportions, because of the smallness of our Island State. We are optimistic, however, that future interpretative refinements through electronic expansion will be more fruitful in this regard.

Of more immediate promise is the hard copy photo imagery currently offered by NASA-AMES employing U-2 high level aircraft. Land use inventories, photo mapping, and shoreline definition are but a few of the benefits we soon hope to realize upon completion of flights scheduled for Hawaii in September of this year.

In conclusion, we fully support the intent of S. 2350 and S. 3484 to assign the ERTS system to a Federal mission agency, thereby assuring the continuing availability of a valuable information source and decision-making tool.

We very much appreciate the opportunity to comment upon the most worthwhile legislation and wish you the best of luck in achieving its early enactment. If we can be of any further assistance, please feel free to contact us at any time.

With warm personal regards, I remain,

Yours very truly,

George K. Ariyoshi
 George K. Ariyoshi
 Acting Governor

STATE OF ILLINOIS
EXECUTIVE OFFICE OF THE GOVERNOR
BUREAU OF THE BUDGET
SPRINGFIELD 62706

Ad *5/17/74*
July 24, 1974

4.5-7(

Mr. Frank Moss
Chairman
United States Senate
Committee on Aeronautical and
Space Sciences
Washington, D.C. 20510

Dear Chairman Moss:

In response to your letter of June 24 to Governor Walker regarding the merits of establishing an operational ERTS system, please be advised that at present no line agency within the state uses ERTS imagery. However, the Center for Advanced Computation (CAC) at the University of Illinois is finding ERTS data to be a valuable input to an experimental land use mapping computer system being developed at the Center.

Sincerely,

Hal Hovey
Hal Hovey, Director
Bureau of the Budget

GEOLOGICAL BOARD

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STATE OF IOWA
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16 WEST JEFFERSON STREET
IOWA CITY, IOWA 52242
Phone: (319) 338-1173

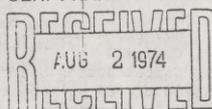


Iowa
a place to grow

Samuel J. Tuthill
Director and State Geologist

Orville J. Van Eck
Assistant State Geologist

SEN. FRANK E. MOSS



WASHINGTON, D. C.

29 July 1974

The Honorable Frank E. Moss, Chairman
Committee on Aeronautics and Space Sciences
United States Senate
Washington, D. C. 20501

Dear Senator Moss:

Governor Ray has asked me to reply to your letter of 24 June 1974, concerning the ERTS System and Senate files 2350 and 3484.

The ERTS System has proven its worth many times over in Iowa and we are concerned that no provisions have been made to insure that earth resources satellite data will continue to be made available to users at the state and federal level.

Those agencies which apply natural resource data should define the scales, accuracies and formats of remotely sensed data that are most applicable to their programs. Our remote sensing program in Iowa was established on the principle that applications oriented knowledge of state user agency personnel is utilized in the research, design, and interpretation phases of remote sensing investigations. Development of remote sensing specialists within our state user agencies obviated the need for development of a large, stand-by, highly specialized, multidisciplinary remote sensing staff within any one agency. The Remote Sensing Laboratory, within Iowa Geological Survey, provides a nucleus of remote sensing expertise and specialized remote sensing equipment that gives impetus to the statewide applied remote sensing program.

An Earth Resources Observation Administration should be established and adequately funded within the U.S. Department of Interior. The U. S. Department of Interior, in close cooperation with the U.S. Department of Agriculture, should develop a program to define the optimum remotely sensed data requirements for the broadest community of users at the state and national level. The translation of operational requirements into optimal design characteristics, for platforms and payloads capable of delivering the desired remotely sensed data of natural resources, should be a responsibility of the National Aeronautics and Space Administration. Therefore an Office of Earth Resources Survey Systems should be established and adequately funded within the National Aeronautics and Space Administration.

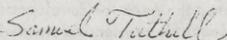
The National Aeronautics and Space Administration should be responsible for the design, development, and operation of earth resources satellites, spacecraft, and aircraft. This responsibility should include operational command and control of earth resources sensing systems. The U. S. Department of Interior should operationally control data reception facilities, even though NASA may design and maintain them. Remotely sensed data analysis and interpretation should be coordinated by a joint U.S. Department of the Interior and U.S. Department of Agriculture team located at the EROS Data Center in Sioux Falls, South Dakota.

In summary, both Senate files 2350 and 3484 are, by themselves, inadequate. Legislation should be developed that would embrace some of the concepts expressed in both articles of legislation. This legislation should require that NASA, USDA, and USDI jointly develop a program to analyze our earth resources from satellites, spacecraft, or aircraft, as cost-effectiveness dictates.

The proposed establishment of an operational ERTS System must provide the organizational framework for inclusion of new technology as it evolves. Although the present ERTS-1 satellite is particularly useful because of its unique multispectral and cartographic characteristics, the spatial resolution of the system must be improved if ERTS data is to be used at the county and city level in Iowa. The establishment of an ERTS System should be view as the first step in a program that will provide us with timely earth resources information.

The proposed Earth Resources Observation Administration to be within the U.S. Department of Interior, and the proposed Office of Earth Resources Survey Systems to be within NASA, should provide the organizational framework for timely monitoring and inventory of our earth resources, provided these organizations are adequately funded and have clearly defined responsibilities.

Very truly yours,



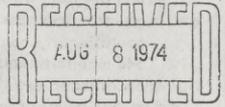
Samuel J. Tuthill
Director and State Geologist

JVT/SJT:jt

cc: Governor Ray
Senator Abourezk
Senator Curtis

STATE OF KANSAS

SEN. FRANK E. MOSS



WASHINGTON, D. C.

OFFICE OF THE GOVERNOR
 State Capitol
 Topeka

ROBERT B. DOCKING
 Governor

August 1, 1974

The Honorable Frank E. Moss
 Chairman, Committee on Aeronautical
 and Space Sciences
 United States Senate
 Washington, D. C. 20510

Dear Senator Moss:

Thank you for your letter of June 24th requesting information on the use of the Earth Resource Technology Satellite system by the State of Kansas.

I have followed the progress of the investigations conducted in Kansas with the ERTS system since they were first proposed under the Kansas Environmental and Resource Study Program. We were very pleased to have investigators at the University of Kansas Space Technology Center, the Kansas Geological Survey and Kansas State University funded by NASA to do research with this new technology. It has been a major objective of the Kansas program to translate the results of the initial research studies into applications within various state and local agencies. In this regard I have called two Governor's Conferences on the application of satellite remote sensing designed to introduce directors and key personnel of Kansas state agencies and those in adjoining states to the potential it offers.

We have been pleased with the success made to date in applying ERTS imagery to a wide range of problems in a number of state agencies. Some such problems could only be addressed with this new view of our landscape, or painstakingly with far greater expense through conventional means over extended periods. I am enclosing a brief summary of the initial research investigations conducted with the Earth Resource Technology Satellite and a listing of some of the applications projects completed or underway in Kansas. I have been pleased to see the progress made in the application of this new technology to the management of Kansas' critical resources; however, I am assured by those more actively involved in our universities and in our agencies that we have only scratched the surface. It is my understanding that the realization of the true potential of satellite based earth observation data will only be achieved when such systems

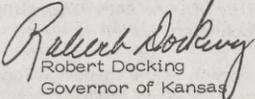
are made operational and the agencies can depend on receiving the transmitted data in a timely and continuing manner. Additional benefits, of course, are expected as the resolution of the sensors are improved based on experience and new developments.

The ERTS-1 research investigators at the University of Kansas Space Technology Center have demonstrated a number of uses for satellite imagery. These uses might be reasonably implemented if data were available from an operational satellite. Among these applications are estimates of crop acreage, particularly winter wheat, which may be prepared on an acceptably accurate and quite timely basis. Satellite images may also be used to monitor the expansion of cropland under irrigation. Since irrigation tends to deplete groundwater supplies, knowledge of the location and amount of land being irrigated is quite helpful. Other types of major land use change may also be monitored from an operational satellite. Water quality as a function of sediment and pollution in Kansas reservoirs may also be monitored.

These results lend to the argument that it would be desirable to assign the ERTS system to a mission agency and change its status to operational.

With every good wish.

Yours sincerely,


Robert Docking
Governor of Kansas

RD:nkm
Enclosures

cc: Dr. B.G. Barr, Director
Space Technology Center
University of Kansas - Campus West
Lawrence, Kansas 66045

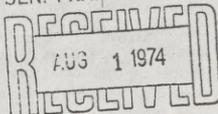
Mr. Charles Buzby
National Governors' Conference
1150 17th Street, N.W.
Washington, D.C. 20036

OFFICE OF THE GOVERNOR
FRANKFORT, KENTUCKY 40601

WENDELL H. FORD
GOVERNOR

July 26, 1974

SEN. FRANK E. MOSS



WASHINGTON, D. C.

Dear Senator Moss:

During the past twenty-four months, the Commonwealth of Kentucky's Department for Natural Resources and Environmental Protection has utilized, on a continuous basis, data supplied by the existing ERTS system.

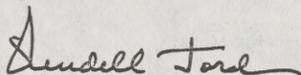
The Department has recently been notified that a proposal entitled "A Feasibility Analysis of the Employment of Satellite Data to Monitor and Inspect Surface Mining Operations" has been tentatively selected as one of the investigations for the ERTS Follow-on Investigation Program. The Department is also conducting a project, funded in part by the Appalachian Regional Commission, which is entitled "Surface Mine Pollution Abatement and Land Use Impact Investigation." ERTS data will be utilized throughout the conduct of that project. The Department is currently investigating the use of the ERTS computer compatible tapes for estimating location and size of small water impoundments. In addition, the University of Kentucky and several other Universities throughout the Commonwealth are utilizing ERTS data in various research and demonstration projects.

At the present time, we are not convinced that the existing ERTS system can be considered operational for routine use in the Commonwealth's program of natural resources management and environmental protection. We are looking forward to furthering research and development in this area, which will provide a system with greater resolution and wider spectral capabilities and which will require less time, manpower, and money for interpretation and application.

If legislation on ERTS operations is to be passed at this time, we would prefer legislation which would enhance the National Aeronautics and Space Administration's operational pervue. This type of legislation would allow the Commonwealth to deal directly with one agency responsible for research, development, and operation of an earth resources survey system. We believe that such an arrangement would make NASA more aware of the needs of user agencies such as the states, and would in turn make the user agencies more aware of the system capabilities.

Thank you for the opportunity to comment on this pending legislation. If I, or any of my staff, can be of further assistance, please do not hesitate to contact us.

Sincerely,

A handwritten signature in cursive script, appearing to read "Dudley Tare".

The Honorable Frank E. Moss, Chairman
Committee on Aeronautical and Space Sciences
United States Senate
Washington, D. C. 20510

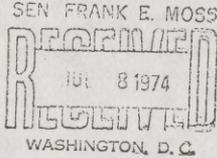


KENNETH M. CURTIS
GOVERNOR

STATE OF MAINE
OFFICE OF THE GOVERNOR
AUGUSTA, MAINE
04880

July 1, 1974

Senator Frank E. Moss, Chairman
Committee on Aeronautical and Space Sciences
United States Senate
Washington, D. C. 20510



Dear Senator Moss:

Thank you very much for your letter of June 24 regarding the future of the first Earth Resources Technology Satellite (ERTS) and the two bills now before the Senate to assign this function on a continuing basis to a federal agency.

I can assure you that it is in the best interests of the State of Maine, and I am quite sure all other states and their local governments, to make sure that this valuable source of data is continued. We in Maine through our State information system are only beginning to use this data with primary emphasis on land and water use planning and as our efforts accelerate in this area, we are beginning to see the future potential of this great technological development.

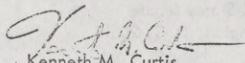
The Maine State Planning Office and its Coastal Planning effort and other State agencies have greatly benefited from NASA operations, specifically the U-2 underflights of ERTS. (We estimate that to do this type of data gathering and mapping on our own would have cost the State over \$50,000. Furthermore, it is obvious that the ERTS satellite imagery will be the most rapid and efficient means of monitoring, updating, and maintaining State information on our natural resources.

Information is the currency of planning and we find too often that lack of information is the main limitation in effective planning decisions. Up to now, such information has not been available in collected, coordinated, and retrievable form by either government agencies or the private sector.

Of the two senate bills, I would prefer S3484, in that an agency such as the Department of Interior is more likely to be acquainted with the domestic data needs than NASA. I would also like to add that the proposed State level land use bill will be administered by the Department of Interior and it would be best to locate the data function within that federal agency that has responsibility for land use planning.

I want to thank you very much for informing me of this very important proposal and I hope that you will keep me informed of developments in the future.

Sincerely,



Kenneth M. Curtis
Governor of Maine

KMC:mg
5500



MARVIN MANDEL
GOVERNOR

STATE OF MARYLAND
EXECUTIVE DEPARTMENT

ANNAPOLIS, MARYLAND 21404

August 12, 1974

Honorable Frank E. Moss
Chairman
Committee on Aeronautical and Space
Sciences
United States Senate
Washington, D. C. 20510

Dear Senator Moss:

We in Maryland are well aware of the benefits and potentials of the Earth Resource Technology Program. As investigators with ERTS-1 data, the Maryland Department of State Planning has proven that there is a substantial role for ERTS and other remotely sensed data in an integrated planning program.

I feel that three substantial points must be made in line with the two proposals before your Committee, the intent of which I concur.

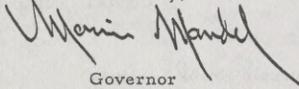
First, there should be a continual and undisrupted flow of both ERTS and high altitude imagery to a broad user community. (A backlog of a month at the Sioux Falls facility is a significant disruption for many users of ERTS).

Second, that every effort needs to be made to increase the imagery resolution of an "operational" ERTS from that of the "experimental" ERTS. Resolutions similar to those produced by the Skylab project might significantly reduce our needs for supporting high altitude photography.

Third, I concur with the specifics of S. 3484 which would place within the Department of Interior, the Earth Resources Observation Administration. It has been the experience of the Department of State Planning that the National Aeronautics Space Administration (NASA) system is one pervaded by technology, with little experience and/or responsiveness to problems and techniques that are not or do not reflect "pure" science.

I hope you find these comments of interest. By carbon of this letter, I request that Vladimir Wahbe, Secretary, Department of State Planning, forward a copy of this final report to NASA which is to be completed during the early Fall of this year. If you have any specific questions, you may wish to contact Secretary Wahbe of his staff.

Sincerely,

A handwritten signature in dark ink, appearing to read "Warren E. Hearnes". The signature is fluid and cursive, with a long, sweeping tail that extends to the right.

Governor

STATE OF MICHIGAN



WILLIAM G. MILLIKEN, Governor

DEPARTMENT OF NATURAL RESOURCES

 STEVENS T. MASON BUILDING, LANSING, MICHIGAN 48926
 A. GENE GAZLAY, Director

NATURAL RESOURCES COMMISSION

HILARY F. SNELL

Chairman

CARL T. JOHNSON

E. M. LAITALA

HARRY H. WHITELEY

JOAN L. WOLFE

CHARLES G. YOUNGLOVE

Ged

July 25, 1974

The Honorable Frank E. Moss, Chairman
 Committee on Aeronautical and Space Sciences
 Washington, D. C. 20510

Dear Senator Moss:

Several of the various state departments, and individual divisions within these departments, are aware of and are using ERTS and RB-57/U-2 imagery in their programs. The Office of Land Use in the Department of Natural Resources has developed and is presently field-testing a land use classification system based upon the proposed USGS system which utilizes both ERTS-1 and underflight photography.

NASA's ERTS and Skylab programs have benefited the state in terms of some information gathered and should probably be changed to an operational rather than research framework. The most relevant part of NASA's program has been the use of RB-57 and/or U-2 underflights for varying land and water information. It is recommended that this part of NASA's program be maintained. There is a wide variety of utilization of aerial photographs taken by NASA at elevations of 40,000 and 60,000 feet.

If further help is needed, please contact Mr. Karl R. Hosford, Chief, Office of Land Use, Michigan Department of Natural Resources, 7th Floor Mason Building, Lansing, Michigan 48926.

Sincerely yours,

James G. Ahl
 Economic Analyst
 Office of Land Use

JGA:jc





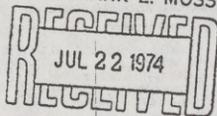
WENDELL R. ANDERSON
GOVERNOR

STATE OF MINNESOTA

OFFICE OF THE GOVERNOR

ST. PAUL 55155

SEN. FRANK E. MOSS



WASHINGTON, D. C.

July 18, 1974

Mr. Frank E. Moss, Chairman
Committee on Aeronautical and Space Sciences
United States Senate
Washington, D. C. 20510

Dear Senator Moss:

Thank you for your letter of June 24 concerning the viability of making the ERTS System operational.

I agree that ERTS has proven its worth and that an operational ERTS System has great potential value. Assuming that an operational system would provide turn-around time on the order of two to three days, that established data acquisition capabilities of ERTS were put in a User's Manual format and that future orbital hardware improvements will allow higher resolution imagery, we can foresee great benefits from ERTS.

If an operational system were permanently established, with imagery regularly available on a long-term basis, we could logically invest more time in establishing a long term program of use and research regarding the potential of the acquired imagery.

To date, other than for experimental projects at the University of Minnesota, little use has been made of ERTS imagery in Minnesota. Applied research into the uses of ERTS imagery has been foregone due to the current status of the program as a research and development project.

Currently, our Department of Natural Resources is contracting with the Remote Sensing Laboratory of the University of Minnesota to develop recommendations to the Department concerning the most effective use of a remote sensing progress. This study is in progress and is scheduled for completion in August of 1975. Formal recommendations as to the use of ERTS imagery will be contained in that report.

If you desire further information, please do not hesitate to contact this office.

With warmest personal regards.

Sincerely,

Wendell R. Anderson

Wendell R. Anderson

WRA/tvb

(see, been in etc.)

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EXECUTIVE OFFICE
STATE OF MISSOURI
JEFFERSON CITY

CHRISTOPHER S. BOND
GOVERNOR

July 24, 1974

The Honorable Frank E. Moss
Chairman, Committee on Aeronautical
and Space Sciences
Washington, D.C. 20510

Dear Senator Moss:

Thank you for your recent letter inviting state government input with regard to the important matter of continuing with the ERTS System program.

Missouri state agencies and university scientists have had opportunities to study and evaluate many of the applications of ERTS imagery through the cooperation of NASA as well as the Department of Interior's EROS Program. We have also utilized data obtained from Skylab and high-level reconnaissance aircraft. Application includes mapping forest coverage in the Grand River Basin, regional structural geology, floodstage mapping, and land-use analysis. Both the Topographic Division and the Water Resources Division of the U. S. Geological Survey have used this data extensively in Missouri, and the Soil Conservation Service is making increasing use of it in their activities.

The potential of the ERTS program is impressive and I am hopeful that it could be established as an "operational" system. Strong emphasis should be maintained with respect to the supportive underflight coverage because of the broad application of that data. The importance of the acceptance and use of the program should not be overlooked.

Your interest in the ERTS program is sincerely appreciated.

Sincerely yours,

Christopher S. Bond
GOVERNOR

CSB:mmd

J. JAMES EXON
GOVERNOR



STATE OF NEBRASKA

August 5, 1974

The Honorable Frank E. Moss
United States Senate
Committee on Aeronautical and
Space Sciences
Washington, D. C.

Dear Senator Moss:

We appreciate the opportunity to provide you with our response to the ERTS program. Our State, through the University of Nebraska, has taken full advantage of the imagery provided by this satellite system.

Two major projects utilizing ERTS imagery have been funded by NASA within Nebraska. A contract (NAS5-21765) provided support for management-oriented mapping of Sandhills rangeland. A University Affairs grant (NGL 28-004-020) promoted the utilization of satellite imagery in areas such as land use classification, irrigated land inventory, detection of tectonic lineaments, reservoir water quality and estimating evapotranspiration. All of these projects were also supported by the University and a broad spectrum of state and local agencies.

A coordinating committee representing all concerned state agencies supported the establishment of a Remote Sensing Center within the Conservation and Survey Division of the University of Nebraska. This placed these remote sensing activities in close coordination with the Division's basic data responsibilities in geology, soils and water. A copy of a recent summary of remote sensing activity is enclosed as well as some of the initial products aimed at serving the citizens of our State.

As you can see, the ERTS system has served as a catalyst to expand the techniques of Remote Sensing in Nebraska. Although initiated by

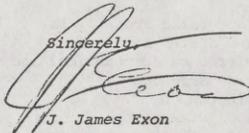
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NASA as a research project, ERTS imagery was quickly established as a tool in applications projects. It would be expected that imagery of this type would continue to be utilized in this manner. It is also of interest that in Nebraska, the applications center for remote sensing was established within a natural resource agency. It has proven beneficial to have the tools of remote sensing, such as ERTS imagery, closely related to a basic data agency.

We feel that both the projects and the products of remote sensing in Nebraska have made full utilization of the data provided by the ERTS system. Imagery of this type, in conjunction with other remote sensing data, provide us with a valuable tool to better understand our State.

Therefore, we would strongly support the intent of the legislation embodied in both S. 3484 and S. 2350. Based upon the direction we have taken in Nebraska, S. 3484 would probably be preferable since the agencies presently involved are more familiar with the Department of Interior.

Sincerely,

A handwritten signature in black ink, appearing to read 'J. James Exon', is written over the word 'Sincerely,'.

J. James Exon
Governor

JJE:ah2

Enclosures



MIKE O'CALLAGHAN
GOVERNOR

THE STATE OF NEVADA
EXECUTIVE CHAMBER
CARSON CITY, NEVADA 89701

August 2, 1974

SEN. FRANK E. MOSS
RECEIVED
AUG 6 1974
WASHINGTON, D. C.

The Honorable Frank E. Moss
United States Senate
Aeronautical and Space Sciences
Washington, D. C. 20510

Dear Senator Moss:

Senate Bills 2350 and 3484 have been reviewed as requested in your letter of June 24, 1974.

Currently utilization of ERTS imagery in Nevada is limited primarily to research being conducted by the Department of Renewable Natural Resources at the University of Nevada. Its work consists of projects designed to determine the feasibility of utilizing ERTS outputs for such things as vegetation changes for grazing management, snow surveys, inventories of standing water in reservoirs, plant phenology as related to fire hazard estimates and precise inventory of areas destroyed by wildfire. Such research involves both Renewable Natural Resources and staff of the Desert Research Institute. A small pilot snow survey is also being conducted in conjunction with the State Division of Water Resources.

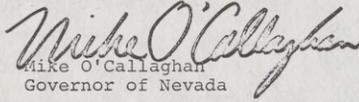
Although ERTS orbital imagery is useful for gross regional measurements, I understand that the high altitude imagery produced with U-2 and B-58 equipment is of much higher resolution and more useful for most purposes.

With respect to the two Senate Bills, observations by staff indicate the following:

1. It is felt that housing the Office of Earth Resources Survey Systems in the Department of Interior rather than NASA might produce results more usable by State and local agencies.

2. In order to encourage more effective utilization of this new technology, especially at the state and local level, incentives such as grants for imagery acquisition or free access to such imagery should be provided.

Sincerely,


Mike O'Callaghan
Governor of Nevada



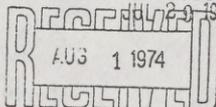
State of New Jersey

DEPARTMENT OF ENVIRONMENTAL PROTECTION

TRENTON 08625

OFFICE OF THE COMMISSIONER

SEN. FRANK E. MOSS



WASHINGTON, D. C.

The Honorable Frank E. Moss
Chairman
Committee on Aeronautical
and Space Sciences
United States Senate
Washington, D.C. 20510

Dear Senator Moss:

The State of New Jersey, specifically the Office of Environmental Analysis, Department of Environmental Protection (DEP), was an ERTS-1 participant under NAS5-21765, "The Application of ERTS Data to the Protection and Management of New Jersey's Coastal Environment." The principal objective of the project was to develop information products from ERTS data to be used in the every day decision-making in the management and protection of the coastal zone.

ERTS data was found to be useful in the area of coastal zone surveillance. Successive orbits were compared to detect changes (mostly developmental) in the coastal zone, which are then reported to field inspectors. DEP regulates these areas under New Jersey's Riparian Law, Wetlands Act and Coastal Area Facility Review Act. As quasi-operational demonstration was completed at the end of the project by quickly processing of computer compatible tapes made available by NASA. Timely delivery of ERTS imagery (3-5 working days rather than the 60-90 day delivery time during the ERTS-1 project) is necessary to the operational use of ERTS data for this purpose.

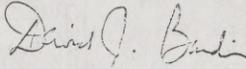
Offshore waste disposal in the New York Bight area was also monitored with ERTS data. The presence and geographical extent of acid and dredge spoil were mapped for each orbit.

File
4-5-7 (m)

Ocean outfall plumes could also be monitored using ERTS data to determine their effect on shore. Also, the percent cover of eel grass and sea lettuce could be estimated from ERTS as an aid for establishing yearly bag limits for the Atlantic brant.

The potential for using ERTS data in an operational mode for New Jersey's coastal zone management program has been shown in this experiment. Timely receipt of data would result in more effective decisions for the benefit of all, and a truly operational ERTS system, sensitive to the needs of the user community, definitely would be in the public's interest.

Faithfully,



David J. Bardin
Commissioner



BRUCE KING
GOVERNOR

STATE OF NEW MEXICO
OFFICE OF THE GOVERNOR
SANTA FE
87501

August 1, 1974

The Honorable Frank E. Moss
United States Senator
United States Senate
Washington, D. C. 20510

Dear Senator Moss:

The State Planning Office under the direction of David W. King, the Technology Application Center (TAC) of the University of New Mexico and the New Mexico State Bureau of Mines and Mineral Resources are jointly involved in studying how the Earth Resources Technology Satellite (ERTS) data may be best used on an operational level.

ERTS data for the State of New Mexico is made available through the TAC at the University of New Mexico. The data is a result of a geological investigation (Geologic Analysis and Evaluation of ERTS-A Imagery for the State of New Mexico) performed by the New Mexico Bureau of Mines and Mineral Resources and the TAC. The emphasis of study has therefore been within a geological vein leading to a greater knowledge of the mineral resources of the State. New Mexico possesses a large mineral wealth as well as excellent geothermal prospects, and a thorough knowledge of the geology is necessary to fully utilize these resources. The value of ERTS in the early investigation has been realized, and a further investigation has been funded.

The ERTS imagery has been increased by the availability of Skylab data and high-altitude aerial photography flown by the National Aeronautics Space Administration (NASA). All of the information is now being housed in one location (TAC) as an effort to localize the data for the region and, in particular, the State of New Mexico.

Through the availability of this data center there has been an increased interest by the public and private sector to use this for mineral exploration, forest disease detection, land use inventorying, updating of drainage maps, detection of increased erosion, phreatophyte invasion, and reservoir changes to mention a few. The interest in this information and in remote sensing continues to increase. To make better

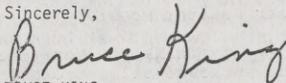
use of this there should be more assistance made to increase the data quality and its effective use. In order to make a transfer of the technology to an operational activity there must be further personalized attention paid to the user and his requirements and limitations. The TAC has performed in this capacity for a large number of people in New Mexico and the Southwest and feels that this is the area of greatest concern at the present—to update the user in the potential and follow through with training, consultation, and service to him.

An operational ERTS system should provide direct applications and realistic expectations to the user in a more usable form than purely experimental and research data. An operational program of multistage remote sensing could assist this Center in its position of research towards application and transfer of experimental results to related user needs.

In view of the urgent need to provide our views to you, I am sending this letter without the rather bulky study of national needs for ERTS data which the TAC prepared for NASA. This study is being transmitted under separate cover.

I hope this information will assist you in your attempts to move the ERTS system into an "operational" status.

Sincerely,



BRUCE KING
GOVERNOR



STATE OF NEW YORK
EXECUTIVE CHAMBER
ALBANY 12224

MALCOLM WILSON
GOVERNOR

July 30, 1974

Dear Senator Moss:

Thank you for your letter of June 24th and the enclosed bills proposing to change the status of the Earth Resources Technology Satellite System to operational.

I agree with your assessment of the value of this satellite system. Several New York State agencies are currently utilizing satellite mapping data for planning, water resources assessment, pollution abatement and other uses. I consider ERTS one of the practical and beneficial products of the space program.

I appreciate the opportunity to comment on the merits of these bills.

Sincerely,

A handwritten signature in cursive script that reads "Malcolm Wilson".

Honorable Frank E. Moss, Chairman
Committee on Aeronautical and
Space Sciences
United States Senate
Washington, D. C. 20510



STATE OF OHIO
OFFICE OF THE GOVERNOR
COLUMBUS 43215

JOHN J. GILLIGAN
GOVERNOR

August 8, 1974

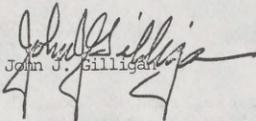
The Honorable Frank E. Moss
United States Senate
Chairman, Committee on
Aeronautical and Space Sciences
Washington, D.C. 20510

Dear Senator Moss:

Thank you for your letter of June 24, 1974 soliciting our opinion of the merits of establishing an operational ERTS system. The Ohio Department of Natural Resources has had extensive experience with using ERTS data on an experimental basis to seek solutions to resource management problems. Two counties in northeast Ohio have been used as a study area for generating current land use map overlays from ERTS computer tapes. Results are very promising and a regular program of using ERTS data to compile land use data is under consideration. Annual updates would be required and much concern has been voiced to the effect that if we start such a program we need to be assured that the ERTS collection system will continue to be a source of input data. It would indeed be good news to have the ERTS system declared operational.

With respect to the two bills (S. 2350 and S. 3484) we recommend positive action on S. 3484, which would establish within the Department of the Interior the Earth Resources Observation Administration. We strongly recommend a distinct separation between the Resource Satellite developments phase and the operational phase. Having an agency such as the Department of the Interior responsible for the operational phase is obviously a very good way to do this.

Sincerely,


John J. Gilligan

JJG/ac



4.5-7(N)

STATE OF OKLAHOMA
OFFICE OF THE GOVERNOR

DAVID HALL
GOVERNOR

OKLAHOMA CITY

July 1, 1974

In answer

SEN. FRANK E. MOSS

RECEIVED
JUL 8 1974
WASHINGTON, D. C.

Senator Frank E. Moss
United States Senate
Committee on Aeronautical
and Space Sciences
Washington, D. C. 20510

Dear Senator Moss:

In the absence of Governor Hall, I am taking the liberty of acknowledging your letter of June 24, 1974, concerning Earth Resources Technology Satellite system.

Upon the Governor's return to the office, I will bring this matter to his attention.

Sincerely,

A handwritten signature in cursive script, appearing to read "J. Schaffner".

James E. Schaffner
Administrative Assistant

JES:se

COMMONWEALTH of PENNSYLVANIA



DEPARTMENT OF ENVIRONMENTAL RESOURCES

P. O. BOX 1467

HARRISBURG, PENNSYLVANIA 17120

July 16, 1974

The Secretary

The Honorable Frank E. Moss
 Chairman, Committee on Aeronautical and
 Space Sciences
 United States Senate
 Washington, D.C. 20510

Dear Senator Moss:

Because my Department has been designated as the lead agency for the Pennsylvania ERTS Program, I have been asked by Governor Shapp to respond to your letter of June 24, 1974.

In February 1973, the Commonwealth of Pennsylvania submitted a proposal to NASA to act as a Principal Investigator for the systems design of a Pennsylvania Environmental Resource and Land Use Information System based on data from the ERTS Program. If feasible, the data acquired would be beneficial to our environmental management needs. Pending a decision by NASA regarding the acceptability of our proposal, various Commonwealth agencies have been utilizing selected ERTS data, to a limited degree, in areas such as land use, land pollution, forestry, subsidence and flooding hazards and geology.

Although we recognize the potential of the ERTS Program, we believe that further research and development is needed prior to the deployment of an operational ERTS system. Therefore, we support legislation which specifies the continuation of the ERTS R & D Program with the specific objective of making it operational. This will insure that ERTS data will continue to be available following the R & D phase.

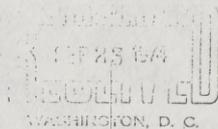
Sincerely yours,

MAURICE K. GODDARD

tot
 ERTS
 Hearings
 45-7(m)



*For
file
m.r.*



State of South Carolina

JOHN C. WEST
GOVERNOR

September 16, 1974

OFFICE OF THE GOVERNOR
COLUMBIA 29211

The Honorable Frank E. Moss
Chairman, Senate Committee on
Aeronautical and Space Science
Washington, D. C. 20510

Dear Senator Moss:

I have solicited the opinions of the men and women of South Carolina State agencies directly involved in uses of remote sensing technology concerning Senate bills S2350 and S3484.

We favor the general concept of a national commitment on the scale proposed to operational satellite collection and dissemination of data on earth resources while recognizing that this is a new tool whose total utility is yet to be developed.

It is the experience of our agency users that the services of both the National Aeronautics and Space Administration and the United States Department of the Interior are essential in the current data collection and delivery system. We use the Satellite data available from the USDI EROS data center in Sioux Falls, South Dakota, certain high altitude aerial photographic film copies flown over the South Carolina coastal plain by USDI investigators, and the general services historically provided through the United States Geological Survey. In addition, the State of South Carolina is a principal investigator on the NASA Skylab Earth Resources Experiment Package, and our agency users currently working with the Goddard Space Flight Center, the Kennedy Space Center, the Mississippi Test Facility and the Johnson Space Center on various aspects of remote sensing using ERTS imagery. We would hope that action taken toward an operational satellite system would enhance the capabilities of both USDI and NASA and not diminish the services of either agency.

Sincerely,

John C. West

JCW:W:JB

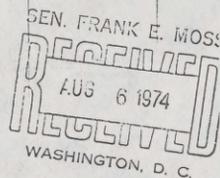


STATE OF SOUTH DAKOTA

RICHARD F. KNEIP
GOVERNOR

EXECUTIVE OFFICE

PIERRE
57501



August 2, 1974

The Honorable Frank E. Moss
United States Senate
Committee on Aeronautical and
Space Science
Washington, D. C. 20510

Dear Senator Moss:

South Dakota, as the home of the Earth Resources Observation System Data Center, is vitally concerned with the continuation and expansion of the Earth Resources Technology Satellite Program. Aside from our interest and pride in being the host state for worldwide users of ERTS data, we are also cognizant of the benefits from the use of ERTS imagery in analyzing land use and resources in South Dakota. We are, therefore, strongly in favor of legislation which would operationalize the ERTS program.

Without the continuing availability of ERTS imagery, the gathering of resource information about our sparsely settled yet resource rich state would be prohibitively expensive. As an example, a land use inventory for the state aimed at identifying land use trends and problems is now underway involving the use of computer tapes from the satellite and photographically reproduced images from the EROS Data Center. It appears that we will be able to assemble state land use information for less than 10% of the cost of the best pre-ERTS techniques.

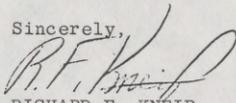
In addition to the direct use of the ERTS data, there has been an upsurge of interest here in South Dakota in a variety of Multi-Spectral Scanning (MSS) programs which, when refined, will greatly enhance the information which can be gleaned from ERTS transmissions.

In reviewing the proposed bills (S2350 and S-3484), we assume that additional satellites are authorized but funds have not yet been committed to NASA for launching further satellites or for the perfection of other specific sensor technology.

We would most strongly endorse Senate Bill 3484, introduced by Senators Abourezk, McGovern and Young, as the best approach to establishing a permanent program of earth resources observation and utilization. It would be preferred, particularly from an applications point of view, to have such a program located within the Department of Interior in order to provide maximum coordination with the existing program of the U. S. Geological Survey.

It would appear that major research and development responsibilities for Earth Resources Satellite Systems would continue to rest with the National Aeronautics and Space Administration in either case.

Sincerely,



RICHARD F. KNEIP
GOVERNOR

RFK/ake



cont
etc
4.5-7(11)

Winfield Dunn
Governor

State of Tennessee

August 8, 1974

The Honorable Frank E. Moss
United States Senator
Committee on Aeronautical and
Space Sciences
Washington, DC 20510

Dear Senator Moss:

I have your letter of June 24 and believe that changing the current ERTS system to one of an operational program would be of assistance to the scientists within our state who currently utilize ERTS data. This would also hopefully eliminate the time delay in getting data from Sioux Falls which in our experience takes from 60 to 90 days.

There are many programs in Tennessee that utilize ERTS data, including the University of Tennessee, East Tennessee State University, the Tennessee Valley Authority and the U. S. Geological Survey. In addition, several state agencies are using ERTS data to monitor change on the earth's surface.

I believe that passage of a bill similar to S. 2350 or S. 3484 would assist the state in many of our programs.

Sincerely,

Winfield Dunn
Winfield Dunn

WD:ccg

THOMAS P. SALMON
GOVERNOR



STATE OF VERMONT
EXECUTIVE DEPARTMENT
MONTPELIER, VERMONT
July 19, 1974

4.5-7(N)
SEN. FRANK E. MOSS
RECEIVED
JUL 25 1974
LEGISLATIVE
WASHINGTON, D. C.

Senator Frank E. Moss, Chairman
Committee on Aeronautical and
Space Sciences
United State Senate
Washington, D.C. 20510

Dear Senator Moss:

Thank you for your letter of June 24th inviting me to comment on the merits of establishing an operational ERTS system.

Vermont is definitely interested in the application of the ERTS system, particularly for environmental surveillance. Dr. Martin L. Johnson, my Secretary of the Agency of Environmental Conservation, is a member of the Space Applications Board, National Academy of Engineering, and he has advised me of the great potential for the ERTS system. As a practical application, the State of Vermont, at the present time, has entered into a modest contract with the Department of Geography at the University of Vermont employing the ERTS system for general surveillance of environmental parameters for the Lake Champlain area.

We anticipate expanding this surveillance in the future, and I feel that the bills, S.2350 and S.3484, would be very helpful in furthering these efforts.

Sincerely,

Thomas P. Salmon
Governor

TPS:AWA

cc - Dr. Martin L. Johnson, Secretary
Agency of Environmental Conservation

4.5-7111

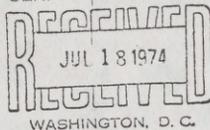


MAURICE B. ROWE
SECRETARY OF ADMINISTRATION
P. O. BOX 1475
RICHMOND 23212

COMMONWEALTH OF VIRGINIA
OFFICE OF THE GOVERNOR

July 17, 1974

SEN. FRANK E. MOSS



The Honorable Frank E. Moss
Chairman
Committee on Aeronautical and
Space Sciences
United States Senate
Washington, D. C. 20510

Dear Senator Moss:

We appreciate your invitation to comment upon the proposals to establish an operational Earth Resources Technology Satellite (ERTS) system. In response we offer the following views.

Although there is currently no practical, on-going use of ERTS data being made by state agencies in Virginia, several agencies have strong interests in exploring the potential for applications of such technology in the future. Informal experimental applications thus far include regional land use and land cover inventories from ERTS, CARETS, and high altitude color infrared products and the possible mineral location based on lineaments shown in ERTS images. The results of these, as well as the results of more formal experiments from throughout the United States indicate a great potential for the use of ERTS data.

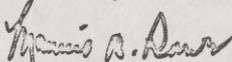
This technology should prove to be a valuable tool in the geographic sciences, planning, and resource management and should continue to be refined and developed toward greater reliability, greater detail, and easier user access and application. Toward this end, it would seem that the establishment of an "operational" ERTS program at this time would be of great merit.

Because the usefulness of remote sensing data is closely related to and in most cases dependent upon the display of the data in map form, it would seem appropriate to assign an operational ERTS program to an agency, such as Department of Interior, U. S. Geological Survey,

which already has much experience in mapping and could provide for the integration of this new technology into an existing program.

The Commonwealth of Virginia is looking forward to taking further advantage of the resource of remote sensing technology in the future. We hope these comments add some support to efforts to make this possible.

Sincerely,



Maurice B. Rowe

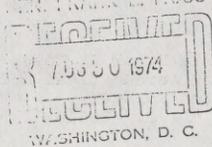
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STATE OF WASHINGTON
OFFICE OF THE GOVERNOR
OLYMPIA

DANIEL J. EVANS
GOVERNOR

August 19, 1974



The Honorable Senator Frank E. Moss
Chairman, Committee on Aeronautical
and Space Sciences
Washington, D.C. 20520

Dear Senator Moss:

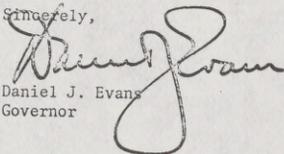
The Earth Resources Technology Satellite (ERTS) has provided valuable information to both the agriculture and forestry industries and to the State of Washington. Our Department of Natural Resources, through its Resource Inventory Division, receives and distributes the ERTS imagery data. We have, for example, used ERTS imagery in evaluating Tussock Moth damage to the Douglas Fir which has been a major problem to this state. On the 2 million acres of state-owned forest land, the Department of Natural Resources has also utilized ERTS to accumulate timber inventory information and data needed to establish the annual allowable timber harvest.

The Department of Natural Resources is not the only agency taking advantage of the ERTS system. The Department of Ecology uses ERTS in several programs; Shoreline coastal zone management to delineate wetlands and ocean beach vegetation; dam monitoring; and water baseline studies relating to oil spill risk areas. The University of Washington has two major projects in their Urban Planning and Civil Engineering Departments, which use ERTS imagery.

We are continually discovering new ways to apply ERTS imagery to the management of our state's resources. We are presently developing computer capabilities which will translate ERTS data into computer generated land use charts. Such developments make us very enthusiastic about the potential long range benefits available to Washington as a result of the ERTS program.

I wholeheartedly support your efforts for an operational ERTS system. If I can be of further assistance in generating support for this project, please feel free to call or write.

Sincerely,


Daniel J. Evans
Governor

DJE:s



STATE OF WEST VIRGINIA
OFFICE OF THE GOVERNOR
CHARLESTON 25305

Gi

4.5.71W

ARCH A. MOORE, JR.
GOVERNOR

July 24, 1974

The Honorable Frank E. Moss, Chairman
Committee on Aeronautical and Space Science
United States Senate
Washington, D. C. 20510

Dear Ted:

Thank you for the opportunity to comment on the Earth Resources Technology Satellite Program.

The West Virginia Department of Natural Resources has worked with the Earth Satellite Corporation in trying to develop a project in the State on both the ERTS-1 and the ERTS-B Satellite, and my Office of Federal-State Relations has worked with Battelle Corporation to initiate a similar program. These projects were aimed primarily at recreation inventory, land-use inventory, mining disturbances, and natural and man-made impoundments. Neither of these programs is a reality at present, so we have no direct experience from which to speak.

However, review of some of the work that has been done elsewhere encourages me to believe that the ERTS Program could be extremely beneficial to the states in the discharge of their planning and regulatory responsibilities.

If I may be of further assistance, please do not hesitate to let me know.

Sincerely yours,

Arch

Arch A. Moore, Jr.
Governor

AAMJr:mkp

Mr. SYMINGTON. Who was the one?

Senator Moss. The Governor from Delaware. Maybe he doesn't have enough area to expose to ERTS.

Mr. SYMINGTON. That may be true.

Senator Moss. During our hearings, we found overwhelming support for prompt development of remote sensing satellite systems in the scientific and user communities.

And, I am sorry to report, it has become clear that opposition in OMB is increasing, or at least hardening.

The full reasons for OMB opposition are not so clear. It has been suggested that a sort of "Catch 22" is at work here. By that I mean the theory that if ERTS isn't cost effective, no one should support it, and if it is, private industry will—so that, in either case, NASA should cease and desist.

In the Senate hearings, we had testimony from NASA, the Department of the Interior, the Department of State, and the Office of Management and Budget. In addition, we heard from both the academically oriented and the profitmaking portions of the user community. And a number of national professional organizations submitted written testimony, all highly favorable to ERTS.

I conclude, from the record developed in the Senate:

(a) That experimental operations with ERTS-type satellites should continue, with specific emphasis on continuity of data availability and evolution in each field of use toward realistic operational status.

(b) That remote sensing technology, and perhaps more importantly our ability to use remote sensing technology, should be pressed forward vigorously.

(c) That particular emphasis is needed on the international policy implications of this rapidly maturing space capability—we should be leaders in seeking solutions, not bystanders while others raise problems.

With these points in mind, let me list the steps that I believe ideally should be taken at this time:

1. ERTS-B should be launched on schedule;

2. Work should start immediately on ERTS-C, incorporating the fifth MSS channel;

3. We should begin promptly to design, develop and prepare for launch an advanced Earth resources satellite, incorporating those improvements which our experience with ERTS-1 indicates we need;

4. Based on careful estimates of the time period required to design, develop and procure this advanced satellite, planning should begin for purchase of that number of additional ERTS-C type satellites needed to assure continuity of data during this experimental phase;

5. We should significantly augment our efforts at improving both the timeliness with which data moves through the ground based systems, and the utility of the resulting information to various users; and

6. The executive branch should devote higher level attention to the foreign policy issues and opportunities that ERTS represents.

In listing these steps, I am willing to grant to OMB that we might ultimately decide not to have an operational system. These steps would not commit us to such a decision. But if each of these steps were taken,

we would be in a position in a few years to decide on the precise structure and type of permanent operational system we need. And our decision could be based on a realistic assessment of the experimental phase, including an assessment of how useful the data was when it was available continuously, promptly, and in the right formats.

I have little doubt that the decision would be to proceed to a permanent system.

Unless the OMB position changes, I believe that what will happen, as opposed to the steps I have outlined, will be that ERTS-B is launched on schedule. And that may be all.

The remaining steps may very well not be taken. OMB testified before our committee that if evaluation of the experience with ERTS-B indicated that a third experimental satellite would be cost effective, then and only then would OMB support a third satellite. This attitude means most clearly that there will be an extended period—perhaps 4 or 5 years—between the time when ERTS-B can be expected to fail in orbit and a third Earth resources satellite would be launched. It is difficult for me to perceive how a realistic evaluation can be made of the utility of the data to the diverse foreign and domestic users under these circumstances. Nothing could serve to more rapidly dampen user interest than the certainty of an extended gap—if not a dead end—after ERTS-B.

The testimony before my committee does indicate a need to improve the spacial resolution of the ERTS data, or at least the need to experiment with improved resolution, before deciding on the technical design of an operational system. I understand that it might be possible to achieve this goal partially in ERTS-C by modifying the return beam vidicon instrument. However, full fledged improvement of resolution would require a new satellite, and thus a lengthy period of design and development.

I believe that the results from ERTS-1 are of sufficient promise that we can well justify the relatively modest investment required to fill the gap between ERTS-B and this improved satellite.

Let me conclude by turning briefly to the bills pending before you. In my opinion, neither bill adequately spells out the institutional arrangements that should be established for continuing the Earth resources satellite program. I believe that improvements in the institutional arrangements now existing are necessary. I note that the executive branch seems reluctant to move forward and I disagree with the OMB that changes are premature. I also reject the OMB contention that settling some of the institutional arrangements now would somehow freeze us into existing technology. However, I believe that the legislation needs further refinement and I hope to work on improved legislation in the immediate future.

If at the conclusion of your hearings you agree with this assessment, I would be happy to work closely with you to see that we correctly determine the kind of legislation needed to provide the efficient and effective fulfillment of the great promise of Earth resources satellites.

This subcommittee, and my committee, have worked toward this end for some years now. Let's keep doing our best.

Mr. SYMINGTON. Thank you, Senator Moss.

You have made a welcome and well-stated, persuasive presentation.

One thought has occurred to me while you were speaking, and I want to sound you out on it. Here we are striving to become energy independent in this country. We are also striving to help other countries to overcome the problems incident to the oil embargoes and the high prices for oil. Most of those problems at the moment are agricultural. They have to do with farming methods. If we really mean what we say to the effect that we are going to help ourselves and others overcome these difficulties, and assume leadership in the world in these matters, why would we want to deny ourselves such a small investment in something which holds such great promise in identifying resources, giving good agricultural information, prognostications of all kinds having to do with crops.

One would think that even the Federal Energy Administration would want to see this thing go. Secretary Butz ought to want to see it go. What Member of the Cabinet wouldn't want it?

The Secretary of Interior has indicated great interest in sponsoring ERTS-C until somebody upstairs told him to lose that interest.

Wouldn't you think in light of all our people face in the next decade, that this, of all programs, would receive full funding, and be given a full-steam-ahead approach?

Senator Moss. Mr. Chairman, you are absolutely correct. I would think that this would get the highest priority from the administration.

I had the opportunity of hearing Vice-President Designate Nelson Rockefeller deliver a speech yesterday. One of the things I recall from that speech was his pointing out that there are only three food exporting nations in the world and they can't go on carrying that load indefinitely. Therefore, one of the things we must give immediate and intensive attention to is developing the food-producing capacity of other nations of the world. Mr. Rockefeller suggested we export our food-related technology, our knowledge of fertilizers and whatever else might help food production, so that others could feed themselves.

ERTS is one of the greatest tools we could use in determining what their arable areas are, what their water situation is and what disease controls are needed. One of the things that was discussed at some length in our hearings was the possibility that we may now be in a cooling phase in our weather. This may be a half a degree per year at present. If there is a cooling trend, the arable lands and the optimum production will decline. We need information for countries other than just the Great Plains of Canada, and the United States, where much of the wheat is grown.

Mr. SYMINGTON. Senator, that is a very important point. In fact, it brings to mind another coincidence, and that is that today's temperatures recorded throughout the country, I think are record lows throughout the Nation.

Senator Moss. That is right.

Mr. SYMINGTON. Mr. Bergland is with us.

The Senator has made an outstanding statement. Do you have any questions?

Mr. BERGLAND. None, Mr. Chairman.

I am impressed with what I have heard.

Mr. SYMINGTON. Senator, I want to thank you very much for joining us today, and taking time from your busy schedule to be with us. We know you have other appointments, so we will conclude your testimony at this point.

Senator Moss. Thank you. I appreciate the opportunity to come.

Mr. SYMINGTON. Thank you, sir.

At this time I would like to call attention to the statement submitted by Senator James Abourezk of South Dakota, a member of the Committee on Aeronautical and Space Sciences, which he has asked us to insert in the record. He has also asked that certain questions be addressed to Mr. Loweth of the Office of Management and Budget, which we will do by inserting these questions into the record at this point. Mr. Loweth and his colleagues can answer these questions and submit the answers for the record.

Without objection, these insertions will be made.

[The statement, questions, and answers above referred to are as follows:]

STATEMENT BY SENATOR JAMES ABOUREZK (DEMOCRAT, SOUTH DAKOTA)

Mr. Chairman, I can't help wondering why success is so hard to accept. In our authorization hearings for both 1974 and 1975, we received convincing evidence of the value of the ERTS systems and the need to insure continuous availability of ERTS data. On December 10th to the 14th, 1973, at the Third Symposium on "Significant Results Obtained from the First Earth Resources Satellite" sponsored by NASA in Washington, D.C., investigators from all over the world presented hundreds of papers in 2000 pages of proceedings outlining the benefits to citizens of the earth from ERTS data. Many of these investigators emphasized the need to insure continuous availability of ERTS data.

Letters were sent to the Governors of all the States inquiring as to their use of ERTS data. The result has been replies from 28 Governors with an overwhelming endorsement of the ERTS program, an indication that the majority of their States use ERTS data routinely and that 80% of them are experimenting with new uses of ERTS data.

I have an extensive study commissioned by the State of South Dakota and performed by the General Electric Company on the use of Remote Sensing for resource management in South Dakota. I was pleased and surprised to discover the extensive use already being made by my State of ERTS data and to understand the great potential which this data has for resource management in South Dakota.

What have we found out from all of these reports, letters and studies?

We are faced with drought and ERTS can make major contributions in water management and finding new sources of water.

We are faced with energy shortages and ERTS can provide an important tool in the search for new sources of fuel and of geothermal energy.

We are faced with food shortages and ERTS can provide aid in improving food production.

We are faced with material shortages and ERTS can provide previously unavailable prospecting assistance in the search for new mineral sources and aid in the management of our forests.

We are faced with environmental problems and ERTS imagery is already important in the control of pollution and the improvement of our environment.

In spite of all these facts, we seem unwilling to accept the success of ERTS. We have no plan to insure continuous availability of ERTS data. An improved ERTS satellite is a long way away and there is little evidence of strong Administration commitment to convert this outstanding research and development success into a permanent program to benefit our citizens.

These are the considerations that led to the introduction of both H.R. 14978 and H.R. 15781. What we need to do now is "get on with it," and organize ERTS to the greatest benefit of our people.

Question 1. The National Oceanographic and Atmospheric Administration was never subject to any of the bureaucratic stalling that EROS has had to face, yet they are extremely similar in most ways. Why is there a difference in the way the two have been handled?

Answer. The meteorological satellite program was different in a very important respect. There was a known well defined demand of very substantial size for meteorological information reflected in the existing uses and users of the meteorological information already produced by NOAA without benefit of a meteorological satellite system. Furthermore, the value of improved meteorological information was relatively well understood. The primary questions then were whether the satellite system could (1) meet that known demand more effectively than the existing methods of collecting information, and (2) improve the quality of the information provided to users.

The situation with respect to the EROS products is substantially more complex. Most of the potential users never had products of this type before. In many cases, the resource information which can be produced from such products has never been available to the resource manager in any form and therefore his decision processes and management processes are not designed to utilize such information. Therefore, the value of the information and the best way to go about using it is highly uncertain.

The difference between the meteorological information system and the earth resources information systems mean that the rapidity with which a new technology can be applied are very different in the two cases. It would be a serious misinterpretation of the facts to attribute this difference in ability to apply new technology to "bureaucratic stalling." We believe that the current pace and development strategy for achieving useful application of the ERTS technology to resource management problems is sound. We recognize, however, that given the complexities of resource management systems, the fact that much of the information is entirely new in character, and the substantial uncertainties about the value of that information and how best to go about utilizing it, that different observers can legitimately disagree about the appropriate pace and strategy.

Question 2. In a letter from Frank Zarb of August 5, I was provided a list of over a dozen studies which have been undertaken on the "estimated costs and benefits of an operational ERTS/EROS system." Could you provide the Committee with the same list of studies?

I understand that the studies which have been made thus far have actually cost more than the total budget for EROS in the last two years. Why does OMB feel another study is necessary? What will you get out of the present study that you didn't get out of the others?

Answer. In response to your request we are enclosing a list of all major evaluation studies which have been completed on the subject of earth resources satellites. This list is identical to the one we provided to Senator Abourezk. These studies, even if all considered together, do not provide an adequate evaluation of the costs and benefits that might reasonably be anticipated from operationally using an ERTS type system in the 1977 through 1986 period. There are several reasons why this is so:

a. With one exception, the previous studies were carried out over the period 1965 through August 1972 prior to the availability of actual ERTS data. They, therefore, could not reflect actual experience in handling ERTS data and extracting information from it. For this reason they are necessarily hypothetical in character.

b. Many of the previous studies were not addressed to the question of quantitatively evaluating the costs and benefits of using ERTS technology, but were aimed more narrowly at identifying and describing potential applications.

c. The previous studies, even if all considered together, do not comprise a systematic survey designed to identify and evaluate all significant sources of benefits based upon current knowledge of actual ERTS capabilities and how they might be used.

d. The economic methodologies in those previous studies which did attempt to evaluate costs and benefits are not consistent from study to study. In some cases the methodologies do not meet currently accepted professional standards for project evaluation purposes. For these reasons, they cannot be taken together to comprise an acceptably systematic evaluation.

With regard to comparing the cost of all the studies to the EROS budget for the past two years, the cost of all of the studies is not readily available informa-

tion. However, the current cost/benefit study is by far the most comprehensive and the total contract cost for it is only slightly more than \$1.5 million. Rather than comparing the cost of the studies with the budget for the EROS program (about \$9.0 million in FY 1974 and \$8.2 million in FY 1975), we believe a more appropriate comparison would be with the potential cost of a fully operational ERTS satellite system which would involve costs ranging in the hundreds of millions of dollars.

Question 3. In an April letter to me, Frank Zarb indicated that the long delay in getting data to the users is primarily due to "the move to the new facility," "late equipment installation," "a large increase in one time customer demand," and "the integration to a new, on-site contractor." Is OMB saying that a major factor is not the fact that the receiving station and the disseminating station are 1500 miles apart and that the data is sent that distance by mail? Wouldn't it alleviate delay to provide the Data Handling Facility in Sioux Falls, South Dakota, with the necessary technical hardware to receive and process incoming ERTS imagery, thus avoiding the use of several locations and handlers?

Answer. The information quoted in your question was supplied to us by the Department of the Interior as an explanation for the delays in filling customer orders at the EROS Data Center during the winter of 1973 and spring of 1974. In September we discussed with NASA the time table for the delivery of ERTS-1 Images from Goddard Space Flight Center to Sioux Falls Data Center. The fact that the receiving station and the disseminating station are 1500 miles apart results in a 2-3 days transit time. Hence the savings would be estimated to be 2-3 days. We continue to believe since the ERTS satellite still is experimental, that heavy costs for additional equipment at Sioux Falls should be avoided when reasonable alternatives exist. The present data receiving and processing arrangement appears reasonable for an experimental program.

Question 4. In Mr. Zarb's April letter to me he stated that by "increasing the prices of EROS data" the "number of unnecessary requests" will be eliminated. What do you consider an unnecessary request? How many unnecessary requests have there been in the last fiscal year?

Answer. The requests characterized as "unnecessary" in the April 26 letter are those requests which users would not find worth making at the increased prices now charged for ERTS products.

For example, Eastman Kodak Company purchased a series of advertisements in national magazines beginning about October 1, 1973 which said, in short, "see your home town from space, write the EROS Data Center."

The one time curiosity purchase customer demand resulting from this advertising series is one example of the kind of "unnecessary" requests meant by the April letter. Such requests not only produce little benefit for the Nation, they also delay the timely filling of requests from users with more serious purposes.

Needless to say, the EROS Data Center will continue to fill all requests from purchasers who are willing to pay the standard prices for ERTS products regardless of the user's purposes. The April letter was simply trying to make the point that the price increases made for other reasons would have the side benefit of helping to expedite delivery times by eliminating curiosity requests from purchasers who are unwilling to pay the new prices.

Question 5. It would seem to me that one indication of the utility of this system would be the demand for it by U.S. taxpayers as well as foreign users. Yet, Mr. Zarb has stated to me that OMB has sharply reduced the number of products available to users. Since this will obviously also reduce the number of users and the ways in which EROS data can be used, isn't it true that will fail in getting an accurate picture of the potential of and the demand for EROS data? Is this being taken into account in the present cost/benefit analysis?

Answer. OMB has not "reduced the number of products available to users." The Department of the Interior had concluded that the demand for certain kinds of ERTS products was not sufficient to justify the continued inclusion of those products on the standard product list. OMB did not make that decision nor did it intervene in it.

Users who may require those products that were dropped from the standard product list can still obtain them by submitting a custom order.

Mr. SYMINGTON. I might note Senator Abourezk has been a leader in this effort on the Senate side along with Senator Moss, and we on the House side are grateful for their joint efforts.

Before we move on to our next witness, the General Electric Co. has been invited to give the subcommittee a short demonstration of a new digital computer technique for analysis of ERTS data.

We have Mr. Sheldon Haas, of the Space Systems Department of GE, who will make this presentation.

**STATEMENT OF SHELDON HAAS, SPACE SYSTEMS DEPARTMENT,
GENERAL ELECTRIC CO.**

Mr. HAAS. Thank you, Mr. Chairman.

I have with me associates from the GE Co., Mr. Bruce Lees and Mr. Earl Schaller. We are very pleased to be here today to bring you this presentation.

Mr. SYMINGTON. We welcome all of you gentlemen.

We are glad to have you here.

Mr. HAAS. We are currently working with many elements of the user community that were described this morning by yourself and Senator Moss.

We are helping them interpret and understand some of the unique qualities of the ERTS data.

This presentation is aimed at establishing those unique qualities. We have very strong convictions that these are the qualities of the program that may not be fully understood by many of the people associated with it, and so we think that this presentation will help to answer some of those questions relative to these qualities.

If you have any questions, we will be pleased to answer it after this short 7-minute presentation.

Mr. SYMINGTON. Please proceed.

Mr. HAAS. Thank you.

[Film presentation.]

Here's a photograph (Scene 1) you're familiar with. It's a photo of the Washington, D.C. area from the Earth Resources Technology Satellite. But this photo was not taken by a camera on board ERTS using film. It was captured by multispectral sensors and transmitted electronically by ERTS to the ground in digital form.

Digital data are simply numbers. More than 25 million numbers describe each scene. We can use the digital data, stored on magnetic tape, to generate a display of the scene on a color tube. Photographs are an efficient and economical way to disseminate ERTS data. But a photo cannot convey all of the information actually transmitted from ERTS as digital data. The digital data contains multispectral information invisible to the eye, but easily analyzed by a digital computer. And the computer always sees the same thing the same way from a digital image.

(Scene 2) The system we use to analyze data from ERTS images is General Electric's IMAGE 100 Multispectral Image Analysis System . . . (one of several such systems developed by government and industry.) We're going to use it now to demonstrate how digital data from ERTS can be applied to land and water resource management.

Our first example involves the Patuxent River Watershed area east of Washington, D.C. (Video Insert #1)

The increase of urban growth along the upper waters of the Patuxent have contributed heavily to the siltation and wastes present in this eighteen mile stretch of the river centered around the Benedict/Chalk Point area. These pollutants forced the State of Maryland in 1973 to close the area to shellfish harvesting for health reasons. (Video Insert—CRT—#2)

(Scene 3) Recently, we performed a study of the Watershed in conjunction with the Maryland National Capital Park and Planning Commission and (Video Insert No. 1) NASA's Goddard Space Flight Center. As part of this study, ERTS digital data and (Video Insert No. 2) IMAGE 200 were used to determine the various classes of water quality indicated by the multispectral data.

(Scene 4) To start the analysis, we place the white rectangle, or cursor, over one section of the river to provide a so-called "training area". The system "learns" to recognize the characteristics of this area by examining all of the numerical values within it. The system then examines the numerical values of the entire image and identifies all areas having the same water quality characteristics. This is the area *highlighted in green*. Working on digital data at computer speeds, the system analyzes more than 350 square miles in just seconds. We can repeat this process of "training" and identification to define additional classes of water quality. Here our first class is now shown in blue and a second class appears in green. This effort resulted in identification of a total of five different classes of water quality within this short 18 mile span of the river. The last three classes contain the area closed by the Maryland State Health Department. This analysis shows clearly the full extent of the area affected and provides significant information for planning on-the-spot water quality testing. This information and the techniques by which it was obtained are being examined now by representatives of Calvert, Charles and St. Mary's counties, who are seeking inexpensive, yet reliable ways to meet their responsibility for water quality monitoring for over 600 miles of river and Chesapeake Bay shoreline.

(Scene 5) From the point of view of environmental impact, this identification of water quality is incomplete without a corresponding inventory of land use in the area. (Video Insert No. 1 CRT) Using the same techniques of training and identification, the digital ERTS data shows the area is dominated by forests and farmland. The assessment of the returns shows 135,000 acres of forest while 55,000 acres of farmland have been identified and assessed. In all, over 1.4 million acres along the river were analyzed, at an average cost of seven-tenths of one per acre.

(Scene 6) In another study, our task is to identify different crops in (Video Insert No. 1 CRT) this scene of south central California transmitted by ERTS on May 26th. The main crop is cotton, although large areas of safflower and alfalfa are also grown. Early and accurate knowledge of planted acres for each crop can aid in meeting agricultural needs on a national and even worldwide basis. The overlapping crop calendar which occurs in this region, and in most other farming areas, often makes accurate inventories difficult, especially when a single image is used. In this case, the system accurately identifies the young cotton, but also enhances certain areas of other crops.

(Video Insert No. 2 CRT) Even using another scene, transmitted by ERTS on a later date, an accurate inventory is difficult to obtain.

But by taking advantage of the repetitive coverage ERTS provides, and combining data from both dates into a single composite image (Video Insert No. 3 CRT) we can eliminate all ambiguity. Cotton appears as turquoise, safflower as pink, and alfalfa as yellow. (Pause)

(Scene 7, Wide Shot, Video Insert #1) In Summary, the ERTS system is demonstrating that it is well suited land and water resource management.

(Video Insert #2-Tapes on Computer) ERTS data is in digital form and therefore can be readily processed and analyzed in minutes by digital computers.

(Video Insert #3) ERTS data is multispectral and therefore does not rely solely on visible characteristics for identification. Features of interest, both natural and man-made, can be accurately classified by their spectral characteristics.

(Video Insert #4, MS Zoom to LS) Since ERTS data is obtained on a regular repetitive basis, change, growth, and new events are readily identified and analyzed by digital processing.

Both government and industry are developing digital systems for processing and analyzing ERTS data. Many of these systems are now in use and more are being installed in the United States and other countries. A continuing flow of ERTS imagery, along with these systems, will let us carry on research needed to develop useful ways to apply multispectral imagery to better managing our land and water resources.

Mr. SYMINGTON. Very interesting. Very encouraging, Mr. Haas, because one of the objections to the ERTS program development has been that data is difficult to analyze and difficult to interpret. It is very difficult to get people to understand and operate the data equipment.

What you have shown us looks to me like a breakthrough in that regard, making the data much more intelligible to a much wider variety of analysts.

Mr. HAAS. We have attempted to implement in this machine the capability of a computer, and to put in the hands of the individual user who is used to looking at imagery, photographic imagery, understanding it, the power of all the information that is contained in the data when it comes from the spacecraft. In this manner he can interact with that information in a much more detailed way. It gives him a great deal of strength and power to use at his command and bring forth all of the information content of the data.

Mr. SYMINGTON. I think it fortuitous that the emphasis in this presentation was on crop predictions because this can have an effect on shipping arrangements that must be made in a particular time as well as all the more obvious aspects of that kind of prediction.

If we are going to try to help mankind solve his food problems, it looks as if this type system isn't just useful; it may be essential at this point.

Mr. Bergland?

Mr. BERGLAND. Thank you very much, Mr. Chairman.

You are certainly right with respect to the need for up-to-date and more precise information, particularly as it relates to crops and crop conditions, not only within the United States, but worldwide.

My question goes to the cost-effectiveness of the system. The case of the Patuxent River was cited as an illustration, an area in which more conventional surveying methods are easily applied, the underground, Indian River testing and measuring systems that have been used over the years. I can understand the application of this system in remote areas where such systems are not feasible or perhaps not possible.

Can you tell me what your results have been with respect to the cost-effectiveness of using this system in areas that are generally accessible to teams using more conventional methods?

Mr. HAAS. We have not made a direct comparison, but we do have a cost for the service and for accomplishing this work and having people on the payroll that do interpretation and support individuals as well. We have not made any direct comparison of what it would cost to go out and obtain the information by having been there and walking the ground.

We are not really sure that in all cases it will directly supplant that. We think that the ERTS right now is a research tool that is providing significant information to the people who are doing it and over a course of time when people will begin to rely on this information much more strongly, we will see some of it supplementing other methods, but right now, I don't think there is a direct comparison.

There is no question that this data can focus people to areas where they need to go, just as described in the presentation.

Mr. BERGLAND. I believe your presentation stated that the cost of surveying the land in that region was seven-tenths of one cent per acre; is that correct?

Mr. HAAS. That is correct.

Mr. BERGLAND. It seems to me that would be very competitive. I would doubt very much any land-based team would do that kind of work for that cost?

Mr. HAAS. I am certain that is true.

Mr. BERGLAND. What kind of costs went into the computation of that figure, seven-tenths of one cent?

Mr. HAAS. The costs were associated with the use of the machine, personnel that did the analysis and the classification that wrote the final report, evaluating what it was we interpreted from the data.

Mr. BERGLAND. Could it be said that this was an accurate reflection of actual costs?

Mr. HAAS. To do that study, yes, sir.

Mr. BERGLAND. Did the information derived from that survey—was it equal to or better than the information that would be derived from ground-based dimensional survey systems?

Mr. HAAS. I think we would have to have that question answered by the Maryland State Park Commission, because they are the user of this data. They have that kind of information available to them.

Mr. BERGLAND. What have they told you, if anything?

Mr. HAAS. I am not sure.

Mr. SCHALLER. The data meets all the known maps that they have. It is being investigated now by other people in other counties but today it has met all of the known plans that were laid out, known maps of land areas, forests, etc., in the area.

Mr. BERGLAND. I am encouraged by this. I think the system offers great potential.

I represent a farming district in Minnesota, a district that has been hit hard by the vagaries of weather this summer. The implications of this of course are represented in the newspapers every day. We really don't know at this point to what extent the crop has been damaged by the adverse weather conditions of this year but we do know that we had better find out because it is going to impact the entire economy.

The quicker we get more accurate information, the better planners and leaders can make their contribution in a presentation to a reasonably stable society.

Thank you, Mr. Chairman.

Mr. SYMINGTON. Thank you for those observations, Mr. Bergland.

I agree with you 100 percent. I want to thank our witness, Mr. Haas and his colleagues, from General Electric for the presentation. It has been of great value to the committee.

Mr. HAAS. Thank you, Mr. Chairman.

Mr. SYMINGTON. Our next witness is Mr. Hugh F. Loweth, Deputy Associate Director for Energy and Science, Office of Management and Budget.

Mr. Loweth has been an official of OMB for 20 years, and he has had a distinguished career with that Agency. He has insight into the attitude and feelings of the Office of Management and Budget for the ERTS program generally and we are happy to have you here.

We look forward to this opportunity to discuss the program with you and hear your views on it. Now, if you would introduce your colleagues, you may proceed with your statement.

STATEMENT OF HUGH F. LOWETH, DEPUTY ASSOCIATE DIRECTOR
FOR ENERGY AND SCIENCE, OFFICE OF MANAGEMENT AND
BUDGET

Mr. LOWETH. Thank you very much, Mr. Chairman.

On my right is Norman Hartness, Assistant to the Deputy Associate Director for Natural Resources, which is a division that is parallel to mine.

And on my immediate left is Thomas Sides, who is a Budget Examiner from our Space Programs Branch in OMB, and further on my left is Mr. Emory Donaldson, who, among his tasks, has been Chairman of the Federal Mapping Task Force that we refer to in our testimony.

I also hope Mr. Chairman, you will permit me the privilege and capability of drawing on my staff.

By drawing on the full staff we will try to deal with what we know is a tough question in your mind, on which we seem to have a very honest difference of views.

Mr. SYMINGTON. We are glad to have the full picture from your office.

Mr. LOWETH. We will do our best.

I might also add that in our prepared testimony we have attempted to reflect the experience of being before Senator Moss and have dealt a little more extensively with the issue of the hiatus in the ERTS data and have otherwise modified our testimony at this juncture to be more responsive, we hope, to what the committee is after.

With that, may I proceed?

Mr. SYMINGTON. Yes, please.

Mr. LOWETH. Mr. Chairman and members of the committee:

I appreciate the opportunity to appear before this subcommittee to present OMB's views on Earth resources survey programs in general and to comment on H.R. 14978 and H.R. 15711 in particular. The Office of Management and Budget views the subject of Earth resources as quite important. We hope that these hearings will serve to more clearly focus the issues which must be addressed as the many nations of the world move forward to better the use of existing technology and management mechanisms, as well as to develop new technologies and management systems, which will help us make decisions for more efficiently using the limited resources of the Earth.

Multispectral remote sensing is, of course, a promising technique to provide Earth resources information. The primary issue is what is the best strategy for developing and using the technology for the benefit of the Nation and the world.

As a first step in developing this strategy we need to consider the extent to which the current multispectral remote sensing technology can be used to produce useful Earth resources information in combination with or as a substitute for other data sources. In this connection, several questions have been under exploration on the basis of information provided by ERTS-1:

a. What are all the kinds of information that can be derived from ERTS-1 type imagery?

b. To what uses can such information be put for making decisions in managing Government programs and private economic activities?

c. What is the value to the Nation of any improvements in decision-making and management which might result from use of information derived from ERTS-1 type imagery?

d. How does this value compare with the costs of producing such ERTS type data or of producing substitutes from other sources such as aircraft or onground data systems?

The first question, namely the kinds of information to be derived from ERTS-1, has been the most extensively explored to date. In a sense it is the easiest question since it involves technical evaluations of the information content of the imagery. Many highly imaginative investigators have been hard at work trying to extract many different kinds of information from ERTS-1 imagery.

Much less effort has been devoted to answering the questions of how such information can be put to meaningful use and of what value and costs such use has to the Nation. We believe that these questions are more difficult to answer. They require an examination of how managers and other decisionmakers would make their decisions without ERTS-1 type information, of how their decisions might be different if ERTS-1 type information were used, and finally, of how these possible differences in decisions might affect the economic and noneconomic well-being of the Nation.

We also believe that unless at least tentative answers are found to these questions, the Nation is likely to make poor decisions about how and when to develop and exploit the technology of multispectral remote sensing. Furthermore we may find ourselves with a premature commitment to a technology that is not sufficiently advanced to satisfy many potential users.

Our primary interest has been and remains one of assuring that these questions and concerns are addressed and that the development of the technology is guided by the best answers that are available.

OMB recognizes that there are those who feel that the ERTS program is not moving as fast as it could. We believe that such criticism does not take into account the complexities of using ERTS information to produce improved resource management decisions. Too frequently experimenters who are developing ways to extract information from ERTS imagery are not the persons or organizations who must ultimately use the information to make resource decisions. As a consequence, such experimenters often do not adequately understand how resource decisions are actually being made, what alternative sources of information are now used and are likely to be used in the near future, and what qualities in terms of identification accuracy, spatial resolution, timeliness, and other characteristics ERTS-type information must have in order to be useful.

Understanding the value of ERTS-type information in any specific resource management application depends upon an understanding and an evaluation of what the decision process and information system would be like both with ERTS-type information and in its absence. Naturally, few of the technical experimenters, as imaginative and innovative as they may be, have the necessary background to make these kinds of evaluations.

Budgetary support of Earth resources activities is a matter of record in the President's budgets submitted over the past few years. ERTS-1 and ERTS-B have been developed as experimental programs to tell us as much as possible about both what information can be extracted from their imagery and how that information might be used in resource management. ERTS-1 has been doing that and ERTS-B will be launched in early 1975 to provide more experimental evidence. Funding for Earth resources survey programs in NASA and the Department of the Interior's EROS program totaled \$54 million in outlays in fiscal year 1974 and \$63 million in the President's budget for fiscal year 1975.

Mr. SYMINGTON. May I interrupt?

Mr. LOWETH. Yes, sir.

Mr. SYMINGTON. Going back to page 4, seven or eight lines from the bottom, "Naturally few of the technical experimenters * * * et cetera, * * * have the necessary background to make these kinds of evaluations."

Who does have the necessary background?

Mr. LOWETH. There we are talking about the decision makers; the people who are in land use planning, who are evaluating crops, policy makers, as well as what we call decision makers.

Mr. SYMINGTON. Suppose those people were involved in making evaluations. Wouldn't that take care of the problem?

Mr. LOWETH. That is what we are trying to do with a major study by the Earth Satellite Corp., that, we believe, will be completed within a relatively few weeks. Certainly we will take that into consideration in the budget season. That kind of hard analysis in our view has really not been completed. We have evidence. Certainly, the presentation earlier today was presumed to be one type of that evidence, that ERTS data is being used, but we haven't had a consistent across the board hardnosed analysis, to use an old OMB term.

Mr. SYMINGTON. Are you just now getting around to trying to define the parameters of this analysis?

Mr. LOWETH. This study has been going on for more than a year. It is very, very difficult to do this kind of analysis. Actually ERTS data has been available for less than 2 years so the study probably got underway about a year and a half ago.

Mr. SYMINGTON. Did you or a member of your office attend the 13th meeting of this committee's Panel on Science and Technology which dealt with remote sensing?

Mr. LOWETH. I don't believe we had any representative there. NASA and Interior were represented.

Mr. SYMINGTON. Has OMB studied the report of that panel meeting and incorporated it into their general assessment of whether this kind of technology is useful?

Mr. LOWETH. We have not specifically studied that report but it is being factored into the study that Interior is undertaking and other agencies.

Mr. SYMINGTON. This is a 2-year-old report, very interesting, and contains statements of people, I thought you might agree, who have the necessary background to make evaluations.

Mr. LOWETH. We will certainly take a look at that in the context of looking at the major Earth satellite study results. Often we find ourselves in the position of not being able to have the time to read a lot of what I would otherwise perhaps refer to as raw data. We rely a lot on input from the agencies in analyzing such reports. We will pay ample heed to that. As I indicated this is still an issue that as far as OMB is concerned is open for further consideration in the context of developing the 1976 budget.

Mr. SYMINGTON. If I recall correctly, there were some 300 experimenters from all over the world involved in analyzing ERTS data. I also recall an Interior spokesman having expressed the hope that they would be able to have ERTS-C as in Interior project, and that they had been dissuaded or inhibited by the Office of Management and Budget from pursuing their interest. So, you were making judgments affecting the plans of a great agency of Government, plans based on assessments that are contained in part in this panel report, which you have not yet read. That is a curiosity.

Mr. LOWETH. I am not sure whether at that time the Department officially came down hard on that question. That may well have been a person representing his own viewpoint.

Mr. SYMINGTON. The spokesman for Interior that day was Bill Pecora, the late Undersecretary. Former Secretary Udall had also indicated he was looking forward to this kind of opportunity.

I just want to make the point here in terms of the sense of urgency we should have to resolve the question. At a time when we are almost desperately searching for ways in which to make progress in our ability to analyze the Earth's resources, we should not hide from ourselves what other people have found and reported and are ready to substantiate. Since we do need money to go forward with these things we just hope that your agency has time to devote making these studies as quickly and as orderly as possible. I will let you go back to your prepared statement.

Mr. LOWETH. Thank you, sir.

I believe I was at the point of indicating funding for ERTS programs.

These are substantial levels of funding for the present stage of development of the remote sensing technology. In contrast, in fiscal year 1974, sales of ERTS products from the Sioux Falls Data Center, the principal distributor of ERTS data, totaled only \$468,614. Although this number does not represent the total demand, we believe that it is indicative of the current level of market demand. We are still in a very early stage of the development of this technology's ability to produce products that are useful in actual resource management.

Mr. SYMINGTON. It doesn't seem to me that this figure of \$468,000 drawn from current sales of ERTS products really represents the value of the data. Aren't there other tests that ought to be considered? For example, it seems a little early to come down so hard on the cost effectiveness of a program which is admittedly still in the experimental stage but which has shown such progress. Dr. Lindgren of Dartmouth University, for example, says by the use of ERTS

imagery, a land use survey can be made of a State the size of Iowa for one-twelfth the cost of using conventional medium-altitude aircraft.

Is that something you would question, disagree with, or dismiss out of hand? Isn't it important to evaluate this kind of effort?

Mr. LOWETH. We are not trying to compare the \$468,000 as against that total. It is somewhat indicative in our view. I will ask Norm Hartness to provide an answer to that question.

Mr. HARTNESS. Well, certainly we are at an early stage in the development of use of this technology. We are on what one would describe as a learning curve, on how to use it. \$468,000 certainly doesn't represent the future potential of the technology. We are looking at it merely as an indicator of where we stand today and an indicator of how far we yet have to go.

Mr. SYMINGTON. If you were using the sales of the images as an indicator of the value of the program, rather than the use to which they are put—

Mr. HARTNESS. No; they are not interpreted in that fashion. We are not using it as an indicator of value of the use of this imagery. We are using it as an indicator of the current market demand. The value is greater than \$468,000. As you are well aware in evaluating the value of some of these things, it is very difficult. We have had Earth Satellite Corp. for approximately 1½ years, attempting to produce an evaluation of those values. They should complete that study in another several weeks and we will have more information as to the actual value at that time.

Mr. SYMINGTON. Yes; and when that report becomes available will you send copies to us?

Mr. LOWETH. It will be available. It will be a public document.

Mr. SYMINGTON. I would like to know how the study arrived at its conclusions. If you have any curiosity about where we get our information, we would be glad to share it with you, too.

Mr. LOWETH. Thank you, sir.

Mr. SYMINGTON. All right. You may proceed.

Mr. LOWETH. We feel, and I hope you will agree, that a premature commitment to a system would delay development of remote sensing Earth resources survey programs into fully effective and useful resource management tools. For example, going operational too early would probably result in a satellite and ground system design that would not produce the maximum possible benefits from improving resource management decisions. With our present knowledge we just do not know what would best meet user needs and maximize benefits. Going operational too early could also institutionalize use of a technology which is in an early stage of development and discredit remote sensing with users whose requirements could not be adequately met by that technology. Resource management systems are complicated institutional arrangements which generally are not changed frequently because such changes require substantial costs.

These concerns are particularly forceful in the light of the evidence derived to date from ERTS-1 about the usefulness of its output for decisionmaking and resource management.

Mr. SYMINGTON. What about the experimental meteorological satellites? I think we have flown 15 or 16, each generation improving the technology. If your argument was made, it certainly was not made at

the outset of that program. According to your argument, we shouldn't have flown those experimental satellites because we had not yet perfected the technology which we felt would be effective operationally. We kept learning by flying improved instruments. This same thing is true here. How can we perfect the technology without flying the missions?

Mr. LOWETH. In the case of meteorology we could determine demand because of an existing capability to utilize the data.

Mr. SYMINGTON. What about the high demand for the kind of information that ERTS has already proven capable of delivering?

Mr. LOWETH. We are back to that question of the usefulness of the ERTS-1 data, where the question of resolution has come up as an issue. I mean the point we cover later by quotes from several sources indicating that there are major barriers to utilization with the lack of resolution.

Mr. SYMINGTON. I will let you proceed with your statement. I am sure you will cover some of this.

Mr. LOWETH. In our view, the evidence to date suggests (1) that information produced from an operational system with ERTS-1 type technology would be only marginally useful for resource management; and (2) that its potential usefulness would be substantially greater if spatial resolution were significantly improved.

We recognize that this evidence does not mean that ERTS-1 data has not been useful to some degree. We understand that geologists have been making use of ERTS-1 imagery to identify geological features never before recognized. However, this is the kind of application in which additional repetitive coverage with the same technology has relatively low value once complete cloud free coverage is obtained. About 45 percent of Sioux Falls Data Center sales of ERTS products to industry in fiscal year 1974 were to the oil and gas industry, presumably for this kind of use.

The cost benefit study now being done by Earth Satellite Corp. is an effort to determine how ERTS information can be applied to decisionmaking and to estimate its value. Both the overall conclusions and the cost benefit evaluations of that study are still incomplete and tentative at this time since the study is not finished. When this study is completed we will all have better information about the usefulness of ERTS-type data for actual resource management decisionmaking. Paraphrasing we hope it will be a matter of weeks, not months, by the time we get that.

Several Federal user agencies now evaluating ERTS-1 have made preliminary comments on ERTS-1 capabilities.

This I think addresses a point that you raised, Mr. Chairman.

The Statistical Reporting Service of the Department of Agriculture has commented as follows:

"Without significantly improved resolution and dependability there is no possible way the ERTS system can achieve any improvements over the existing crop forecasting system."

The Forest Service has commented by saying that:

"There is as yet no demonstrable need in forest inventory, the apparent major area of benefit in forestry, for frequent acquisition of the relatively low resolution information produced by ERTS."

The Office of Research and Development of the Environmental Protection Agency has commented that :

“For the simple reason that the essential elements of information for environmental monitoring are numerous and often subtle, it is imperative that EPA acquire, or have access to, imagery collected over wide areas at very high ground resolution. While some benefit may be derived from the examination of low resolution imagery, the great bulk of the essential elements of information required to produce a piece of finished environmental information lies well below the 30 feet ground resolved distance that marks the transition from medium to low resolution.”

Please understand that I am not quoting these comments to question the value of ERTS as an experimental program. We still believe that remote sensing of earth resources has substantial promise and that the results of ERTS-1 and ERTS-B experimentation will develop our understanding of how remote sensing may assist decision-making and will help to guide the further development of the technology.

The points to be made are that the tentative evidence to date strongly suggests that :

1. The present ERTS technology is not yet good enough to justify a commitment to present technology and to an operational system.

2. The potential applications and potential benefits would be substantially increased if the technology were advanced, particularly to achieve significantly better resolution.

3. NASA, in cooperation with agencies which use earth resources data for decisions, should, at this time, put their efforts into determining how to advance the remote sensing technology to produce data useful for decisionmaking rather than into developing an operational Earth resources satellite system.

4. Any additional launch, beyond ERTS-B of a remote sensing satellite should be carried out only when such a launch can be shown to be the most cost effective way to achieve a significant advance in the state-of-the-art.

5. Advanced sensor technology should be extensively tested and evaluated using high altitude aircraft as platforms, while concurrent efforts are made to better define the needs of major users for resolution, repetitiveness of coverage, and other dimensions of a possible operational system.

I would like to discuss an issue that relates to these conclusions, namely the belief that it is essential to have continuity of currently collected data from an ERTS-type vehicle; such continuity being argued as necessary both to meet ongoing demand and to create new demands for its products.

It is often asserted that current output from an ERTS-type vehicle should be continuously available at all times in the future and therefore that an ERTS-C should be initiated now to avoid an expected coverage hiatus in about 1977. This view is sometimes based upon the argument that there are existing users of ERTS data who require such continuous coverage and sometimes upon the argument that there are many potential users who are not using the present ERTS product only because there is no commitment on the part of the Government to continuous coverage in the future.

We see three differing approaches to maximizing future benefits from this technology;

Accepting, in the near future, possible periods without continuous availability of current data while emphasizing improvement of the remote sensing technology; or

Devoting more resources to obtaining continuous availability of data while advancing the technology at a slower rate; or

Advancing the technology at a rapid rate while simultaneously assuring continuity of data.

Which of these approaches is best for the Nation depends upon:

1. The volume and value of near term benefits which may be foregone by accepting gaps in continuous availability of currently acquired data from one data source, the ERTS satellite, taking into account the continued availability of other sources of Earth resources data.

2. How rapidly net benefits may increase as the technology is improved.

3. The potential for successfully improving the technology.

4. The level of funds available for Earth resources survey programs versus other programs.

Different observers may disagree about which of the three above approaches is best for the Nation since the situation is complex, the facts are obscure, and the uncertainties remain substantial. Our view at this time is that the Nation will be better served by advancing the technology rather than by getting continuity of coverage with the present technology. Although the consequences of not having continuous coverage are not well defined, it has not yet been demonstrated that there is much existing use which requires continuous coverage.

I think here is an area of basic disagreement.

Few, if any, applications have been identified where continuous coverage with today's technology is both necessary and productive of significant benefits. We will, however, during the development of the 1976 budget continue to look for uses and benefits, I want to emphasize this, which would be adversely impacted by gaps in continuous coverage. We intend to evaluate very carefully what the potential losses of benefits resulting from such gaps would be, and whether some of these losses might not be avoided or mitigated by use of other available sources of data such as aircraft remote sensing.

With respect to the question of how benefits might be increased by improvements in the technology, I have described above some of the reasons why we believe that improved technology will substantially increase the benefits. We will also be exploring this question in detail in the coming months using the study now being done by Earth Satellite Corp., and other judgments and evaluations by NASA and user groups.

I might add, we will also be taking into account the concern and interest of Congress in this matter.

In short we believe that the best strategy for the Nation is to emphasize improving the ERTS technology rather than obtaining continuous coverage with the current level of ERTS technology. However, we will reassess this judgment as new and additional information bearing on the issue becomes available.

Turning specifically to H.R. 14978 and H.R. 15711, each of these bills would mandate a new organizational unit, in the one case in NASA and in the other in the Department of the Interior, to develop Earth resources satellite systems. We would recommend against enactment of such organizations at this time for two important reasons.

First, they are premature. As I pointed out earlier, we have yet to determine the real value of Earth satellite systems as a contributor to our total capability to assess natural resources. We would therefore not want to find ourselves locked into an organization until our understanding of the technology is on firmer ground.

Second, the organizational proposals in H.R. 14978 and H.R. 15711 do not address the whole problem as we see it. Last year, a Federal Task Force on Mapping, Charting, Geodesy, and Surveying chaired by Mr. Donelson, on my left, submitted a report in which it was pointed out that, in fiscal year 1972 there were 39 different agencies which had spent a total of \$304.8 million for mapping, charting, and geodesy activities. In addition, there were 11 other agencies which spent an additional \$142 million for such related activities as soil delineation, oceanographic surveys, and geologic investigations. These activities obviously use all kinds of Earth resource data collection techniques and not just satellite systems.

Thus, we feel that we are going to have to deal with the whole broader range of Earth resources data collection, analysis and dissemination activities and issues covered by that task force report. The task force recommended that a central mapping and charting agency be created to provide a single service organization to meet user needs throughout the civilian sector of the Federal Government and to reduce the duplication and inefficiency that now exist. We believe this idea has merit and must be given consideration. We believe that such a mapping and charting agency would be entirely consistent with the concept of a Department of Energy and Natural Resources, and that such an approach would be preferable to either an Office of Earth Resources Survey in NASA or an Earth Resources Observation Administration in the Department of the Interior.

I might say the question of a DENR is being vigorously explored by the new administration, although no decision has been made as yet.

Our basic concern is that the allocation of Federal dollars for collecting, analyzing, and disseminating land and Earth resources information should be done in such a way that the budget eliminates these duplications and inefficiencies while reflecting the users' priorities for the various kinds of information products which could be made available through a combination of on-the-ground, aircraft and satellite data.

We are strongly opposed to the establishment of new organizational units which would be concerned with the advancement of any particular kind of technology as such. In our view the first order of business is to determine which kinds of information will be used for the greatest number of applications and how frequently such information should be updated to be valid for actual use in decisionmaking.

In closing, the question of how to organize Federal Government efforts supporting the collection, analysis, and dissemination of Earth and land resources information is a subject to which OMB is giving continuing attention.

Mr. SYMINGTON. Thank you. I appreciate your statement. You mentioned the Earth Satellite Corp. Is this an outfit that OMB placed under contract for cost-benefit studies?

Mr. LOWETH. The Interior Department contracted with Earth Satellite. Mr. Hartness can give you an analysis of that if you would like it at this time.

Mr. SYMINGTON. If I may, I would like to call attention to what seems to be a basic difference of opinion that exists already.

You say on page 11, "Our view at this time is that the Nation will be better served by advancing the technology rather than by getting continuity of coverage."

But in a recent statement by Doctor Levin of Earth Satellite Corp., he said:

Nothing could be so damaging to the ultimate demonstration of the economic and social benefits of the Earth Resources Survey Program as a protracted interruption in the flow of satellite data. It will, in my opinion take many years, possibly a decade or more, of continuous experimentation and preoperational use for some of the different economic sectors the diverse and diffuse user communities, to become acquainted with this new kind of information system, to gain experience in its characteristics and its effective use, to change where necessary from their conventional methods, to adopt new operational procedures, or to develop the new instructional arrangements needed for efficient utilization of satellite data. It is clearly in the interest of the United States and of the world community to sustain the active interest of these would-be users in the public and private domains through the periods of experimentation and learning which must be prologue to operational adoption of the new information systems in their economic activities.

Since continuity of data flow depends on continuity of the program, I heartily endorse in both S. 2350 and S. 3484 those three essential provisions which assure the program, namely, a charter or mission, an organizational home, and the authorization of funds.

So we seem to arrive at a fork in the road whereby there are those that feel that the only way to advance this technology is to have continuity. I guess that they have faith that from what they have seen already great benefits will accrue down the road from this Earth observation capability, but that the only way to determine the parameters of those benefits is to continue the program. So that there are two reasons, in their view, for continuous data. One is because many users find the data quite useful and they are very anxious not to have it interrupted.

The other is because the way to improve the system is to use it, and work with this data, study it, and see how it can be analyzed more readily and determine what steps have to be taken to render the equipment more sensitive.

You, on the other hand, seem to feel that improvement of this technology can be done without flying, and that there are no real advantages from continuous use and that we can learn enough about what the future satellites will be like right here on Earth.

Is that the idea? Have I defined the difference of opinion properly?

Mr. LOWETH. I think there were several questions wrapped into that comment of yours. I guess first the question on continuity. In typical OMB hardnosed fashion we are saying that an effective case has yet to be made by our standard of analysis to argue the criticality of the continuity of data.

There is a lot of data "in the can," to use an expression, that can be worked. We have not been really given a strong enough argument in our view to counter our position. ERTS-B will give us additional information on which to base further judgments on that matter. On the matter of Doctor Levin's testimony, I presume he was testifying as an individual and not necessarily, I hope, prejudging the results of a study which is contracted for by Interior. We need the analysis. I know there is a lot of enthusiasm and interest. We share it in our own organization, but we do take the position that we need to see the analysis rather than operate on episodic information from here, there and elsewhere that ERTS data is useful. We know it is being used. We measure usefulness in the ultimate by tougher standards of cost-benefit than we think have been adequately addressed as yet, although we hope it will be coming along.

Mr. SYMINGTON. A subject of curiosity to this committee is related to your statement on the top of page 13, that you don't want to find yourselves locked into an organization until your understanding of the technology is on firmer ground. Does OMB have people on its payroll with the same skills and disciplines as those who are developing this technology and making the argument for it, or are you taking just an economic look at it?

Mr. LOWETH. We do have access to technical people. In this particular area, we do not have immediately on our staff technical people but we have access to them. For example, to the Science Adviser's office and in former times to the Office of Science and Technology in addressing problems. I cannot say, or be sure, whether the Office of Science and Technology in its later stages specifically addressed this problem.

Mr. SYMINGTON. But you say here "until our understanding of technology is on firmer ground." I wonder who is the author? Is it a person like yourself?

Mr. LOWETH. No, I think probably that statement was not so much with regard to our understanding of the technology as to our understanding of the applications area. That is probably an unfortunate remark at that point. I mean our understanding of the technology relies primarily on NASA, and to the extent we needed any independent advice we would have gone to the old Office of Science and Technology and now to the Science Adviser's Office. I don't think we have any serious conflict with NASA over the fact that technology can be advanced. It was in the Sky Lab experiment. There are other sources of information that lead us to believe that there is no doubt that the technology can be advanced, so I am afraid that I will have to modify that sentence. It is a bit strangely worded for the purposes of this question.

Mr. SYMINGTON. What you are saying I believe is that OMB does not have the capacity really to understand the technology. If someone whom they trust explains it to them, then they make inferences and judgments on the usefulness of the technology as explained?

Mr. LOWETH. I think we have, in all candor, sir, as much capability to understand it as the Congress. In my view, one of OMB's jobs is to be part of the interface between translating something from the technical world into what the lay world can understand. And I think

that we try to draw as much as possible technical judgments, although, again, I say I don't think there has been any issue between us and NASA over whether something would work or not work, or whether the technology could or couldn't be advanced, which may be different in some areas where there are differences of opinion as to whether something will "get off the ground" or not.

Mr. SYMINGTON. Without admitting that our understandings are equal, let's assume our capacity to understand is roughly comparable. You are suggesting that the sources you go to include the Science Adviser. Would you like to name the others?

Mr. LOWETH. First off, I would say we primarily go to NASA, and if there is no question about what NASA states in our view and they make a good case, looked at from the standpoint of a layman, that something will work there is no reason to question their judgment on a technical issue. The issue here is not a technical issue on applications. The NASA issue is can something fly, can you get an improved capability.

Mr. SYMINGTON. NASA has people who understand technology. You say you go to NASA, and that is where we go, too. We hear from them that they are very excited about the prospects which this technology offers. I must candidly say to you that when their witnesses are before us, they are almost always constrained to let us know, on the one hand, that they would very much like to go forward with a program such as ERTS and, on the other hand, that they are held on a tether by OMB. So if you are going to them for their hopes and aspirations as well as the technical possibilities and probabilities, it seems to me you would get a go-ahead signal from them, and I might add, from the Science Adviser, too. Can you check that point? As I recall, Guy Stever was quite interested in this program. How is it that we arrive at different conclusions with the same advice?

Mr. LOWETH. I want to make clear that there are two different issues involved. One is the technical issue of whether something can fly, will work from a technical standpoint. That we go to NASA for.

The question of user groups and user needs I submit is really not a primary responsibility of NASA. If you take the meteorological satellite, it was NOAA that described the need. It was NASA that developed the capability to get that particular need met by both the "bird" and the booster.

Mr. SYMINGTON. Dr. Jim Fletcher was not putting us on when he said the current ERTS system is good and provides valuable, usable data. To realize the full potential of ERTS-type systems, future experiments will probably be needed, and he outlines the kinds of things which will be needed?

Mr. LOWETH. We won't dispute the information hasn't been valuable as an experimental program but the point is that that value hasn't been put yet to the full and complete hard test of the marketplace in terms of tradeoffs with other ways to get data and other data sources.

Mr. SYMINGTON. You are convinced you would like to stop this experimental program with ERTS-B?

Mr. LOWETH. I think obviously, sir, that is where we are at this juncture and I say again "at this juncture," because we are not in a position to make final judgments on budget issues, as you know. We

differ with the committee. It is a question, I guess, of degree almost more than kind, because we are not disputing the need for an experimental program, both for technological reasons as well as user experimentation, but we do have a different view on the question of whether we need to fly what we feel is essentially not a really advanced satellite, and there is also a difference I believe in the view as to what a truly advanced satellite is.

Mr. SYMINGTON. So Dr. Fletcher is wrong in your view when he says:

We see the need for a continuous evolutionary approach in which operationally useful data from space are provided the users for research, for experimental demonstrations, and for routine operations when they are ready, while at the same time and with the same satellites, necessary improvements to the system can be developed and tested.

Mr. LOWETH. Sir, without being impudent, let me say we interpret that statement differently. I think that there is some——

Mr. SYMINGTON. Differently from the plain meaning of it?

Mr. LOWETH. I think as I heard you read it, there are some caveats in the middle of that statement which would imply that what we are doing is in the spirit of that statement, but I must hasten to add that there are differences of view with NASA at this time.

Mr. SYMINGTON. I can accept the latter part of your response more easily than the former. I don't see how you can get a wedge into that sentence that would indicate that he has any doubts as to the utility of continuous evolution.

Mr. LOWETH. I was listening to the qualifiers and I thought I heard a couple. Maybe I didn't.

Mr. SYMINGTON. It was page 8 of his statement before the Senate Space Committee in August. In any event we will provide you with a copy of it.

Mr. LOWETH. I have it in front of me. I guess the question is what is the interpretation of "evolutionary." Does that mean minor gradations or improvements, or does it mean major improvements in such matters as resolution? That would be one comment. I think that the issue, for example, of resolution indicates from the quotes that I made from user organizations that they feel substantial improvement is needed. Now there is some consideration given to doubling resolution from 300 to 400 feet down to 150 to 200, improving it by a factor of 2. Most agencies that have already looked at that resolution improvement do not consider that a significant step and would rather get down to 30 to 50 feet. So I think there are questions about the meaning of the word "evolutionary" in our view.

Mr. SYMINGTON. Well I am sure there are questions of that kind. I think however, his statement clearly indicates his desire to see satellites fly and be tested and used at the same time.

Mr. LOWETH. I believe that is probably a true interpretation.

Mr. SYMINGTON. In any event it is clear there is a difference of opinion, assuming that we are equivalent in our ability to understand these things. I hope you will recognize that we on the committee are inclined to believe we ought to go forward with this program. With our limited background in science we have learned to listen to scien-

tists and technologists who have come before this committee testifying about past performance as well as future prospects for ERTS satellites.

It would be very interesting to continue the dialog here with you, but we have other witnesses. It has been highly useful to the committee. Your testimony has been very helpful. I have some additional questions which I would like to submit in writing. But since we do have other witnesses to move onto, I will excuse you now, Mr. Loweth, and your colleagues, with great thanks.

Mr. LOWETH. Thank you very much.

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COMMITTEE ON SCIENCE AND ASTRONAUTICS
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October 17, 1974

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Mr. Hugh F. Loweth
 Deputy Associate Director
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Dear Mr. Loweth:

At the conclusion of your testimony before the Subcommittee on Space Science and Applications, I noted that time did not permit all matters of interest to be fully covered, and I proposed submitting additional questions to you in writing. I would be pleased to have your responses to the following questions for inclusion in the record of our hearings.

1. In your prepared statement, you stated that answers -- at least tentative answers -- must be found regarding "how such (ERTS) information can be put to meaningful use and of what value and costs such use has to the Nation", in order that wise decisions can be made as to how and when to proceed with the program. Other witnesses take the position that it is unreasonable to apply a cost-effectiveness test at this early stage in an experimental program in which only a single satellite has been launched to date. In this connection, your colleague, Mr. Hartness, testified that "certainly we are at an early stage in the development of use of this technology. We are on what we'd describe as a learning curve, how to use it". Would you expand on the reasoning behind OMB's applying a cost-effectiveness test to ERTS at this early stage? Has OMB applied a cost-benefit test to other experimental systems, such as NASA's meteorological satellites?
2. As part of OMB's cost-effectiveness analysis, you recommended that the cost of producing ERTS type data be compared with the costs of producing substitute data from other sources such as aircraft or on-ground data systems. You also testified that the value of ERTS data "hasn't been put yet to the full and complete hard test of the

marketplace in terms of tradeoffs with other ways to get data and other data sources". Would you agree that much of the data produced by ERTS cannot be produced in any other way? If so, wouldn't such comparisons be impossible, and such a test unrealistic? Shouldn't satellite data be considered as both complementary and supplementary to aircraft and ground-based data, rather than in competition with traditional data sources?

3. You expressed the fear that the Nation might find itself "with a premature commitment to a technology that is not sufficiently advanced to satisfy many potential users," that such a "premature commitment...would delay development," that "going operational too early could also institutionalize use of a technology which is in an early stage of development and discredit remote sensing." Can you cite examples in which a premature commitment to a particular space technology has tended to freeze the technology at an early stage of development and has inhibited progress? How would you explain the remarkable technological progress that has been achieved in both communications and meteorological satellite systems over the years in spite of the fact that in both cases operational systems have been functioning concurrently with several generations of experimental systems?

4. If ERTS-C and subsequent satellites are delayed, would you agree that there will probably be a hiatus - perhaps a long hiatus - in the flow of data? And if that happens, doesn't it seem likely that many scientists and others associated with the program will lose interest and discontinue their work? Doesn't it seem likely that such a data gap will also discourage private enterprise from making capital investments and playing an active role in the development of various aspects of the system? And won't that assure that the desired advances in technology will be inhibited, and the evolution and eventual development of a cost-effective operational system will be delayed?

Are you aware of the recent report of the National Academy of Sciences entitled Remote Sensing for Resource and Environmental Surveys? What is your response to the recommendation "that the federal government take immediate action to minimize the potential gap in earth resource satellite imagery after the follow-on ERTS-B completes its useful life"?

5. Are you aware (1) that the reports of all four committees of Congress which have responsibilities regarding the NASA budget for fiscal year 1975 contain specific recommendations that ERTS-C should be undertaken as soon as possible, and (2) that additional funding was provided by Congress for that purpose? Is it OMB's position that such clearly stated congressional policy direction can and should be ignored?

- 3 -

In closing, may I note that your assertions that "information produced from an operational system with ERTS-1 type technology would be only marginally useful for resource management" and that "additional repetitive coverage with the same technology has relatively low value once complete cloud-free coverage is obtained" are completely inconsistent with the expert testimony received by this Subcommittee over the years.

Let me thank you in advance for your cooperation in responding to the above questions.

Best wishes.

Sincerely,

JAMES W. SYMINGTON
Chairman
Space Science and Applications
Subcommittee

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

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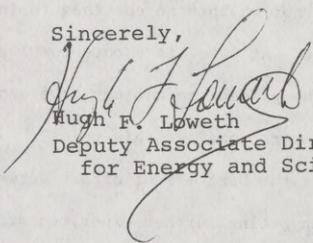
Honorable James W. Symington
House of Representatives
Washington, D. C. 20515

Dear Congressman Symington:

I am enclosing OMB's responses to the questions which you raised at the close of your hearings on H.R. 15711 and H.R. 14978. Upon receipt of your letter of October 17, we have given your questions high priority and have tried to be fully responsive to them. We understand the nature of the concerns raised on page 3 of your letter, and we are actively gathering additional information on these issues of disagreement.

Your hearings on the earth resources survey programs served to provide a useful forum for exchange of viewpoints. I thank you for providing OMB with the opportunity to participate in these discussions and to make our views known.

Sincerely,



Hugh F. Loweth
Deputy Associate Director
for Energy and Science

Enclosure

1. In your prepared statement, you stated that answers -- at least tentative answers -- must be found regarding "how such (ERTS) information can be put to meaningful use and of what value and costs such use has to the Nation", in order that wise decisions can be made as to how and when to proceed with the program. Other witnesses take the position that it is unreasonable to apply a cost-effectiveness test at this early stage in an experimental program in which only a single satellite has been launched to date. In this connection, your colleague, Mr. Hartness, testified that "certainly we are at an early stage in the development of use of this technology. We are on what we'd describe as a learning curve, how to use it". Would you expand on the reasoning behind OMB's applying a cost-effectiveness test to ERTS at this early stage? Has OMB applied a cost-benefit test to other experimental systems, such as NASA's meteorological satellites?

OMB is attempting to use any of the tools of analysis which may be useful in evaluating how best and at what pace to proceed with the development of the products of ERTS technology into useful decision-making and resource management tools.

At the outset it should be noted that the decisions which analysis may illuminate in this case are not a discrete go/no-go question of the kind encountered in building a flood control dam or similar project. The question is not whether to continue to invest in the ERTS program or to terminate it. At issue is a more complex set of questions:

- Does the present technology have enough valuable uses to justify going operational at this point?
- What is the best mix of effort between improving the technology and supporting further experimentation and initial operational application with the present technology?
- What are the losses and gains from accepting a hiatus in current coverage after ERTS-B in order to push the achievement of an improved system?
- At what point in the improvement of the technology would the benefits from operational uses justify a commitment to go operational and provide future continuity of current data availability?

The complexity and difficulty of these questions are heightened by the fact that the complete range of valuable uses which can be met by data produced from a given level of technical capability are not immediately apparent. Potential users of such data are on a learning curve with respect to how to use such data and what its value might be. Hence, evaluations of any given level of ERTS technology need to project what its value would be in the future after potential users had gone through the learning process.

For these reasons cost-effectiveness or cost-benefit analyses can provide only tentative and partial guidance to the decisions which must be made about the pacing and strategy of the program. We in OMB are fully aware of both the complexity of these questions and the limitations of these kinds of analyses in illuminating these questions. However, we do believe that cost-benefit and cost-effectiveness analyses, if used cautiously with due regard to their limitations in these circumstances, can in conjunction with other kinds of information and analyses provide better information with which to make program decisions. Mr. Zarb in testifying before Senator Moss' Committee on this question said that using benefit-cost ratios as the sole criterion is nonsense since such analyses are only a part of the total picture.

With respect to the application of cost-benefit or cost-effectiveness tests to other experimental systems, we should point out first that we have not applied such tests to ERTS-1 and ERTS-B. Clearly the predominant value of these satellites is in the opportunities for experimentation which they provide. However, when decisions are faced involving longer term commitments to provide data for permanent operational use, we feel that cost-benefit or cost-effectiveness analyses are an essential part of the information for

decision making. Such analyses have been frequently utilized both to assess the potential value of experimental systems and also when experimental systems have reached decision-points involving longer term or operational commitments. Some examples are:

- An analysis was performed of the incremental effectiveness of developing the TIROS-N meteorological satellite versus adopting a military satellite alternative.
- DOT and NASA jointly did an economic analysis relating to the development of short take-off and landing aircraft systems.
- Cost-benefit analyses of the space shuttle have been done.
- The tracking and data relay satellite was studied for trade-off and lease-buy question purposes.
- NASA is currently carrying out an economic assessment for the SEASAT satellite.

4. AS part of OMB's cost-effectiveness analysis, you recommended that the cost of producing ERTS type data be compared with the costs of producing substitute data from other sources such as aircraft or on-ground data systems. You also testified that the value of ERTS data "hasn't been put yet to the full and complete hard test of the

marketplace in terms of tradeoffs with other ways to get data and other data sources". Would you agree that much of the data produced by ERTS cannot be produced in any other way? If so, wouldn't such comparisons be impossible, and such a test unrealistic? Shouldn't satellite data be considered as both complementary and supplementary to aircraft and ground-based data, rather than in competition with traditional data sources?

The issue, as we see it, is not whether ERTS data may be unique in one or more of its several characteristics but whether the information of the quality and timeliness needed by specific decision-makers can or cannot be provided at less cost by other sources than by additional coverage with the current ERTS technology.

For example, experimenters believe that the current ERTS technology is capable of monitoring the condition of forage on the public range lands on a broad regional basis. On the other hand, range managers are currently experimenting with condition monitoring using color infrared film in small cameras mounted on light aircraft. It's possible that the latter method will cost-effectively produce the greater precision and discrimination of condition required by the actual decisions faced by range managers.

To take another example, many observers have suggested that ERTS might play a significant role in decisions needing information about world production of major food crops by monitoring acreages planted to those crops in conjunction with information about meteorological conditions affecting yield projections. Whether this kind of use of ERTS data could improve decisions which depend in part on world production of major food crops is problematic. For most major food crops the year to year variance in production depends much more on differences in yields caused by

meteorological and disease conditions than by differences in acreages grown. Furthermore, for many purposes evaluations of the world food situation do not depend directly upon production predictions but upon decisions by producer or consumer nations to enter the world market to buy or sell. Such market decisions involve a broad range of considerations including foreign exchange availability, domestic and foreign political considerations and transportation and storage capabilities as well as production results.

The existing efforts to assess these considerations depend upon a multitude of sources of information including sources as mundane as historical information and foreign press reports. Whether use of ERTS data could improve U.S. decisions in this area is not at all self-evident. In short the proper test would be a comparison of a possible information system using ERTS data with the existing and anticipated systems not using ERTS data.

While ERTS data may have unique characteristics in one or more respects which cannot be exactly duplicated in other ways, this does not mean that the information needs of decision-makers cannot be met using other combinations of sources of information. For this reason any assessment of the value of ERTS data needs to compare the cost of producing that data with the costs of producing substitute data from other sources.

3. You expressed the fear that the Nation might find itself "with a premature commitment to a technology that is not sufficiently advanced to satisfy many potential users," that such a "premature commitment... would delay development," that "going operational too early could also institutionalize use of a technology which is in an early stage of development and discredit remote sensing." Can you cite examples in which a premature commitment to a particular space technology has tended to freeze the technology at an early stage of development and has inhibited progress? How would you explain the remarkable technological progress that has been achieved in both communications and meteorological satellite systems over the years in spite of the fact that in both cases operational systems have been functioning concurrently with several generations of experimental systems?

3. A decision to allocate resources into an institutionalized framework based upon ERTS-1 technology clearly would not allow the use of those resources to address the requirements of those potential users who want a better product (e.g., greater resolution). To the extent to which these unmet needs represent significant benefit, progress will be inhibited. The user community is not yet well developed and therefore their requirements are still not well defined. As Dr. McKelvey of the U.S. Geological Survey pointed out to the Senate Committee on Aeronautical and Space Sciences: "We are just beginning to learn how to get the most out of this data; their importance is just beginning to be realized." OMB does not know of a specific situation where the government has in the past been committed prematurely to a particular space technology. But we still believe that progress can be inhibited by premature commitment to a given technology in the case of earth resources satellites.

The remarkable technological progress of both the meteorological and communications satellites stems from the fact that in those cases there were and are

both well-defined missions and a group of users who are willing to pay for the services they receive. These users clearly believe that the use of satellites is the most cost-effective manner to meet certain requirements for data. We would also point out that much of this technical progress is a result of military activities in both communications and meteorological satellites. In addition, this progress to some degree resulted from launch vehicle development which made possible synchronous orbit placement and the successes achieved in reducing the costs of electronic components with long life characteristics.

4. If ERTS-C and subsequent satellites are delayed, would you agree that there will probably be a hiatus - perhaps a long hiatus - in the flow of data? And if that happens, doesn't it seem likely that many scientists and others associated with the program will lose interest and discontinue their work? Doesn't it seem likely that such a data gap will also discourage private enterprise from making capital investments and playing an active role in the development of various aspects of the system? And won't that assure that the desired advances in technology will be inhibited, and the evolution and eventual development of a cost-effective operational system will be delayed?

Are you aware of the recent report of the National Academy of Sciences entitled Remote Sensing for Resource and Environmental Surveys? What is your response to the recommendation "that the federal government take immediate action to minimize the potential gap in earth resource satellite imagery after the follow-on ERTS-B completes its useful life"?

4. We believe that with the present two-year data base generated by ERTS-1 and a potential doubling of this base by ERTS-B, the scientists, experimenters, and others associated with the program should have ample data available to carry out a wide range of investigations for many years. We note that useful analysis of earth resources data gathered by Skylab will continue through January, 1976.

Should the capabilities and resources of NASA be directed toward achieving significant technological improvements in earth resources remote sensing rather than enlarging the current data base, we believe both experimenters and users would display greater interest in the area.

We have reviewed the recent report of the National Academy of Sciences entitled Remote Sensing for Resource and Environmental

and the recommendation on program continuity. Unfortunately, the report does not provide the specifics of who these users of an ERTS-C would be or whether these users would prefer to have an ERTS-C rather than significant technological progress. NASA has provided OMB with its assesment of the most likely Federal programs and users who would want ERTS-C data and we are contacting these groups to ascertain the nature of their requirements. We also expect that the results of the forthcoming Department of Interior cost/benefit study will provide additional insight into the question of trade-offs between continuity and technological improvement.

5. Are you aware (1) that the reports of all four committees of Congress which have responsibilities regarding the NASA budget for fiscal year 1975 contain specific recommendations that ERTS-C should be undertaken as soon as possible, and (2) that additional funding was provided by Congress for that purpose? Is it OMB's position that such clearly stated congressional policy direction can and should be ignored?

5. We are very much aware of the statements in the Committee reports indicating that development of an ERTS-C should be undertaken as soon as possible and that NASA was urged in the reports to reprogram funds to move forward on this project. OMB's participation in the hearings on S. 3484 and S. 2350 and in the hearings of your committee on the subject of earth resources survey programs demonstrates, we hope, our awareness of congressional concerns about ERTS and the desire to make our views on the full scope of earth resources survey programs fully available to the committees.

It is our view that legitimate differences of opinion should be recognized and that efforts should be made to find common ground for understanding and agreement. I can assure you that we will continue to work vigorously to resolve this issue.

Mr. SYMINGTON. Our next witness is Dr. Wallace B. Howe, director of the Research and Technical Information Division, Missouri Department of Natural Resources. Dr. Howe is a graduate of the University of Missouri at Columbia, and earned his Ph. D. from the University of Kansas. He has worked for the Missouri Geological Survey for more than 20 years. He was appointed Missouri's 16th State geologist in 1971, and he is presently serving in that capacity. He is the author of several publications on geological subjects, and I welcome Dr. Howe to the subcommittee as a person who, I think Mr. Loweth would agree, is an expert in these matters. The committee is delighted to have you with us and pleased to hear your testimony.

STATEMENT OF DR. WALLACE B. HOWE, DIRECTOR, MISSOURI DEPARTMENT OF NATURAL RESOURCES

Dr. HOWE. Thank you very much, sir.

I appreciate the opportunity to present information about our experience with ERTS-1 data in Missouri, and hope that my comments will be helpful to you in your decisions.

I think it is important that I qualify my remarks by explaining that I am reporting the work and conclusions of others, chiefly that of my staff.

Mr. SYMINGTON. Dr. Howe, I might say if it is convenient with you, since you have a very thorough statement, if you would like to summarize it, it might be helpful to the committee.

Dr. HOWE. I would like to delete part of it, sir. Otherwise I think I should read it.

Before proceeding I want to note that I should qualify my remarks by explaining that I am reporting the work and conclusions of others, chiefly those of my staff. That is not only a disclaimer, it is an effort to give credit where credit is due.

In my testimony, my intent will be that of identifying work done in Missouri that illustrates some of the applications of information obtained through phase 1 of the Earth resources technology satellite program. Following that, I will offer some comment on the question of the need for an "operational" phase of an ERTS-type system for providing information about our Earth.

We have been fortunate in Missouri that several of the staff members of the State geological survey have become quite interested in the application of a number of types of remote sensing data to geology and closely related fields. Not so fortunately, we have been so short on professional staff and funds that we have never been able to justify full commitment of even one man to explore the potential that remote sensing data like that available through ERTS-1 might have for our State. However, various members of our staff have been able to accomplish some worthwhile objectives in relatively short periods, and this effort has served the purpose of illustrating the potential that is offered for application in Missouri.

We have had much encouragement and cooperation from the National Aeronautics and Space Administration in our studies, and also from the Department of the Interior through their EROS program. The decision to make the information widely available in a format that could be easily utilized was a very important one. The approach taken by NASA in encouraging scientists in agencies like ours, and in the universities, to experiment with ERTS data, has served the

important purpose of alerting these people to some of the potential offered and must have resulted in a remarkably comprehensive catalog of direct applications and remaining research needs. I would imagine that the entire scientific community is appreciative of their philosophy.

Missouri became involved in the Earth resources technology satellite program early in the planning stage when NASA invited agencies and companies to submit proposals for the utilization of data to be acquired by ERTS-1. Because we could not anticipate what the usefulness of such data might be, my agency submitted a proposal that asked for no Federal funds, we were primarily interested in learning what useful applications might be made of the data in Missouri. Our interest was quite frankly at that time selfish. We wanted to see what we could get from it.

Our proposal was for the investigation of the growth corridor between Kansas City and St. Louis, Mo. We had developed information in the area north of Kansas City and in the St. Louis area. We anticipated being able to apply and transfer information throughout the corridor.

Imagery began to arrive in mid-1972, and it immediately became obvious that data acquired by satellite had applications far beyond those we had foreseen.

Several of the members of the Geological Survey staff began to view the imagery as a potential reconnaissance tool for their specific studies, and other Missouri State agencies began experimenting with the data in their work. In addition, we made the imagery available to University of Missouri-Rolla staff and students, and to mining geologists.

As a result of our increased understanding of the potential offered by the ERTS material, we proposed to NASA that the investigation be expanded to a statewide study. NASA accepted, and our principal aim then became a statewide inventory and analysis of geologic ground patterns in Missouri. This initial project was identified as No. SR168A. A summary report is in preparation. Reports based on the ERTS-1 data and addressing the general subject of geologic interpretation include the following:

"First-Look Analysis of the Geologic Ground Patterns on ERTS-1 Imagery of Missouri"—Allen, W. H., Martin, J. A., Rath, D. L., Symposium on Significant Results Obtained From the Earth Resources Technology Satellite—1 Volume I: Technical Presentations Section A; National Aeronautics and Space Administration, March 1973, p. 371 (major structural features, principal physiographic divisions, major geologic divisions, possible locations of morainal systems).

"Geologic Ground and Drainage Patterns From ERTS-1 Imagery in Northern Missouri"—Martin, J. A., Allen, W. H., Rath, D. L., Symposium on Management and Utilization of Remote Sensing Data, American Society of Photogrammetry, October 1973, p. 333 (blocked preglacial drainage systems indicated by high soil moisture retention characteristics, major lineaments as related to mineral resource exploration).

"Summary of an Integrated ERTS-1 Project and Its Results at the Missouri Geological Survey"—James A. Martin, William H. Allen, David L. Rath, and Ardel Rueff, December 1973, Second NASA Symposium (in press) (gross soil materials classification, land-use classification, structural features, flooding and flood-prone areas).

"Orthopolygonal Tectonic Patterns in the Exposed and Buried Precambrian Basement of Southeast Missouri"—Geza Kisvarsanyi and Eva B. Kisvarsanyi, presented at the Utah Geological Association's Basement Tectonics Symposium, 1974 (ERTS-1 imagery provided broad perspective of lineament and other structural features pattern).

A second example of ERTS-1 data application in Missouri was carried out as a part of a cooperative project between the USGS and a number of State Geological Survey organizations across the Midwest. It is identified as: "An Evaluation of ERTS-1 for Mapping Pleistocene Deposits and Land Forms in the Midwest and Great Plains (SR-238)"; Roger Morrison (USGS), principal investigator for Missouri; William H. Allen (MGS). This is a visual evaluation of ERTS-1 imagery which to date has aided in developing a program for the study of the surficial deposits of the State. The use of satellite imagery has provided an economical means of isolating specific areas for study and updating existing knowledge of the Pleistocene deposits of northern Missouri (soil drainage characteristics, possible morainal features, buried drainage systems).

INVENTORY OF NON-FEDERAL DAMS (MISSOURI GEOLOGICAL SURVEY FOR U.S. CORPS OF ENGINEERS)

ERTS-1 imagery obtained through our project with NASA and conventional air photography purchased from ASCS (Agricultural Stabilization and Conservation Service) were used as a base for an inventory of dams in Missouri by the State Geological Survey in compliance with the National Dam Safety Act (Public Law 92-367) administered by the U.S. Army Corps of Engineers. A total of 2,995 bodies of water were located on ERTS-1 imagery. Of these, 1,500 were identified on available conventional air photos. Bodies of water as small as 5 acres were located satisfactorily from this imagery. The 1,500 lakes that were located on air photos were also located on ERTS-1 imagery as 1/250,000 prints became available. Location was accomplished with ERTS-1 imagery in a fraction of the time necessary using conventional photography. More importantly, the ERTS imagery was far more current than available aerial photography. Since Missouri has had no provision for the reporting of dam construction, there was no other means of locating these lakes within the time frame and funding restraints. In the dam inventory work, the 9 x 9 positive transparencies provided by NASA were used to prepare negatives, and paper print enlargements to 1/250,000 scale were made from the negatives.

STATE FOREST INVENTORY (MISSOURI DEPARTMENT OF CONSERVATION)

The Missouri Department of Conservation has inventoried forest cover in 20 counties comprising 7 million acres using ERTS-1 and Skylab data (where the latter was available). This was accomplished through a project—(Grand and Platte Multipurpose Land Use Planning Study—funded by the U.S. Forest Service. The success of their inventory prompted the Forest Service to expand the work to cover an additional 2 million acres. The new study was identified as the northern Missouri River Basin tributary study. There is interest

now in mapping the entire State with the methods developed in these projects. One of the objectives is to compare the resulting inventory with the last complete State forest cover inventory—conducted in the 1930's—in order to establish long-term trends. The thousands of acres of land in Missouri cleared yearly for cattle grazing illustrates the need for repetitive coverage to monitor our forest lands.

THE SPRINGFIELD LAND USE MAPPING EXPERIMENT (NASA EARTH RESOURCES LABORATORY AT BAY ST. LOUIS, MISS.)

The purpose of the experiment is to test experimental land use mapping procedures in a seven-county area in south-central Missouri, using procedures developed at the NASA laboratories. The procedure being used is a computer-implemented land use classification with ERTS digital data supervised patterns recognition software. Anticipated result of the experimental work is land use inventory.

LAND USE ANALYSIS OF ST. CHARLES COUNTY (MISSOURI GEOLOGICAL SURVEY AND DEPARTMENT OF COMMUNITY AFFAIRS)

A level 1 land-use classification (after USGS circular 671) of the entire county was produced from ERTS-1 imagery. Mapping was on ERTS-1 imagery enlarged to scale of 1/250,000. This interpretation was produced in 6 hours by one person. As a means of determining reliability a small segment of the county was remapped at larger scale from available corn blight photography provided by the University of Missouri's Agricultural Extension Service. Detail provided allowed level II classification. In contrast, the same compilation by conventional methods would have taken 9 months.

OZARKS REGIONAL LAND-USE PROGRAM, SPRINGFIELD AREA

GEOGRAPHIC APPLICATIONS PROGRAM (GAP), DEPARTMENT OF THE INTERIOR

The area in southwestern Missouri covered by the Springfield AMS 1:250,000 topographic sheet was used by GAP as a test area for their land-use mapping inventory procedures. Classified photography was available to GAP workers for this purpose. They evidently intend to extend this program of map use inventory to cover very broad sections of the country and their plan is to use ERTS imagery to monitor land-use activities and to periodically have the capacity from that to update the land-use inventory.

This program is now being expanded with plans to cover the entire United States within the next few years. The GAP plan is to use ERTS imagery to monitor land-use activities and update these maps on at least a level I and if possible level II classification (after USGS Circ. 671 revised).

1973 FLOOD MAPPING (FEDERAL AND STATE GEOLOGICAL SURVEYS)

ERTS-1 recorded the devastating 1973 spring floods along the Mississippi River allowing for an excellent opportunity for its use in flood mapping on a regional basis as was done by the Department of the Interior, U.S. Geological Survey. Extensive cloud cover did not

permit full coverage by ERTS-1 along the Missouri River. On April 12, 1973, weather permitted NASA to provide U-2 coverage of the river from St. Louis to Kansas City. Although April 12 occurred some 11 days after the first of four crests, it was discovered that the aerial extent of inundation during the first crest could nevertheless be mapped with color infrared U-2 photography. If we had had ERTS coverage, similar but not as detailed interpretation probably could have been made since ERTS supplies information in the infrared spectrum.

In addition to the U-2 photography, we were able to contract for backup photography of the Missouri River, through the Kansas Space Technological Center, 7 days after the main flood event which was the third crest. The combination of NASA U-2 and Kansas Space Center data will undoubtedly have wide use in the future especially in the identification of flood-prone areas and location of areas protected by levees but subject to seepage. Our principal use with this data so far has been in preparation of a flood inundation map of St. Charles County, and will be published in a forthcoming report. The 1973 flood was of the longest duration of any flood measured at St. Louis.

RESEARCH AND EDUCATION

Several comments relating to research and educational effort with regard to ERTS-1 imagery in Missouri are pertinent to this discussion.

1. DIAZOCHROME ENHANCEMENT OF ERTS-1 IMAGERY

Our lack of false color enhancement equipment has necessitated use of an inexpensive method for image enhancement for visual analysis. One method that we have found to be practical is the use of diazo-chrome color transparency film. We routinely make color composites and have encouraged experimentation at the University of Missouri-Rolla in image enhancement by this method using different color combinations. A graduate student explored possibilities of diazo-chrome color enhancement of ERTS imagery as the subject of his masters thesis. Results indicate that density slicing is possible with diazo-chrome materials using additive color combinations and masking techniques. By varying exposures and using color negative masks, spectral response patterns not apparent on the false color infrared image are isolated. The resulting color separations aid in delineating selected terrain parameters of interest to the earth scientist and engineer. The reason for bringing this to your attention is that this procedure offers a means of enhancement of basic imagery without the need for expensive equipment. The entire enhancement procedure can be accomplished in a short time at a cost of approximately \$2 per frame which is a fraction of the cost through other methods. It is recognized that this method has a number of shortcomings but we have found it to be useful.

2. COMPUTER ENHANCEMENT OF ERTS-1 IMAGERY

Computer enhancement and classification have been employed for nearly a decade, first in experimental research and now for applica-

tions research. Computer enhanced imagery increases detail inherent in ERTS imagery that is lost in the photographic enlargement of the 9 by 9 black and white imagery. Coverage (August 29, 1972) has been color enhanced (and enlarged) by the Laboratory for Remote Sensing at Purdue University, for central Missouri. The color composites are made from bands 4, 5, and 7. Such enhances imagery would be of value to regional planning, land-use inventory, environmental quality monitoring, and other applications. The enhancement of all available ERTS-1 data for Missouri should be high-priority objective, and ERTS-B information should have similar processing when it becomes available.

3. SHORT COURSES

The University of Missouri-Rolla and State geological survey held a short course this past spring for State employees who would be directly involved with remote sensing applications in their respective agencies. A number of this group also attended a workshop at the NASA-EROS Regional Remote Sensing Laboratory at Bay St. Louis, Miss., applying what they had learned to ongoing State projects.

4. ERTS-1 MOSAIC OF MISSOURI

An ERTS-1 mosaic of Missouri was prepared during the past summer by the State geological survey with assistance from the USGS Topographic Division in Rolla. This is in press and will soon be available to the public. The 1:1 map was completed from the 9 by 9 positive transparency bulk product supplied by NASA.

RECOMMENDED IMPROVEMENTS IN SYSTEM FOR ERTS-B

It is my understanding that because of technical difficulties a decision has been made to delete the thermal channel from the ERTS-B system. However, I wish to take this opportunity to indicate our interest in a thermal gathering system on future programs. Our interest in this is we had forwarded a proposal to NASA for ERTS-B coverage which would have required thermal imagery. So I want to take this opportunity to indicate our interest in thermal data on future programs.

My agency in cooperation with Water Resources Division, U.S. Geological Survey, has carried out some thermal infrared studies in southern Missouri. This technique, the detection of temperature differentials, shows promise as a means of identifying gaining or losing sectors along streams where a part of the water flow is either being lost to groundwater or the flow is being augmented by groundwater discharge. Addition of a thermal imagery system to ERTS-B would offer the possibility of additional research of this kind in Missouri and in other regions, where karst conditions occur. The system must be capable of imaging during predawn hours, according to results of work thus far. And folks working with this wanted it to be emphasized, repetitive coverage would be required in order to obtain baseline data, and to monitor variations in that data.

In our work we have been able to obtain high quality enlargements and other photographic modification of bulk product ERTS-1 imagery

on relatively short notice through informal arrangement with personnel at the U.S. Geological Survey's Mid-Continent Mapping Center at Rolla. Other users, relying upon the EROS Data Center, have experienced significant delay in receiving service. These users included the State Conservation Department, the University of Missouri and mining interests. This is not meant and is not necessarily a criticism of EROS. Provision should be made for improved services.

Mr. SYMINGTON. I don't like to stop you because we are pressed for time. So far as you know, has the OMB sent any people out to talk with you or any of these State agencies to analyze their interest in this information and advise them whether or not they could get it more cheaply and in other ways.

Dr. HOWE. We had a visit from a Mr. Donelson who did make a tour of that part of the country and did inquire about our use of this material. That visit was on the order of 10 or 11, possibly 12, months ago.

Mr. SYMINGTON. Were you with him on that occasion?

Dr. HOWE. Did I meet with him?

Mr. SYMINGTON. Yes.

Dr. HOWE. Yes.

Mr. SYMINGTON. And did he indicate to you how in their view this kind of information could be derived in other less expensive ways?

Dr. HOWE. No. He did not indicate other less expensive ways.

Mr. SYMINGTON. You understand the direction of my questions?

Dr. HOWE. Yes, sir.

Mr. SYMINGTON. You heard Mr. Loweth's testimony. OMB seems to feel that they don't have sufficient encouragement to go forward with this kind of a program, and I detect from your statement, which I would like to say I think is a competent statement, that you would like to go forward with this program.

Dr. HOWE. Certainly. It offers tremendous potential. We would have the same questions others would about how to phase in to an operational stage.

Mr. SYMINGTON. I will let you conclude your statement.

Dr. HOWE. State Remote Sensing Center.

One of the benefits of the ERTS-1 data dissemination program is that many States have felt the need for a remote sensing center facility to serve as a focal point for data development as a clearing house for remote sensing projects, and as a source of technical assistance to State agencies and the public. We have begun to answer this need in Missouri with the initiation of a Cartographic Data and Remote Sensing Center, which will operate under the general guidance of a newly established Inter-Departmental Council for Natural Resources Information. Current membership on the council is essentially the same as that of a special Advisory Committee on Natural Resources Data Sharing, which was formed at Governor Bond's request late in 1973. Much of the diversity in ERTS-1 data application described herein resulted from a critical study by the advisory committee, and the establishment of a Cartographic Data and Remote Sensing Center was a recommendation of the committee.

Missouri's effort in development of such a center will be slow and deliberate owing to limited funding and, more importantly, the need

to be certain that the center is actually responsive to the State's needs. Furthermore, we want to utilize all related facilities that may be available through the federal sector, such as a "User Service Center" that we hope will be developed in the USGS Topographic Mapping Complex located at Rolla.

NEED FOR AN OPERATIONAL ERTS-TYPE SYSTEM

In reviewing the matter of desirability of establishing an operational system that would make the benefits of the ERTS-1 experiments available on a continuous basis, we are able to identify three principal issues. These are (1) the importance of repetitive coverage, (2) the need to provide for supplemental underflight coverage as required, and (3) the need to provide for a historical record as an information base.

The question of need for the repetitive coverage made possible through satellite imagery is one that requires response from many disciplines. Repetitive coverage, which was provided every 18 days by ERTS-1, is a factor that may not seem to be of much importance to geologists. This is not really the case—the earth is dynamic, and meaningful changes that can be detected do occur. A number of the applications that I have noted implicitly require repetitive coverage in order to provide:

(1) Current data, as in the case of land use and other inventory work such as that of surface mining activity and lake and reservoir construction,

(2) Continuous record for reference in trend development as in urbanization and prolonged drought conditions,

(3) Flood inundation information and a basis for better interpretation of developmental history of given floods,

(4) Assurance that data responding to seasonal variations is available. Variation in soil moisture, vegetation, snow cover, and Sun angle are among the factors that are important in the mapping of soils and surficial deposits as well as bedrock features,

(5) Provide continual baseline data for references in interpreting thermal imagery.

In that connection in cooperation with—and we have had a lot of it from geological people, we have prepared a photo, an ERTS image mosaic of the State of Missouri, and it is interesting to note that in the time ERTS-1 was functional, we did not really get adequate coverage of the whole State, during that relatively short period adequate coverage of the whole State in comparable quality for each of the images and pieces of images that had to be mosaiced together. So it takes longer than you think to get the amount of information that is actually required in these 10-day repetitive passes to get some of the results you really want, and to get information for the seasonal periods that you may wish to have it in—you need to have it in.

We believe that provision of repetitive coverage is highly desirable in applications of ERTS data that are strictly geologic in nature. In certain other applications such as land use inventory, it would appear that repetitive coverage is essential.

Insofar as we are aware, the need for repetitive coverage by high-altitude aircraft cannot be met economically. You mentioned that in a comment you made a few months ago.

It is the combination of the perspective and repetitive imaging available through ERTS, plus the supplemental detail available for specific areas through the underflight program that has made ERTS so useful. If imagery of greater resolution were to become available from a satellite system, it would meet some, perhaps many, of the needs now met by underflight coverage. Seemingly, even with the capacity for greater resolution in a satellite-based system, the flexibility of a supplemental underflight program would be required, in order to record catastrophic events.

Our hope considering the enormous advances that have been made possible by ERTS-1, and the promise that this system holds in the area of natural resources surveys, is that you will see fit to support the concept of an operational system.

Finally, and with regard to House Resolutions 15781 and 14978, we are concerned that the effort already well under way by Department of Interior through its EROS and other programs, which are designed to address the matters of natural resources inventory and management, may be weakened by transfer of these responsibilities to NASA, which historically has not had the responsibility for this important aspect of our economy.

Mr. SYMINGTON. Dr. Howe, I thank you very much for an extremely interesting statement, one which I know the committee will be glad to study as perhaps one of the first comprehensive reviews by a spokesman for a State's usage of these materials and this kind of information derived from satellite observation.

Dr. HOWE. I wish I had the wit or foresight to have suggested that you, maybe you did, ask the people in Iowa. They have a program in remote sensing applications quite some ways beyond ours and have done more work with it.

Mr. SYMINGTON. That is good to know. I imagine you work with them on a number of things.

Dr. HOWE. We do.

Mr. SYMINGTON. If we have any further questions, we will take the liberty of writing you and you may respond at your convenience. I want to thank you very much for taking the trouble to be with us today, and express the gratitude of the full committee.

Dr. HOWE. Thank you.

Mr. SYMINGTON. Thank you, sir.

Our final witness this morning is Dr. Robert Colwell, professor of forestry at the University of California at Berkeley. Dr. Colwell is also associate director of the Space Science Laboratory at the university. He has appeared as a witness before this committee in the past on remote sensing systems. Specifically, he is one of the experts who participated in the 1972 Panel on Science and Technology when we met on that subject.

Dr. Colwell is a rear admiral in the Naval Reserve and has just come from a meeting of his Reserve organization, which explains his attire.

Welcome, Dr. Colwell. We are very pleased to have you with us and will be glad to hear from you.

**STATEMENT OF DR. ROBERT COLWELL, PROFESSOR OF FORESTRY,
UNIVERSITY OF CALIFORNIA AT BERKELEY**

Dr. COLWELL. Thank you, Mr. Symington.

Not only was I obliged to be in uniform in a session with the Navy this morning, but I am obliged to be back as soon as I can, in uniform, to meet with the Secretary of the Navy, Chief of Naval Reserve, and a few others this afternoon. This makes me the first one, for better or worse, who has appeared before this committee in tropical khakis.

Mr. SYMINGTON. We will place Dr. Colwell's prepared statement in the record at this point.

[The complete prepared statement of Dr. Colwell follows:]

STATEMENT OF ROBERT N. COLWELL, ASSOCIATE DIRECTOR, SPACE SCIENCE LABORATORY, UNIVERSITY OF CALIFORNIA, AND DIRECTOR, BERKELEY OFFICE, EARTH SATELLITE CORPORATION

Mr. Chairman and Members of the Subcommittee: It is both a pleasure and an honor to appear before this Committee to present my views on the present status and potential future usefulness of earth resources survey programs in general and of earth resources technology satellites in particular.

At the outset and in the interest of avoiding redundancy, I must mention two previous statements of mine which overlap somewhat the one which I have been asked to give today. The first of these (Colwell, 1972a) was presented before your Committee nearly 3 years ago and dealt with the future for remote sensing of agricultural, forest and range resources. That presentation was given on the eve of what I referred to as "the most important photographic experiment in history,"—the one which would begin with the launching of the world's first Earth Resources Technology Satellite, ERTS-A.

The second of these earlier statements of mine (American Society of Photogrammetry, 1974) was presented only a short time ago to the Senate Committee on Aeronautical and Space Sciences. Since my second statement was prepared after ERTS-A (ERTS-1) had been in operation for a full two years, it provided me with an opportunity to summarize briefly how things had been going in that highly heralded experiment.

My basically optimistic evaluation, as given on that second occasion, was in marked contrast to the following pessimistic evaluations quoted to that same Committee by a distinguished representative of the Office of Management and Budget (Zarb, 1974).

1. The Statistical Reporting Service of the Department of Agriculture has asserted that "without significantly improved resolution and dependability there is no possible way the ERTS system can achieve any improvements over the existing crop forecasting system"

2. The Forest Service has stated that "there is as yet no demonstrable need in forest inventory, the major area of benefit in forestry, for frequent acquisition of the relatively low resolution information produced by ERTS" and

3. The Environmental Protection Agency, in commenting on ERTS, has similarly stated that "while some benefit may be derived from the examination of low resolution imagery, the great bulk of the essential elements of information required to produce a piece of finished environmental information lies well below 30 feet resolution" (as compared with the 10-fold poorer resolution, approximately, that is provided by ERTS).

Comments such as these prompted Dr. Zarb to testify with a fourth, and summarizing statement, as follows:

4. "the present ERTS technology is not yet good enough to justify a commitment to an operational system". Pointing to the need "to achieve significantly better resolution" he concluded that "any additional launch, beyond ERTS-B, of a remote sensing satellite should be carried out only when such a launch can be shown to be the most cost-effective way to achieve a significant advance in the state of the art".

There is a remarkably good consensus among the 4 viewpoints which I have just quoted. Furthermore they come from some of the most authoritative offices in this country. Therefore, there would seem to be no justification for me to occupy

the time of your busy committee if it were merely so that you could hear additional testimony that was basically in agreement with these assertions. Such is not the case, however. Therefore, I will now proceed to indicate why I disagree with them. However, I will do so not because of any inherent belligerence that causes me to enjoy disagreeing with the experts, even to the point of questioning whether they know how to run their own business. Having worked closely for many years with such officials from the agencies quoted, I have great admiration and respect for their abilities, despite a few honest disagreements. Instead the rationale for my perilous course of action is simply as follows: your Committee obviously needs to know whether there are any valid challenges to the 4 assertions which I have just quoted as it seeks to decide whether it should favor the commitment of this country to the launching of ERTS-C in the near future and thus to the sustaining of a long-term and continuous ERTS-type of operational remote sensing system.

1. Can ERTS-Type Data Help Improve Crop Forecasting Systems?

Crop forecasting systems that presently are in use are able to acquire quite accurate information periodically on crop type and probable crop yield in selected sample areas or "segments". Two possibilities for sizable errors exist, however, under these systems: (1) The selected sample areas may not be adequately representative of the entire area to which such sample data are applied, and (2) The total agricultural acreage (a factor which is of great importance in developing "expansion factors" for the sample data) may not be known with sufficient accuracy.

If a crop forecasting system were to be based on ERTS derived data, the fact that the entire agricultural area could be viewed would reduce the potential for errors due either to unrepresentative sampling or to uncertainty as to the total agricultural acreage. Two possibilities for sizable errors would exist, however, if only the ERTS-system were to be used:

- (1) those due to the misidentification of crop types, and
- (2) those due to inaccurate forecasts of crop yields.

Experience with ERTS in California and elsewhere has shown that the multi-date coverage of agricultural areas which it provides (at 18-day intervals, weather permitting, throughout the growing season) permits one to identify the more important crops in many instances to an accuracy of greater than 90 per cent. Furthermore there is reason to believe that two factors could greatly improve the accuracy with which crop yields, field-by-field, could be forecasted from ERTS-data.

(1) The use of pertinent data readily available from meteorological satellites, on temperature, precipitation and light intensity conditions existing in various parts of the agricultural area and at various critical times during the crop growing season and (2) the compilation, over a period of several years, of aids to crop yield estimation known as "photo interpretation keys". The value of such keys for similarly difficult photo interpretation problems already has been demonstrated on numerous occasions.

In this instance the keys would consist of two components: (a) ERTS image examples of fields that had been monitored on the ground so that both crop type and crop yield were accurately known, field-by-field, and (b) word descriptions which would set forth in concise terms the photo image characteristics which were of greatest diagnostic value both for the identification of crop types and the forecasting of crop yields.

In summary of this section, 3 points seem worthy of emphasis: (1) It is quite unlikely that a crop forecasting system based entirely on ERTS data would ever provide sufficient accuracy to satisfy the needs of those using such forecasts; (2) Even at the present time, however, ERTS could be of great value as a supplement to the on-the-ground crop forecaster by permitting him better to select representative "segments" and better to determine the expansion factors to which data collected from such segments should be applied. It is at this point that I find myself in substantial disagreement with the previously quoted statement that "there is no possible way that the (present) ERTS system can achieve any improvements over the existing crop forecasting system", and (3) If we were to be given a continuous period of several years during which to develop photo interpretation keys and to derive empirical relationships between crop yield and the data provided by both ERTS and meteorological satellites, we would make great progress, indeed, toward improving present crop forecasting methods. With the ever-increasing demand for food and fiber and the ever-dwindling amount of

arable land, the importance of developing such a capability in order to help ensure adequate crop production (whether regionally, nationally or globally) can scarcely be overemphasized.

2. Can ERTS-Type Data Help Improve Forest Inventories?

Forest inventory techniques that presently are employed make effective use of aerial photographs, but rarely do they make use of space photography such as that which ERTS can provide. Some of the most knowledgeable experts in the field of forest inventory have stated that a system, such as ERTS, which cannot resolve individual trees offers nothing of value to them. Others soften this viewpoint by asserting that the frequent acquisition of such imagery is not as yet a demonstrable need.

Although the second of these assertions is significantly different than the first, and although even the first does not address itself to all potential forestry uses, the net impact on many decision makers appears to be essentially the same, viz. that, at least from the forestry stand point, "present ERTS technology is not good enough to justify a commitment to an operational system".

My colleagues and I at the University of California have been conducting studies during the past year to determine the potential usefulness of ERTS-1 data as an aid to the making of timber inventories. Our test area has been a representative portion of the mixed conifer forest of California's Sierra Nevada Mountains. In this work we have maintained close contact with local personnel of the U.S. Forest and with numerous representatives of the forest industry the better to ensure that our research would be truly meaningful.

In one such test we investigated the usefulness of ERTS-1 data as an aid to determining timber volume only since this is perhaps the simplest kind of forest inventory worthy of testing. A basic premise in this study was that timber stand density (i.e. the proportion of the ground that is obscured by trees when the forest is viewed from overhead, as on ERTS-1 imagery) is a very useful, though admittedly rough indicator of timber volume. Based on this criterion a rough timber-volume classification was made from the ERTS-1 data every resolution cell. Since each such cell is slightly greater than 200 feet on a side the result was essentially an acre-by-acre classification.

Using sampling techniques based on probability in proportion to volume, (ppv), sites were selected within which to obtain large scale aerial ektachrome photography through use of a 35mm camera mounted in a light aircraft. On this photography tree heights and crown diameters were measured thereby providing much more refined estimates of timber volumes.

From the results thus obtained, and again using "p.p.v." sampling techniques, still smaller subsamples were selected. Ground survey crews visited these few sites and accurately measured the volume of each merchantable tree with the aid of an optical dendrometer.

Once this three-stage ERTS-based sampling scheme had been completed, the proper expansion factors were developed and applied, thereby providing a timber volume estimate for each portion of the test area and for the property as a whole.

Results of this test indicated that an acceptable order of accuracy could be achieved more quickly and at less than half the cost through use of this ERTS-based method as compared with conventional methods for timber volume assessments.

While some skeptics might raise the question of whether a "random success" was achieved in this instance, Forest Service personnel at both the local and national level are far more appreciative than they previously were of the value of ERTS-type data as an aid to forest inventory.

In most parts of the United States a timber inventory deals not merely with the estimation of timber volumes, but also with an appraisal of timber stand conditions and growth rates. Consequently our group has been conducting additional tests along these lines and appears to be achieving similar success, although final results will not be available until about 2 months from now.

Still another sense in which the term "forest inventory" is used by some is with respect to the entire "resource complex" of a forested area, including the timber, forage, soils, water, minerals, fish, wildlife and recreation potential. Under sponsorship of the Bureau of Land Management our group is nearing completion of such an inventory for a 2-million acre area in north-eastern California. Based on results achieved to date there is little doubt among either the investigators or their sponsors that the most cost-effective way currently available for making such a survey involves the use of ERTS-type data as the first stage in a multistage sampling scheme.

3. Can ERTS-Type Data Help Improve Environmental Analyses?

As previously indicated the Environmental Protection Agency considers that ERTS-type data can be of only limited interest because of the limited spatial resolution which it provides. This may be true as applied to the making of traditional "environmental impact" studies of local areas and especially when the concern is primarily with respect to the immediate or short-term environmental effects. However, there is increasing evidence that environmental concerns and in consequence that environmental analyses should be macroscopic as well as microscopic (even to the point of providing broad regional or even global analyses) and that these concerns should also consider long term as well as short term environmental impacts. To the extent that these broader considerations become important, so does the potential usefulness of ERTS-type data. A century ago man's appreciation of his environment was essentially limited to what he could acquire while observing it from the ground—a vantage point which offered him little better than the "worm's eye view". With the advent of the aircraft he was provided with the "birds-eye" view that greatly broadened his environmental perspective. And since the dawning of the space age he has been provided with what some enthusiasts refer to as the "God's eye view". I hasten to state that it does not follow that man is thus able to acquire God's full perspective of what is happening to the earth's environment. There are numerous instances, however, in which the broad perspective and limited resolution of space-acquired ERTS-type data can elucidate environmental relationships that man previously was unable to discern. This is true not only because of the more limited perspective of earlier systems, based on aerial photography, but also because the resolution of such systems provided such a large amount of detail that he couldn't appreciate the true nature of a forest (for example) because of the high-resolution noise from the individual trees.

And as for the short time-span that often is used as the frame-of-reference of the environmentalist as he makes detailed environmental impact studies, it often is too short, I believe, and certainly too short to achieve maximum benefit from ERTS data. In this regard, it is my flat prediction that the greatest value of all of the data acquired to date by ERTS-1 will emerge some 50 to 100 years from now when environmentalists of that day can go back to the first adequately detailed look that man ever obtained of this globe, viz, the look that was obtained and faithfully recorded by ERTS-1 in the early 1970's—shortly before man irreversibly ruined major portions of it. By thus discerning clearly what environmental tragedies occurred on a grand scale, and thus by better understanding why they occurred, man hopefully will then be able to learn in the nick of time how to avert similar environmental tragedies in such parts of the globe as he has not by then got around to ruining.

4. Is Present ERTS Technology Good Enough to Justify Commitment to an Operational System Now?

Dr. Zarb seemingly answered this question with great finality when he said, "Any additional launch, beyond ERTS-B, of a remote sensing satellite should be carried out only when such a launch can be shown to be the most cost effective . . ."

The time when that will come seems to be related more to the development of faith than technology. The faith to which I refer is one that needs to be developed between budgetary officials and the potential users of ERTS data.

On the one hand, it appears that even now budgetary officials would approve the timely launch of ERTS-C if they had faith that enough potential users of its data would, indeed, do so.

On the other hand, it appears that a major deterrent to the receiving of such declarations from potential users is their lack of faith that budgetary officials will appropriate the funds required to insure the availability of ERTS data on a continuing basis.

For example, many of the resource managers with whom my associates and I work, (particularly those who seek to manage such *renewable* natural resources as agricultural crops, timber, forage and water) and also many of the environmentalists with whom we work, are convinced that ERTS technology already is good enough to justify abandonment of their old data basis and their switching to new ones which would use ERTS as the primary initial data input. They have no intention of making such a dramatic, and perhaps traumatic switch, however, until they have more faith than at present in the continuing availability of ERTS data. Because of the dynamic nature of these renewable natural resources, any system designed for use in monitoring them must provide updating information

at suitably frequent intervals. The ERTS system has that capability, but obviously if ERTS vehicles do not continue to fly the required capability is lost. Quite understandably faith in the continuity of such a system is difficult for the potential users of ERTS data to develop under present circumstances. This is especially true when those officials who would need to authorize the funds for such a continuing effort make assertions such as the one which I previously quoted, VIZ. that "the present ERTS technology is not good enough to justify an operational system".

In the presence of this dilemma it is perhaps essential that I cite one or two specific instances in which potential users of ERTS data are, even now, on the threshold of switching to an information system which would make cost-effective use of ERTS data. In so doing I will continue to confine myself primarily to potential users and uses of ERTS data in the geographic area with which I am most familiar, VIZ, the state of California.

A. *Preplanning in Relation to the Suppression of Fires in Wildland Areas.*

More than half of California's 100 million acres is classified as "wildland". Much of this vast area contains either highly inflammable brush and herbaceous vegetation or highly valuable timber. Furthermore, these vegetation types in many instances clothe steep and highly erodible slopes and often they are intermingled with expensive summer homes and recreational developments.

Because of this combination of circumstances, several federal agencies including the U.S. Forest Service, the Bureau of Land Management and even the Department of Housing and Urban Development have expressed great interest in minimizing the damage inflicted in these areas by wildland fires.

One step that has long been recognized as an aid in reducing these losses is known as "Pre-planning" by means of which a strategy is developed in advance for use in combatting wildland fires wherever they may develop. The effectiveness of this strategy is greatly improved if a detailed knowledge of fuel types, area-by-area, is available. Preliminary research results obtained by my research group working in concert with the interested agencies, have demonstrated the value of ERTS data as the basis for mapping fuel types to uniform standards throughout California. From such information fire-fighting officials and agencies can intelligently engage in various pre-suppression activities, including the locating and building of fuel-breaks, helicopter landing sites and water storage tanks.

The value of this information would be enhanced if, in addition, accurate and current information were to be available at all times relative to fuel flammability and fire danger ratings, area-by-area, throughout this vast acreage. There is reason to believe that the thermal infrared scanner proposed for inclusion on ERTS-C, together with timely information provided at frequent intervals by meteorological satellites, would do much to provide this additional information.

B. *Post-Burn Damage Assessment and the Planning of Rehabilitation Measures.*

Large sums currently are expended each year in California in attempting promptly to rehabilitate wildlife and areas following burning.

Fire officials within the California Division of Forestry are among those who have developed a healthy respect for ERTS data as a means to that end. For example, less than 72 hours after ERTS had been launched it photographed a recently burned area in California with sufficient clarity to permit ERTS data analysts to estimate its areal extent 25 per cent more accurately than was done by conventional aerial and ground surveillance techniques. Such an increase in informational accuracy is of interest to many groups including those who must pay their pro-rated share (on an acreage burned basis) of the fire suppression costs and those who must develop a prompt and effective post-burn rehabilitation program.

In my oral presentation of this paper I will cite other examples with the aid of lantern slides. Those examples will serve to emphasize the essentiality of our having a continuity of ERTS-type data over a period of several years, the better to develop empirical correlations between ERTS data and ground truth and the better to determine the amount of year-to-year variability that can be expected with respect to this nation's renewable natural resources. It will be obvious from my discussion of these examples that I strongly favor a commitment being made now to an ERTS-type of operational system and, axiomatically, to the launch of ERTS-C at the propitious time for ensuring a continuity of ERTS data.

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Dr. COLWELL. As I have already indicated, the remainder of the story that I have to tell is best told with the aid of lantern slide examples which illustrate both the usefulness and the limitations of ERTS-type imagery from the agricultural, forestry and environmental protection standpoints. In this concluding portion, as in the earlier portion, I will build my comments around the 4 statements presented by Dr. Zarb of the Office of Management and Budget.

The first of these statements, as previously quoted by Dr. Zarb, is attributed to the Statistical Reporting Service, U.S. Department of Agriculture: "Without significantly improved resolution and dependability there is no possible way that the ERTS system can achieve any improvements over the existing crop forecasting system." My group in Remote Sensing at the University of California has worked closely with SRS in the past. I submit that the quoted statement may have been an accurate appraisal at the time when personnel of SRS made it and that they themselves probably are in the process of revising that statement more optimistically toward use of the ERTS system. But rather than relying on words let me show you examples that will document the value of ERTS in crop forecasting.

This is an ERTS image of an area in California, taken from an altitude of 570 miles, and on this simulated Infrared Ektachrome "false color" presentation you and I can see differences in colors of fields. We can tell the acreage of fields. We can do the following with reference to the problem of crop forecasting that SRS is interested in, based on my experience with them:

Every field, with no exception, having this color (yellow) at this time of year is barley. Every field having this color (golden brown) is safflower. Every field having this color (blue-grey) is fallow, a category that SRS obviously is interested in relative to crop forecasting.

This bright red color is rice. Every field that has this black color now (at the time of the ERTS overflight) was barley until about a week or two before, and is now burned stubble.

The remaining fields that are red or pink could be any one of forty or fifty crops but in this vast area, including some not shown here, it turns out that most of this is either seed alfalfa, which eighteen days later will have a golden brown color (the same as the safflower has now, but which by then will have been removed), or cotton, coming up in the areas that are fallow at the time of this photography, or sugar beets, a crop that does not change its appearance during this midsummer part of the growing season.

SRS would seem to need this kind of an overall survey showing the acreage occupied by each of these crops. They also would seem to need something of the total acreage of the agricultural area, the better to decide what their expansion factors must be as they take sample information on the ground. I am not saying that they might do this crop forecasting just from ERTS in the future but that they certainly could use ERTS data to advantage, the statement I just quoted notwithstanding.

As for the ability to see the entire area, a slide soon to be shown will relate to that problem.

Here we see in even greater detail a portion of the area we saw before. Again we see the unique coloration of the safflower, barley, fallow ground, etc. Note that we clearly see these colors, field-by-field, even though the resolution we have here figures to be only three or four hundred feet, when we use the standard way of measuring this nominally. Despite this "nominal" resolution limit, we know there are features no more than fifty to a hundred feet across such as this canal which can be discerned by virtue of good color contrast and linearity.

As seen by this next slide, it is possible to perform "automatic data processing" of ERTS data. This again, at reduced resolution, is a portion of the area we were just looking at and the computer, with better than 95 percent accuracy, prints out every resolution cell (each cell representing one acre roughly) in a unique code so all of the safflower is printed out with this symbol, all barley with this second symbol, and all of the other major crops with similarly unique symbols.

By keeping a running total of this printout it is possible to get directly (and essentially instantaneously, if the state of art is advanced to where we have not only instantaneous transmission of this data from satellite to ground, but also essentially instantaneous data processing) accurate information as to the acreage, in a vast area, of each of these crops that is identifiable. I do not say that all of these crops are identifiable but as we have just seen some of the most important ones are, and to a very high order of accuracy.

This next slide, showing on a single ERTS frame a vast area extending clear across the entire Sacramento-San Joaquin Valley in California, indicates that it is possible to tell where agricultural land ends and to get the total acreage of it and tell into what strata this agricultural land might be stratified to get the necessary expansion factors for use in a multistage sampling system. For example, the sandy soil is known to be *here*, and the best crop grown in such soil in this area is grapes. The area is seen to have a unique signature on this ERTS imagery. Deep loam soils (seen in this *second* area) are best to grow orchard crops in. These are the orchard crops and you can see that they also have a unique appearance on ERTS imagery. The soils have to be

deep so the trees won't be windthrown. You can recognize in this *third* area as seen on ERTS imagery, the barley and associated small grains. The soils here also are loamy but too shallow for orchard crops. In this *fourth* area, also of unique appearance, are peat muck soils in the delta region, growing such crops as asparagus, corn and sugar beets. In this *fifth* area there is rolling topography and hence only dryland agriculture can be practiced here. In the month of July when the ERTS imagery was acquired the crops in this fifth area, again almost entirely small grains, have already been harvested.

The kinds of ERTS-derived information just discussed are not the ultimate answer to the SRS's need. In our opinion, however, such information is certainly a valuable input. Hence the statement would not seem to be correct that "there is no conceivable use that can be made of ERTS data in relation to crop forecasting." All elements I mentioned are among the essentials of crop forecasting when fortified by a limited amount of ground observation.

Here is still another view to show at smaller scale the area we were looking at, and its environs. This is an entire ERTS frame, you see. Now we can see that the smaller area we were talking about is simply part of this one frame of ERTS imagery, extending almost from the crest of the Sierra clear over to the Pacific coastline, with the city of San Francisco hidden beneath the fog here. This picture was painted in a period of twenty seconds by the ERTS vehicle, travelling 18,000 miles an hour, getting essentially nine million data points on scene brightness, recorded digitally on a scale of 0 to 64, in each of four separate bands in that period, and this remarkable vehicle has been doing this kind of data collection continuously since its launch more than two years ago.

This next slide of ERTS-1 imagery illustrates another factor which crop forecasters are interested in. This is an area in which shortly before the ERTS imagery was acquired a flood had occurred locally because of a break in the levy in the San Joaquin River. The flooded area is seen to extend clear to here. There is interest in knowing what this prolonged flooding will do to crops this year and in future years, and therefore the matter is of interest in crop forecasting.

This next slide shows the same area on ERTS-1 imagery several weeks later. The flood-water previously was up to here. It has now receded to here. These images match directly. We can tell by comparing imagery of the 2 dates how much of the area that was flooded before, now is not flooded. This observation, supported with some empirical work done on the ground to determine what this period of flooding does to the yield of crops is certainly a vital item in relation to crop forecasting.

The second of the four statements that I wanted to comment on is the following: "There is as yet no demonstrable need in forest inventory, the major area of benefit in forestry, for frequent acquisition of relatively low resolution information produced by ERTS." This comment was made by officials at the highest level of the U.S. Forest Service some time ago.

I again submit the possibility, based on recent sessions I have had with them, that they are in the process of revising this statement more optimistically.

Let us look at a few slides which will serve to illustrate what the possibilities are with reference to this statement.

This slide is of another ERTS image showing all of the forested area, at least from left to right, throughout the entire Sierra. Here is the Sacramento area, Sutter Buttes, Nevada here, the Pacific coast just off the field of view to the left here, so we get a tremendous area. It is from this broad view that people would conclude: "All I can see is where the forest is. That does not help me much." In a moment I will show you more detail in this portion of the forested area so that you can see for yourself whether it is true that we get no useful detail there in relation to the making of forest inventories.

This slide shows a portion of our NASA Bucks Lake Forestry Test Site as seen on an enlarged portion of the ERTS frame shown in the previous slide. We can see in some detail here differences in timber growth conditions, but certainly not enough to resolve trees.

In order to demonstrate the usefulness of this ERTS imagery, let us consider the next slide which shows this enlarged area and then let us compare it to a high altitude photo (taken from 65,000 feet) having a resolution that others have said is useful, or even to conventional aerial photography, scale 1/20,000, which in times past has been used for forest inventory by the U.S. Forest Service and on which still their system essentially is based. All 3 types of photography appear side-by-side on this single slide.

Suffice it to say that some of the significant boundaries between timbered and non-timbered areas and between high-producing areas and low-producing areas obviously can be better seen on this ERTS imagery than on this "high-flight" aerial photography, or even on this conventional 1/20,000 scale aerial photography. It does not follow that we can use ERTS alone to make a forest inventory but it certainly is true that our Forestry Remote Sensing Group at the University of California and the Forest Service personnel that we work with locally on this project say that ERTS is valuable. It provides an important new look at the forest, and in the future we would welcome the opportunity of using this as the first look, the better to decide in a multistage sampling scheme where to locate our more detailed sample plots.

From this ERTS-based look at the entire forested area, foresters may select small areas where they should get large scale aerial photos in order to acquire more detailed information and finally decide where to acquire still more detailed information on the ground, but in still smaller areas—a process known as "multistage sampling."

Here is a high-flight photo showing the San Francisco Bay area. We see important resource boundaries here, not as seen on ERTS but as seen on the higher resolution photography that is obtained from thirteen miles up, in this case by a U-2 or R-57 aircraft.

I would like you to notice *this* boundary and also *this* boundary right here as we now look at that same area from an altitude of 570 miles.

This next slide shows the same area as imaged by ERTS. The first of the boundaries is here; the second here and both are essentially as discernible on ERTS as on the high flight photo. If we were to single out other significant boundaries we would see that this ERTS imagery

is indeed useful in making the first of the important distinctions here, viz. separating the woody vegetation from the grassland or other kind of condition. In this way one can get the total acreage of the woody vegetation, which is an important step in this multistage sampling system designed to come up with forest inventory data. If we do pick a spot such as this to get a more detailed look we apply whatever we see in such a local area to other areas having similar appearance on the ERTS image. That possibility is illustrated in the next slide.

Here is an extremely large scale aerial photo on which we can determine the species composition of trees by virtue of the fineness of detail that can be seen. For example, the fact that these are compound leaves helps identify the tree species. You see the individual leaflets. You can see that this first species is different from a second one here, even though they have the same tone. A third species is here, a fourth one is here, et cetera, but we only obtain this expensive large scale photograph for very limited areas and apply it in each instance to the timber type boundaries as delineated on the smaller scale imagery.

As seen in this next slide, we sometimes need to have a "bridge" between remote sensing and contact or proximal sensing. John Wear of the U.S. Forest Service, one of our cooperators, is among those able to provide such a bridge. In this instance he is shown immediately after he has finished taking from a helicopter very large scale photos such as you saw previously, but in this case of a Douglas Fir stand. As shown by this slide, he is now in the process of checking each tree from the same helicopter and on the same flight, since the objective was to determine which trees were insect infested, fungus infested, etc. at the time of photography. From the hovering helicopter shown here he is actually able to excise branches with a pruning pole. Thus still less ground sampling is required by virtue of his using ERTS for the first look, this hovering helicopter for the second look, and then finally the on-the-ground sampling of very limited areas.

A determination of range condition is also of interest in forest inventory. Here we have selected an area in which deferred rotating grazing, presumably a practice of benefit in improving range conditions, has been employed during the two-year interim between the time when the left and right photos shown on this next slide were taken. You can measure two-dimensionally, as seen here, or three-dimensionally on large scale stereo photos of this area (taken within sites selected from ERTS), what the increase in the volume of each plant has been. Note, for example, a range plant such as this, compared to this or this one on both the left and right photos, to determine what the plant growth has been during the two-year interim.

In this way you can quantify better than by ground photos, ground measurements or other means, what the improvement has been in this and other areas, and using ERTS or other imagery find out what regions have been similarly handled, so that if there are benefits from this range management practice here, we can apply them with benefit in other areas to increase forage volumes and values.

Here we see a contrast in another area where conventional grazing has been practiced and in which, during the same period, there has been no increase in volume of vegetation. Again we can quantify what the differences have been.

The third of the four statements (and this is from EPA) as quoted by Dr. Zarb is as follows:

"While some benefit may be derived from the examination of low resolution imagery, the great bulk of the essential elements of information required to produce a piece of finished environmental information lies well below 30 feet resolution."

Let us look at an illustration. Here on ERTS imagery is Los Angeles and environs on a smoggy day and on a clearer day. It does not require high resolution to show the dramatic difference there. It seems to me that one of the big impacts of ERTS, potentially, is something that essentially defies cost-benefit or dollar value assigning to it. How much is it worth if John Q. Citizen realizes that if he does things properly, as the experts monitoring these conditions from ERTS say he should, he can insure days like this clear one in the future instead of days like this smoggy one. This is not something you can cost-effectively describe nor is this environmental analysis something that requires high resolution. It is of interest to EPA, however, based on work which my colleagues and I have had occasion to do with them periodically.

This next slide shows another environmental factor demonstrating the capability of ERTS to repeatedly cover the same area time after time, in this case (and again despite the low resolution of ERTS imagery) in order to monitor the "green wave" in California's grasslands. While there is a vast series of these ERTS images, suffice it to say that on January 4, 1973, as seen in this matching ground view, the annual grasses are just coming up through last year's dead straw, and therefore the corresponding area (with this ground shot having been taken from here on the ERTS imagery, looking in this direction) shows only a little pink on the infrared false color rendition of ERTS imagery.

By April 4, when most of this dense straw has now been overgrown with green grass, we have on this ERTS false color imagery a much brighter red color. This is the optimum time for range readiness and a comparing of the photos shown here with similar ERTS images for many other years, and with associated ground truth for those years, would illustrate in this case whether this is going to be a good or poor year for livestock grazing. Unfortunately such a multi-year comparison of ERTS imagery is not presently available, however.

With reference to the desired continuity of ERTS-type data, it is almost impossible to tell, in one or two years of data collection (and perhaps even in three or four), what the variability of range readiness pattern will be, yet it does vary from year to year, and each year if we have this kind of record and the associated ground truth in selected spots, we can empirically develop a capability over the long period that we could not possibly develop in only a few years.

How would this same annual grassland area look later, with the onset of the warm summer season? By April 22, part of the area now is turning brown due to drying of this year's vegetation, and so the optimum period for range readiness is about at an end here. This, again, is reflected by what we see in the ERTS imagery. There is a "rain shadow" here with precipitation coming in from over here. The rain shadow is having its effect here but a little different pattern

this year than last. By May 10, much brown grass has appeared so the area is much browner here, and this area is certainly past range readiness to the point where if, by this time, you have not gotten the goodies out of it for livestock production, you won't for this year.

As for the agriculturists that have land right nearby it is entirely possible, based on conversations we have had with them, that this wild-land forage annual grass is such a good indicator of the "complex" of soil, vegetation and climatic factors as applied to this particular area, and this period of time, that they could use this kind of ERTS imagery (if we had a continuity of it) to decide better than by other means in any given year when they might need to start irrigating their crops. Without such a guide they might conceivably either be wasting water or else, by withholding water, could be suffering crop damage because of the onset of the drought season—and not even know it.

There obviously are other, better ways to acquire such information locally. But if the agriculturists are trying to get the overall pattern, the better to decide what they have in the way of crops in his vast region and what the requirements for water will be, this ERTS imagery may easily turn out, with a satisfactory continuity of data, to provide one of the best measures.

Notice also the ability on four images such as you saw here to acquire something that virtually no other system does acquire. That is, for areas that exhibit little change we have a uniform color signature that can be applied not only in those same spots but all the way from the left to the right edge of the ERTS frame of imagery so that we can avoid the problem of "fall-off," of tone or color values in the corners, a factor we want to avoid if we are to use automatic discriminant analysis of ERTS digital data, or if we want to use a given combination of tone values in these four bands. This uniformity of the scene-brightness record is something that ERTS provides, at least in my experience, to a greater extent than any other kind of imagery.

These two ground photos show the annual variation in range growth and time of range readiness. They were taken on exactly the same date, but one year apart, from the same station. While you may not be able to see it clearly, certainly range readiness is not the same on the left photo as it is on the right. We need to have a continuity of at least several years to find out what the range of such variability is, and the extent to which we can estimate that variability primarily from the ERTS imagery.

The last of the statements on which I wish to comment is one from the conclusion of OMB as recorded by Dr. Zarb:

"The present ERTS technology is not yet good enough to justify a commitment to an operational system. Any additional launch, beyond ERTS-B, of a remote sensing satellite should be carried out only when such a launch can be shown to be the most cost-effective way to achieve a significant advance in the state of the art."

I raise the question as to whether the ultimate measure has to be entirely one of cost effectiveness. Obviously it needs to be an important part of the measure of how useful ERTS imagery is. However, I submit the possibility that some of the fringe benefits relating to an increased amount of national pride in this kind of system, or to an

understanding of what the environmental problem is and the role which each individual can play in it, may defy our giving cost benefit values to them, and yet they are indeed an important part of the overall merit of this program to the United States.

I don't think people of this country were primarily preoccupied by cost effectiveness in sending men to the moon, nor was OMB. There were some things that transcended cost effectiveness in that instance such as national pride and factors related thereto. I don't think it was cost effectiveness that prompted the present OMB predecessors to say many years ago, "let us build a Washington Monument or Lincoln or Jefferson Memorial" or "let us fly two flags on the National Capitol Building instead of one," as indeed is the situation that I noticed across the street as I entered this building a few minutes ago.

Sometimes you don't try to get quite that refined on cost effectiveness; so while I am a cost effectiveness proponent myself I think it is overdoing it a bit here to say that ERTS must be proved with hard dollars to be cost effective before we decide to have a continuity in the program, as with the timely launching of ERTS-C.

Relating to the last point, then, this next slide illustrates what I want to show you, just quickly, about the many things that people get a thrill out of seeing on ERTS here, whether it is cost effective or not, and in so doing get an appreciation of the potential benefits of ERTS and even a sense of pride that Americans have been the first to develop such a system.

I have already talked about the correlation between soils and vegetation as seen on this ERTS frame. The geologist, however, looks at this area quite differently. He notices, for example, that all of the geology trends in this northwesterly direction, whether it be the valleys, the mountains, the coastline or the fault lines. He is interested in looking for "geologic anomalies" which trend in some other direction and with which he is likely to find that mineral or petroleum deposits are associated. The trained geologist, therefore, looks at something in this ERTS image that others might overlook. For example, there obviously is marshland in this area and this light-toned structure in middle of it has to be a "topographic high" surrounded by low swampland. Note that its major axis is in the left-right direction and in this respect it is an anomaly.

Is it possible that this might be what is called an "anticline" where the rock strata instead of being horizontally bedded have been upwarped. If there is petroleum anywhere in this general area it would likely be beneath the center of this structure, floating on the surface of the water. If you look closely perhaps even from where you sit you can see a suggestion of a halo inside this anomaly, darker in tone, which further encourages the geologist to consider that this might be an anticline.

The fact is that the most promising place for petroleum anywhere in the 12,000 square miles covered by this one ERTS frame is known to be right here. In fact oil and gas are being extracted commercially from this area now. Therefore we might ask ourselves: "Of what value is ERTS if we already knew it?" If we are able to tell in an area such as this (where ground information is already available) the extent to which the features discernible on ERTS give us this information, we might consider applying this same technique in other parts of the globe where we have ERTS imagery but no ground information.

Incidentally, if cost effectiveness is the sole measure of the value of ERTS, I suppose that, as other people have stated here, this is a good example of where the big payoff from ERTS can come, and yet it is only a one-time or at the best a one-season or a one-year look that is required to make most geologic discoveries and hence no argument exists, perhaps, for continuity of such data beyond ERTS-B to facilitate geologic discoveries.

I submit that there may be a little shallow thinking there but in an entirely different respect: It could easily be that if we use ERTS primarily to locate these exceedingly valuable mineral and petroleum deposits and if we then exploit them as fully as we seem inclined to in the present energy crisis, this may in the long run prove to have been a negative value of ERTS. By such extensive exploitation of our few, non-renewable resources now we are selling the birthright, perhaps, of all succeeding generations. Consequently, I think that sometimes we have sort of a reverse view of what is cost effective and what is not.

In my view, the biggest value of ERTS type data, at least within the next few years, will come from repeated looks at the renewable natural resources, such as agricultural crops, timber, forage and water resources, where one cannot infer from one time, one season, or one year of observation what the situation is going to be in other years. Yet current information is needed each year if these dynamic and renewable natural resources are to be managed wisely.

Notice, in this same slide, how readily you can inventory every bit of the rice up here. In the month of July rice is the only "continuous cover" vegetation that is healthy and flourishing in this vast agricultural basin and therefore appears uniquely bright red on this kind of "false color" photography.

If time permitted we could tell much more about the value of information derivable from the ERTS image. For example, we could explain why we need reservoirs and underwater storage here in the populous San Francisco Bay area to prevent salt water intrusion and to provide local supplies of water during the few hot days that come periodically in the summer here. But where does the necessary water come from? Not from a little watershed here, immediately surrounding the reservoir, but from the Sierra seen 100 miles away on this same ERTS frame. Even the laymen can readily understand from such ERTS imagery why we have these engineering structures and the need for building them. Engineers and resource managers, therefore, have less of a problem with getting the public to cooperate in this kind of a venture, all because the interrelationships are so clearly portrayed in a single broad synoptic view by ERTS.

Perhaps the number one environmental debate right now in the State of California is with reference to the delta region shown here, on this same ERTS frame, where there is a confluence of the Sacramento and San Joaquin rivers. We need to transport water, either through or around this delta, from northern California to southern California, and we can better do this with a canal system yet to be built. But we would have to have some kind of a system bypassing the present water channels in the delta region to do this efficiently.

The argument as to what harm this would do, by removing the "flushing action" through the delta, and through the San Francisco

Bay, and eventually through the Golden Gate, and what it would do adversely to "psyche" of salmon (because the currents might then be such that the salmon would have to swim downstream to spawn instead of upstream, part of the time, because of tidal action)—these are some of the arguments advanced, whether superficial or profound, that relate to what needs to be done in the way of resource development and environmental protection in the state of California.

The point here is that it is hard again to assign any dollar value to these considerations, but it is indeed important to have a "picture" that shows what the real situation is. And, I do think that it is entirely possible that ERTS imagery such as this gives a better view or picture than we have ever had before. In fact, in this regard, if I were to summarize as what the ultimate greatest benefit of ERTS might be, it is likely to come 50 to 100 years from now, when environmentalists will realize that it was back when ERTS images were first being acquired in the early 1970's, that man had his first good look at the surface of this earth in such detail as to find out what the environmental problems and consequences were and to locate areas in which man's activities had caused great environmental degradation. Man may then come to realize that such imagery permitted him to learn in the nick of time, how to avoid such tragedies in other areas which he had not yet gotten around to ruining and which were of similar appearance on this earlier global coverage provided by ERTS.

If anybody had asked me as recently as three years ago, with respect to this next slide: "At what altitude do you think that picture was taken?", to my discredit I would have said: "Well, that is about the way it looks when I fly over such areas in a jet at an altitude of about 30,000 feet, so I would say five or six miles—something like that." I would have been off by a factor of one hundred, i.e., by two full orders of magnitude! This is an ERTS image as enhanced on a closed circuit color TV system, and it was taken, not from five or six miles, but from 570 miles. Incidentally, it is more than a pretty picture. Here we not only have enhanced the crop types but also the soil differences and the yield characteristics, as our ground checking in this area has proven. We believe that with additional research, this will prove to be not only a useful, but perhaps even an essential look at the landscape as we try to monitor it in relation to crop blights and crop forecasting.

Limited spatial resolution seems to be the thing that has been singled out by OMB as the primary inadequacy of ERTS. We have learned that high resolution is important for some purposes but that low resolution may actually be preferable for trying to delineate certain broad relationships and resource boundaries.

This is not an ERTS photo that we see in this next slide, but it is a Gemini photo of approximately the same resolution and will thus serve to make the point. It shows an area in which one could draw certain boundaries and then relate them to boundaries already accurately drawn for the same area on existing resource maps: i.e., boundaries drawn in this particular "test site" even before the space photo was taken, so that the usefulness of the space photo might better be evaluated. You will find, in general, remarkably good correlations between boundaries that are apparent on this space photo despite its limited resolution and the significant boundaries drawn on these previously

prepared maps in relation to vegetation, geology, soil and land use. But with reference to resolution, I wanted to document the important point that low resolution sometimes is preferable to high resolution, because we can draw resource boundaries more uniformly, on the low resolution imagery. Can you visualize with reference to resolution, what a high resolution aerial photo across this vegetation boundary would look like if we took a picture from a 15 hundred-foot altitude, looking across that boundary? Such an aerial photo is shown in this next slide, and I submit that on this photo, as we look across the same vegetation boundary as we saw on ERTS, *you* might want to draw that boundary here, but *I* might want to draw it out over here instead, and someone else might want to draw it over here in this third position. So, this is an instance in which the broad delineation of what are called "land-systems" (and differences in the vegetation and soil conditions associated therewith) actually is better done by virtue of poor resolution. That doesn't mean therefore that we have no use whatever, for high resolution. Indeed we have such a need but only for subsample areas, in situations of this type.

Here in this next slide we see where poor resolution, again, permits us to infer from this space photo some very valuable things. In the area shown here, which happens to be near Phoenix, Arizona, what if we had a high resolution aerial photo of this same area? Let us acknowledge that on the space photo, because of poor resolution, all we can identify here is a range of mountains, with a ridge here, together with a bajada that is sloping down toward the river here, and maybe an alkali flat over here.

What we would like to know, and presumably could discern with high resolution imagery, is the total resources complex in this area comprised of the vegetation, soils, geology and hydrology resources, as well as the land forms. Let us now take a high resolution aerial photo from here, looking in this direction as in this next slide.

In this instance we see the river, the bajada, the alkali flat, and the ridge over here. We can even see individual bushes. But we are no better off from our study of this high resolution image in coming up with detailed information on the geology, soils, vegetation, and hydrology resources—information which we need to have in order to decide what is the best ultimate use for each portion of area. Despite this fact, the ERTS image or space photo, itself, is adequate, as shown in the next slide.

Here we see the correlations that almost invariably exist in a desert area such as this between the landform sequence (all the way from the ridge top on down through the stream channel, the bottom land, et cetera), and the vegetation, soil, geology and subsurface water conditions. So the essential point is that even on space photos of limited resolution, we are (in cases such as this one, where we have worked out the necessary correlations), able to infer merely from landform interpretation the things that we need to know in order to decide what the total resources complex is. Given a continuing availability of ERTS type data we would be better able to understand what season of the year and in what parts of the globe these same kinds of relation-

ships could be identified. Wherever they could be, high resolution photography probably would not be essential, except in those areas where intensive development of Earth resources was contemplated.

The two photos shown on this next slide also were taken near Phoenix, and show one of the most serious problems in the U.S., viz. the encroachment of suburbia on agricultural land. In the two-year interim between when this left picture was taken and this right one, houses were continually being built on agricultural land at the rate of 11 houses per day, each on a half-acre lot. So every working day, five and one half acres of agricultural land are being lost. In fact, a total of thirty thousand acres of this land has been lost around Phoenix in the short time that my group has been studying this area, and you can see the enormity of the problem in the next slide.

Here overprinted on a space photo is a red color code showing how much land centered around Phoenix still is suitable for agriculture and also how much (as indicated by the brown) might be suited not to agriculture but to the construction of suburban housing. We are losing agricultural land, and needlessly so, here in Maricopa County, Arizona (which is the third most valuable county in the U.S. in terms of agricultural production) at such a rate that, in just a few years, it is likely to be wiped out as an agricultural or food producing area. If we have an overall impact like this brought to our attention best by such space photography, is it "cost effective" or not to have that kind of look? If it prompts real estate developers, perhaps as a result of public pressure, to get with a program that serves to preserve this rapidly dwindling agricultural land, and to start building on other lands I assume it is a very valuable result although hard to assign a dollar value to.

This concluding slide is an attempt to show in graph form much of what we have talked about. Note that the Y-axis shows "Resources Information Derivable through Remote Sensing," such as by ERTS. The X-axis shows "The Number of Remote Sensing Techniques Employed." Here, by means of this horizontal line, is diagrammed a threshold value of cost effectiveness, i.e., where the benefit cost ratio is one. If we used only one of the various techniques that I have mentioned (such as multi-band or multi-date or multi-stage or multi-disciplinary analysis, or multi-enhancement of the images) we might never get to this cost effective plateau. But through the simultaneous use of two, or three, or four, or five we almost always would succeed in crossing this threshold.

If this is true, then we need to find out where we have hit the point of cost-effective returns, and also of diminishing returns, and we also need better to define the various plateaus shown on this graph in relation to each resources management and environmental protection problem. This is the kind of work my group is engaged in and this is the kind of work which remote sensing scientists can best do in the future if we do not have an interruption in the flow of ERTS type data.

I would say finally—we can have the lights on as I conclude—that several of the groups that we work with, i.e., the user agencies, indicate

that they would be prepared to use ERTS type data right now, except for the following dilemma: On the one hand they are reluctant to switch away from their present resources inventory techniques, until they can be assured that, having gone through this traumatic experience, they will have a continuum of ERTS imagery in the future. On the other hand we have the other half of the dilemma in which OMB in effect says, "We don't want to okay this continuum until we hear these people saying that they are ready to use ERTS data cost effectively now." So in contrast to the statement which Doctor Zarb made to the effect that we can't go further with this ERTS program until it has been proven cost effective, and until the ERTS technology has improved, it seems to me that it is not so much a question of technology, even at the present moment, as it is a matter of mutual faith among these two groups. And, if I were to point out the single key item that would rectify that difficulty, it would be some kind of assurance from OMB, certainly beyond what we have at the present time, that there would be a continuity of ERTS type data, at least for several years, as would be assured with the timely launching of ERTS-C, for example. These resource managers and user agencies would then feel that it would be cost effective to start switching to these techniques now.

Thank you very much.

Mr. SYMINGTON. Doctor Colwell, thank you for your splendid, if not spectacular, statement of the case.

I don't know whether you were here during the statement by OMB's representative?

Dr. COLWELL. I heard the last half of one of their statements.

Mr. SYMINGTON. Of course you had obviously read it, because you prepared your presentation with it in mind. I think that has proven very helpful to the committee.

Of course, the date and the context of the statements that you quoted are crucial. Those attitudes could well be modified by now. We had a presentation today by General Electric on a new system of digital analysis of crop forecasting and things of that sort, which I think none of us has seen and I doubt that OMB's witness had seen yet. It is a thing that happens almost daily.

Dr. COLWELL. In this regard might I cite an analogy which is credited to one of my associates, Doctor Levin. Although perhaps it was not part of his testimony to Senator Moss' committee, Ben Levin gave me a couple of days ago the following analogy which I think is well worth considering. "At the present time we are asked to evaluate the usefulness of ERTS, much as though we had been asked, through detailed anthropomorphic measurements of a 7-year-old child, to estimate whether this child will become a great heavyweight boxer. We just can't make an accurate estimate from measurements made that early in the child's development." I would submit then, with reference to the comments you have just made, Mr. Symington, that even in the interim during which the potential of ERTS has been debated in the last few months, researchers have progressed to where we are now (to use the same analogy), able to measure a teenager instead of a seven-year-old and we are about to say "yes," this will be a good heavyweight boxer—something we would not have been able to say with any certainty a few months or a few years ago. I think it is a very useful analogy.

Mr. SYMINGTON. I wonder if you would accept an appointment as director of the OMB as soon as we can arrange it.

Dr. COLWELL. I am distressed by the fact that people of OMB who need to see images as well as hear words missed my lantern slide presentation today. Without the slides, my paper is just some more words. I can hardly talk about the real capability of ERTS, however, without getting tears in my eyes. I wish OMB could get that kind of tears once in a while by seeing this kind of testimony.

Mr. SYMINGTON. They have sort of a fog which takes the place of tears.

Mr. Bergland?

Mr. BERGLAND. Mr. Chairman. I want to congratulate Doctor Colwell for his very splendid presentation and I am curious to know, Doctor, have representatives of OMB seen your work?

Dr. COLWELL. I am fairly sure they have not. California is pretty far west compared to Missouri and some of these other places, from which reports on the usefulness of ERTS have been submitted.

Mr. BERGLAND. They have not had the benefit of first hand exposure to the kind of thing that you are doing and the enormous potential that many of us see in your efforts?

Dr. COLWELL. Well, I think they have not seen or heard my particular report. However, I am highly respectful of the very valuable research done, primarily under NASA funding, by a whole host of groups, so while I wish OMB could have seen this presentation, if they have not yet been convinced, I am among those that are inclined to despair that they ever will be. If OMB rejects ERTS-C on the grounds that present ERTS resolution is no good, and that ERTS-1 must be proven cost-effective before OMB can approve ERTS-C, then I consider them wrong on both counts and these are essentially the arguments which I am rebutting here. But everyone else that has worked with this imagery instead of merely philosophizing about it arrives at essentially the same conclusions as I do. I doubt that OMB is going to do a 180° turnabout just because I get up and show my slides and do a little arm waving. I would welcome a chance of trying to persuade them, but I think it would be discourteous to my fellow researchers across the country if I implied that there is something so unique about my aspect of ERTS research that therefore OMB has to hear my story.

Mr. SYMINGTON. You project rather well. You are very persuasive, Doctor.

Dr. COLWELL. Thank you, sir.

Mr. SYMINGTON. Thank you.

Your statement, Doctor Colwell, will be made a part of the record, the written statement as well as, of course, your verbal one.

I wish that the OMB representatives or at least one of them might have stayed behind to listen. I don't think any did. At least, nobody in the audience is holding up his hand to that effect. So, we will just try in some fashion to bring them to an awareness of the approach you have taken.

I think without the sort of integrity and fire such as your presentation comprises, we wouldn't be able to get this committee to move the Congress in the direction I think the country ought to go. So we are extremely grateful to you for visiting with us again today. We hope we can count on you in the future.

Dr. COLWELL. Yes, sir. Finally, my apologies for the in-and-out appearance I had to make here. It happened that this is a pretty busy day for me. I am pleased that you adapted yourself to this schedule. Thank you, sir.

Mr. SYMINGTON. Very happy to do so. Thank you very much.

The subcommittee will meet again tomorrow at 10 o'clock in this room.

The meeting is adjourned.

[Whereupon, the subcommittee adjourned at 12 noon, to reconvene on Friday, October 4, 1974 at 10 a.m.]

EARTH RESOURCES SURVEY SYSTEM

FRIDAY, OCTOBER 4, 1974

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10 a.m., in room 2318, Rayburn House Office Building, Hon. James W. Symington, chairman of the subcommittee, presiding.

Mr. SYMINGTON. Good morning, everyone. The subcommittee will be in order.

This is the second day of hearings on H.R. 14978 and H.R. 15781, similar bills designed to establish offices in the executive branch to operate an Earth Resources Survey System.

As I indicated yesterday, these hearings have been called to explore with expert witnesses whether the time is ripe to create an operational satellite system, and if so, to attempt to determine the most appropriate institutional arrangements.

The more urgent questions, however, deal with the accomplishments of NASA's ERTS experimental program, and whether the scope and pace of that program is adequate. Recognizing that the ERTS program is in its early stages—only one experimental satellite having been launched thus far—we would like our witnesses' views on what needs to be done during the next several years in order to achieve the necessary technological progress and to insure the orderly development of an economically viable system.

In this regard, the subcommittee has received the testimony of a representative of the Office of Management and Budget. OMB feels that the cost-effectiveness of the first ERTS satellite has not been proven; they have concluded on the basis of the evidence to date that ERTS-1 data is only marginally useful, and that additional repetitive coverage with the same technology has relatively low value once complete cloud-free coverage is obtained.

Furthermore, they feel that the program should end with the launch of the second satellite, ERTS-B, unless a significant advance in the state of the art can be achieved by an additional launch. Finally, OMB has stated that

Although the consequences of not having continuous coverage are not well defined, it has not yet been demonstrated that there is much existing use which requires continuous coverage. Few, if any, applications have been identified where continuous coverage with today's technology is both necessary and productive of significant benefits.

I have taken the time to summarize part of yesterday's testimony since it represents much of the basis for this subcommittee's disagree-

ment with OMB's position. Historically, this subcommittee has favored a more vigorous experimental ERTS program. We believe significant technological advances will be achieved only if the Nation mounts a program comprised of a series of experimental satellites incorporating successive generations of sensors—in the same manner as the communications and meteorological satellite programs were pursued.

In this connection, it seems unrealistic to this subcommittee to expect cost-effectiveness in an experimental program in which only a single satellite has been launched to date.

It seems apparent that OMB relies upon information from sources other than those available to this subcommittee, since our sources have not said ERTS-1 data is only marginally useful, nor have we been told that repetitive coverage has relatively low value. On the contrary, our sources tend to agree with Dr. V. E. McKelvey, Director of the U.S. Geological Survey, who has stated that

We are just beginning to learn how to get the most out of the data; their importance is just beginning to be realized. A most important requirement for Interior and other users is continuing availability of data products.

Along similar lines, Dr. S. Benedict Levin of Earth Satellite Corp. has stated:

Nothing could be so damaging to the ultimate demonstration of the economic and social benefits of the Earth Resources Survey Program as a protracted interruption in the flow of satellite data.

Finally, a report just released by the National Academy of Sciences concludes

That the Federal Government take immediate action to minimize the potential gap in earth resource satellite imagery after the follow-on ERTS-B completes its useful life.

I would like to insert the Preface and Summary of the Report of the National Academy at this point in the record.

PREFACE

In late 1966 the Administrator of the National Aeronautics and Space Administration requested the National Academy of Sciences to make a comprehensive study of the useful applications of earth-oriented satellites, giving priority to both technological considerations and assessment of relative benefits that might be achieved. The Academy responded with a two-year study effort—"Useful Applications of Earth-Oriented Satellites" (now known as the Woods Hole Study)—that involved over 200 highly qualified scientists and engineers. A total of 13 technical panel reports were issued. Nine of these reports are related to environmental monitoring and resource survey.

At about the same time, the Director of the U.S. Geological Survey, Department of the Interior, asked the National Academy of Sciences to establish a continuing committee to advise his agency on remote sensing applications. In response, the Academy organized the Committee on Space Programs for Earth Observations (COSPEAR). Because of the broader applications of remote sensing the responsibility of this committee was expanded in 1972 to include other federal agencies having a potential interest in the useful applications of remote sensing—not only from spacecraft platforms but from aircraft as well. These agencies included the Departments of Agriculture, Commerce, Interior, and the Navy, the Environmental Protection Agency, the Civil Works, U.S. Army Corps of Engineers, and the National Science Foundation. To reflect this broader interest the name of the committee was changed to the Committee on Remote Sensing Programs for Earth Resource Surveys (CORSPERS).

Since the use of remote sensing for meteorological applications was already well established in the mainstream of the National Oceanic and Atmospheric

Administration activities, the Committee gave only secondary attention to meteorological sensing systems and concentrated primarily on earth resource surveys and environmental monitoring applications.

In September 1972 the federal agencies sponsoring CORSPERS requested that the Committee evaluate the results of the Earth Resources Technology Satellite (ERTS-1) investigations as the results became available. This evaluation was to consider the scientific validity of the conclusions and the relevance of the data to earth resource management and environmental monitoring. The complementary value of remotely sensed data from other sources—including the meteorological satellite data center, airborne imaging sensors, and ground observations—were also to be considered in this evaluation. The Committee was asked to render program and policy recommendations that might be helpful in making the demonstrated and potential capabilities of remote sensing for resource management and environmental monitoring available to the user community.

To conduct this review CORSPERS organized the following five scientific discipline panels and three support discipline panels. All reported to a Parent Committee in which each panel chairman was also a member:

Scientific Discipline Panels

Biology : Agriculture, Forestry, Range & Wildlife.

Geography : Land Use.

Geology : Mineral and Land Resources.

Hydrology : Water Resources.

Oceanography : Marine Resources.

Support Discipline Panels

Cartography : Mapping and Charting.

Environmental Measurements.

Information Management.

With the exception of the Environmental Measurements Panel which was organized too late to participate fully in this review these panels attended various symposia where the results of the ERTS investigators were presented. Discussions with individual investigators were arranged when considered necessary. Formal investigator reports were also made available. In addition, each panel was briefed in detail by representatives of the federal agencies on resource management and environmental monitoring tasks that they considered likely candidates for using remotely sensed data.

The panels made independent reports of their findings and recommendations to the Parent Committee. Based on these reports and additional program briefings and discussions with the federal agencies and some state agencies, the Parent Committee isolated the issues it considered appropriate for review, discussion, and possible recommendation.

This report includes an Action Summary, which highlights the principal recommendations, and an appendix, which includes consolidated panel recommendations and summaries of the panel chairmen reports to the Parent Committee.

The present report is focused on the Earth Resource Technology Satellites (ERTS) and their extensions because the Committee believes that these systems can be the cutting edge in the improvement of broad scope management of earth resources. Clearly, other sources of data and a commitment of many individuals and organizations to provide the tools, knowledge, and policy are required to make this management possible. While the longer range potentials for technology, application development, and science in remote sensing are exceptionally bright, these extended vistas are not treated with high priority in this report. The concern here is one for the intermediate range future.

The Committee is grateful to the liaison representatives from the sponsor agencies, who spent many hours with the Committee discussing the relevance of remotely sensed data to enhance their resource management and environmental monitoring capabilities. The Committee also wishes to thank the panel coordinators from each agency who worked with the individual panels in this review.

ARTHUR G. ANDERSON,
Chairman, CORSPERS.

ACTION SUMMARY

PROGRAM PROGRESS

The primary objective of the first Earth Resources Technology Satellite ERTS-1 was to demonstrate the feasibility of collecting useful earth resource data from orbiting satellite sensors. ERTS-1 has now been in orbit nearly two

years, and its operating sensor—the multispectral scanner (MSS)—has exceeded its designed lifetime by nearly one year with no apparent degradation in data quality. The information content of the data has also exceeded initial expectations. The distributed Data Collection System (DCS) spacecraft relay receiver and transmitter has similarly exceeded its planned one-year life and technical expectations.

During this period, other parts of the program have also progressed. Data processing involved reduction of incoming digital data to hard copy photo images for subsequent processing, correction, manipulation, and analysis. Advances in digital processing techniques now make possible point-by-point storage and correction of these original data. This method preserves the total information content of the original incoming signal—an advance equivalent to a significant increase in resolution of the working data. In land use management, for example, it is possible to work with the image data at scales of 1:125,000. When the original analog processing technique was used, 1:250,000 seemed to be the limit. Similar improvements are noted in crop identification, flood plain monitoring, color plume detection in rivers, lakes, and near-shore waters, and in numerous other investigations.

The design of ERTS-1 was a compromise between a conservative approach to the state of the art in the late 1960s—i.e., tight budgetary limitations, a relatively unfocused user community—and concern about international reaction to the general availability of high quality earth resource survey imagery. Major segments of the user community can now specify their data requirements relative to the demonstrated capabilities of the MSS. Internationally, the data have gained broad acceptance, and many countries have expressed a growing interest in the beneficial use of present vintage ERTS imagery.

In the detailed scope of resource management and environmental monitoring, the significance of ERTS data is variable. If the spectral range were expanded to include selected parts of the thermal IR spectrum (such a channel covering 10.4 to 12.6 micrometers was removed from the ERTS-B because of development delays), another dimension would be added to agricultural measurements. Major progress could also be made in surveying living marine resources if sensors in an appropriate orbit, covering the proper spectral band, were used in combination with the deployment of surface assay ships with real time satellite data readout.

The review confirmed the technological readiness of the multispectral scanner and gave strong evidence of the probable importance of the data in several management areas. While the significance of aircraft imagery was already well established, its complementary role with space imagery was also established. The use of the DCS, whereby *in situ* sensors in remote or inaccessible areas are read out via satellite relay communication links, was again demonstrated. The DCS can be used not only to relay data from *in situ* sensors to complement space imagery but also sensors monitoring primary environmental parameters.

The Committee noted that because of the urgency imposed on the ERTS investigators, many limited their attention to the obvious information contained in the imagery. While a good case can be made for operational use of the data in some applications on that basis alone, the Committee feels that major values of space imagery will also be derived from subtle changes that can be detected only by repetitive measurements or observations under varying conditions. This is true even in such fields as geology. Information derived from surrogate measurements can also be expected to have major significance in both resource management and environmental monitoring. The information potential of temporal changes and surrogate data measurements can be expected to accelerate in an operational environment.

The Committee has concluded that:

1. Multispectral scanner sensor technology is sound and provides a firm foundation for the design of increased sensor capabilities.
2. Intercomparison of data from different spectral bands has demonstrated a significant technique to recognize cultural and physical features on the earth's surface.
3. Repetitive satellite coverage contributes significantly to recognitions of cultural and physical features and environmental phenomena and describing their dynamic behavior.
4. Digital techniques for data processing have been demonstrated and provide an enhancement of data product quality and the potential for greatly increased flexibility in data processing, analyzing and storage.

5. The experience with the Data Collection System (DCS) has reconfirmed the value of this technique in relaying resource survey and environmental monitoring data from remote or inaccessible locations to data receiving stations.

6. Collectively, the sciences and technologies of remote sensing for earth resources survey show substantial room for growth and improvement, providing society with a long-range capability of important dimension.

NEAR-TERM ACTION

To continue progress toward operationally useful systems, emphasis must be shifted from technology development toward the development of application demonstrations.

While impressive results were achieved in some of the ERTS-1 investigations in agriculture, geography, hydrology, and cartography disciplines, there is still a wide chasm between these experiments and routine use of the information by the user communities. There are many reasons for this gap, none of which seem to be disabling. The data are dramatically different, in both information content and format, from those normally used by most managers. Therefore, a period of accommodation or adaptation is necessary to modify existing decision models, to develop new decision models, and to develop a common language. In the Committee's view this gap between the remote sensing technology community and the resource management community can be bridged in part by representatives from both communities, working jointly on ERTS-based quasi-operational resource management projects. These joint efforts should demonstrate the complete task, including the use of supplementary data sources, development of new knowledge, the necessary modification of decision models, the creation of training manuals, and, where appropriate, a plan to eventually enlarge the quasi-operational project to routine operational functions.

While the present ERTS-1 spacecraft is still providing high quality data after nearly twice its one-year designed lifetime, sensor failure must be anticipated in the near future. Action is being taken by NASA to launch ERTS-B as soon as possible after the quality of the ERTS-1 MSS data degrades below a useful level. It is not reasonable to assume that the ERTS-B MSS will equal the ERTS-1 record lifetime. Since there is no approved follow-on spacecraft in the procurement cycle after ERTS-B, a serious disruption in data will probably take place after ERTS-B fails.

The initial design of the ERTS-B multispectral scanner included a fifth channel which covered the 10.4 to 12.6-micrometer portion of the infrared spectrum. This channel was removed because of delays in the development program. Aircraft infrared scanner data on crop stress during the 1970-1971 Southern Corn Leaf Blight Experiment provide strong evidence that data from this channel may be significant in strengthening the capability of the MSS data in identifying selected crops under less than optimum conditions. These data should also be helpful in wetlands management. NASA is planning to launch a heat capacity mapping mission in 1977 to obtain thermal inertia data for rock and soil mapping, which will carry two sensing channels: 0.8 to 1.1 micrometers (near infrared) and 10.5 to 12.5 micrometers (infrared) in an early morning and mid-afternoon orbit. This, unfortunately, is not a good orbit for general earth resource sensing. To use the thermal data most effectively with other MSS data they must be sensed simultaneously from the same platform under identical conditions.

The use of an orbiting spacecraft as a readout platform or communications link for *in situ* sensors in remote or inaccessible locations, known as DCS, has been repeatedly demonstrated in various programs, including the present ERTS program. DCS can be used to relay ground calibration measurements for space imagery, environmental monitoring, and other measurements made by implanted sensors. NOAA is preparing to operate an *in situ* readout capability as part of the recently launched Synchronous Meteorological Satellite (SMS). Improved sensor reliability and longer unattended lifetime would be helpful for monitoring environmental quality parameters. NASA should continue to assist users as necessary in developing improved sensors. Overall responsibility for integrating the user requirements and for planning, deploying, and operating such a capability to serve the broad range of possible users has not been assigned.

The Committee recommends the following near-term actions:

1. That primary emphasis in the ERTS investigator program now change and be concentrated on quasi-operational projects. These should involve both the remote sensing technologist and the resource manager.
2. That a thermal infrared channel be included in future MSS configurations after ERTS-B.
3. That a management structure be established for DCS to integrate user readout requirements, to provide sensor platform standardization guidelines, to coordinate sensor development assistance, and to coordinate the operation of an adequate readout capability.

DATA MANAGEMENT ACTIONS

The present ERTS data handling system at Goddard Space Flight Center was designed primarily to provide hard copy photographic image data to selected investigators, to the federal agencies, and, through the EROS Data Center at Sioux Falls, South Dakota, to nonfederal government and foreign users. It was not feasible at that time to respond to the poorly understood operational needs of the widely dispersed and diverse user community. No provision was made to interface other information systems with the ERTS ground data system. From an operational point of view, the crucial role of timeliness of results and perishability of data were not considered. Rather, emphasis was placed on the analysis of static map-type data in the form of images. Similarly, less attention was directed to temporal changes in multivariate data indicating the behavior of dynamic phenomena associated with, for example, floods, crop yield, range management, water management, and water pollution factors.

Experience with digital data processing indicates that major system improvements can be gained by shifting from analog to all-digital-processing techniques or radiometric and geometric correction and storage. The end product can be either in the form of digital type or hard copy imagery, depending on user needs. Because of the cost of a first-rate facility for digital processing, storage, and services, first priority must be given to establishing one central facility. In addition to this central facility, regional and user subcenters are needed to meet considerations peculiar to the region or application and to integrate regional or locally available data and knowledge with available data from a central facility. The nature of these facilities is expected to vary, depending upon the dominant interests and economics of each area served. These subcenters may involve different countries that receive data direct from the spacecraft, or they may be direct access to the data and information at the central facility.

The Committee believes that, as operational users gain confidence in remotely sensed data, the task of integrating these data with other data—and eventually interpreting and analyzing the combined data set to derive useful information—will migrate to centers of specialized capabilities. These specialized centers would respond to information specifications established by the operational user community. The research scientist, on the other hand, will probably always want to use or have access to the basic data. The development of topographic maps by the U.S. Geological Survey and the meteorological forecasts by NOAA, both of which respond to specified information needs of operational user communities, provides an historical analogy that could portend the future in earth resource management and environmental monitoring. For this trend to be successful, it is essential that the application research user have not only a complete understanding of the analysis process but also be able to specify the analysis process used in developing this information. Initially, this requires the intimate involvement of the user in the analysis process. The quasi-operational phase, recommended in this report, should include efforts to identify information products that can be accurately specified and then produced by a specialized center. Ideally, these information products would be sold or made available to all users who have need for the information regardless of agency administrative boundaries or jurisdictions.

Reviewing the information requirements of various segments of the user community and relating these to the limitations of any one data collection system, it was evident that multiple sensing systems involving spacecraft, aircraft, and implanted *in situ* sensors are needed. For example, water runoff predictions can use data on areal extent of snow supplied by ERTS imagery, moisture content of snow measured by an implaced sensor (snow pillow) remotely read out by spacecraft relay or terrestrial communication link, anticipated weather condi-

tions from meteorological information sources, and watershed model information from topographic surveys. Similar relationships exist in crop forecasting, environmental quality monitoring, and coastal zone management. This probably will require that a particular user have direct access to nodal points within other relevant data sources or networks. The form of this access brings about a host of intersystem compatibility issues: data format, archival coordination, analysis techniques, common data reference system, system funding, product sales charges, and many others. Proper integration to ensure compatibility between multiple sources is a substantial information management problem that needs considerable study.

It was evident during the early phase of the remote sensing program for earth resource surveys that the potential user community was a large, amorphous group of resource managers and agencies. Users within the group generally felt that improved information, including remotely sensed data, would be helpful in achieving their management goals. The ERTS investigations identified discrete segments of the user community that could effectively use the ERTS data in its present form. The investigations also provided a better appreciation of the need to optimize sensor systems to gather data with the necessary characteristics required by other users. Using the ERTS MSS data as a comparison base, it was evident that various segments of the user community required data with different numbers and channel bandwidths within the total spectral band of the MSS, different frequency of coverage, different spatial resolution, and in some cases spectral coverage not included in the ERTS MSS design. Other sources of data, such as from SKYLAB, give one an understanding of possible future improvements.

The Committee recommends the following actions:

1. That earth resource data processing be converted to all-digital techniques and that the primary archival medium be digital storage.
2. That planning for the earth resource ground data network include both a large central data processing complex and several prototype regional and local data centers to ensure that a decentralized structure develops. In addition, experimental centers in being and functioning as part of the ERTS investigator program should assist with exploratory work to help define the role of regional and local data centers.
3. That early definition of standard information products be encouraged and should start with the quasi-operational programs.
4. That the federal agencies, under the leadership of NASA, initiate a broad based information management study (1) to explore and define the beneficial interrelationships between different data/information systems for resource management and environmental monitoring and (2) to identify the critical system interface factors that need to be harmonized to establish necessary intersystem compatibility.
5. That NASA, in close cooperation with the user community, identify priority data requirements that are compatible with reasonable sensor system configurations and proceed with the necessary optimization analysis and initial design studies for these systems.

POLICY ACTIONS

* The Committee's overriding impression during this review is that practically every management area requiring global, national, or regional data could benefit significantly by having access to data from several sensor systems covering the same geographic area. Variations in coverage frequency, different spatial and spectral resolution and the use of different sensing techniques often provide synergistic improvements to the information that cannot be achieved any other way. The availability and proper integration of other knowledge, information, and data sources is essential in maximizing the operational utility of any earth resource or environmental monitoring system. The Committee is convinced that the multispectral ERTS data provides an important source of continuing information on dynamic features of the earth's surface. Sensors based on other technologies and designed against different data optimization specifications can add significant strength to the final information product. In management of the more dynamic resources, where data timeliness is all-important, complex intersystem communication links may be needed. Intersystem compatibility can be achieved most readily during the system design phase. A compatible interface during operation requires not only a continuing close alliance between system operators but

also the use of a common data reference system, a compatible data format, a compatible computer language, and many others. All this requires coordination and guidance at the national level. Even more importantly, the user community at all levels needs to know current and planned remote sensing capabilities in order to do concurrent planning in its areas of responsibility. At present, lack of a definitive coordinating policy at the national level runs the risk of future operational incompatibilities between, for example, the National Environmental Satellite System, an operational Earth Resource Observation Satellite system, and the Oceanographic Satellite (SEASAT) now in the planning state, as well as others that may follow, and more importantly, out-of-step planning by the user community.

Past efforts to produce a single federal plan on remote sensing have centered on coordinating the federal agencies' proposed ERTS program activity, as a means of assisting the Office of Management and Budget to formulate an approved program. Future efforts should be directed to inform the user community of available remote sensing capabilities and approved extensions of these capabilities.

The Committee recommends the following policy actions:

1. That either a single-point management agent of all remote sensing systems be designated, or an effective intersystem coordination mechanism be established, to ensure a compatible interface between systems and the ready access to required data sources of any user who has the need.

2. That pending the establishment of a single-point management agent, the Department of the Interior be designated as lead agency and working with the other federal agencies and NASA, proceed with the planning phase of an initial operational remote sensing system for earth resource surveys.

3. That an annually updated federal remote sensing capability plan be prepared by the system manager or coordinating body to inform all users of (1) the approved federal capabilities in remote sensing and policies relating to the availability of the data and information (2) the approved development plan to enhance existing remote sensing capabilities, and (3) the readiness schedule of future capabilities under development.

Mr. SYMINGTON. Our first witness this morning is Dr. James Boyd, president of Materials Associates of Washington, D.C. Dr. Boyd has had a distinguished career, having previously served as Executive Director of the National Commission on Materials Policy, Director of the U.S. Bureau of Mines, president and chairman of Copper Range Co., vice president of Kennecott Copper Corp., and dean of the Colorado School of Mines.

Welcome, Dr. Boyd. You may proceed with your prepared statement.

**STATEMENT OF DR. JAMES BOYD, PRESIDENT,
MATERIALS ASSOCIATES, INC.**

Dr. BOYD. Thank you, Mr. Chairman. Thank you for your introduction, Mr. Chairman.

I think you have given that introductory paragraph in my prepared statement, so I will jump it.

The part of my career which is perhaps of particular interest to you is my training in and practice of geology and geophysics, both in the field and as a supervisor of large exploration activities. My first field experience after graduating from college in 1927 was a field geophysicist. This was in the early days of the science of remote sensing, and throughout my career I have had the opportunity of working with all kinds of remote sensing, devices, either from the ground or from airplanes.

I had the privilege last summer of attending a 2-week study group on behalf of the Space Applications Board of the National Academy

of Engineering in Aspen, Colo. This study group dealt with the ERTS program for NASA. I went to Aspen with a healthy skepticism for what remote sensing from space could do in the exploration for raw materials. To those of us in the industry who have been studying the Earth's crust from airplane photographs and airborne geophysical equipment for many years, it did not seem likely that we were going to see anything better from 900 kilometers high. After listening and debating with scientists in the educational field, as well as from industry and the Government, I came away with a different attitude.

I understand that you would like me to discuss with you my observations of the present experimental Earth resources survey systems involved in ERTS. I should like to say at this point that nothing in what I say today necessarily reflects the conclusion which will be reached by the Academy of Engineering after they have reviewed the work of the summer session of the Space Applications Board. I hadn't realized they had issued that report.

These comments are purely my own observations, based upon past experience. This experience was enhanced by many hours of discussion with those who are currently dealing with these problems in more sophisticated fashion.

Although ERTS is essentially an experimental program, I was amazed to find how much of the information is actually being used operationally today. For particular example, approximately half of the data being sold from the U.S. Geological Survey Data Center at Sioux City is being bought and paid for by industry all over the world. Even if this information developed from ERTS is experimental, it is being used both experimentally and operationally in industrial affairs already.

Although many of the systems of ERTS-1 have now ceased to operate, there is still information coming from it that is being used as a factor in many daily operations today. So important have the data obtained from ERTS-1 become that it is essential for these same systems to be put into space as quickly as possible. I understand that this will be done towards the end of this year or early next year in ERTS-B.

ERTS-B will not, however, have the next generation of sensing devices required and planned for ERTS-C, particularly thermal sensors. In the light of the essentiality for finding where we can reach sources of geothermal energy, it is important to have a survey of the crust of the earth, indicating where the heat rising from the core of the Earth is closest to the surface. This alone would justify the launching of ERTS-C into orbit on schedule; it can perform this task. At the same time it can be prepared to pick up the research duties of ERTS-B, which will have come to the end of its operating life in about 1 year, or will continue as ERTS-1 did until about the time of the launching of ERTS-C under the present plan.

I have listened very carefully to the industrial, academic and governmental scientists who know more about the physics of the remote sensing than I do. I have sufficient scientific training to be able to comprehend their language. The state-of-the-art is now to the point where the resolution of the sensing devices, the multispectral scanner as now developed, the thermal scanner and the ability to move across

the targets more rapidly are sufficiently well developed to provide some operating data.

They now can provide a large part of the requirements of the several agencies already making greater use of the systems than I thought possible. These devices can still be improved, but they will be improved more quickly if they are producing data which is being used routinely in actual operation. The ERTS program in stage C is to me the final pilot plant type of research before the system becomes fully operational.

I should now like to go over briefly the parameters of the use of these remote sensing devices in the search for mineral deposits buried in the crust of the Earth.

We have throughout the history of mineral exploration been faced with new scientific discoveries. Each one has been promoted as being capable of revolutionizing the search for ore bodies. We find, however, that they become useful tools, but never a panacea. The extravagant claims for the discovery of new mineral deposits from space satellites is hardly impressive. It is unlikely that any one sensing device will ever find and measure mineral deposits for us. Help will always be needed from other devices, and eventually from the hard slugging geological field operations, diamond drilling or sinking shafts.

The search for minerals is a long, hard, complicated and very discouraging science unless you are imbued with eternal optimism. Many thousands of geologists have been carefully trained and have spent a lifetime in the field without ever having been involved in the discovery of a new mineral deposit. It is like looking for a needle in a haystack.

Therefore, each geologist needs the help of all kinds of scientific devices and inputs in order to build or improve his ability to analyze the crust of the Earth and determine whether or not there is any likelihood of an ore body being beneath the surface in any given locality.

What, therefore, can the amount of information coming from the Earth satellites do for geology? These data will give additional information on which the geologist can base his inductive reasoning. Particularly, these devices can delineate the broad aspects of the geological features of the crust of the Earth through the indication of major structural features. They will improve the possibility of understanding the geological structure in which man is attempting to find currently economic concentrations of materials.

When the geologist can locate himself continuously on the Earth's surface from the navigational satellites now under contemplation, he will spend far more of his time solving geological problems rather than determining where he is.

When we are able to accurately measure the movements in the crust of the Earth along fault planes, we will have better knowledge of the nature of the structural tectonic plates. Tectonic plates are the newest concept in geological understanding of the crust of the Earth, along which we are sure geological activity has taken place to concentrate mineral deposits in ages past.

I have read the testimony of Mr. Zarb from OMB. I simply cannot agree that it is either wise or necessary to wait for much further development in the science of remote sensing before we put up the ERTS-C

satellite. The systems even on ERTS-1 are very good, and have added materially to our store of useful knowledge.

ERTS-B still can add much more. The urgency of discovering new reserves of minerals—fiber, land and water, while getting better control of our food resources—should dictate using these satellites even in their present state. They should be provided with continuity and that means that the program on ERTS-C should proceed on schedule.

In reviewing H.R. 14979 and H.R. 15781, I become concerned about the prospects for new bureaus. The Department of Interior, through the U.S. Geological Survey, took advantage of the ERTS program to establish evaluation and translation systems and works increasingly satisfactorily with the other Interior bureaus, thus eliminating the need for a new bureau.

Other agencies, perhaps, did not see the need as quickly as Interior, but they now have an example and can designate the proper bureau in their own structure to perform this service. Properly authorized existing agencies can perform the tasks provided for in these bills.

Interior's bureaus have worked on developing a system to evaluate the information content of the imagery. Industry is, I think, quite rapidly fitting the results of the ERTS systems into their own information base, as evidenced by the steady increase in their call on the Sioux City system.

Information sold to industry has gone from about \$200,000 during the first year to the \$468,614 that Mr. Zarb mentions in the 1974 fiscal year to the current rate of something near \$900,000 in fiscal year 1975. That growth alone attests to the value of the program. The final value of this information, after it has performed its function, is immeasurable.

The National Commission on Materials Policy found a substantial need for more, improved, and integrated information systems with respect to resources, reserves, and production. One entire chapter, "Inventories of Materials," addresses just this question. That chapter emphasizes reserves and productive capacity; reserves and production are predicated on proving resources—which process will be enhanced by data obtained from ERTS. That chapter identifies one specific advantage of the ERTS program when it states:

A complete inventory of the mineral and energy resources of the United States, including domestic reserves and potential resources known or postulated, will support estimates of the future supply of materials and provide a quantitative basis for a national materials policy.

It is my belief that the Earth resources technology satellite program has already demonstrated its value in the monitoring of resources. The search for mineral deposits could not in itself justify the expense of the program for it can make only an indirect contribution. Inasmuch as the renewable resources are constantly changing, there will always be a need to monitor the various factors governing their health.

The fact that the same sensors provide the basic data for mineral, agricultural land and water resources reveals the interrelationship of them all. These, taken together with an urgent need for action for continuing the research, and at the same time maintaining the momentum for experiments in operations, mandates continuing the program.

Thank you, Mr. Chairman.

Mr. SYMINGTON. Thank you, Dr. Boyd. It is a most helpful statement.

You have obviously had a chance to study OMB's position on this program. OMB talks about proof of cost-effectiveness, as you know, in their statement. They claim that they can determine from the results to date from ERTS-1 that ERTS is not cost-effective. Do you think that is reasonable for them, for anyone for that matter, to expect cost-effectiveness to be perfectly delineated in an experimental program in which only one satellite has been launched to date?

Dr. BOYD. I have headed industrial operations where we do a lot of research on new processes and new sources of information. To make a cost-effectiveness analysis at the initial research phases is difficult. I don't think anyone really gets very good results from cost-effectiveness studies at this level.

You have to build a pilot plant and put the thing into operation to be able to get the parameters of cost. That is why I said that ERTS-C to me is the pilot plant, where you begin to see the cost-effectiveness of a new system.

Mr. SYMINGTON. I was interested in your reference to geothermal energy, which ERTS-1 and ERTS-B will not be equipped to explore, but perhaps ERTS-C will include such an instrument.

Dr. BOYD. Yes. I talked with the scientists who are involved in this. It is clear that the resolution of the thermal sensors do not need much further development before it will be capable of giving us a vast amount of information in this area fairly quickly. This is what we need.

Mr. SYMINGTON. Mr. Winn, do you have any questions?

Mr. WINN. Thank you, Mr. Chairman.

I too want to thank you, Dr. Boyd, for a very fine presentation, and I think you made a very good point that practically everyone can understand, whether he is a geologist, Congressman, scientist or a man on the street who has to pay the bill. That is the fact that we are now just beginning to understand the state-of-the-art, and to me it is the difference between the latest automobiles on the road and the Model T, and even though it might not be cost-effective, as OMB has pointed out regarding ERTS-1, and possibly ERTS-B, many of us are hoping that ERTS-C will be, will provide the difference in what we might discover. On page 8, you pointed out something that I think is very important, in your last question, when you talk about the inventories of materials and the National Commission on Materials Policy report.

I think that is something that the members of this subcommittee and members of the full committee would want to enlighten themselves on, because to me it is a part of the overall picture that can be so important. I don't think there is anyone on this committee who wants to continue to fund programs that are not beneficial to this Nation, because we are under tremendous pressure from the taxpayer and because of the costs of inflation. I just wondered, in your mind if we are not able to put the experiments aboard ERTS-C that you refer to and that the geologists and scientists that you talked to would expect that we might put aboard ERTS-C, do you think that the scientific community would demand and push for ERTS-D, so to speak? In other words, they are going to want more and more and more?

Dr. BOYD. That is what you always face when you are dealing with the improvement of industrial systems. What we need to do more than anything else, to battle with inflation from a resource point of view, is to provide an ample supply of basic raw materials and energy to meet not only our requirements for subsistence but give us a dynamic economy without waste.

To do this we must develop our sources of supply. This is a little different from identifying resources themselves. Resources are geological formations which you may prove into reserves and build sources of supply upon. In minerals and in energy you must find those sources of supply from the resources; the economic reserves must be proved and put into the supply system.

This means that an enormous amount of basic geologic work, particularly from the metal department, is constantly going on before you even go out and find out whether you have got a viable deposit.

This ERTS program is going to cost us about \$65 million a year; I think that is the order of magnitude. When you think what the lack of copper or zinc does to the price of industrial products, that \$65 million disappears in a hurry; if you can maintain supply, keep your costs to the minimum, and facilitate both discovery and production, then you certainly do reduce the pressures on inflation. That is the first question.

The second question is continued demand for research. As you go along you begin to see this. As you get into ERTS-C and understand more clearly what the operational mechanisms are, how you obtain the imagery and can translate it into a useful form for industry and scientists, then you will begin to find out that you need more refined research. You will always be improving the science, so you will always be under demand to do a certain amount of research.

Essentially, when you get to a point of industrial development where the development of the resources and the production from them will provide the means by which you can carry on that research. ERTS can become part of the resource cost. That can aid the funding.

Mr. WINN. You made a pretty interesting statement about the shortages of various types of ore in this Nation, ore that we depend upon. Also, looking at it from a very broad scope, from an international standpoint, whether we could become self-sufficient by 1980, as President Nixon said he hoped we would in the energy field or in any of the fields that we are discussing under the potentials of ERTS-C. If we could, through ERTS-C and the experiments aboard, become more self-sufficient in the basic resources of ores that we find in our own country, we would not be dependent upon foreign nations.

Some foreign countries might not be able to put us over the barrel so much as they have in the last few years.

Dr. BOYD. This is a very important question which you have asked. It is one that must be clearly understood. This country is a technological society or economy with a complex materials system; it is impossible to become self-sufficient.

There are certain materials which we do not have and never have had in this country as indigenous resources. We have always been without them. As the rest of the world gains in its industrial development and affluence, the demand on materials becomes very, very much

greater; that factor, interdependence becomes more and more important.

We can make ourselves independent at great cost by the process of substituting one material for another. In other words, independence can come from using alternative materials to accomplish the functions we need to perform in an industrial society. Any particular function doesn't necessarily have to be done by any one particular material. There are alternative materials to do most things.

We have to face this particular question in that light; as we make this ERTS information available to the rest of the world, which we are doing today, it makes them able to find and produce these economic resources for the international system. Until more diverse sources of materials come on stream, independence becomes a very important factor.

We have to take into consideration the fact that until we reach that point, there are pressures from the world to get a bigger part of the pie with a little more economic blackmail. It is understandable as a development. We have to protect ourselves against that so we can carry on our development. This is another subject.

Mr. WINN. It is. It is part of the game which is being played now between countries, and right or wrong I do think we have to continue to make efforts on behalf of our own country. We are a very large part of the entire world and it just points out, as you just did, that we share our information that we gather from these various satellites that we put up.

We share that with the world. That has been our policy all along.

Dr. BOYD. That is a good point. The best we can do for the rest of the world to help development is to make our own resources strong, to make our own resource industries strong.

Mr. WINN. Help them to help themselves.

Dr. BOYD. Yes.

Mr. WINN. Thank you, Dr. Boyd.

Mr. SYMINGTON. Dr. Boyd, I think you were pleasantly surprised by ERTS-1?

Dr. BOYD. Yes, sir.

Mr. SYMINGTON. If I can interpret that from your statement. You weren't expecting such dramatic possibilities and I think you would agree, therefore, that it has in one sense become operational. People look forward to the continuous flow of ERTS data. OMB contends that to establish an operational office at this time would freeze the ERTS technology at its present level.

Doesn't that seem unreasonable to you to make that assumption?

Dr. BOYD. It does seem unreasonable for the simple reason that, as you develop technology by operational means and use it, you begin to see the need for improvements in your sensing devices and your resolutions, etc. As you get the using agencies, in industry and government developing the need for these materials, and this information, they will see where they need improvement in the technology.

They will be the ones that will press for improvements. If you have an agency responsible for improving the technology, such as you have today, the pressure will be on them to continue to do just that. That is the way it goes, back to the other question of Mr. Winn. There will be more work to do.

Mr. SYMINGTON. We discussed this matter with Mr. Loweth of OMB speaking for Mr. Zarb.

Dr. BOYD. Unfortunately I didn't see his testimony.

Mr. SYMINGTON. I would like you to get a copy of it. We will make that available to you.

From your exchange with Mr. Winn, which I think is invaluable to the committee, you opened up a question that is before the whole world, and that is the materials shortage, resource shortages, high prices, and the demand for energy. Can I elicit from you a direct statement as to what you think the relevance of ERTS would be in helping mankind solve these problems within the next decade? In your view, will ERTS effectively contribute to the solution of materials shortages and energy shortage problems?

Dr. BOYD. Well, Mr. Chairman, after spending 2 solid weeks of doing nothing else but thinking about this, I have become completely convinced of the value of ERTS. In the interrelationships of all of these resource matters, as I pointed out, the mineral resources are not going to be benefited as much as the renewable resources like the forests and the farms; all will be strengthened, however. I don't know how we will solve these great vast international problems we have without this kind of help. I think we must have it.

Mr. SYMINGTON. Thank you very much, Dr. Boyd, for a most helpful statement. With your permission we may address further questions in writing to you.

Dr. BOYD. I am at this committee's service any time.

Mr. SYMINGTON. Thank you, sir, very, very much.

Dr. BOYD. Thank you.

Mr. SYMINGTON. Our next witness is Dr. Norman H. MacLeod, senior research scientist, Department of Biology, of the American University here in Washington. Dr. MacLeod is an agronomist. For the past 2 years he has been developing analytical techniques for ERTS images and studying their application to rehabilitation and development programs in West Africa, a part of the world which has suffered severe drought, as we all know, in recent years.

We welcome Dr. MacLeod to our witness table. You may proceed, sir, with your statement.

STATEMENT OF DR. NORMAN H. MacLEOD, SENIOR RESEARCH SCIENTIST, DEPARTMENT OF BIOLOGY, THE AMERICAN UNIVERSITY

Dr. MacLEOD. Thank you, Mr. Chairman.

The opportunity to testify before the subcommittee on Space Sciences and Applications is much appreciated, particularly when the matters under consideration affect the access to Earth resources data to citizen scientists like myself. I hope we are using this resource information in the public interest and that we are addressing significant methodological and conceptual problems related to man's continued use of renewable and other natural resources in a stabilized and productive terrestrial environment.

Today I wish to discuss first, various spatial resolutions of Earth observations data to indicate our views of the effectiveness of high

versus low resolution imagery; second, our experience in using ERTS data in agricultural and climatic applications to demonstrate that the new tool of remote sensing does give rise to new kinds of perceptions about natural resources and methods for their rehabilitation and productive use; and third, conclusions from these experiences related to the legislation before you.

SPATIAL RESOLUTION

In referring to spatial resolution I mean the smallest area on the ground that can be resolved by either digital or analog analysis of a space image or aerial photograph. The Nimbus III High Resolution Radiometer (HRIR) data has a resolution of about 10 kilometers. It resolves an area about 100 square kilometers. Some of the NOAA spacecraft sensors have a 1-kilometer resolution. The resolution of ERTS-1 imagery is about 0.1 kilometer or 100 meters or less.

Several investigators and agencies have called for Earth observations image resolutions of 5 to 10 meters in order to conduct studies of crop production, forest inventories, range evaluation, and other agricultural resource purposes.

A decrease in resolution size by a factor of 10—for example, 100 meters to 10 meters—results in a reduction in resolvable area by a factor of 100. For example, if 100 square kilometers were observed with Nimbus III HRIR at 10 kilometer resolution, there would be information from one resolvable element to be transmitted to the ground from the spacecraft. If the same area—100 square kilometers—were observed from the ERTS Multispectral Scanner (MSS) with 100 meters—0.1 kilometer—resolution there would be information from 10,000 resolvable elements to be transmitted to Earth.

This factor is reflected in the very high data rates—16 megabits per second—of the ERTS spacecraft system. This data rate is accommodated with wideband high-speed recorders and other sophisticated equipment in the NASA Data Processing Facility (NDPF). Large computers are required to perform digital analysis of the ERTS data.

If the Earth observations program were to provide sensors with a special resolution of 10 meters—0.01 kilometer—the bit rate requirement for similar areas covered at the same observing frequency would be 100 times that of ERTS or 1.6 billion bits per second.

This is a formidable and expensive requirement, not only for the spacecraft equipment but also for ground stations and for the investigator and his computational or analytical facilities. The special facilities for processing of ERTS data at Purdue and other universities would be overwhelmed by such a volume of data.

There are some tradeoffs available. For example, the frequency of coverage could be reduced by a factor of 10. This would mean that 10-meter resolution imagery of the same area now covered by ERTS every 18 days would be obtained every 180 days or twice a year—not very good for following crop production during the growing season.

One could also reduce the geographic coverage—swath width—by a factor of 10. In effect this is the same thing as a reducing frequency of observation because 10 times as many swaths would have to be covered to obtain the current geographic coverage of ERTS—taking 10 times as long.

The statistics of good opportunities for observing over the United States vary from coast to coast, but are probably one acceptable observing pass in each three passes. This means that a reduction in observing frequency by a factor of 10 would provide an observing opportunity only every year and a half on the average.

An improvement in spatial resolution would require facilities and technology development which would delay ERTS-C, increase costs enormously and complicate the use of Earth observations data unnecessarily. The unnecessary complications result from national security considerations here at home and national sovereignty questions for other countries.

Already some members of the international community have expressed their concern about the observations from space of their natural resources. One said: "natural resources have the character of absolute sovereignty," referring to the inviolability of information relating to his country's natural resources. Reasonably or not, increased spatial resolution increases these concerns.

With increased resolution, the access to Earth observations data for investigators like myself would necessarily be restricted because some of us will have nothing to do with classified programs, programs whose results are not available to all and discussed and analyzed by all who wish to do so. Particularly for American scientists working on data from other countries there would be additional strains upon those scientists' credibility if they were not able to share their findings with nationals of the country observed.

And yet the work of such scientists has reduced the cost of foreign aid to developing countries through scientific assistance using remote sensing as a resource analysis tool. Let me give an example.

The Republic of Niger is located within the Sahelian Zone, an area of West Africa which has been afflicted by several years of drought. The United States has contributed millions of dollars' worth of relief supplies and transportation and continues to do so. ERTS imagery of the area accompanied by field survey in Niger has shown the location of favorable areas for year-round crop production under irrigation, using more or less traditional farming techniques. ERTS imagery also showed the beneficial effects of simple range management.

Recommendations concerning these facts were made to the Niger Government in the context of developing a national resource management plan. The Niger Government has outpaced the investigators and has implemented the recommendations for irrigation agriculture, for range management, and for planning, using their own resources as well as aid funds from Canada, the European Economic Community and private nonprofit sources in the United States. There are now hopes to conduct a soil survey of the country using remote sensing data from ERTS in addition to plans to rehabilitate large areas of rangeland to initiate sustained livestock production.

In effect, there has been a change from complete dependence upon foreign aid concepts of how the country should be developed to internal initiatives based upon new information about Niger's resources and opportunities for development and rehabilitation of food production capabilities.

The work done with ERTS imagery would be very difficult to accomplish with higher resolution imagery. The acquisition of data will be delayed by waiting for advances in technology of Earth observation to be implemented. Continued flow of data from ERTS-type spacecraft sensors is furthermore essential to the formation of an adequate data base to establish the nature of seasonal and annual changes in the natural resources basic to rehabilitation of Niger and other developing countries—not to speak of the similar needs of our own country.

Agricultural and Climatic Applications: I would like now to discuss some of the recent work done in Africa with ERTS data to illustrate an important point concerning Earth observations and resource management, not only in Africa but in the United States as well. The point is that ERTS imagery forces a new and integrated view of the Earth's surface which leads to new and sometimes radical concepts of natural resource management. That is, ERTS imagery analysis inevitably creates a set of perceptions of how specific natural resource systems interact. Quite naturally, the new context leads to new resource management concepts as well.

I have already mentioned ERTS analyses of imagery of Niger. From this ERTS imagery we have made a map of "potential agricultural zones." Such zones are ecologically defined regions in which the climate and soils form the physical aspects (the soils and land use being mapped from ERTS) and the social and economic factors form the political aspects of the resource context. Within each of the four zones shown in figure 1 we have suggested a set of resource management objectives and agricultural practices. Resource management objectives flow from a systems analysis of the resource factors and from interactions with Government authorities who set social and economic goals and policies.



Thus the ERTS information is used to understand the ecological setting or, in other words, to obtain a resource inventory. But in addition the imagery itself integrates the ecological factors—this is the new view provided by ERTS, a new view which forces one to rethink resource utilization concepts. (In appendix A, these concepts are presented in more detail.)

In a second application we have been very concerned about the stability of soils in the Sahel and the potential for recovery of rangelands

in West Africa. Imagery of the Sahel obtained during the last winter indicated major sandstorms were occurring over thousands of square miles of range and cropland. Figure 2 is such an ERTS image of Western Niger and Eastern Mali.



These data indicated to us that a critical point in ecologic instability had been reached. To determine whether or not such was the case I went to Niger this summer and did a field survey—very limited—in the region. We found our worst fears were justified, that a serious deterioration had occurred and unprecedented sand and dust storms had occurred during the past winter and spring. They continued in June and July during my visit.

We knew from study of ERTS and Skylab data that large areas of West Africa outside the Sahel, in coastal areas as well as in the Sahel, were losing vegetative cover to cropping and deforestation. We then began to consider the overall climatic and ecological situation, and have developed a model of climatic change in the Sahel related to the loss of vegetation, a model which leads to drought in the Sahel and to climate and weather anomalies in the United States as well. (These concepts are presented in appendix B.)

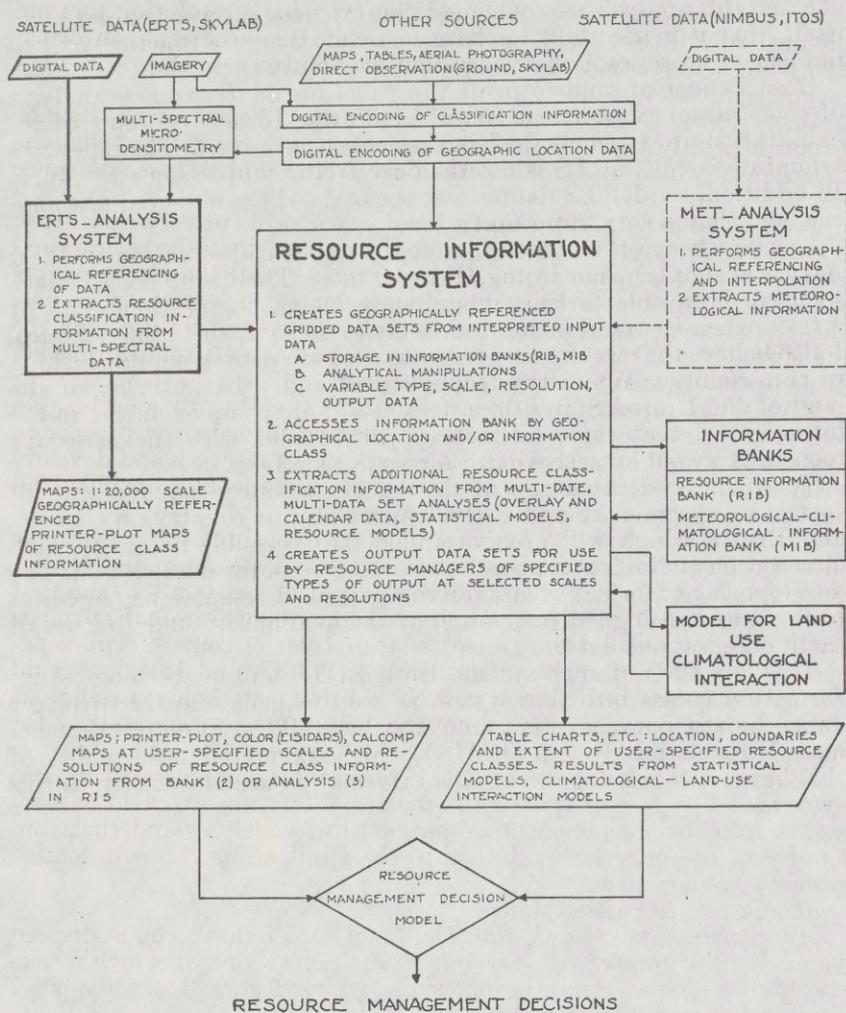
From this analysis we concluded that the drought was feeding upon itself, that it is necessary to change current land use practices and to implement a program of revegetation as rapidly as possible.

Observations of sandstorms in the Sahel forced us to a new analysis of the state of resources in West Africa and to new concepts of rehabilitation of extremely depleted resources in the area. The repetitive synoptic view of ERTS is not the only factor supporting such work. In addition, the ERTS data are at the scale of the observed phenomena, and that is very important.

In many ways the climatic, ecologic, and social situation in West Africa is simpler than in the United States. This being so, I believe we have been able to learn how to use Earth observations data of Africa when it would be more difficult to do so in the United States. I also believe that we are now ready to use such data in similar fashion in this country. While the technological and urban overlay of the land of the United States does present a more complex fabric to the investigator, that same technology provides us with the necessary tools to carry out extensive natural resource analyses.

To enable systematic use of these tools, resource management information systems are under development in this country, in Canada, and Brazil, which will archive and make accessible not only earth observations data from space, but existing resource data as well. The development of such systems for computerized resource management procedures is a logical outgrowth of the availability and full use of earth observations data.

This is a slide of such system. Both ERTS and meteorological information comes into this system as well as soils maps, hydrologic data, climatic data, et cetera, into what we call the Resource Management Information System (RMIS), which is centered in the middle of this figure. Models for use of this information are also shown in this system.



The system has been developed to the extent of the ERTS-analysis system and the meteorological data system shown on the right. We are progressing with a rather complicated data filing system that constitutes the resource management information system itself.

Throughout this testimony I have indicated that we are obtaining a new view of the Earth's resources which leads us to new resource management concepts. That view is incomplete. While it is important to have information on crop yields—which is very difficult to obtain through analysis of ERTS imagery—it seems to me far more important to know that the crops being grown are the best, most suitable and most productive use of the Nation's natural resources.

We do not have sufficient information to answer such questions—though we do have the technology. I feel, therefore, that the ERTS

program should continue. The addition of a high resolution thermal channel to ERTS-C will provide very valuable additional information. Higher spatial resolution, and particularly a hiatus in data acquisition, will not.

With respect to the placement of the Earth Observations System or program within the Federal Government, may I recommend that the experience gained in the meteorological program be drawn upon once more.

We find that data from operational spacecraft are very difficult to obtain for research and development purposes, that the operational requirements of the meteorological program override the arrangements which would permit archiving and accession of such data. Of course, the Department of Interior has operational responsibilities for the management of federally owned resources and can utilize information from dedicated spacecraft for that purpose.

NASA has repeatedly demonstrated its capability to conceive, develop, and prove new spacecraft systems and information processing systems. I would hope that NASA's work in the research and development of the emerging Earth observations system would continue, and continue unfettered by operational programs.

I would hope that the original data will continue to be available directly from NASA for research purposes. Data from the NASA NDPF is both more quickly available and of higher quality than that from Department of Interior sources. Data for operational purposes could certainly come from Department of Interior sources. This separation of R. & D. and operations between NASA and Interior would parallel that between NASA and NOAA for meteorology, and be as useful to the respective research and management communities for natural resources.

In summary, I feel that the ERTS program is only now getting into gear, that we are now learning to make ERTS imagery yield new insights into the management of our natural resources and that continuity of the program is critical to the application of our lessons in resource management.

Thank you, Mr. Chairman.

Mr. SYMINGTON. Thank you, Dr. MacLeod. I think you addressed yourself to a number of very important points, one of which covers the higher spatial resolution question, which I guess has some other foreign policy dimensions, too.

Did you find that ERTS data with low resolution were a source of concern for the African countries' leaders? Did they distrust this system because of the information that it provides the managers?

Dr. MACLEOD. I have, I think, two kinds of experience of that, in that area. One is where I am using the information directly with the governments concerned; that is, I would be the investigator and the government had available to it the ERTS imagery. There is little concern in those circumstances.

Where there is a third country involved, there has been concern of the government expressed to me that the third country did have the information that the government itself did not have. I think perhaps the proper answer to your question is that where the information is made freely available to the government, and directly to the govern-

ment, where the government knows who else has the imagery, there is little concern. Where the government does not know who else has the imagery or they find that a third party interested in their natural resources has the imagery and they do not, there is considerable concern.

Mr. SYMINGTON. It seems to me that if there is any concern at all, one thing that would seem to prove it is, there is value to this information. OMB doesn't seem to feel that the system is what it would call cost effective. I think perhaps they are looking with blinders at certain aspects of use that can be made of ERTS data, perhaps by being made available to some governments. Certainly, you pointed out that the foreign aid program, which is always a little unpopular here in Congress could be enhanced by the use of this intelligence and with appropriate diplomatic use of this type of information.

It could save a lot of money and do a lot of good, wouldn't you say?

Dr. MACLEOD. That is certainly my view. I think I would agree with Dr. Boyd that it is a little early to do cost effectiveness studies when we don't really know what the full use of the information might be. I can point out perhaps an example, in addition to the one that I discussed, and tie it to geothermal activity as well.

We have just very recently come across some imagery that indicates to us that drifting in West Africa is associated with structures in central West Africa that are known to have thermal activity. By the way, we look forward with great interest to a thermal channel with high enough resolution to look at that data, to look at that area in detail.

The information actually comes from the Skylab imagery. It looks as though there is a series of potential geothermal sites across the region just south of the bend of the Niger River. And we will continue to investigate that.

Now, as people go looking for these, there is a cost in utilization of the geothermal activity. ERTS will only indicate the possibility of the presence of a resource or the possibilities for the use of the resources. I think that in doing a cost-effectiveness study, the costs associated with resources discovery, which always are high, are perhaps particularly so when we don't know how to do this very well from ERTS. We are perhaps unjustified to include them in the cost-benefit study.

I think in terms of renewable resources, let's think about rangelands as for instance, it is very much cheaper to conduct a range resource survey in the Sahel with ERTS than it is by any other means. Travel is extremely difficult in the area. Putting Western scientists into the field in that area is extremely expensive as well.

The areas to be covered are very, very large. A study, botanical study, done in the inland delta of the Niger River, for instance, was conducted over a period of some 4 years. The investigator who carried out the study indicated it would take him approximately 2 months to obtain the same results using the imagery made available to him—this kind of resource discovery or monitoring or mapping certainly is far less expensive than traditional techniques, and it would be far more expensive than ERTS if it were to be done with high resolution photography.

Mr. SYMINGTON. Well, OMB seems to have made its cost-effectiveness determination without knowing either the likely technology to be developed or the uses to which it would be put.

Dr. MACLEOD. I think with any new instrument you begin to get used to it and understand its potentialities. You create a research context around that instrument. I think what is needed in the case of ERTS, in terms of applications, is to extend that research context further into applications.

We are still learning how to use that tool.

Mr. SYMINGTON. If ERTS-C and subsequent satellites are delayed or the program is terminated with ERTS-B, there would be a hiatus in the flow of data. If that happens, isn't it likely that many scientists would be forced to discontinue their work on programs of ongoing Earth observations for the benefit of foreign governments? It would have to stop.

Dr. MACLEOD. I think it is true for our domestic purposes as well. As I mentioned, I think it is very important to get an adequate data base so that we get the seasonal and annual variations, particularly in biological resources, forests, rangelands, et cetera, that we have a better record of the hydrologic situation over a period of time.

That is not going to happen just with 2 years of data.

Mr. SYMINGTON. And you would want to bring private enterprise into play as much as possible, I assume. Would you think any data gap would discourage private investment in these things?

Dr. MACLEOD. That is an area in which I am hardly expert.

Mr. SYMINGTON. I think you would agree that the magnitude of opportunity we are talking about is not one that would attract only governments, but would include anybody who is looking for agricultural opportunity or improvement, or industrial research for resources, private or public. They would all be disappointed, if not dismayed, if there were to be a gap in this kind of helpful information?

Dr. MACLEOD. I think this would be particularly true in discussing, for instance, livestock production investments that would be made in terms of large-scale ranches, that sort of thing, that an investor would very much like to know not just what the land is like this year but what it is like over a period of years. But I think there is a value that is coming out of ERTS that is beyond simple monitoring of seasonal changes, simple discovery through ERTS of new resources, and that is the changes in management concepts of natural resources, which I think would be of more interest to governments than simply knowing how much area they have in any particular use.

Mr. SYMINGTON. Thank you.

Mr. Winn, do you have any questions?

Mr. WINN. Thank you, Mr. Chairman.

I just want to reiterate what the chairman says about the possible data gap, because when you have a gap for a length of time, much of the work and much of the information that you have been able to secure would probably be wasted.

I doubt that bothers OMB very much. It doesn't show up in dollar signs, at least in their eyes.

Dr. MACLEOD. It does show up in dollar signs.

Mr. WINN. I don't think it does in their eyes.

Dr. MACLEOD. In the sense of constructing and then tearing down research institutions and discounting the investments that industry and government have made in image analysis activities, including the staff that goes along with that, the expert staff that goes along with that.

Mr. WINN. I think that is a very good point. I believe the chairman was trying to point out that the free enterprise system is just now, it seems to me, beginning to get very interested in the information that they are able to secure and if we tone down that interest, we may lose a lot more than just the information that you have to study.

I was very interested in your remarks, and I am very interested in your experiences too, in Niger, because I am on the Foreign Affairs Committee and we have talked a great deal about the problems over there and the constant pressures on that committee to give more and more money and to buy more and more food, and we have been a part of the overall operation.

I am sure somewhere will come the question of what did we find out from ERTS and such programs that we couldn't have found out on the ground. That is pretty basic, but this is the type of thing we are here for. Can you tell from ERTS-1 the amount of water that might be available in the area? Talking about Niger.

Dr. MACLEOD. In answer to the first question, the location of specific objects on the surface of the Earth is pretty well known at the present time. The thing that is not known is the condition of those objects. The synoptic view and multispectral view of ERTS gives us an idea of what is happening to the condition of the surface in any particular area.

This is particularly important in West Africa, where a process, the so-called desert encroachment, is occurring. We would not have been able to obtain the same kind of information concerning sandstorms, for instance, from any source of data I know. The meteorological satellite does give large-scale information on dust flow in the atmosphere, but we found that this was on the ground, very close to the ground, that it was not an ephemeral event. This kind of information is very valuable. I don't know where you would get it otherwise.

Mr. WINN. Timewise what would you say we save from that information received from the satellite compared to on the ground or on foot? How long would it take you to get basically the same information? That may be a real tough question.

Dr. MACLEOD. Well, I don't think you can get the same information in any other way. You get some indication that a serious problem is occurring. You can't get the idea of how large an area in which the problem is occurring, so perhaps that is not a good example to use for the question how much time is there to save in doing research survey. It is an immediate answer, or there is an immediate response to looking at the imagery, that something is wrong.

We haven't seen the sandstorms before. With regard to the ranch in figure 2 it took quite a long time for us to realize what that was. We asked people who had served in that area, we asked the resource management people in the country and we asked the President of the country and nobody could tell us what this object was. It was a very

large ranch. Obviously, they knew what it was after we made a field survey, but in going into other sources of information, particularly photo reconnaissance that had been flown by the French, which took quite a long time for the French to do, it took a long time for me to get to the data. It took me a long time to look at the data. I would say that I spent probably 3 or 4 months in background research, which related to this area and to that particular phenomena of the ranch. (It is a polygon figure in figure 2, about a one-quarter million acre ranch.)

The experience that I quoted of the French botanist in the Inland Delta, the ratio of time there was about 1 to 25. The ERTS information took him one-twenty-fifth of the time that it would otherwise take him to do the work on the ground.

With regard to the question on water, there are about three different kinds of water resources in the Sahelian region, one, surface water, small ponds that aren't being used. Those ponds are not quite as ephemeral as we thought they are. They exist up in the Sahel. You can very easily map the extent, the surface extent of such water.

We have done so in the case of the Inland Delta and published some results.

The second kind of water resource that I would mention is in the dry valleys, where water collected from rainfall flows under the soil into the dry valley regions. It is available but not exploited, particularly in the valley areas. I would say to a certain extent the ERTS analysis has had some effect on getting people to realize that there is an opportunity for rather inexpensive irrigation agriculture to be developed in that area.

Mr. WINN. Do they have storage capability?

Dr. MACLEOD. The valleys themselves have storage capability.

Mr. WINN. They don't have any major artificial types?

Dr. MACLEOD. There are some and Kainji Dam in Nigeria has such a facility which is silting in very badly. There is a dam that was built across a dry river bed well up into the dry area of the Sahel. This did not work very well either. Surface storage of water in the Sahelian Zone is an extremely expensive operation in terms of the efficiency of water storage.

For example, only about a third of the water entering the Inland Delta region goes out by Timbuktu at the end, two-thirds of it is lost through evaporation. There is about 2½ meters of potential evaporation per year in that area. It is extremely high. The dry valleys that I am talking about, the storage of water is in the valley itself. The water is subsurface but near enough to the surface, 5 to 10 meters beneath the surface, to be used with traditional wells. (The soils of the Sahel are not suitable to irrigation.)

The third kind of water in that area, so-called fossil water, is in deep aquifers. There have been a number of surveys made on the ground concerning their location but it is very difficult to get information from ERTS concerning those water resources. That kind of water reserve is probably the largest that Africa has.

Mr. WINN. It is hard to tell where those reserves might be, from the satellite.

Dr. MACLEOD. Yes; from the satellite.

Mr. WINN. Can you tell at all from the satellite whether they are water reserves there or in the case of the dry valleys, how much is subsurface?

Dr. MACLEOD. In the case of dry valleys you can do that, yes. You have to have climatic information to go along with it, and some well data, but with the additional data, you can generalize the system. It is hazardous to generalize too much because people may become quite dependent upon that water, and the availability will vary annually. The well data would relate to the driest periods that people have experienced in some years in the Sahel, so there is some assurance that that water resource is good in terms of reliability. As far as the deeper water is concerned there have been a number of surveys made by the French, in the French language area, and there is ground water information available from the French for the most part, not necessarily available directly to the countries themselves. It is available.

Maps have been made, and it shows large reserves of water of varying quality. Not all of it is high quality water. We can't get very much from the satellite on that.

Mr. WINN. Thank you very much. I think we could go on and on with this subject matter because it is interesting to a lot of us but we have another witness, I believe.

Mr. SYMINGTON. That is right.

Mr. Winn, I think it is of great interest, because fresh water is one of the resources we are most short of in the world and I hope that some day remote sensing can help us find sources of it. Maybe with your help, Dr. MacLeod, it will. Thank you very much for your very helpful testimony. You have submitted two additional papers which will be included in the record at this point.

[The material follows:]

USE OF ERTS IMAGERY AND OTHER SPACE DATA
FOR REHABILITATION AND DEVELOPMENT PROGRAMS IN WEST AFRICA

By

N. H. MacLeod
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Washington, D. C.

(Presented at the COSPAR "Seminar on Space Application of Direct Interest
to Developing Countries," June 21, 1974, Sao Jose dos Campos, Brazil.)

Introduction

Three applications of ERTS imagery analysis developed at The American University with NASA support have evolved through study of and correlation to the drought conditions, rehabilitation problems and development potentials in the Sahelian Zone of West Africa.

First, the possibilities of reversing the process of desertification in the Sahel through simple range management techniques were demonstrated in the course of analyses and interpretation of the imagery of western Niger.

Second, a regional assessment of ecological zones for agricultural and livestock production potential based on analysis of ERTS imagery has been accomplished with the provision of subsequent rehabilitation and development recommendations to Sahelian governments.

Third, a new and ominous development (the regional movement of sands and dusts in unprecedented intensity, duration, and frequency) has been observed and related, through field and image analysis, to deterioration of Sahelian plant communities and soil surfaces.

Taken together, these analyses show many opportunities for rehabilitation and development of the Sahelian region, but, in addition, there is every indication that time is short--that the region is deteriorating rapidly into a "dust bowl" condition.

In these studies of West African imagery from ERTS, we have utilized the classical triad of observation, interpretation, and integration--using the ERTS imagery as a tool to attack urgent problems of human need.

Observations on Rangeland Control

The Drought Analysis Laboratory was formed at The American University as an organization to receive, analyze, and interpret ERTS imagery of the Sahelian Zone of West Africa. In the imagery studied, a polygonal form in Niger was observed in an ERTS image covering western Niger and eastern Mali. The polygonal form was obviously man-made, because of its six straight sides, and was obviously different in surface characteristics from its adjacent surroundings (Figure 1).

After analysis of the aerial photography of the region, acquired by the French "Institut Geographique Nationale" during the 1950s and '60s, we found no lineations in the aerial photographs which would account for the feature observed in the ERTS image in 1973.

Because the interior of the polygon was moister, with more vegetation cover than the exterior areas, we felt that a significant change must have occurred. One can see in the ERTS imagery that the polygon is located in a region which is not different geomorphologically from its surroundings--for example, that there are sand dunes inside and outside the polygon.

A field survey was made with the assistance of the Niger government, and we found what others had surmised: a very large, fenced-in ranch, called the Ekrafane Ranch. The interior area of the ranch is 110,000 hectares, the perimeter 113 kilometers, enclosed by a five-strand barbed wire fence. This fence had been erected in 1968, five years prior to the acquisition of ERTS data. Thus, what we had observed in the imagery were the changes in vegetation and soils which had taken place in the past five years. Observing the ranch from a helicopter, we could see the gross differences delineated by the fence line (Figure 2). On the ground, we found that only nominal pasture management had permitted the establishment of acacia seedlings and maturation of annual grasses so that both an accumulation of forage reserves (dead stems and leaves) and seed formation had occurred (Figure 3)--in the same years the now notorious drought was devastating the Sahel.

The soil surface inside the fence was loose sand of a few millimeters depth, overlaying a layer of thin but compacted silts, and the silts lying

over more but quite compacted sand. Soil samples revealed little profile development.

Outside the ranch, beyond the protection of the fence, the surface sand was several centimeters in depth, with no silt layer and again no profile development.

We were looking at juvenile soils; but inside the fence, management had permitted the stabilization of the soil surface--while outside, the animal traffic had stirred the surface and left it vulnerable to movement by the winds. Indeed, ripples of sand, the result of light winds, were frequent outside the ranch.

We were seeing the positive effect of minimal pasture management on the fragile soils of the Sahel. If desertification is the removal of vegetation, an increased aridity in the microclimate, and a destabilization of soils, we were observing the halt and reversal of desertification. The significance of the Ekrafane Ranch lies in its ecological success: the increased vigor of plants, the increase in acacia and grass seedlings, and the improved soil stability--all showing that the microclimate has been moderated, and the encroachment of the desert reversed, by the action of men during the very years of the Sahelian drought.

To us, this clearly demonstrates that similar, favorable changes can be brought about through management in other locations as well. Enclosure experiments elsewhere in the Sahel have brought about the same results.

The problems associated with enclosures are more social than technical or even economic. Fences keep people and animals out as well as in. The fence around Ekrafane Ranch has become symbolic to us. We feel that there are other means of controlling access to the open range, through political and economic agreement among the users of the range. Such arrangements are being discussed with the Sahelian governments.

In this case, the space imagery stirred our imagination to try to determine the nature of the differences between the ranch and its surroundings. It was necessary to visit the site to be sure of the source of difference. The sign at the ranch gate was not sufficient for explanation of

the space-observed features. It was also necessary to invoke both ecologic and agronomic information to interpret our observations. More important, it was necessary for us to have the social and economic significance explained to us by the people and government of the country. Only then could we recommend further actions to the government.

In summary, to fully utilize space imagery, it is insufficient only to observe or simply correlate imagery with field surveys. The ecologic context must also be defined. To be useful, the interpreted imagery must be placed into a socio-political context as well. We should emphasize that where we have ignored these factors, we have not been helpful to the people or governments of the Sahel. When we have observed with imagery and in the field, interpreted on the basis of ecologic principle, and integrated this knowledge with social and economic factors, we have been helpful, we are told by governments in West Africa.

Development of Concepts of Potential Agricultural Resource

In the course of our analysis of ERTS imagery and the associated field observations, we became aware of the possibility of graphically summarizing our thinking concerning the potentials for rehabilitation and stabilization in the Sahel. From an ecological viewpoint, the limitations of water supply--from precipitation or from shallow and deep wells--and the necessity to restabilize the surface with vegetation have put bounds on the possibilities of practical techniques to be recommended to the governments concerned.

Because we have so little information on the potential natural vegetation of the Sahel (that which would form climax or mature and stable plant communities after sufficient release from cultural pressures and after sufficient time for plant and animal communities to mature), we can only infer that a particular technique would be useful. Again, the ecological significance of the Ekrafane Ranch is that in a very short time a visible and positive set of changes developed, whose character is very like that found in enclosure studies throughout the Sahel. A not very stringent grazing management scheme imposed for less than six years had begun to

stabilize soil and permit accumulation of organic reserves and moderate the microclimate--all of these in a productive management scheme.

Such are the clues to ecological management that we must glean from space imagery, from the people of arid regions, and from the many studies of arid zones available. Using these clues in conjunction with known ecological principles, we can begin to sketch the outlines of a program of rehabilitation.

ERTS images lay before us the present ecological situation, something of the character of land-use practices in the Sahel, something of the geography of both critical land-use problems and development opportunities, so that the graphical representation of rehabilitation can be done directly as an overlay on an ERTS mosaic. Figure 4 is such an overlay.

There are four zones of potential agriculture use indicated, each related to both the ecologic and social situation. There is a zone of crop production (blue), one of mixed agriculture (green), one of livestock production (brown), and one of intensive agriculture based, to some extent, on irrigation (yellow). While these zones appear as large, generalized regions, they have been mapped directly from the ERTS images using the following criteria:

- Blue zone — contiguous cropping pattern visible, dense village patterns
- Green zone — cropping present but not contiguous, scarce village patterns
- Brown zone — no cropping visible, no village patterns
- Yellow zone — demarcation of tertiary valleys and modern rivers (the Niger River flood plain)

Included in these blue, green, and brown zones are laterite capped plateaus which are not productive at present, though they might be used in the future for run-off agriculture. The map is by no means detailed or finished, being an initial remote sensing look at regional potentials and at zones where particular management techniques are considered to be most useful.

For example, subsistence crop production is prevalent in the blue zone. This is the sedentary zone where traditional agriculture consists of the production of millet, and where cash crops of peanuts and some cotton are produced. The major problems of this zone is one of overuse in the context of traditional rain-fed agriculture. We have calculated that the fallow-time (the period of years during which fields are allowed to return to bush so that soil fertility may be restored) has been reduced from fifteen years to three years or less. These calculations are based on a model using ERTS images as a data base. They indicate that in many areas continuous cultivation of grain with no release for fertility restoration has become the rule rather than the exception. That is, the present management techniques--that of crop and fallow rotation--has broken or is breaking down. Soil fertility is not restored or maintained as in the past. As people must use arable land to a maximum to produce grain for their survival, a return to the fallow rotation won't work. In theory, the fallow rotation is a valid technique for maintenance of ecological stability. The ERTS data show that it is not working, and where and to what extent it is not working. The alternative techniques which might work are not suggested through simple analysis of the imagery. Instead, one must first define objectives, then survey and select techniques based upon ecological principles.

The objectives in this zone are maximum production of food crops, year-round vegetation cover, maximum increase of soil organic matter, and other fertility factors. These objectives are to be attained in the minimum time--i.e., immediately, if possible. The time factor means that no time is available to gather large capital and technical resources or to train large numbers of people in a new agricultural technique. There is only the land and the people on which to base recommendations.

Some ecologic principles which are useful are those which maximize in situ use of rainfall (i.e., reduce run-off, moderate the local microclimate, surface winds, temperature, albedo, etc.) and those which combine secondary cropping with the primary grain crops to maximize available environmental resources.

The techniques that we recommend are simple enough:

1. Interplanting a food legume with the grain (millet). This does not represent a new technique. It stresses the need to implement a known technique. The legume might be *vicia sinensis* (cowpeas, already grown in the Sahel). Sufficient seed stocks need to be developed; farmers strongly encouraged to use the crop; and a program established to ensure inoculation of this legume (to assure maximum nitrification and benefit).
2. A grass cover crop seeded near millet harvest time should be used to maintain a dry season cover. (Millet stalks are used for construction and are therefore not available for residual cover, though such use can be encouraged.)
3. An accelerated program of leguminous tree planting in grain fields to provide protection from solarization and a source of high-nitrogen organic matter (from leaf-drop and root nodule nitrification) should be undertaken. In Niger, this program is being carried out with excellent increases in grain yields in several areas.
4. Untimely use of fire for sanitation and fertilization should be discouraged. Vegetative cover should be maintained during the dry season instead. Slash burning should be restricted to the beginning of the rainy season.
5. Small animals, such as poultry, which can scavenge their own food, should be encouraged through government distribution of stock and information.

Now, these recommendations do not suggest that people should completely change their traditional ways, but that certain aspects of their present way of producing food and shelter be modified. The recommendations envision a more intensive use of land and a more intensive management of land. They also take into consideration the ecological dynamics of the region.

The expected outcome is a moderated microclimate, a more intensive use of environmental resources, an increase in soil fertility and, most important, a rapid increase in grain and food production.

ERTS imagery, the Skylab photographs, and Skylab astronaut commentaries permit us to define the particular regions to which this set of recommendations apply. The area or size of the region can be calculated and situations which have high action priority can be located. Thus, both the space data and the recommendations are used together in discussions with Sahelian governments.

We should add that this discussion is not held in the context of a demand upon the government to take certain actions. Rather, the discussions are considered to be of possible assistance in decision making by the governments themselves.

The sedentary zone case, just discussed, is only illustrative of the possibilities of using ERTS imagery, and summarizes our thinking concerning the potentials for rehabilitation and stabilization in the Sahel. A similar discussion of recommendations can be presented for the other potential agricultural zones.

A Dust Bowl in the Sahel?

While we have observed surface conditions in the West African Sahel through analysis of ERTS-1 imagery since September 1972, we had not seen dust or sand streaming in the region (that is, the sparsely vegetated Sahel--not desert areas) until 1974. This spring ('74), imagery of Mali and Niger obtained on 27 and 28 December 1973 became available to us. In Figures 5, 6, and 7, the region between 15°N and 16° 30'N and 0° 30'E and 2° 30'E is shown to have suffered from widespread incidence of sand movement between November 1973 and January 1974, but particularly (if only because we can see it in the only available images) on the 27th and 28th of December.

Bowden and others published a report of sand streams induced by the Santa Ana winds of southern California (USA) which they observed in ERTS

imagery.* They described dust plumes 10 to 30 km in length covering 300 km². Average wind velocities for the dates were about 10 km/hr. Putative sources for the dusts were disturbed regions where vehicular traffic had stirred the surface.

In the Sahelian case, such sand plumes were often more than 150 km in length, covering many thousands of square kilometers of range and cropland. Because the "plumes" seen on 27 December can be overlaid on those in the adjacent frame acquired on 28 December (24 hours later), we surmise that the plumes are streams located on the surface. For atmospheric streams to retain their orientation and shape for 24 hours seems to us implausible.

We agree with Bowdon that the source of dust or sand is recently disturbed surfaces where stability factors have deteriorated. In the Sahel we postulate that these factors are removal of vegetation through the effects of drought and overuse of range and cropland, loss of soil aggregation factors such as organic matter and moisture, and increase in surface windiness again through reduction or lack of vegetal cover (trees, shrubs, and annual grasses). We consider that a very serious and new set of environmental factors has come into play in the Sahel which requires urgent attention.

The blowing of sand and dust affecting such a large area can be called a "dust bowl" condition, similar to the same type of condition that plagued the midwestern United States in the 1930s. The American condition was cured by development and application of soil conservation measures which were aimed in toto at stabilizing the soil surface: by revegetation which maintained a cover year-round on cropped land, the development of minimum tillage techniques, and through use of shelter belts. Over the years, a full spectrum of techniques was developed and put to use.

*Bowdon, L. W., Huning, J. R., Hutchinson, C. F., and Johnson, C. W., "Satellite Photograph Presents First Comprehensive View of Local Wind: The Santa Ana," Science, 184, 7 June 1974, pp. 1077-1078.

In the Sahel, a similar campaign will be called for if the conditions are found to be as interpreted from ERTS imagery.* We have little reason to doubt that sand is blowing badly in the Sahel now; the question is how much. A cover of six inches of new sand in interdunal patches where most of the forage is found would critically diminish the feed available to nomadic herds. In subsistence cropping areas, the damage may not be so intractable as seeds can be planted in moist sands or in fields not affected by new small dunes. However, repeated blowing will put urgently needed productive fields beyond feasible use by the farmers.

Conclusion

There are techniques of water, soil, and plant control and conservation which are applicable to the Sahel. Their application represents a major recovery campaign, a campaign which should be considered as the first priority in the implementation of major rehabilitation programs or at least in conjunction with such programs. If satellite imagery is any guide--and we believe it is demonstrably so--then we have seen similar surface conditions throughout the northern Sahel and in cropping regions as well. Those areas outside the observed "dust bowl" are not immune to the development of similar dust and sand storms. This again means that the priorities and pace of rehabilitation must be adjusted to the realities of the surface deterioration brought about by the drought.

*MacLeod, N. H., "Dust in the Sahel: Source of Drought?", Ceres, No. 2 (Washington, D. C.: The American University, 1974).

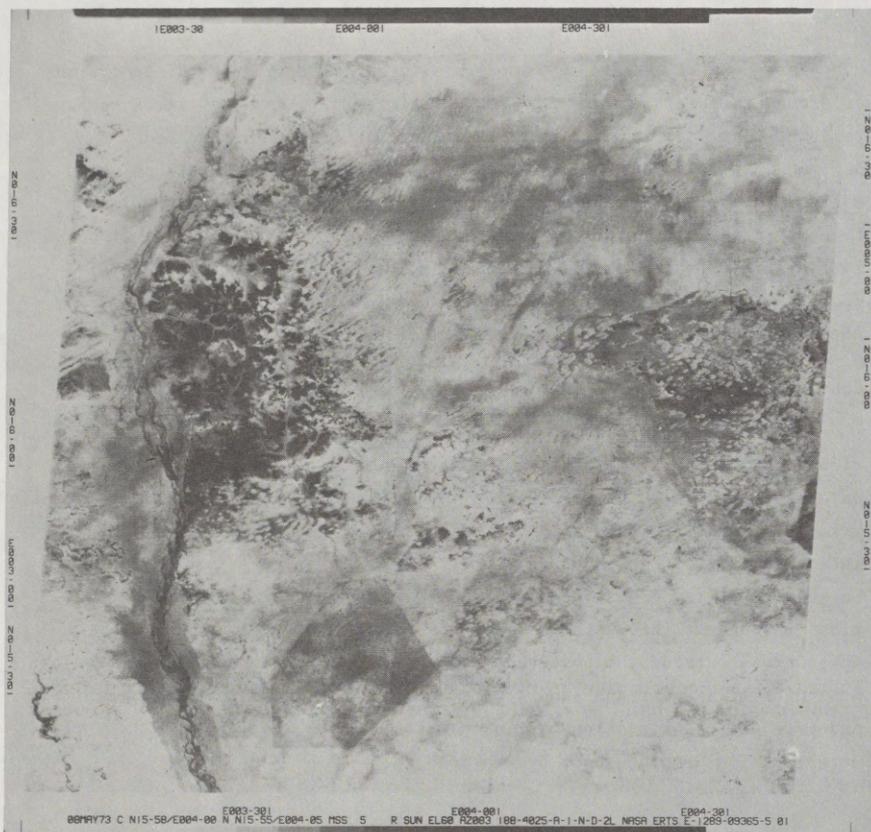


FIGURE 1.—ERTS image of Eastern Mali, Western Niger, with Ekrafane Ranch (bottom center), a polygon which can be identified because of improvement in vegetation and soil conditions since 1968, when the range was fenced. (ERTS-1 Image 1209-09365, 8 May 1973.)



FIGURE 2.—Helicopter view of northwest border of Ekrafane Ranch. Interior of Ranch is on left-hand side, and is darker because of heavier vegetation cover. (View is to the south.) (28 August 1973)

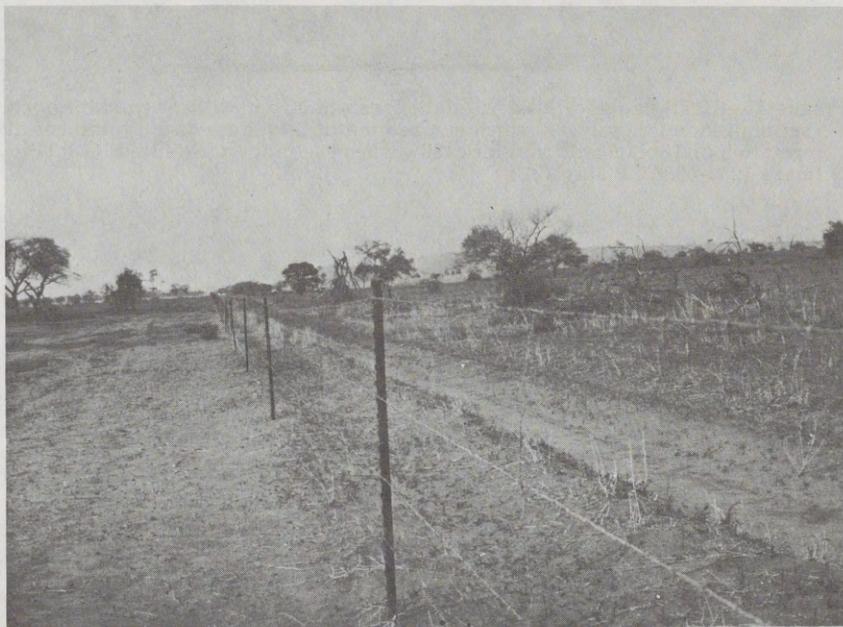


FIGURE 3.—Fence line at northwest boundary of Ekrafane Ranch. Right-hand side of fence line is inside Ranch. Dead plant stalks, many seedlings, accumulation of dead wood show the improvement in accumulation of organic reserves and plant vigor. (28 August 1973)

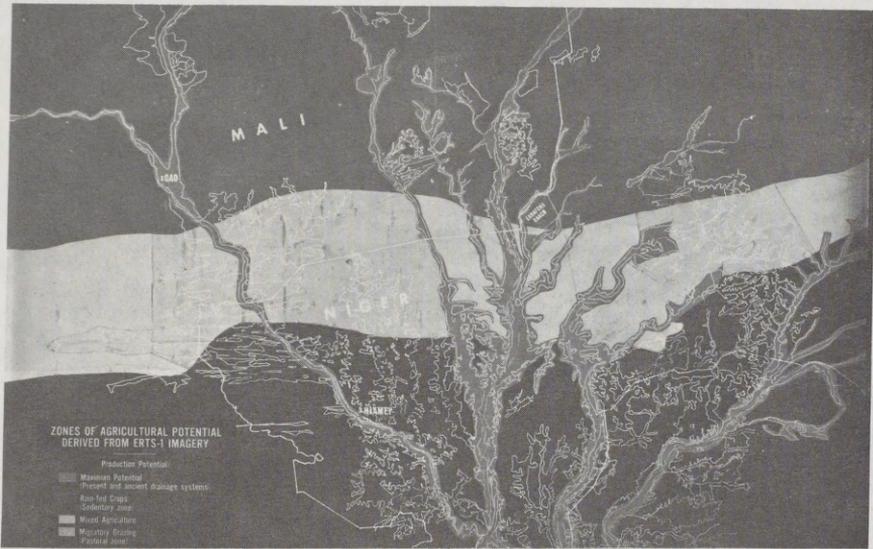


FIGURE 4.—Zones of agricultural potential derived from ERTS-1 imagery.



FIGURE 5.—Sand streams in Tchén Tabaraden region of Western Niger. The sand streams are small linear features trending east to west. In this image, the streams are less than 70 km in length but extend beyond the western border of this image. (ERTS-1 Image 1522-09273, 27 December 1973.)



FIGURE 6.—Sand streams in southwestern Niger, Tahoua Department (Tahoua is located at top-center of image). Sand streaming is found particularly in the upper two-thirds of the image, west of the dark-toned upland in the image-right. The lowland is heavily populated with many villages (light-toned small circles with dark dot in center). (ERTS 1 Image 1522-09200, 27 December 1973.)

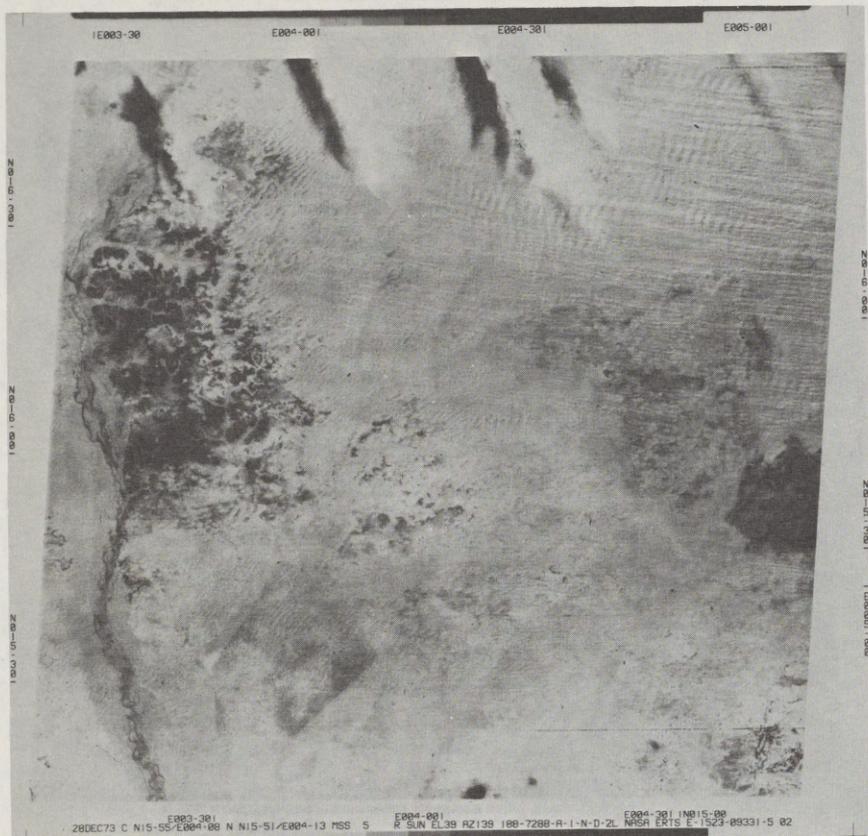


FIGURE 7.—This image is of the same area as Figure 1. Sand streaming is most intense in the upper right-hand quadrant. These streams are a continuation of those seen in Figure 5 of this paper. The images were acquired on 27 Dec. (Figure 5) and 28 Dec. (Figure 6), 24 hours apart. (ERST-1 Image 1523-09331, 28 December 1973.)

DUST IN THE SAHEL: CAUSE OF DROUGHT?

by

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The current drought in the Sahelian Zone of Africa has brought about widespread suffering which has, in turn, set in motion a worldwide effort to provide both short-term relief and long-term rehabilitation assistance. A basic assumption underlying these programs is that the drought will end. However, recent papers by Bryson (1), Lamb (3), Winstanley (5), and others present information suggesting that a long-term climatic change is under way. The change in global climate they suggest includes equator-ward shifts of climatic zones which have already resulted in the droughts observed not only in Africa but on the Indian subcontinent in Asia and in the Western hemisphere as well. The trend of climatic change forecasts a bleak future for mankind.

Several theories have been advanced to explain such a global temperature drop; among them, changes in solar output, sun-spot activity, as well as an increase in terrestrial albedo (decreasing energy flow within the atmosphere) due to increased atmospheric dustiness. The effects of these postulated changes on man and societies, the droughts currently experienced globally, as well as floods and cooler weather in northern latitudes, have reduced the food production capacity of the globe. If the trend intensifies or simply continues at the present level, it is also postulated that a larger proportion of mankind will go hungry--an even larger proportion

than at present. In the models of Bryson and Lamb, there are essentially no parameters under the control of man. It is a doomsday prophecy.

The doomsday is in some measure already upon millions of people in Africa and Southeast Asia, where there is widespread suffering from prolonged drought. For example, in the Sahel bordering the southern reaches of the Sahara Desert, millions of cattle have succumbed and, while estimates vary, hundreds of thousands of people have lost their means of food supply and thousands have died from a multitude of diseases, if not outright starvation. If Bryson and Lamb are correct, the remaining people should be evacuated from the Sahel now and the international mechanisms set in motion to ease the massive effects of such a social displacement.

Bryson's arguments are compelling and lead to a profound concern for the future of human society. That concern has led us to analyze the Sahelian drought, searching for a method of reversing the trend to drought and famine. We conclude that there is such a means: revegetation of the Sahel--an enormous and complex undertaking. Even so, the restabilization of the land through establishment of plant cover is a real alternative to drought and famine.

In this paper, we advance some alternative hypotheses concerning the African drought and offer some ecological perspectives which permit a model of Sahelian climate, including drought. In this model or set of models, there are some parameters which can be controlled by man--although with difficulty and great expense. If man does control these parameters, some of the outcomes of the models are the cessation of drought and the productive greening of the desert; a revegetation of the Sahel and parts of the interior Sahara. Thus, these hypotheses are to be examined carefully

for they are not doomsday prophecies, but a path to increasing global food production.

In Bryson's view, a principal factor in global climatic changes is a substantial increase of dusts in the atmosphere. In this paper, the causes of drought in the Sahel are assessed from the viewpoint of regional climatic factors. Within the Sahel, the generation of dust from surfaces denuded by man is a principal factor producing and prolonging drought. The revegetation of the range and crop land of the Sahel is advocated not only for ecological rehabilitation, but as the critically needed method for reversing the trend toward drought in the Sahel--perhaps on a global scale as well.

Considering the reports of increasing amounts of dust in the Sahelian atmosphere and our direct observations of dust and sand storms as well as satellite evidence of major movement of sands, we formulated simple models for dust generation and dust effects on the regional climate regime. It is important to analyze potential sources of dust so that it can be determined whether or not corrective actions are possible. The alternative, social adjustment to climatic change, requires such profound change in an unknown and undefinable context that men stand helpless and hopeless in calamity.

The following discussion concerns the drought in West Africa and some recent observations of sand and dust movements, an analysis of the cause of the movements and of the effects of dusty atmospheres on the climate of the Sahelian Zone. The evidence presented by Bryson suggested to him that human activities may have an important influence on the present droughts through introduction of dusts into the atmosphere. We agree with this point of view, and present a model of dust generation into the atmosphere

of West Africa, its global dispersion, and a set of recommendations for human counteractions which might alleviate the drought problems.

The climate of West Africa is dominated by seasonal shifts in the zonal weather systems, particularly the Inter-Tropical Convergence (ITC). Moving north in summer and south in winter, the leading edge of the ITC is the location of maximum precipitation. Places located south of the maximum northern excursion of the ITC have two summer rainfall maxima, one as the ITC moves north and a second when the ITC retreats to its winter position (Figure 1).

North of the ITC, climate is dominated by westerly high pressure systems formed by descending dry, cold air. These highs produce the Harmattan, a very hot, dry northeasterly wind which also moves in a seasonal pattern much like the ITC. In recent years, the northeasterly Harmattan winds have penetrated much further south than normally--last year to the coast of the Gulf of Guinea.

Between the Harmattan airs and the southwest monsoon of the ITC, easterly winds are found in a persistent low pressure trough. At the southern edge of this trough, where the ITC is located, a series of cumulus formations--squall lines--move from east to west, the result of the interaction of wet monsoon airs and the dry Harmattan. The latter rides over the monsoon air, blocking and lifting the monsoon air and thus producing rainfall.

This is the normal climatic regime in the Sahel. But for several years, and particularly for the last three years, pilots have reported unusual and increasing amounts of dusts in the Sahelian atmosphere. During

the NASA Skylab-3 mission in winter 1973-74, the Skylab crew reported large-scale movement of smoky dust clouds out of West Africa into the Atlantic, and out of East and Central Africa into the West Indian Ocean. Another study of dust movements across the Atlantic was conducted with analysis of Nimbus meteorological data (2). This showed that the dusts were contained in a large, coherent stream of warm air (flowing between 4,000 and 20,000 feet altitude) from the west coasts of Africa to the Caribbean Islands, which suppressed normal exchange of energy (water vapor).

In late June and early July, 1974, the altitude of the dust formation was observed (from commercial aircraft) to be about 27,000 feet near the southern coast of West Africa (Sierra Leone and Liberia) and 21,000 feet at 13 degrees north latitude (near Ougadougou, Upper Volta).

Rainfall since 1968 has been either scanty or poorly distributed through the summer season. While this series of years is not the only period of drought experienced by the Sahel, it is the most extended and also the most destructive of crops, livestock, and people.

During the winter of 1973-74, we observed with ERTS imagery extensive movement of sands in Western Niger (Figures 2, 3, 4). Covering thousands of square miles, the moving sands indicated to us that the deterioration of vegetation and soils in the Sahel had passed a critical point and that a "dust bowl" condition had fully developed.

A field trip to Niger was undertaken to establish correlations between the features observed in ERTS images and the actual conditions on the surface. During this trip, reports of unprecedented sand and dust storms were received. These storms had occurred in the same regions where sand

movements had been observed in the satellite imagery. New extensions of sand dunes in the Tchén Tabaraden area of Niger were photographed (Figure 5), as well as a new form of sand movement. Normally, sands in the Sahel are coated with iron oxides which give a yellow or reddish color to the dunes. Now, white quartz sand from flat areas occupied by silty soils of hydromorphic origin are dusting the dunes. The white sands are those not exposed to the process of iron coating and only recently removed--separated by winds--from the soils. The blowing of white sands is an indication that soils which were previously protected from wind erosion by vegetated surfaces or accumulated organic matter had lost that protection and become unstable.

After a "good" rain in early June 1974, approximately thirty days elapsed before rains occurred again. We observed that when rains do occur in Western Niger, they are preceded by a more-or-less severe sand storm. Two very severe sand storms occurred during the field survey. One, in Ougadougou, preceded a torrential downpour. Extensive electrical activity accompanied both the sand storm and the rain storm. Lightning and thunder occurs during strong local vertical motions in the atmosphere. Rapid up-and-down transport of dust and water particles produces an electrical potential which is discharged through lightning flashes. The second storm was observed in Niamey, Niger. Again, electrical activity was severe--but no rain followed the storm. Such storms are reported to have become common in Western Niger.

Both the severity and the infrequency of thunderstorms in the early rainy season suggest a slow development of a disequilibrium between the

monsoon wind and the NE Harmattan winds. The inversion formed by dusts in the monsoon air prevents a normal mixing, which results in an abnormal energy potential difference. When a breakdown across the potential gradient occurs, the flow of energy is abnormally great. This flow of energy produces a very severe storm.

In dust-free air in which a normal lapse rate (cooling with altitude) and energy transfer occurs, such severe storms should occur frequently. Thus, the severity of dust and rain storms and their infrequency suggest the importance of dust-generated inversions in the Sahel: their importance lies in the reduction of storm frequency (rainfall distribution) and the increase of storm intensity. (Such storms produce severe soil erosion and crop damage.)

During the day, in both Ougadougou and Niamey, the underside of clouds were a brick-red color (Figure 6). Some meteorologists felt this color was due to reflectance of sunlight from the soil surface. As the cloud color was uniform, and the surface color is not uniform (green in vegetated areas, dark red on laterite plateaus, "silver" on sheet metal roofs of urban areas, etc.), we speculated that the cloud base was colored by dust picked up as the clouds passed along the top of a dust layer. The brick-red color is just that of the fine dusts of the Sahel collected on white cloth.

We also felt that if the cloud color were due to reflected light from the land, the intensity of the cloud base color should change with change in the relative positions of the sun, cloud base, and observer. Photos taken in four compass directions do not show such intensity or spectral changes. We reach the tentative conclusions that the cloud base does pick up dust, that a dust layer extends to the base of the clouds, that the dust

layer rises during the day with diurnal heating--its upper boundary marked by the cloud base level. Further, we hypothesize that mixing of this low-level dust generated during the day and the regional monsoon air occurs primarily during the nighttime. This low-level dust layer also constitutes a weak inversion which is frequently observed in radiosonde data obtained at Niamey.

It is possible, then, that the peculiar cloud base colors are related to local upward transport of dust brought into the atmosphere by micro-turbulence, as discussed below. The local dust is transported from the surface to the lower atmosphere during daylight hours, and from the lower atmosphere aloft into the regional monsoon air during the night.

Analysis of ERTS imagery of the Sahelian Zone and the savannahs and woodlands south of the Sahel shows a very large proportion of the land surface to be open--that is, unvegetated. Skylab and other space observations show the same situation. Even without exact data on the rate of loss of vegetation and without thorough examination of specific causes of vegetation loss, we can observe that the terrain has become less vegetated especially in the past few decades, and at an increasingly rapid pace.

The microclimate of bare soils in the Sahel is very different from that of vegetated soils. The most important difference is found in the temperature gradient, and particularly the location and size of the diurnal temperature maxima (4). Figure 7 shows these differences schematically. Obviously, the particular plant community examined will have unique thermal characteristics. However, the temperature maximum in a closed plant canopy is not located at the soil surface, but within the plant canopy. On bare soil, this maximum is located at the soil surface. In addition, temperature

maxima of bare soils are much higher. Differences of 30°C have been measured in the tropics and 10°C in temperate climates of the United States. Further, the temperature gradient near the surface is much steeper over bare soils than in plant canopies (superadiabatic).

The implications of microclimate differences among soils are profound. Micro-turbulence developed during convective energy transport is easily observed near irradiated surfaces in the form of shimmering heat waves. Because such energy transport occurs within a plant canopy, not at the surface of a vegetated soil, the convective air movements do not bring dusts into the atmosphere. However, with bare soils, which contain silts and clays, dust is brought into the atmosphere during the daily development of steep temperature gradients through the concurrent development of turbulence at the soil surface. It is not necessary to invoke strong surface winds to conceive of a means of atmospheric dust production in the tropics. Surface winds are higher over unvegetated regions because of the lower surface roughness of bare soils. This factor should intensify the production of dusts. And, as pointed out earlier, there are high concentrations of dusts in the Sahelian atmosphere.

Having analyzed the principal sources of dust, it is now important to assess the effect of dust on the Sahelian climate. Because the source of moisture for Sahelian precipitation is the SW monsoon, it is this system in which the effect of dust should be examined. The lapse rate of the atmosphere measured by daily radiosonde at Niamey is shown in Figure 8. This generalized figure shows that the warm, moist air of the monsoon tends to be isothermal instead of cooling with altitude. The air above the monsoon is very much warmer than a standard atmosphere, showing the influence

of the Harmattan blowing above the monsoon air and in an opposite direction. In between the hot, dry air and the moist, warm air, a small region of cooler air is frequently found.

There are several effects of the isothermal character of the monsoon air. First, precipitation will obviously not occur until the air is cooled below the dew point. The elevated temperature of this isothermal system suppresses updraft which would cool the air. (The energy gradient in this system is opposite to that which would produce rising air.) Second, the dust aerosol is well mixed or uniform within the system. This tends to maintain the isothermal character; that is, the system is stable, and tends to be stabilized by the dust. Third, the pressure of the system is reduced because of the higher temperatures aloft. This may be the most important effect relative to regional aspects of the drought (Figures 9 and 10).

It is along the ITC front that the greatest rainfall occurs in the Sahel. This is the region in which SW monsoon is blocked by the Harmattan winds and lifted and thereby cooled. In stable, dusty monsoon air, the Harmattan wind does not mix as effectively with the monsoon, though some clouds are formed along the front. Another way of describing the situation is to say that cumulus cloud formation along the ITC is suppressed by the presence of dust in the monsoon air. Therefore, rainfall along the front is also reduced, producing a drought.

Because the pressure of the dusty monsoon is reduced relative to non-dusty air, there should be an increase in the size of the trough (Intertropical Depression) in which the easterlies blow. The NE winds should flow farther south and the monsoon more gently north. That is, the ITC

should be located in a more southerly position in dusty monsoon airs than would normally be the case. If this were to occur, more northerly parts of the Sahel should experience a shorter rainy season, if any. Savannah regions to the south of the Sahel should have a longer rainy season than normal, but with less actual precipitation.

This summer (1974) it was observed that the ITC is approximately 6° south of its normal location and that some areas in southern Upper Volta, for example, have experienced a longer period of rainfall. Thus, the effect of high dust loading is twofold: rain-producing systems do not go as far north; cumulus (rain) cloud formation is suppressed.

If the model of dust introduction and that of dust effects are substantially correct (i.e., are descriptive of the actual mechanisms), then we can state that the drought is feeding upon itself--that is, it is self-perpetuating. Because enormous amounts of dust are transported out of West Africa, possibly in sufficient quantity to affect global temperature and thus global climates, the solution of the Sahelian drought problem should have beneficial global effect. We can do something to break the cycle: revegetate the Sahelian Zone of Africa.

In other papers, we have presented recommendations for revegetation and rehabilitation of the Sahel--based on the assumption that there would be time for long-term programs. The implications of the present discussion are (1) that an immediate regional action program is required, (2) that until the dust problem is laid to rest, there will be no improvement in rainfall, and (3) that the remedial program must have priority over all other development and projects now under way or being planned in the Sahel.

Revegetation of the Sahel can be accomplished through range and crop management--including, as an essential, cover crops for the dry season, and installation of soil and water conservation measures. Revegetation does not mean setting aside the Sahel as an unproductive reserve. It does mean that range management and crop management, including cover crops, are essential. In short, immediate programs to cover the land are needed. That precious water which is available should be expended on this program.

We have recommended the following actions:

1. Revegetation of surfaces through range and crop management, soil and water conservation measures of small scale but with extensive regional application;
2. Reforestation on a practical scale; but in pastoral regions, revegetation through grazing management, installation of small structures to maximize water retention (prolong growth season), introduction of suitable forages, and dune controlling vegetation;
3. In cropped areas, maximize mixed cropping, introduction of cover crop through direct government intervention and farmer incentive.

This should occur throughout the Sahel and sub-Saharan zone.

The principles involved are:

1. Insuring a maximum year-round plant cover;
2. Insuring maximum plant growth through use of water retention (soil-water conservation) techniques;
3. Insuring maximum range and forest stabilization through pasture management.

(While this paper is concerned primarily with the technical problems of the drought and of the possibilities of overcoming drought effects, we recognize that these proposals have extensive social ramifications with which we do not deal herein. There must be a comprehensive program of interaction with the farmers and herdsmen involved, dealing with the changes in their life-styles that will be necessary to achieve the objectives of these recommendations and principles. Social and political factors must be an integral part of the consideration, planning, and implementation of programs fitting into this framework of objectives if they are to be successfully reached.)

From an ecological viewpoint, the limitations of water supply--from precipitation and/or from shallow and deep wells--and the necessity to restabilize the surface with vegetation restricts the possibilities of practical techniques to be recommended to the governments concerned. Because we have so little information on the potential natural vegetation of the Sahel (that which would form climax or mature and stable plant communities after sufficient release from cultural pressures and after sufficient time for plant and animal communities to mature), we can only infer, from a few examples, that particular techniques would be useful. In Niger, a not very stringent grazing management scheme imposed for less than six years had begun to stabilize soil and permit accumulation of organic reserves and moderate the microclimate--all of these in a productive management scheme. The significance of this pasture management in the Sahel is that in a very short time a visible and positive set of changes developed. We must glean clues to ecological management from space imagery, from the ancient and successful practices of nomadic peoples of arid regions, and from the many studies of arid zones available. Using these clues in

conjunction with known ecological principles, we can begin to sketch the outlines of a program of rehabilitation.

As ERTS images lay before us the present ecological situation, something of the character of land-use practices in the Sahel, and something of the geographic distribution of both critical land-use problems and development opportunities, the graphical representation of rehabilitation can be done directly as an overlay on a mosaic of ERTS images. Figure 11 is such an overlay.

There are four zones of potential agricultural use included, each related to both the ecological and the social situation. One is a zone of crop production, one of mixed agriculture, one of livestock production, and one of intensive agriculture based, to some extent, on irrigation. While these zones appear as large generalized regions, they have been mapped directly from the ERTS images. The map is an attempt to look at regional potentials--and at zones where particular management techniques are considered to be most useful.

For example, in the sedentary zone, where traditional agriculture consists of the production of millet and where cash crops of peanuts and some cotton are produced, the major problem is overuse in the context of traditional rain-fed agriculture. We have calculated, with models using ERTS images as a data base, that the fallow-time (the period of years during which fields are allowed to return to bush so that soil fertility may be restored) has become reduced from fifteen years to three years or less. Traditional management techniques--crop and fallow rotation--are breaking down or have already been disrupted, so that soil fertility has

not been restored or maintained as in the past. A return to the traditional fallow rotation will not work, since arable land must now be put to maximum use to produce the food the population needs for its own survival.

The objectives in this sedentary zone are maximum production of food crops, maximum year-round vegetation cover, maximum addition of organic matter, and improvement of other fertility factors. These are to be attained in the minimum time--immediately, if possible. The time factor allows no delay to gather large capital and technical resources, or to train large numbers of people in new agricultural techniques. There are only the land and the people on which to base recommendations.

This does not suggest that people should completely change their traditional ways, but that certain aspects of food production be modified. These recommendations envision a more intensive use of land with more intensive management, taking into consideration the ecological dynamics of the region. The expected outcome is a moderated microclimate, better use of environmental resources, an increase in soil fertility, and, most important, a rapid increase in grain and food production.

There are techniques of water, soil, and plant control and conservation which are generally applicable to the Sahel. Their application represents a major recovery campaign which should be considered prior to the implementation of major rehabilitation programs, or at least in conjunction with such programs. If satellite imagery is any guide--and we believe it is demonstrably so--then we have seen similar surface conditions throughout the northern Sahel and in cropping regions as well. Those areas outside the observed dust bowl are not immune to the development of similar

dust and sand storms. This, again, means that the priorities and pace of rehabilitation must be adjusted to the realities of the surface deterioration brought about by the drought.

The foregoing discussion is not presented simply as an academic report of a research project. Rather, we have presented a situation report and a general action program in order to point out that it is possible to take constructive action directed at causes of the drought that will be far more effective than expensive relief programs which deal only with the symptoms.

We have seen instances during the period of Sahelian drought in which these management techniques have resulted in recovery of the soil surface and increases in production beyond that found prior to the drought. We feel, therefore, that these management techniques should be integrated into a regional recovery program under collective guidance and implementation of the Sahelian States with major funding and technical assistance through the international community's family of development and environmental programs.

While we might agree with Bryson and Lamb in many particulars, and while we recognize that our hypotheses are more or less untried, we do not agree that drought is inevitable. We feel that every possible action should be taken to prevent the deterioration of semiarid regions, and to act positively in retaining and increasing the productive capacity of these areas.

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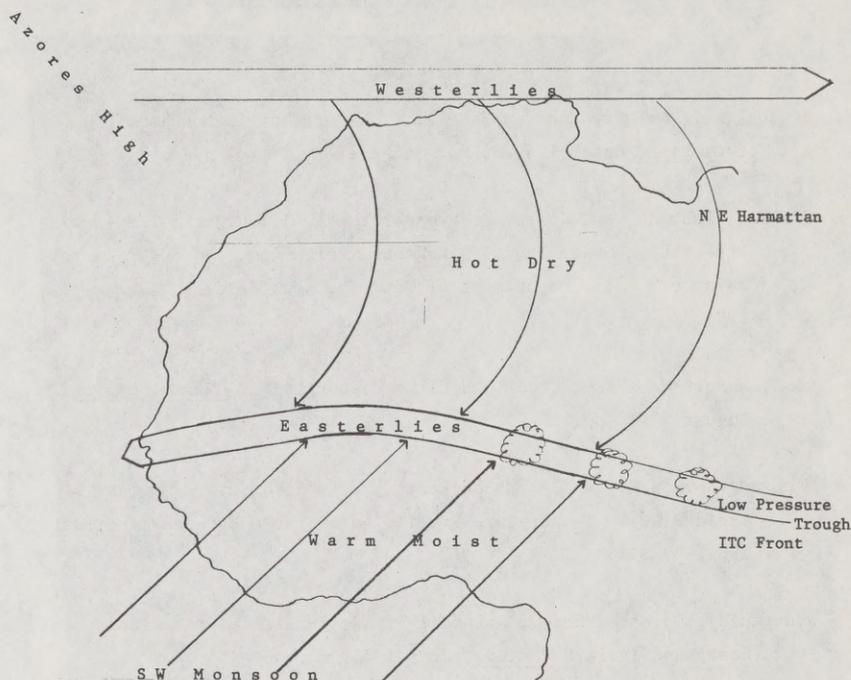


FIGURE 1.—Regional Atmospheric Circulation in West Africa

NOTES ON FIGURE 1

Regional atmospheric circulation in West Africa is dominated by four systems: the Westerlies; the desert high pressure zone which generates the hot, dry Harmattan; a low pressure trough in which the Estuaries are found; and the warm, moist winds. At the Intertropical Convergence (ITC) northern front, maximum precipitation occurs with lesser amounts of precipitation occurring south of the front.

These systems "follow the sun," moving northward in summer and south in winter. This motion gives rise to the seasonal weather pattern of the Sahel, rain in summer, dry in winter; the length of the rainy season is dependent upon latitude. Occasional low pressure systems move westerly from the Azores High. When this occurs, monsoon airs flow north across the desert bringing occasional rainfall to the Sahara. Such rainfall occurs particularly in late winter.

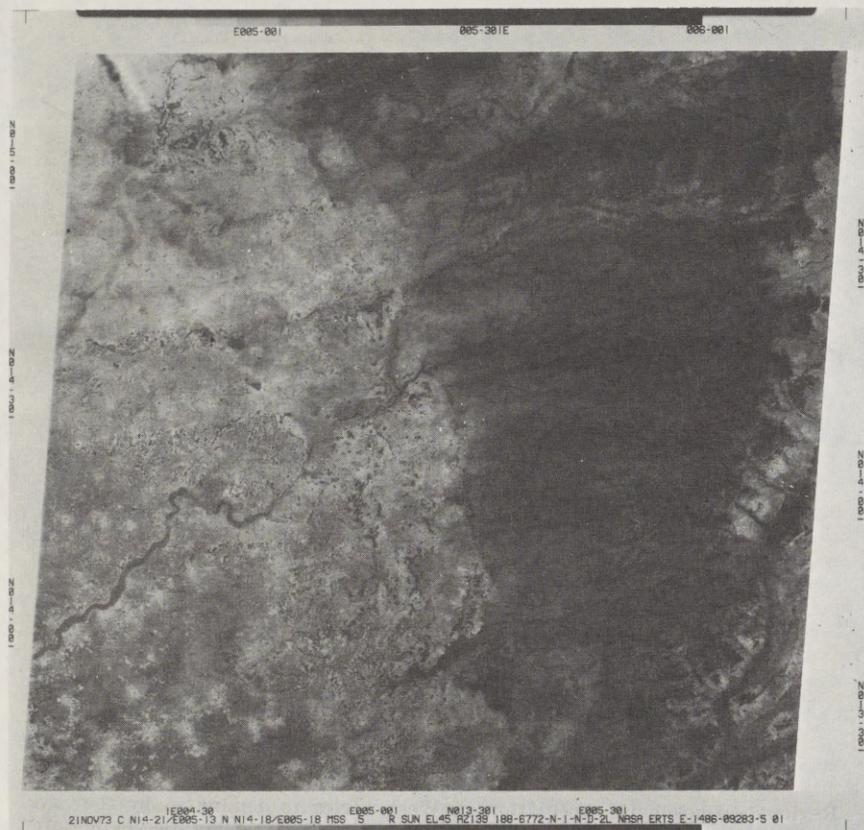


FIGURE 2(a).—Earth Resources Technology Satellite (ERTS) image of the Tahoua region, Republic of Niger, showing normal surface conditions

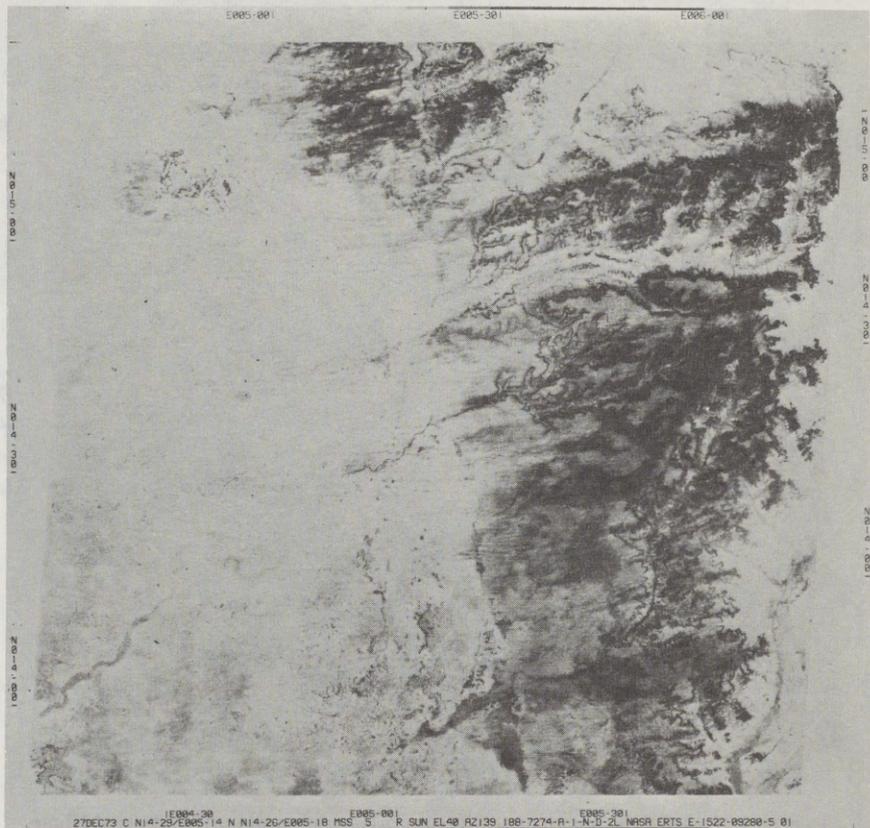


FIGURE 2(b).—Earth Resources Technology Satellite (ERTS) image of the Tahoua region, Republic of Niger, showing sandstreaming conditions

NOTES ON FIGURES 2(A) AND 2(B)

In Figure 2(a) no sand streams are observed. In Figure 2(b) sand streams cover several thousand square miles (each ERTS-1 image covers 10,000 square miles). In 2(a) the dot and circle patterns are villages and surrounding cultivated fields. The density of this pattern indicates a heavily populated area of sedentary agriculture.



FIGURE 3(a).—ERTS image of the Tchén Tabaraden region, Republic of Niger, showing normal surface conditions



FIGURE 3(b).—ERTS image of the Tchén Tabaraden region, Republic of Niger, showing sandstreaming conditions

NOTES ON FIGURES 3(A) AND 3(B)

Sandstreams are seen in 3(b); the "normal" scene is 3(a). While these streams are less defined than those in Figures 2(b) and 4(b), they occupy much of this December frame.



FIGURE 4(a).—ERTS image of western Niger and eastern Mali showing normal surface conditions



FIGURE 4(b).—ERTS image of western Niger and eastern Mali showing standstreaming conditions

NOTES ON FIGURES 4(A) AND 4(B)

These images contain the Ekrafane Ranch, the polygonal shape at the lower left. The existing "old" dune patterns were oriented north-south, and are particularly large and well defined in the northeast quarter. These streams are not seen in earlier imagery. They occurred during a period of "unprecedented" sand and dust storm activity, according to sources in the region.

NEW SAND FRONTS ON AN OLD DUNE
Gaugaram Region, Tahoua Department
 (Niger, 15°52'N, 5°15'E; 12 July 1974)

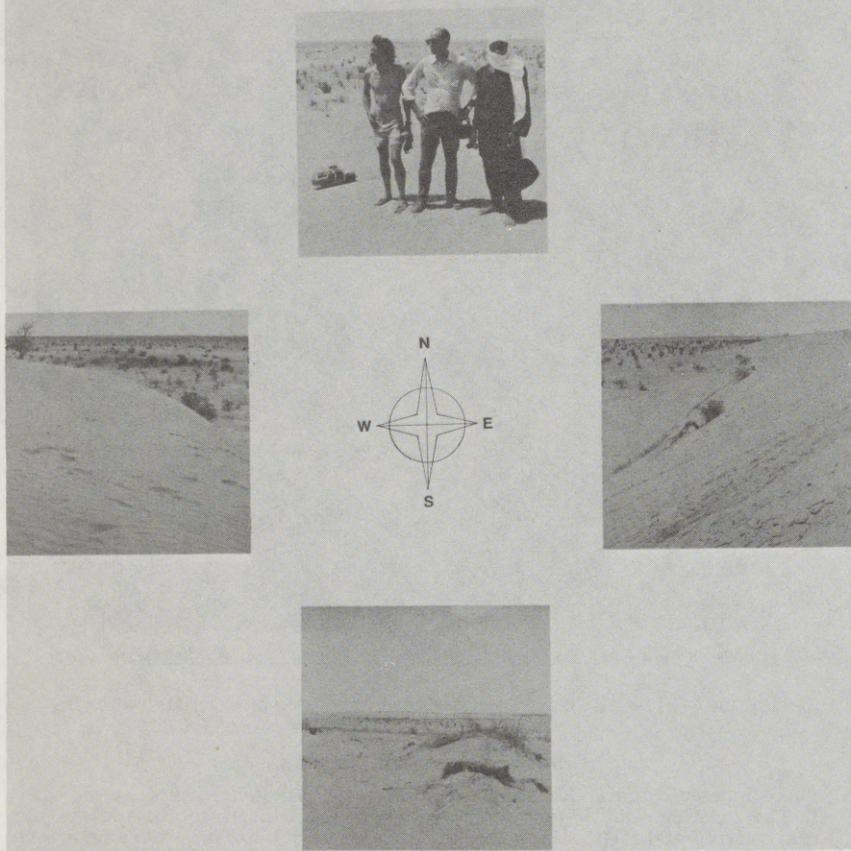


FIGURE 5

NOTES ON FIGURE 5

Approximately three meters (10 feet) have been added to this dune. The southern view (bottom) shows the established vegetation of the old dune. The perspective of the northern view (top) gives some indication of dune height (approximately 20 meters)—the people are at the top of the new dune, the vehicle at the base. East and west views (right and left) indicate the length of this dune (about a quarter mile). The dune is one of many in the region.

**CLOUD BASES IN ALL DIRECTIONS TINTED
RED LIKE THE SAHELIEAN SAND
(Niamey, Niger, 1730 Hours, 5 July 1974)**

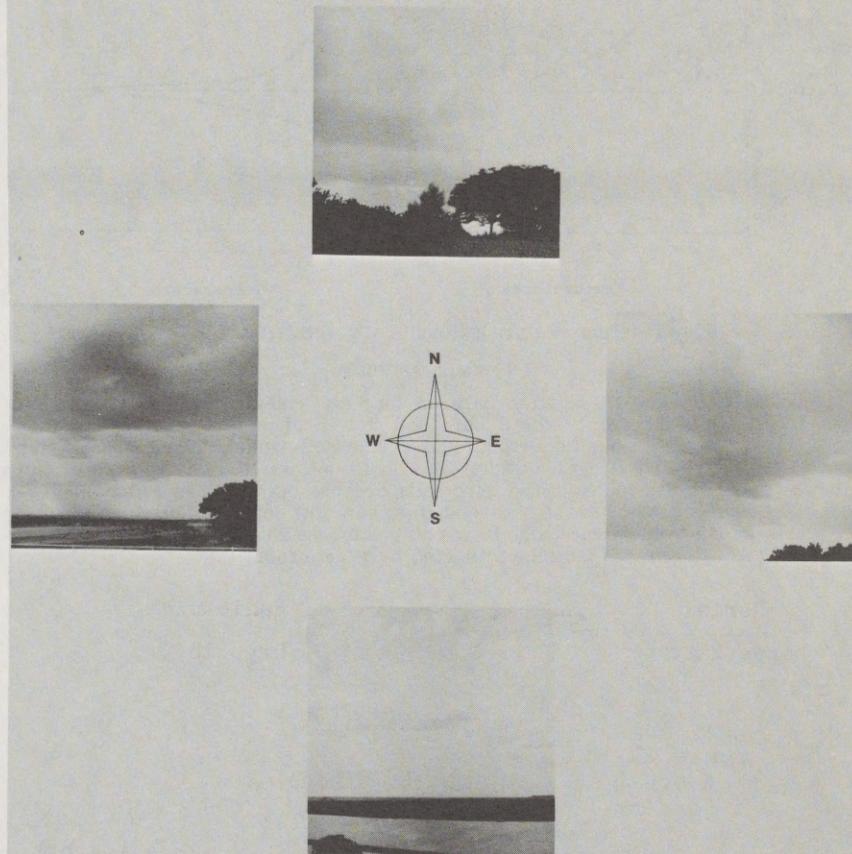


FIGURE 6

NOTES ON FIGURE 6

During late June and July, 1974, in Niamey, Niger, the cloud-bases were often tinted a brick-red—the color of fine air-borne dusts in the Sahel. These photos taken in late afternoon show the red coloration of the cloud-base. Photos were taken in four directions to record the similarity of hue and intensity of the cloud color. If the color were due to reflection from the surface alone, then the hue and intensity should differ with the direction from which the photo is taken. If however the color is due to dust caught up from the top of the dust layer in the atmosphere, the hue and intensity should be fairly constant. The latter condition was observed. Therefore, it is likely that the color is due to the dusty state of the atmosphere in the vicinity of Niamey. The same phenomenon was observed in the northern Sahel of Niger and in Ouagadougou, Upper Volta.

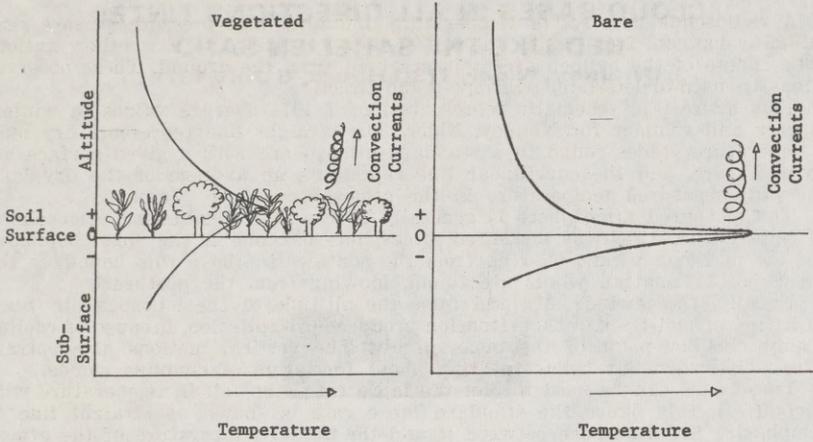


FIGURE 7.—Temperature gradients of vegetated and bare soils

NOTES ON FIGURE 7

Dust is easily generated from bare or sparsely vegetated soil surfaces, but not from vegetated soils. Over a bare soil, the temperature gradient is very steep and the maximum temperature is at the soil surface itself. Convection currents (micro-turbulence) develop over both vegetated and bare soils, but they are more vigorous over the bare soils because of the steeper temperature gradient. The turbulence over a bare surface can and does pick up dust because it starts at the soil surface, not in a plant canopy. To prevent the generation of dust, the soil surface must be protected by vegetation.

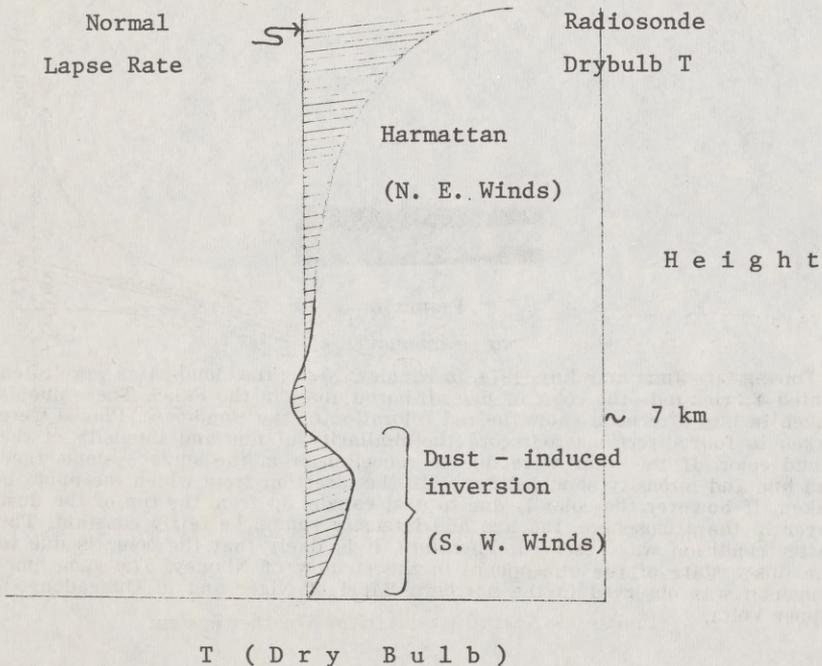


FIGURE 8.—Radiosonde Data from Niamey, Niger

NOTES ON FIGURE 8

A radiosonde is a set of temperature, humidity and pressure sensors sent aloft by balloon, from which the sensor data is radioed to a weather station. The course of the balloon ascent is observed from the ground. These observations are used to determine wind speed and direction.

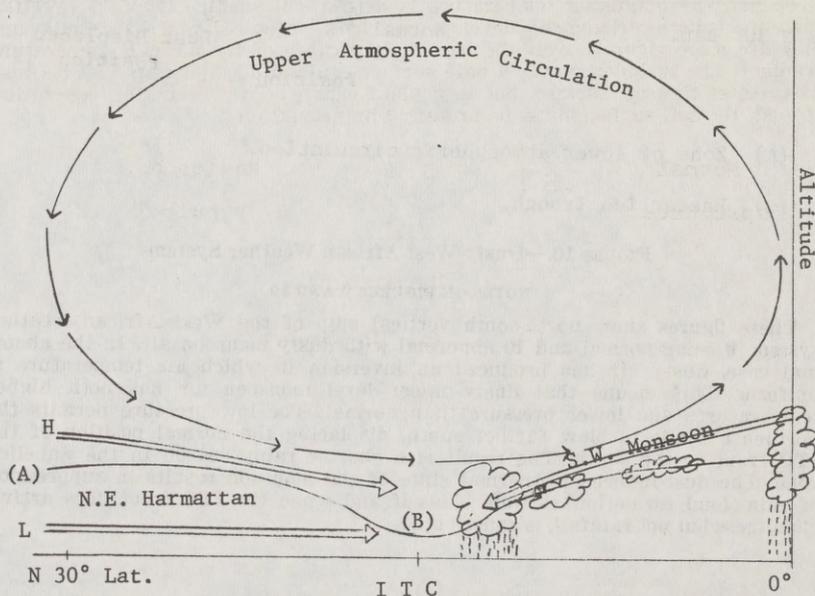
This figure is a schematic representation of 1974 average values in winter, spring and summer for Niamey, Niger. The straight line represents dry bulb temperature values found in a standard atmosphere with a given surface air temperature, and the curvilinear line represents an average of the dry bulb actually measured temperature in the atmosphere above Niamey.

The measured atmosphere is generally hotter than a standard atmosphere. The region in which the measured atmosphere is cooler is the upper boundary of the monsoon winds, blowing from the southwest. Above this boundary the very hot Harmattan winds are found, blowing from the northeast.

Usually, these winds mix and raise the altitude of the monsoon air. Such a lifting of moist air in this situation produces precipitation, because of cooling below the dew-point of the monsoon air. The vertical motions also entrain the moist warm air below to bring about formation of cumulus clouds.

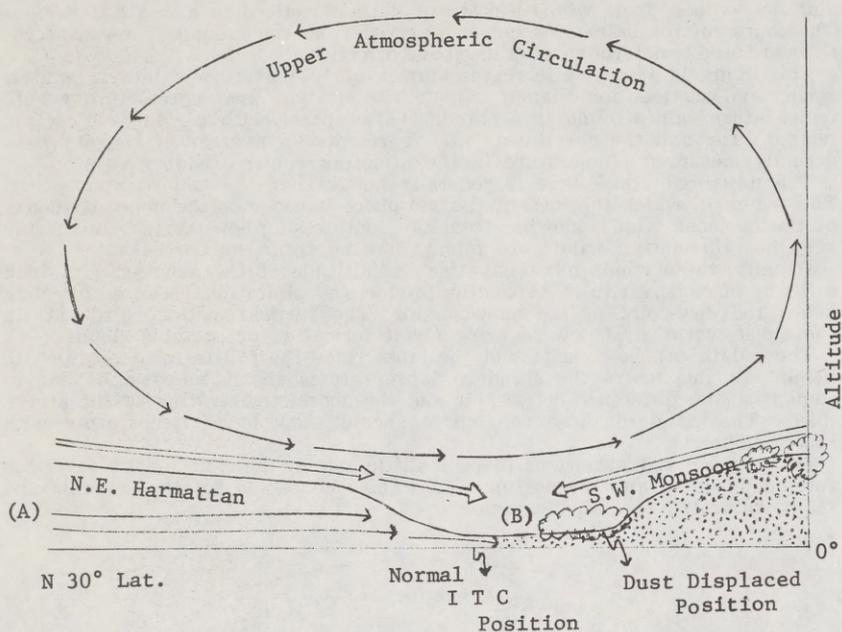
These data can be used to plot the lapse rate—the fall in temperature with height. In this figure the standard lapse rate is shown as straight line to emphasize the difference between it and the actual temperature of the atmosphere. The standard lapse rate curve should show lower temperature with increased height.

In the observed situation, there is little mixing because of the inversion formed by dusty air. We postulate that this one reason for the sporadic and scanty rainfall in the Sahelian region.



- (A) Zone of lower atmospheric circulation.
 (B) Easterlies Trough.

FIGURE 9.—Normal West African Weather System



(A) Zone of lower atmospheric circulation.

(B) Easterlies Trough.

FIGURE 10.—Dusty West African Weather System

NOTES ON FIGURES 9 AND 10

These figures show north-south vertical cuts of the West African weather system, 9 being normal and 10 abnormal with dusty monsoon air. In the abnormal case, dusty air has produced an inversion in which air temperature is uniform. This means that dusty upper level monsoon air has both higher temperatures and lower pressure than normal. The low pressure permits the northeast winds to blow further south, displacing the normal position of the ITC front to the south. The result is a shorter rainy season in the Sahelian zone. The dust-induced isothermal state of the monsoon results in suppression of rain-cloud formation as well. Thus if and when the ITC front does arrive, cloudiness but not rainfall, is experienced.

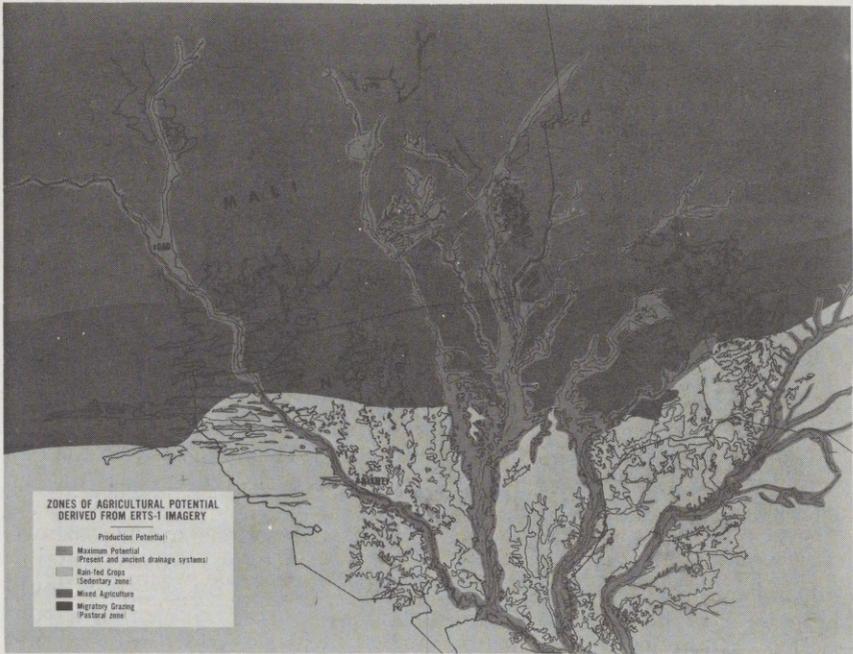


FIGURE 11

NOTES ON FIGURE 11

Zones of agricultural potential derived from ERTS-1 imagery.

Mr. MACLEOD. Thank you, Mr. Chairman.

Mr. SYMINGTON. Our final witness this morning is Dr. Franco Fiorio, Scientific Counsellor of the Italian Embassy here in Washington. Doctor Fiorio is a good friend of the committee, has been with us several times and has given us very valuable advice and counsel. During the past 3 years he has served as Chairman of the U.N. Working Group on Remote Sensing of the Earth by Satellite which has been considering the international implications of such systems. Dr. Fiorio participated in the 1972 meeting of our Panel on Science and Technology which dealt with this subject. We are very glad to have you back to give us an updated version of your thoughts on ERTS and remote sensing in general.

Dr. Fiorio.

STATEMENT OF DR. FRANCO FIORIO, CHAIRMAN, UNITED NATIONS GROUP ON REMOTE SENSING OF THE EARTH BY SATELLITES

Dr. FIORIO. Thank you very much, Mr. Chairman.

As always, it is an honor to cooperate with the work of the Science and Astronautics Committee and of this subcommittee, and I feel that I have to clarify immediately that I am here as a private individual. My views therefore do not reflect the views of the U.N. working group, which is made up by 38 member countries of the

U.N., nor of my own country, Italy, but it will draw on the experience that I had in this field, participating in millions of meetings on remote sensing and listening to thousands of experts expressing their views and going around the world, also, like I did last week, when I went to Cairo to attend the remote sensing panel of the Commission for Africa, where the United Nations experts were having an exchange of views with the expert of the various countries of Africa about the usefulness of remote sensing techniques from space in order to solve their planning programs.

Incidentally, if you will allow me a digression here, in the overall great problem we are facing of energy shortage remote sensing from space can really give a global idea of what we have, what is available, and it is probably one of the items which is lacking now in assessing our future, the fact that in reality we only have a knowledge of some of the resources, but not of the full range of them and only—through a global effort such as it is possible through remote sensing of the Earth from space can this kind of knowledge be achieved with today's sensors on ERTS-1 or with the more sophisticated sensors on the succeeding satellite.

For example, in my country where fossil resources are very short, I should say nonexistent, one of the sources of energy we are banking on, is geothermal. In this respect, thermal sensors on satellites could help us very much in locating additional sources which might contribute to our energy programs. A little while ago we were talking about hydrology. The thermal sensors might help also in hydrology in the discovery of water because of the difference in temperature between the water and the ground.

Coming back to my remarks, which I prepared for today, I shall try and expound the findings that we were able to report to the U.N. Space Committee after 3 years of work in the working group, which was set up by the General Assembly, to examine the various aspects of remote sensing of the Earth by satellites.

Here I would like to clarify some semantics of the program. We have heard about operational and experimental remote sensing systems and in the Working Group, at the outset, the two words were immediately the subject of a discussion, which was strictly related to the legal problems, and it appeared immediately that there was a need of a definition which would leave no doubts or misunderstanding.

The definitions which we adopted and that were sanctioned by the General Assembly were the following:

An operational system is a system resulting from the commitment to supply a space remote sensing service on a continuous and permanent basis, coupled with a commitment by interested users to use such a service on the same basis.

Conversely an experimental system is—

one whose prime purpose is the testing of any technology and/or new producers. The information resulting from it may or may not have applications.

These are two very clear-cut definitions, but in reality we have been operating and interpreting the activities up to now somewhere in between them so that while we argue about the subject of operational or not operational we might be talking about the same goals and speaking the same language.

The Working Group on Remote Sensing of the Earth by Satellites was established by Resolution 2733 of the 25th General Assembly, and that was upon a very strong campaign waged by three countries in the Space Committee. These three countries were Canada, Sweden, and Italy. This, incidentally, was one of the reasons why I was elected Chairman of the Working Group.

The mandate of the working group was the following:

To promote the optimum utilization of this space application, including the monitoring of the total Earth environment, for the benefit of the individual states and of the international community, taking into account, as may be relevant, the sovereign rights of states and the provisions of the Space Treaty which governs the activities of the states in the exploration and uses of outer space including the Moon and other celestial bodies.

The report of the Working Group should review all factors relevant to programs of establishing such a system in order to have an adequate basis for making recommendations which the states might consider when they come to solve specific environmental and resources problems through the use of remote sensors in satellites and of the data thereof.

In the framework of such a mandate, the Working Group was also requested to review the scientific and technical development concerning sensors and methods for the collection, processing, and interpretation of data in order to (a) assess their potential in relation to their practical uses; (b) consider whether there are operational systems capabilities which might be of special value to meet international, regional, and global requirements, and (c) make recommendations for possible development, provision, and operation of data collection and utilization systems in the U.N. or other international framework, taking into account the economic, social, and legal implications for the international community that might arise as a result of selecting any particular system.

The Working Group had the composition initially of 28 members, same as the Space Committee and when the General Assembly decided to increase the membership of the Space Committee to 38, the Working Group was also increased to 38, and I have here the list, the names of the members.

Incidentally, the new members which were accepted were the two Republics of Germany, Democratic and Federal, Chile, Indonesia, Kenya, Nigeria, Pakistan, Sudan and Venezuela. Those were the members which were added to the 28 original members and the reason was clear, that the General Assembly wanted the Space Committee and the Working Group to have more representatives of the developing countries.

After 3 years and 15 meetings, the Group produced as requested a "final" report in the spring of this year (Doc. A/AC. 105/125) which couldn't present any specific recommendations inasmuch as the task of assessing in detail the economic, social, and legal implications of remote sensing of the Earth from space turned out to be much more complex endeavor than it had been anticipated, and requiring further studies in depth by qualified experts in each of those fields.

However, the Group performed an analysis of all the aspects of the applications of this new technology for practical benefits and set the stage for future decisions to be taken by the General Assembly, once

the legal and cost effectiveness experts will have completed their review of the matter and presented their recommendations.

In substance, the report of the Working Group has fully satisfied one of the requirements of its mandate by expressing a positive assessment of the potential of remote sensing from space for the achievement of practical benefits for the people on Earth. In synthesis such benefits have been generally recognized as the possibility of achieving: Synoptic pictures of sizable areas; acquisition of near-real-time data; repeated coverage to record changing phenomena (such as environmental changes) even in areas which have been well surveyed and mapped; reduced data acquisition time; uniform measurements; wide-area coverage (reducing the problem of assembling broad-scale mosaics), coverage of areas beyond practical range of aircraft; global survey without large onsite support requirements; and reduction of costs for large-scale coverage.

To support such positive assessment, the report of the Working Group contains, as typical examples, the description of a number of experiments conducted to date which represent an impressive array of successes in the utilization of data supplied by the ERTS-1 satellite and by manned spacecrafts for immediate practical benefits. But the literature on this subject is growing at such a tremendous pace that the positive assessment of the Working Group would be confirmed in any case beyond any possible challenge.

The second step taken by the Working Group was, logically, to ascertain the general response by present and future potential users to the possibility of using space remote sensing techniques in their development planning programs, especially in the developing countries. To this effect the Group sent to all members of the United Nations, about 135 now, two successive questionnaires aimed at obtaining the views of the members on a variety of topics, including legal and organizational implications, related to the application of remote sensing techniques from space, to the solution of earthly problems.

From the answers to these questionnaires three facts emerged very clearly: First, that many countries had a limited knowledge of the possibilities of this new technique; some of the countries didn't even know they existed, and were not in the position to produce any answers. Second, that even the countries which were in the position to answer didn't have a clear idea about the possible priority of a space remote sensing utilization's program vis-a-vis with other established techniques, for lack of detailed data on the cost-effectiveness involved; third, that almost all of the countries answering the questionnaire had very much in mind the problem of national sovereignty in regard to the collection and utilization of the remote sensed data of their own territory.

On the other hand, most of the developing countries indicated a preponderant interest in addition to thematic mapping and cartography, in the application of remote sensing to agriculture-related uses as well as to hydrology and ecology; activities, by the way, which require repetitive surveys and do not fit too well with a statement I heard from a distinguished witness at the Senate hearings which

was repeated, as I understand, at this hearing on this same subject; namely, that "this is the kind of application in which additional coverage with the same technology has low value once complete cloud-free coverage has been obtained." This is in contrast to what most of the countries have stated; namely, that they require both repetitive coverage and possible real-time coverage.

According to the experts who have been consulted by the Working Group, the demand for remote sensed data might reach a peak in the near future as far as "first view" imagery is concerned, such as that used for cartography and thematic mapping of natural resources, which incidentally is already available in scale 1:250,000 for the land masses of the Earth. The demand might indeed subside afterwards, but only to blossom again on an unforeseeable magnitude once the need for repetitive sensing and real time imagery will be clearly established by each user's competent authorities. This is rapidly coming to a reality because of the ability with which such authorities are learning how to use remote sensing, in line with their growing experience in utilizing space data with the maximum cost effectiveness.

Here I can digress a minute on cost-effectiveness. We shouldn't make a fetish of cost effectiveness as far as all countries are concerned, because one thing is to keep the criteria of cost-effectiveness in a very developed country, which has sophisticated means of planning. Another thing is for a country which doesn't have any planning yet prepared, as for example, a country which doesn't have a map of its own territory and thus will do anything to obtain such a map; here the criteria of cost-effectiveness might not apply. Some developing countries would pay anything to have thematic maps of their territory, so that cost-effectiveness means different things to different users.

The questionnaires sent by the Working Group and the responses to them brought to light further proof of positive assessment of the usefulness of space remote sensing techniques by revealing that at least 10 countries were designing or planning to install or preparing to consider the installation in their territory of receiving stations to be used for the collection of space remote sensing data transmitted by ERTS-type satellites.

Some of those stations are in advanced state of preparation such as the Italian station at Fucino which will be ready next May, and the station approved recently by the Government of Iran. Other stations of various capabilities and cost are under consideration by the Governments of Saudi Arabia, Kenya, Venezuela, Zaire, Indonesia, Japan, Thailand, and so forth.

During the recent United Nation meeting in Cairo, there were more ideas on the subject, which might be translated in proposals later on.

Of course until the ERTS-type satellites will be the only source of space-sensed data, the operation of each one of such stations will be strictly dependent upon the good will of the United States of America in sending the satellite signals to them, and subject to bilateral pacts between NASA and each national authority concerned.

But the very fact that space data receiving stations are blossoming around the world indicates that the rest of the world expects an uninterrupted availability of data from space that is, a continuity of space remote sensing activities, on an international, cooperative basis.

Furthermore, this is also the expectation of some of the United Nations specialized agencies such as the Food and Agricultural Organization, which are taking the lead in this field, and are putting their bets and their future planning on space remote sensing from space as a major tool capable to allow them to perform their task on a truly global basis and with recognized criteria of cost-effectiveness.

It might appear a contradiction at this point the fact that general agreement on the need of continuity in the supply of remote sensed data from space was matched within the Working Group by a wide disagreement on the U.S. policy of "free dissemination" of the data acquired from space. Many countries, and amongst them some which are already steady beneficiaries of such a policy, have clearly expressed their views that their acceptance of such policy at today's state doesn't imply at all that they favor it for future operational systems, stressing the point, without openly stating it, that continuity of the service is required, but that, at the moment when such a service would be officially transformed in an operational one, in line with the definition expressed at the beginning of these remarks, the legal implications of such service would come in full play and a proper legal framework for it should be universally adopted.

The report of the Working Group reviews, and I could later on supply details if needed, without entering into detail, some of the legal frameworks proposed by various members and mentions the ongoing polemics between the supporter of an "organizational solution" to overcome the legal difficulties, and those in favor of the adoption of a set of legal principles first, as the only way to proceed to the organizational framework. In other words, some members felt that if joint effort, or a joint organization can be agreed upon, then the legal problems will disappear. But some others felt that first you have to solve the legal problems in order to have an effective organization.

It is very likely that such a debate will go on for a long time and the Working Group has synthesized the situation in the final paragraph of its report, which reads:

The Working Group, in accomplishing its mandate, as it has been indicated in the preceding chapters, was confronted with the difficulties inherent in this new space application, which is still in a dynamic state of development, particularly in regard to the degree of awareness of its benefits for its users, its full technical, economical and organization possibilities, and the understanding of its legal implications. Consequently, although the present Report should be considered final, according to the letter of the mandate of the Working Group, it cannot be considered as an exhaustive Report as far as the implications of the terms of reference are concerned. It rests therefore within the competence of the parent bodies of this Working Group (namely the Scientific and Technical Subcommittee and the Committee for the peaceful uses of outer space), to decide whether the assessment and promotion of the developing activities of remote sending of the Earth from space should be further pursued and under what terms of reference.

In subsequent action the Scientific and Technical Subcommittee, in commending the report of the Working Group, recommended to the main committee that the subcommittee itself could further pursue the organizational and financial matters indicated by the Working Group as subjects necessitating further considerations, and that, at the same time, the Legal Subcommittee could consider the legal questions.

In order to facilitate the work of both subcommittees, the Secretary General of the United Nations has been invited to prepare detailed documents on cost effectiveness of space remote sensing; organizational and financial requirements for the establishment of one or more international storage and dissemination space data centers, and the organizational and financial requirements for the establishment of an international center under U.N. auspices, including studies on organizational and financial implications of space remote sensing educational and training facilities.

The Space Committee in its last meeting last July accepted those recommendations and decided to postpone the reconvening of the working group until a time when it would be able to proceed with useful work, if necessary, after the two subcommittees would have completed the consideration of the matters of respective concern.

To the habitual critics of the United Nations' way of doing business, it could appear that the events and decisions I have just described might be interpreted as a typical case of passing the buck from a U.N. body to another, due to the fundamental weakness of the decisionmaking process within such a body.

In effect, if we want to avoid the easy slogan that while the United Nations keeps talking the remote sensing satellites proceed steadily with their development ignoring the complexities of international politics, I believe that the activities of the U.N. bodies on this subject, from the General Assembly resolution through the working group, subcommittees and committees, have been timely and beneficial. Through the detailed and open debate held in the working group, an advanced and complex technology such as remote sensing of the Earth from space has come to the awareness of a great number of developing and developed States. I should say many developed States were also not fully aware of such possibilities. And that was made at the leadership level, much faster and in a more orderly way that it could have been done by any other unbiased means.

And since all decisions and reports have been adopted unanimously, the respect of the rules of the game in future developments has been reasonably assured.

I am sure that in due time even the controversial matters related to the legal implications and to the organizational framework of the utilization of this new space technology for the benefit of all, will find their common ground on the basis of a better understanding of the possible trade-off between practical benefits achievable and minor concessions on national sovereignty principles.

As far as the specific problems these hearings are concerned with, namely the debate on the merit of H.R. 14978 and H.R. 15781, it is obvious that, as a foreigner and as a private individual, it would be both impossible and improper for me to express any comments. I can only point out the wish clearly expressed by the international community for a continuity in space remote sensing and disseminations of its data. Of course this continuity includes progress and new developments. I don't know how ERTS-B will be better in relationship with ERTS-1, but I am sure that ERTS-C, if hopefully it would be developed, with the addition of thermal sensors, will really bring a new dimension on the activity of remote sensing from space.

And I should add that to your great country, to which goes the gratitude of all those who have benefited and will benefit from the practical applications of remote sensing from space, brought to reality by the ingenuity of your scientists and engineers, belongs also the responsibility to be prepared to bring its experience and wisdom in this area to bear in the decisionmaking process of the international community. It would be naive and improper for me to suggest how the United States should prepare for such an action, but I am sure that the line of conduct which will emerge from such preparation will take into account the feeling of the international community on this important subject and will be aimed at the use of remote sensing from space to move the nations of the world a step closer to the single earth concept, through the coordinate use of the modern tool of remote sensing from space in the most efficient joint management of the environment and of the resources of our small planet.

Thank you.

Mr. SYMINGTON. Dr. Fiorio, I must thank you for what I consider to be an extremely valuable contribution to our understanding of the complexities and perplexities that technology of this kind inevitably imposes on the United Nations as the organization to which we entrust mankind's ability to sort out these questions intelligently and sensibly, and I think your paper well expresses and well explains the difficulties these various countries at various levels of understanding have in arriving at a consensus on this, how, when and how often to use this information and on what terms.

It reminds us that we are talking about our world. We are talking about your world and the world of every member nation and it presents the committee with questions of immense importance which perhaps we won't be able to resolve in this subcommittee, but I think we can play a constructive role in finding the answers to those questions.

Certainly you have given us hope that the world in general, as it comes to understand this technology, wants it and wants it used on a steady basis for reasonable and constructive purposes, related at the moment to Earth resources, which are in short supply and hard to find.

I would like to mention that there has been speculation to the effect that weather and climate conditions around the globe are becoming less favorable to agriculture. Do you think that the ERTS system would make a contribution to monitoring this kind of phenomenon as well as forecasting hydrologic and other conditions that effect agriculture?

Dr. FIORIO. Definitely so, Mr. Chairman. I believe that the FAO has taken a very aggressive stand on this subject and is planning to use ERTS remote sensors from space to check both the agricultural situation around the world, and the variation in yield and type of crops, and, something that I forgot to mention, the resources of the oceans too, because FAO is interested in fisheries too, everything which is related to food.

ERTS-1 has provided some important contributions, but there will be major contributions when there will be a thermal sensor in a satellite that will be able to identify much better both fisheries and crops. I think that both on an agricultural basis and on a food basis, the ERTS-type satellites will be fundamental to the operation of the

FAO. I can anticipate that FAO is already stipulating on agreement with our ERTS receiving station in Rome, to cover the agricultural aspects of all the area which the antenna of our station would cover, namely the whole of Europe and the northern-third of Africa.

One of the aspects that might interest you, as a little example, is assessment of the crop of olives, olive oil, olive trees. So far it had been almost impossible to find out what the availability of the European olive oil could be. This is one of the things that it is hoped to be resolved with space sensing, because once the signature of the olive tree has been checked and confirmed, then you have possibly not only to find out how much olive oil you will produce but also how the crop is going, after repetitive measurements.

Mr. SYMINGTON. Very interesting.

Mr. Winn, do you have any questions?

Mr. WINN. Thank you, Mr. Chairman.

Dr. Fiorio, it is nice having you back before the subcommittee.

On Page 11, maybe I am reading between the lines or maybe it is your subtle way of saying in the last paragraph, that the United States should maybe push a little harder to get more decisionmaking process of the international community.

Am I reading you correctly on that?

Dr. FIORIO. Yes, Mr. Winn. Of course, I wouldn't be so presumptuous to say what the United States has to do, but with the experience that your country has in this field, which is unique, the United States is in the best position to make some proposals about what an international organization may be. So far, what has emerged was some sort of neutral position, which has had the effect of postponing the consideration of the subject within the competent U.N. bodies.

There has been a development which was very interesting and very much appreciated, the offer by the United States of the master tape of all the surveys and all the data collected from ERTS-1. Even that, which was very appreciated, didn't have a practical effect because once you have the tape you don't know exactly what to do with it. It is a complicated matter. For instance you have to define what the tape contains, how to elaborate and process it, and who will do the elaboration and processing. The proposal was that it would be offered to an international body, but it was not specified which international body, so I think that some study ought to be performed, some preparation ought to be dedicated to a specific proposal in this area, which would be of course very welcome. It would take time, because there is a need of listening to all of the opinions of all the others, considering that practically each country has a different opinion, but as I mentioned here, this country has such a tremendous experience on the subject, that it is probably the best suited to present a proposal which would be acceptable to the international community.

Mr. WINN. The problem that you mention of dissemination of the material from ERTS-1 is a problem in this country, too. I don't think we have all the answers to it, because many on this committee have been concerned with what are we doing with the information that we are gathering. We don't think we are doing a very good job of dissemination of that material to our own private industry, to the Government agencies, and to the colleges, here in this country.

Dr. FIORIO. It is a big program.

Mr. WINN. It is a problem. We are constantly harping at NASA and similar agencies to do a better job, and to spend more time and if necessary to allocate more funds to do a better job.

Of course, I suppose from a political standpoint, if the United States takes too much leadership, and maybe would seem too pushy in this field, there might be some nations that might resent it somewhat. I don't know. I haven't been in on any of the discussions of U.N. Maybe not in this field.

Dr. FIORIO. Well, Mr. Winn, I don't know really but there are precedents in other activities, space activities. For instance, nobody objected to the United States taking the leadership in the meteorological satellites. The meteorological network is practically a United States network. The data is distributed to everybody. The organization is perfect. Of course it doesn't present the problems that remote sensing presents. Then there was the space communications program that was a very typical case, evolved into the communications satellite consortium. It was proposed by the Western World, led by the United States, and after very lengthy discussions, about 27 weeks of discussions, a general agreement, was achieved—namely the INTEL-SAT agreement—which at the outset was looked upon by some countries with very serious concern. They were very worried about it, but strangely enough the ones who at that time were most opposed to that organization are today among the ones who are the most active members in it, so sometimes you have to overcome some hostility, I should say, when you know you are right.

Mr. WINN. Thank you very much.

Thank you, Mr. Chairman.

Mr. SYMINGTON. I want to thank you, Mr. Winn, and Dr. Fiorio for that splendid statement. It is very useful to us.

We hope to see you again. I am sure we will have more questions in the future for you.

Thank you, sir.

The subcommittee will meet again next Wednesday, October 9, at 10 a.m., in this room, at which time we will hear witnesses from NASA, and the Interior Department.

The subcommittee is adjourned.

[Whereupon, at 12:01 p.m., the subcommittee stood in adjournment, to reconvene at 10 a.m., on Wednesday, October 9, 1974.]

EARTH RESOURCES SURVEY SYSTEM

WEDNESDAY, OCTOBER 9, 1974

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10:25 a.m., in room 2318, Rayburn House Office Building, Hon. James W. Symington, chairman of the subcommittee, presiding.

Mr. SYMINGTON. The subcommittee will be in order.

This is our third and final day of hearings on H.R. 14978 and H.R. 15781, similar bills designed to establish offices in the Department of the Interior and NASA, respectively, to operate an Earth Resources Survey System.

The purpose of these hearings is to consider the desirability of creating, at this time, an operational satellite system for surveying the Earth's resources, and to attempt to decide upon the most appropriate institutional arrangements.

The subcommittee is also vitally interested, however, in NASA's experimental remote sensing satellite program—ERTS—and we have invited our witnesses to give their views on the status, accomplishments, and future prospects of that program.

In this regard, all our witnesses thus far, with the sole exception of the representative of the Office of Management and Budget, have spoken favorably about the results of the ERTS-1 experiment and even more favorably about the future. OMB considers ERTS-1 data only "marginally useful."

Previous witnesses also expressed the belief that repetitive satellite coverage will be extremely helpful to scientists and managers for agriculture, water resources, land use planning, and geology. OMB feels that once complete cloud-free coverage is obtained, additional repetitive coverage with the same technology has "relatively low value".

Finally, previous witnesses were agreed that continuity in the flow of satellite data is important both in terms of learning how to use that data, and encouraging technological advancement. Scientists and managers, we're told, are more likely to invest their time and resources in a continuing program, rather than in one which effectively ends after the launch of a second experimental satellite. OMB, by contrast, takes the position that

Any additional launch, beyond ERTS-B, of a remote sensing satellite should be carried out only when such a launch can be shown to be the most cost-effective way to achieve a significant advance in the state-of-the-art.

It is OMB's view that a hiatus in the data flow after the failure of ERTS-B would be acceptable.

Thus, the issue is drawn. It isn't often that we receive testimony so clearly in conflict regarding a program that has been under study for almost a decade.

This morning, we have witnesses from the two Government agencies most directly involved in the ERTS projects, NASA and The Department of the Interior.

We will begin with Dr. Rocco A. Petrone, NASA's Associate Administrator. Dr. Petrone is accompanied by Mr. Charles Mathews, Associate Administrator, Office of Applications. These two gentlemen are well known to the committee as hard workers in space-related science.

We welcome you, gentlemen. You may proceed with your statement, Dr. Petrone.

STATEMENT OF DR. ROCCO A. PETRONE, ASSOCIATE ADMINISTRATOR, NASA; ACCOMPANIED BY CHARLES W. MATHEW, ASSOCIATE ADMINISTRATOR, OFFICE OF APPLICATIONS, NASA

Dr. PETRONE. Thank you, Mr. Chairman, and members of the subcommittee.

I am pleased to appear before you today to present NASA's views on the Earth Resources Technology Satellite program and on H.R. 14978 and H.R. 15781, two bills relating to Earth resources survey activities. Appearing with me today is Mr. Charles W. Mathews, Associate Administrator for Applications.

As we have testified in detail on previous occasions, we feel the ERTS-1 satellite has been a great technical success. It is still providing high quality, useful, multispectral data after more than 2 years in orbit, even though its design life was only 1 year. The tape recorders on board have now ceased to function, but real-time reception of data by NASA's ground stations in the United States, and by the ground stations established and placed in operation by Canada and Brazil, is continuing without impediment.

However, I would like to add here that within the last 2 weeks we have had difficulty with the automatic attitude control system of the satellite—this function is performed by momentum wheels on board—which may indicate we might foreshorten the expected remaining life. One can not predict this, but we did get this indication of a problem, and we just wanted to note it here.

We are preparing to launch ERTS-B early next year. We expect it to work well for at least 2 years, including its tape recorders, as a result of fixes that have been made to components that failed on ERTS-1.

Results of investigations with ERTS-1 by the more than 300 original investigators are continuing to flow in; another 93 investigators for follow-on work with data from ERTS-1 and ERTS-B have recently been selected, with an emphasis on operational-type uses of ERTS data. The Departments of Interior and Agriculture, the National Oceanic and Atmospheric Administration, and the Corps of Engineers, among other agencies, are today using ERTS data and learning how to apply them to their specific uses.

ERTS investigations are now increasingly oriented toward a new focus. In the first phase, the emphasis was on finding out what could be done with this new space tool. Now we are entering a second phase in which the users are learning how to apply ERTS-derived information to real problems of monitoring and managing our national resources on a significant scale.

NASA's technical assessment of what we have learned to date in the ERTS and related Earth resources programs can briefly be summarized as follows:

1. Repetitive, global, multispectral data in digital form has shown its potential for providing social and economic benefits in the areas of agriculture, water resources, and land use, among others.

2. The current ERTS-1/ERTS-B system provides valuable, useful data in its present form. To realize the full potential of ERTS-type systems, however, future systems will probably need:

(a) More spectral channels to increase the variety of phenomena that can be distinguished and measured with precision from satellite data. The thermal infrared "fifth channel" is one high-priority example. We and the users also see important advantages to some increase in the number, and narrowing in the width, of the bands in the visible range.

(b) We also need more rapid handling of data, from its acquisition by the satellite through the ground processing equipment and to its delivery to the user. For some time-dependent applications, processed digital data will have to be routinely available in a matter of days, not weeks, after collection.

(c) Also, we will need more frequent repetitive coverage. For some applications, it may be desirable to have repetitive satellite data every 9 or 10 days instead of on the 18-day cycle currently determined by the ERTS orbit.

(d) Also, higher ground resolution, in the multispectral mode, will be desirable for some applications.

3. The ERTS-type earth sensing satellites can make their most effective contributions when used in proper conjunction with other available data sources and capabilities, including satellite relay of data collected on the ground, data collected by aircraft, and data available from conventional ground sources. The optimum mix of data acquisition and distribution systems has yet to be established for each particular application.

4. The benefits from the use of earth resources satellite data will come in several forms. In some areas, there will be cost savings to the Federal Government and others, in that existing operations can be carried out with less effort than before. In other areas, use of ERS data will provide wholly new services and benefits not before possible or otherwise available. The identification and assessment of the specific benefits ERS satellites can provide is a continuing task for all prospective users as their experimentation with ERTS-1 and -B data proceeds and as they consider their plans for the potential use of such data in an operational mode.

This, in brief summary, is our current assessment of what we have learned to date in the experimental phase with respect to the utility of ERTS-type systems. The next questions are: What do we see for the future? What are the next logical steps in moving from the present investigative phase toward the eventual delivery of solid, measurable values on a continuing basis?

First, we see the need for a steady evolution from the early experimental phases with ERTS toward improved, more flexible hardware systems in space and on the ground. I have mentioned the need for additional spectral bands, more rapid throughput, more repetitive coverage, and higher resolution for some applications.

Second, we can now see some interesting possibilities of economies in future satellite systems by combining experimental and operational capabilities in a single satellite, which could provide data from proven sensors and also test and demonstrate experimental new capabilities. For example, a five-channel multispectral scanner could be used to provide operational users with the four-channel data they have learned to use from ERTS-1 and -B, and at the same time provide new experimental data from the fifth infrared channel for new potential uses and users. There is no reason for having two separate types of satellites.

The most important point that has become clear to us during the past year, however, is that there should not be, and in fact there is not, a clear-cut distinction between experimental and operational phases in the Earth resources program. This distinction has been a premise on which most of our thinking in the past, as well as the two bills now under consideration, has been based. Our present thinking is pointing clearly to the conclusion that the actual dynamics of the transition from experimentation to operations and the most economical conduct of the entire ERS program require an evolutionary approach in which:

First, both experimental and operational needs are met with a single series of satellites, as discussed above, and

Second, each operational use of ERS data moves from the experimental to the operational phase on its own timetable, depending on when its utility and cost-effectiveness have been clearly and sufficiently established to support the necessary investment decisions.

The need for experimental work in earth resources is continuing in nature. There is no sharp cutoff point when a whole system, or even any particular use of ERS data, stops being experimental and becomes purely operational in nature. The same data can be used, for example, both for geophysical research and for water resources management. Continuity from experimentation into operations is essential in sensor development and other hardware aspects of the program, and especially in the development of data utilization techniques and other elements of user systems. On the one hand, experimental data can be used operationally, as we have already seen with ERTS-1; on the other hand, operational uses of data will continue for some time to be partly experimental as improved ways of utilizing data are conceived and tested.

In summary, then, we see the need for a continuous evolutionary approach, in which operationally useful data from space are provided to users for research, for experimental demonstrations, and for routine operations when they are ready, while at the same time, and with the same satellites, necessary improvements to the system can be developed and tested. With this approach, each of the prospective users will be able to make his investment and management decisions committing to the use of ERS data with the knowledge that data will be available to enable him to get the values he seeks from an operational system.

Let me now turn to the two bills under consideration here, H.R. 14978 and H.R. 15781, both of which address the question of organizational arrangements for Earth resources programs.

Under the approach I have suggested, it would seem premature to define ultimate institutional arrangements by legislation. If we can have continuity of ERTS-type data flow for experimentation and demonstration, the transition to operational uses can begin within the current legislative and organizational framework. Legislation could be considered at a later time when the needs and problems to be addressed can be more precisely defined.

While legislation at this time could establish for potential users the promise that there would really be a permanent operational satellite system eventually and thereby give them a basis for making the necessary investments in learning how to use the data, the problem is that the Government is not yet ready to make these assurances. Such assurances must wait until more user-oriented satellites have been flown and further analyses are made to determine optimal national investment in systems, systems mixes, uses, and modes of operation.

With respect to the details of the bills themselves, we feel that H.R. 15781, as drafted, would pose several problems for NASA. In establishing by statute a separate office within NASA, it would unduly reduce NASA's flexibility to organize itself most effectively to carry out all of its functions. Specifically, the bill, as drafted, would artificially separate earth resources activities from similar and closely related satellite applications programs in areas such as oceanography, pollution monitoring, environmental measurement, and meteorology.

We believe NASA should retain the flexibility we now have under our basic legislation to revise NASA's internal organization when necessary to conduct our programs in the most effective and economical manner. In addition, we believe that to accomplish its intended purposes, H.R. 15781 would have to define explicitly the necessary interfaces between the space segment, that is—the data acquisition system—and the users and beneficiaries of the data, that is—other agencies, the private sector, and foreign and international entities.

H.R. 15781, as drafted, also does not adequately recognize, in our opinion, the large and complex functions involved in turning data collected by Earth resources satellites into useful information for the users and beneficiaries.

H.R. 14978 would appear to have drawbacks from the Department of the Interior's standpoint similar to those of H.R. 15781 with respect to NASA which I have just discussed. As far as NASA is concerned, H.R. 14978, as drafted, has another major flaw: it would appear to limit NASA's research and development in Earth resources to activities supported and funded by the Department of the Interior. NASA opposes this as creating an artificial compartmentalization in the space program which would complicate the program and be contrary to the basic concepts of the National Aeronautics and Space Act of 1958.

We should also note that some important national and international policy issues are not addressed in either bill, such as the role of the private sector, safeguards against unfair exploitation of information, allocation of costs, and reimbursements for services. More experience and study is needed, we feel, before sound policies can be set in these areas.

Mr. Chairman, as I have indicated, continuation of the current Earth resources survey program into a broadly based transition phase ap-

pears to be the most appropriate and beneficial next step. This course preserves all options for the future and gives both the executive branch and the Congress the time to learn the lessons of the experimental phase, while at the same time continuing and increasing the flow of benefits from space to all users. Thus, the considerations discussed above suggest an approach that is somewhat different from that contemplated by either H.R. 15781 or H.R. 14978. However, we believe that further consideration by NASA, the user agencies, and the Office of Management and Budget is required before we can present a specific alternative proposal and before the need and nature of additional legislation that may be required can be determined. For this reason, we suggest that the Congress defer action on the pending bills and request NASA, in concert with the other agencies, to come forward with a proposal in connection with the fiscal year 1976 program.

Mr. Chairman, this concludes my statement.

Mr. SYMINGTON. Thank you very much, Dr. Petrone.

I gather in a general way that you feel that we should go forward in this country with the ERTS-B and the ERTS-C, without trying to reach and define at each point what we mean by "operational." Is that right?

Dr. PETRONE. Yes, Mr. Chairman. We believe that evolutionary steps will increase the overall use of the systems.

Mr. SYMINGTON. Looking at page 8 of your testimony where you refer to continuity as being essential in sensor development and other hardware aspects, it's difficult, isn't it, to have continuity without an ERTS-C flight in the program?

Dr. PETRONE. Yes, sir. We're at the stage in the game where the investors need to see this repetitive data and need to be assured before they make their investments that we'll continue to produce this data and, therefore, continuity, we feel, is a very essential factor in this evolution into the operational phases of Earth resources systems.

Mr. SYMINGTON. This is true. Continuity is important in things like the development program and data acquisition, in order to retain their interest so that they will devote time and effort to sensor development.

Dr. PETRONE. We certainly would not support a termination of the ability to acquire this data, which we feel is so vital to the investigative techniques now being developed.

We just feel certain we have not developed nor investigated all of those techniques. That's why we are pursuing those, and we need new repetitive data to be able to exploit the information it contains.

Mr. SYMINGTON. If we fail to do that, are we not likely to freeze technology at the current state and then possibly become discouraged with it, and decide not to go forward at all, thus never producing useful data?

Dr. PETRONE. I do believe that what it holds in the future is much greater than we've been able to exploit today, and therefore the development of new sensors, new techniques of understanding and interpreting this data, are very important to the future role that the Earth resources system can play in our management of the natural resources of our country.

Mr. SYMINGTON. I expect that you're in some kind of contact with the Office of Management and Budget on these ideas and on the conclusions you draw from your observations of the program?

Dr. PETRONE. Yes, we are. We have exchanged information on various steps and studies underway.

Mr. SYMINGTON. A more specific question: It is our understanding, or was our understanding, that the ERTS-B had a design life of 1 year. You mention on page 2 that it could have a 2-year useful life.

Was that estimate based on your findings, or how did you come up with that?

Dr. PETRONE. I'll ask Mr. Mathews to address that question.

Mr. MATHEWS. Yes. As you know, Mr. Chairman, the design life of the ERTS-1 spacecraft was 1 year. This is really an estimate that was made prior to actual experience with the spacecraft, and is based on considerations of how much fuel there is for control on board, and considerations of various possibilities for the wearout of the spacecraft.

These things are really rather difficult to define. As a matter of fact, they are always fairly conservatively estimated because there are difficulties with them.

So the expectation and the general experience is that the spacecraft do last longer than the estimate of design life. This has been the experience with ERTS-1, which has now operated for about $2\frac{1}{4}$ years, and we would have every expectation that ERTS-B would, in fact, last a comparable length of time, in the neighborhood of 2 to $2\frac{1}{2}$ years.

As Dr. Petrone indicated, ERTS-1 is showing some evidence of wearout at the present time. But we do feel that ERTS-B will last the length of time that I mentioned.

One must remember, Mr. Chairman, however, that this program has no backup, but is a single threaded program, so that even though we carry out these flights, it is essential that they be successful. If we would have a launch failure, for example, we wouldn't have an ERTS program. Or if for some reason the ERTS-1 failure did become total at this time, we would have a gap in the program.

Mr. SYMINGTON. And the lesson there is that we should really be working on ERTS-C, so that if ERTS-B doesn't achieve the anticipated lifetime, we can close the gap.

On page 2 you mention that there are 300 original investigators working on ERTS-1 data, and the selection of 93 new investigators. Are the original 300 expected to continue in their work or not?

Dr. PETRONE. Mr. Mathews will answer that, Mr. Chairman.

Mr. MATHEWS. We initially started with an investigative program comprised largely of people who were looking at detailed techniques; in other words, coming up with, "Yes, I can identify the crop," or "I can measure the acre-feet of a water body," for example. Our investigative program at that phase is essentially concluded, and now we're in a phase where the activities are more oriented to what I call a practical application of these abilities to detect these things, or determine these quantities. It involves entirely new dimensions of skill, in that all facets of the application have to be considered, particularly with things like the timeliness of data, can you get the data out in time to make the proper decision, etc.

Mr. SYMINGTON. There is a reduction in funding, is there not, supporting the investigations work?

Mr. MATHEWS. That's correct. As a matter of fact, there's a commensurate or somewhat larger reduction in the magnitude of the investigations underway because the scale of the investigations are larger.

Dr. PETRONE. Mr. Chairman, this is part of our evolutionary approach: first, what would the pictures tell you, and then how you would group the information into operational uses. With ERTS-B, we're going to attempt to come up with packages on the way people have worked together and used the data as part of an operational system. Then with ERTS-C we'll continue that and also start more research with our new channel. So it's part of the steps that we talked about, of moving from very basic ABC's to maybe where now somebody can start composing sentences, and later, paragraphs, with the information we'll get back from the ERTS system.

Mr. MATHEWS. Mr. Chairman, in talking about this, though, we're talking about where the emphasis is, because even today there are still people inventing some new interpretive techniques to back us up, and, in fact, even today the Corps of Engineers is worrying about actually surveying all of the impounded water in the United States, and is using the ERTS information in somewhat of an operational mode. So all facets of it are being covered today, so what we're really talking about is the transition and a series of steps, but it's where the main emphasis is.

Mr. SYMINGTON. What you're saying is that the reduction in funding of investigators is not a constraint, that you feel that you're investigating what you need to be investigating?

Dr. PETRONE. It's a deliberate step on our part to handle it this way.

Mr. SYMINGTON. Mr. Downing?

Mr. DOWNING. Thank you, Mr. Chairman.

I wonder if you could give us some practical beneficial results of the ERTS program? You mentioned something about measurement of waters.

What other results have been beneficial? Would you give us some examples?

Dr. PETRONE. We've had many studies. We have put some of this together in land use planning, and some of the urban activities. Some of these investigative programs look at how can repetitive data be made available and a community, a county, an area, or an on-going development. We have sponsored and worked with many of these investigators and also some of the universities on the use of the information.

I mentioned land use planning. There is much activity on range lands and range readiness in terms of the foraging of the herds of cattle and sheep.

Mr. DOWNING. Who requested that information?

Dr. PETRONE. In terms of range readiness and forage production estimation, they're using it, for example, in the Department of Interior. We have many users. The Department of Agriculture has activities going on in one area of crop production estimation. And in the development of the rudiments we still have got to get to, you might say, the lowest element that's going to use the information: the county agent, the county planners, the people in the field who now have to get this information another way. So we want to develop these

tools, these deduction techniques, so that the data they must use can be presented to them easily, because in the ultimate it's the people in the field who are using much of this data.

Mr. DOWNING. Your direct users are still the Federal Government agencies and they, in turn, disseminate this information to localities?

Dr. PETRONE. No. It's very much used, but not solely, the private sector. For example, one looks at zoning of an area and looks for water runoff and where would one put the high water mark. It's what the local governments do for themselves, and also to assist the builders who want to have an area zoned to develop.

Mr. DOWNING. Who would make a request for that information?

Dr. PETRONE. In that case it would probably be the land use people of the community, the county doing the zoning, but done in a way that would really assist the developer of the property to know where the high water mark would be for water runoff.

Mr. DOWNING. Do you get permission from the Land Use Commission? If you got a direct request from a Land Use Committee and they wanted to obtain that information, would you answer that request?

Mr. MATHEWS. Yes. We've had requests from just about every State in the Union with respect to activities in land use, and activities with respect to things like strip mining activities; for instance, Ohio and Maryland are surveying the degree of recovery of the land from strip mining. The State of Georgia has a very comprehensive program entirely funded by themselves. They do not request any Federal funding for the activities for which they're planning on using the ERTS data, and one of their State geologists, Mr. Pickering, actually testified before the Senate committee this spring on that particular activity.

But I could name practically every State that has used ERTS data for land use purposes, either in an investigative sense or in an actual application. Many States, of course, are generating legislation in this area, and in many cases the economical way to comply with this legislation in providing data is with imagery such as the ERTS type.

Mr. DOWNING. Dr. Petrone, you said there is need for repetition. Is there really need for more repetition? They take a picture every 18 days now; is that right?

Dr. PETRONE. We have that capability. We do not always take the picture. We would only take it if you had a need for it.

So the purpose of repetitive data, the ability to have it, would be if one were looking at watersheds, or high water marks, or, in the case of crops, if one wanted to measure them on a periodic basis.

The fact that we can get over any area every 18 days does not necessarily mean one would always take this the total, but a high rate of repetition, plays a very important part in how you use the data in some uses like snow mapping, or snow runoff, for water resources management. In the case of land use, probably once every 6 months would be sufficient, or once every 3 months. That's something you are able to control and manage.

Mr. DOWNING. In looking over this proposed legislation, H.R. 14978 and H.R. 15781, it would appear to me that these bills set up in other Federal agencies offices to carry on the mission which the

Office of Applications is assigned, and in my opinion, it would be redundant, unless, of course, your job is solely space R. & D.

Dr. PETRONE. In coming up with coordinated positions, we would, of course, want to continue to take on that challenge. We feel that we today are doing the experimentation and are carrying that forward, and we would like to continue carrying forward both the development as well as the steps to let that data be used operationally by the users. We would like to continue doing that. It's in our present legislation that allows NASA to do the space R. & D. work.

Mr. DOWNING. Thank you, Mr. Chairman.

Mr. SYMINGTON. Mr. Winn?

Mr. WINN. Thank you, Mr. Chairman.

Dr. Petrone, on page 3, down at the bottom, you talk about the thermal infrared fifth channel as one high-priority example. You say you see important advantages in some increase in the number, and narrowing in the width, of the bands in the visible range.

Can you go into detail on that? I truthfully don't quite understand it.

Dr. PETRONE. Mr. Winn, if I first might talk about the fifth channel?

When we're looking across a field of crops or a forest on a broad basis, a difference in temperatures radiated could very well be an important indication of a difference in either a state of health or an indication of potential yield. It's a new phenomenon one can measure, and one which we can then interpret.

We've done some work with IR from airplanes, and we've gotten an indication of the potential for new knowledge from that channel. The purpose of this on the ERTS-C flight would be strictly as a research and development channel, not an operational channel, to see from space if we can learn many new things by measuring the temperature to something like 1° across a field, or fields, or miles. We hope that would tell us something. It's research and development, and in truth, until we do it and then let investigators see what it means and compare it with ground truth, only then would we know how useful it could be.

Mr. WINN. You don't really know then whether this fifth channel is a definite possibility, or still in a research and development, or experimental stage? You don't know that you can prove anything?

Dr. PETRONE. We have hints of its utility from our aircraft work and from Skylab, but for the true use of it on a repetitive basis, really, ERTS-C would be the proving ground. But we do, from our research today, have great expectation that it's another vista, another window, through which one can look at the Earth and through which one can interpret surface conditions.

Mr. WINN. I gather by your response to Mr. Downing that these two pieces of legislation that we're really having these hearings on, that you want to retain the authority yourselves, and so, if I understood you correctly, you indirectly answered Mr. Downing by saying that you wanted to retain that authority yourselves, and so possibly these bills don't meet with your approval.

Dr. PETRONE. As I have testified, we feel that they would constrain us in a research and development program. Also, we feel they are too early, in terms of trying to establish a Government structure at a time

when we are still both doing R. & D. and taking our first steps operationally. We do feel they are premature.

Mr. MATHEWS. Mr. Winn, I think it is also fair to say though that we contemplate other agencies of the Government using this information to provide services to their constituency and to their clientele in the same manner they would provide any other information. That is, we are not going to provide direct services to the clientele of another agency. This would go through the other agency.

Mr. WINN. I understood that, in response to Mr. Downing. But he asked a point that's very important: Have any of these land-use planning agencies come to you with a direct request for any of this information?

Dr. PETRONE. I would say the States, yes. I'm specifically very familiar with one. It was a study of the coastal lands in the State of Louisiana, a very worthy one: a definition for mapping and legal parameters to establish where were the estuaries and where were the legal limits. ERTS data was used to help define the estuarial limits in the State. I believe the State is using that study as a legal document for purposes of zoning.

Mr. WINN. A comparative document?

Dr. PETRONE. Yes.

Mr. WINN. To compare to what they had before?

Dr. PETRONE. Yes, to what they had before.

Mr. WINN. On this service that you talk about to Government agencies—and it seems like every time that we have a new request either for funding or for a new agency, part of the excuse is that, "We're going to give this information, pass this information on to other Government agencies," and in many cases this is where it gets lost. This is why we are criticized on the dissemination of much of the material from the space program in general.

If a free-enterprise operation would want the same information as you furnished to the coastal group—I don't even know what group that is. I don't know if it's a State organization.

Dr. PETRONE. That was the State organization in the particular program that I mentioned.

Mr. WINN. What State was it?

Dr. PETRONE. Louisiana.

Mr. WINN. OK.

If a free enterprise would come to NASA or to you, would you furnish that to them?

Dr. PETRONE. We do furnish the raw material. There is a way that they can ask for it. We mention in our testimony that we've got to increase the speed with which we can deliver data, from the time the picture is taken, so it can be given out to reusers.

But what's most important, Mr. Winn, is that they have techniques to interpret that data. A picture by itself, without having been worked in terms of definitions of areas and elsewhere, can be difficult to interpret. Now, sometimes a large company has the ability to come up with their own techniques so that they can use the data directly. Some of the smaller organizations would have to have that interpreted by somebody else.

So these are the things that are being developed in our system. We in NASA do not want, and cannot provide, really, the service all the way down to, say, the county agent, who may want to know something about the crops in his area. That would be through the Department of Agriculture's system. Our technique, or what we would do, is to see that he gets the data in the right system where it can be interpreted and then disseminated to him through the agricultural chain.

Mr. MATHEWS. Mr. Winn, actually there are two facets to the operation. One is the commercial operator has the information available to him as rapidly as any other person because there are three dissemination centers in the country that put this information in the public domain, on sale for only the price of a copy. This has been greatly used by, for instance, oil companies. They go directly because they're interested in using that information in the way they see fit.

At the same time, it's entirely possible for a company to become a NASA investigator by submitting a proposal, and that's certainly true of a State, or a university, or whoever would have a proposal in an experimental program. However, operationally, they either acquire the data directly or they acquire it through a source associated with the Federal function that would be involved there.

As Dr. Petrone indicated, in the case of Agriculture, for example, information would most logically flow from Agriculture into that land-use area.

Mr. WINN. I can see partially how Agriculture could go into that. I can see the oil companies, for instance.

But if there is a commercial venture, my point is, what do they pay? Do they pay \$1.95 for a Government pamphlet? They don't pick up any of the original costs of this information at all? You call it an experiment. An experiment to me is what the Government has funded.

Mr. MATHEWS. I would anticipate that as the activity does mature that we would actually provide in our charging provision for at least partial amortization of the hardware costs. As an indication of our attention to this matter, in the case of ground stations rather than data, we are including in our agreements with other countries an option for an access fee.

Mr. WINN. I'm aware of that, and that's why I can't figure it out. Of course, there's the old story that the taxpayer would be paying it twice that way. But oil companies, who spend, supposedly hundreds of thousands of dollars in research and exploration, and we're saving them thousands of dollars in their research and exploration, then they ought to be paying more for it than just the price of buying a pamphlet or a report on that, it seems to me, if we're going to charge other countries.

Mr. MATHEWS. That is certainly true, when it has passed the experiment phase, yes.

Mr. WINN. Thank you very much.

Mr. SYMINGTON. Thank you, Mr. Winn.

Mr. Hanna?

Mr. HANNA. Thank you, Mr. Chairman. I appreciate your courtesy, since I'm only a visitor here to your subcommittee.

I have been following up on your great work and your international cooperation in science, keeping an eye on where these things get crossed, in terms of our international cooperation. I notice, Dr.

Petrone, you made reference to the fact that the two bills before you do not address important national and international policies, and I agree with you that this is something that we should address.

I would like to have your comments on a matter—and I'm not sure it was true, but at least it was reported to me as true—in Saudi Arabia. They were doing, as they are continuing to do, a very intensive job on locating water resources in that country which, of course, is one of the highest priorities in terms of their resource needs. I was told that they went to the USGS to get the information from ERTS and were unable to get it through USGS. Because of the way this thing is configured they were not in a position to provide the information. But the British, who had immediate access under agreement, provided it for them, and so it happened that the flyover backup in terms of mapping where these resources were, and going from imagery to some lower flight information so that they could begin to relate to a total mapping, the end result was the British got the contract for the flyover, and the United States had no active opportunity, and I thought that rather passing strange.

Is that a possibility, that such a scenario could have been acted out?

Dr. PETRONE. I'm really not aware of the incident you refer to, Mr. Hanna. I've seen many things happen, as I know you have, in international coordination of activities, but I'm not aware of that.

Might you be?

Mr. MATHEWS. No.

Mr. HANNA. Would you check on that, just to see what happened, and then give us some advice as to how we might be more effective in terms of the manner in which we make the information available so that we come out of it with as much a positive position as we can?

The other thing is that I think that this program offers a tremendous opportunity of working with the lesser developed countries in bringing on line some very important location inventory management of their resources. This is so important, and I would hope that we could address ourselves to this, as apparently from your statement you hope to do.

Dr. PETRONE. In the case of certain countries where there are ground stations, where they negotiate to have a ground station located, of course, they can get the information directly.

Brazil, for example, does have a ground station and they're able to get coverage of their entire country, much of which is yet to be developed. They do have now this new tool to use.

Mr. MATHEWS. Mr. Hanna.

Mr. HANNA. Yes.

Mr. MATHEWS. There are fairly substantial numbers of ERTS investigations going on in foreign countries. About 50 countries are involved in those, and there are a fairly substantial number of them in which American companies are supporting the foreign country in the investigation.

Mr. HANNA. I think that would be interesting to the committee to know all about this.

When the question was asked: What are some of the beneficial fall-outs on this program, I would certainly think that would be one of them.

Thank you very much.

Mr. SYMINGTON. A question to the gentleman. Was that Saudi Arabia story in testimony before your subcommittee?

Mr. HANNA. No. I talked to a member of the USGS involved out there.

Mr. SYMINGTON. It might be a good idea to let the witnesses know, so that they can go to the source of the story. That's one way of checking it out.

Mr. HANNA. Yes. I'd be glad to provide them with that.

Mr. SYMINGTON. Mr. Downing?

Mr. DOWNING. One question, Mr. Chairman.

Many are interested in extending the economic control of the United States of the sea, and the question enforcement comes up.

Would the ERTS satellite program be of any value in determining whether other foreign fleet patterns were violating that zone? Could you do that?

Dr. PETRONE. I don't believe our resolutions or our repetitiveness would necessarily show you what you might want to know of a fishing fleet being in an area. They would come in and go out. However, the techniques of Earth observation satellites specifically tailored for that program could be used, yes. In other words, ERTS-1, B, and C may not be of value, but other Earth resources evaluation systems may be of value in that case, Mr. Downing.

Mr. DOWNING. Then they could detect ships at their locations on the high seas?

Dr. PETRONE. There's a question of resolution, a question of identification, whether you'd be able to identify them, but you would certainly be able to observe the traffic. You would know generally what was there. You maybe would have to tie it in with what you call ground truth, using the Coast Guard, or something of that nature, to tie in with what you have observed. But it would be a new development, something as a step beyond what we have now on ERTS-1.

Mr. DOWNING. Thank you.

Mr. SYMINGTON. Dr. Petrone, we've touched on ERTS-C and the desire of NASA to go forward with it, as indeed does this committee.

Have you requested OMB authorization for ERTS-C for a portion of the OMB appropriation for the 1976 program?

Dr. PETRONE. We have requested apportionment of the funds starting with the fiscal year 1975 appropriations. We have requested authorization of funds to commence ERTS-C, yes.

Mr. SYMINGTON. You're in discussions with them on that?

Dr. PETRONE. We are also in discussion with OMB on the ERTS-C funding for fiscal year 1976.

Mr. SYMINGTON. We are very grateful for your testimony today. We may submit some additional questions in writing.

We appreciate your appearance, and we excuse you, Dr. Petrone and Mr. Mathews, and thank you very much for your testimony.

Dr. PETRONE. Thank you, Mr. Chairman.

Mr. SYMINGTON. Next we will hear from Dr. Vincent McKelvey, Director of the U.S. Geological Survey, who is accompanied by Dr. John DeNoyer, Director of the EROS program. If you will sit at the witness table, gentlemen, we'll welcome your testimony. I might add

that I have a recent news release by the U.S. Geological Survey which is timely and topical which will be inserted in the record at this point. [The news release follows.]

DEPARTMENT OF THE INTERIOR,
October 2, 1974.

GEOLOGICAL SURVEY—NEWS RELEASE

ERTS CAN HELP LOCATE ENERGY RESOURCES, PROTECT ENVIRONMENT

NASA's Earth Resources Technology Satellite (ERTS) program can not only help the U.S. and other Nations in locating energy resources. It can also aid in protecting the environment, according to Dr. V. E. McKelvey, Director, U.S. Geological Survey, Department of the Interior.

In a paper presented for discussion before the Ninth World Energy Conference, Detroit, Mich., September 23-27, 1974, McKelvey cited a number of experiments by USGS and other scientists involving the use of ERTS images in resource and environmental studies. For example, he said, images recorded by the satellite can be used to spot surface clues to possible petroleum deposits; to monitor snow cover as an aid to power generation, irrigation and flood control needs; and in monitoring the extent of strip mining.

In reporting on the "down-to-earth" benefits resulting from ERTS, McKelvey noted that the Survey is the largest recipient and user of the satellite's data in the agency's role of managing the Interior Department's EROS (Earth Resources (Observation Systems) program.

"Our long experience in collecting, analyzing and reporting earth science data," he said, "tells us that a balance between environmental concerns and energy resources development cannot be obtained without an adequate information base. The absence of this information often results in inconclusive public debate, nonoptimum planning, and a public that loses trust in managers."

"ERTS—with its ability to orbit the Earth, passing over the same spot every 18 days—provides another dimension in data-gathering and monitoring, and helps to fill the 'baseline' information gap," McKelvey said.

The USGS Director said that one of the objectives of the ERTS program is to obtain at least one-time image coverage of the major land masses of the world. This coverage already is complete for over 80 percent of the world, and has been completed for the North American continent.

"Most of the North American continent has been observed several times," McKelvey said, "providing an environmental baseline of dynamic conditions during the 1972-74 time period. The dynamic features reflect basic environmental parameters such as vegetation, surface water, soil moisture, snow cover, and coastal processes, and the value of using these dynamic characteristics for environmental baseline studies is being demonstrated by studies in many disciplines."

Citing the value of environmental monitoring from space, McKelvey said that ERTS images had revealed less residual environmental degradation than had been expected from exploration of an area on the North Slope of Alaska near Umiat shortly after World War II.

"Much public concern has been expressed about the long time required for recovery of Arctic tundra and possible irreversible damage that can follow exploration," he said, noting, however, that "the ERTS data indicate that most of the trails have been revegetated during a 25-year period since the exploration stopped. What we have learned is that if treated properly, the tundra can recover from at least some man-made changes in about 25 years, instead of centuries, as had been feared."

Other examples given by McKelvey of how ERTS images are being used included:

Monitoring major smoke plumes over Lake Michigan from heavy industry. The snow line on the western part of Michigan appears to be the result of an inadvertent weather modification phenomenon caused by the effluents from heavy industry. Whether this increased snowfall is beneficial or detrimental is not yet determined; however, this documents a case of weather modification resulting from the use of energy.

Spotting a pattern of lakes and other surface features in the Umiat area of northern Alaska that might indicate a deep-seated geologic structure with petroleum potential.

Monitoring sea ice in the Canadian Arctic to enable marine seismic exploration crews involved in the search for petroleum to plan survey routes through the ice. Using ERTS data experimentally during the summer of 1973, the crews were able to improve their efficiency by covering additional miles of seismic traverses because they knew where open water existed.

"These are only a few examples of the uses of ERTS data," McKelvey said, "the same data apply to forestry management, agricultural assessments and management, broad-scale geologic interpretations, and land use assessments. New ingenious uses for these data are being found continually."

In concluding remarks to the international group, McKelvey emphasized that a satellite that adequately covers North America is in such an orbit that it can acquire data on a near-global basis. "This opens the door for environmental baseline and resource exploration information for the whole world, and a common base of information for all mankind is of immeasurable value," he said, reminding the group that "ERTS satellite images are readily available to any individual or organization in the world."

STATEMENT OF DR. V. E. MCKELVEY, DIRECTOR, U.S. GEOLOGICAL SURVEY; ACCOMPANIED BY DR. JOHN DeNOYER, DIRECTOR, EROS PROGRAM

Dr. MCKELVEY. Thank you, Mr. Chairman and members of the subcommittee.

It is an honor to appear before this committee and have the opportunity to comment on H.R. 14978 and H.R. 15711. Both of these bills have a common objective—to establish a new institutional framework as one way of realizing continuing benefits from the research successes and investments of the experimental Earth Resources Satellite program.

The experimental Earth Resources Technology Satellite program has been developed and operated by NASA in close coordination with other agencies, particularly the Earth Resources Observation Systems program of the Department of the Interior. Technological accomplishments of the ERTS program have resulted from interagency teamwork, and the Department of the Interior is proud to be a member of the team. We have been a leading user agency in working with NASA to define the experimental ERTS system, in analyzing the data, in providing facilities and resources to make the data available to the public, in training domestic and foreign users and in working closely with NASA to consider what steps should be taken next in the experimental program.

A large amount of experimental results has been obtained. The contract evaluation of the possible costs and benefits from an operational system is analyzing these experimental results. Some areas where ERTS satellite-sensed data might be applied in conjunction with data from other sources in the Department of the Interior are in geologic mapping, uses of data collection platforms for water data, resource inventories on public lands, rangeland management and management of water resources derived from snow melt.

We have only had experience with one Earth Resources Technology Satellite. We are just beginning to learn how to get the most out of the data; their importance is just beginning to be realized. A most important requirement for Interior and other user agencies is con-

tinuing availability of data products which represent the most advanced current technology as improvements are achieved in data quality. Such availability during the developmental process will be essential to user evaluation of both the technology and the potential for application to actual resource management decisionmaking. A successful ERTS-B flight will provide additional data from the current technology for these purposes.

The Department of the Interior is confident that present institutional arrangements are fully adequate to meet this need. The EROS Data Center at Sioux Falls, S. Dak., will continue to provide data produced by ERTS-1 and later by ERTS-B, as well as data available from other sources. As more advanced technology is tested, its products will also be made available. We will be continually examining this Center and related systems in order to improve its capability to meet user needs.

We would expect the Department of the Interior to continue to take an active role in defining requirements for further experimentation and for possible operational satellite systems in those cases where they prove to be able to collect the data needed by decisionmakers more cheaply than alternative systems. We will continue to work with NASA and other user agencies to develop a definition of user requirements and to evaluate the extent to which a satellite system could provide the data at a competitive cost. The Department of the Interior will evaluate results obtained from the experimental program and make recommendations for modes of operation or capabilities needed to improve the value of the data. This involves evaluation of satellite, aircraft, and on-the-ground collection methods to compare costs and benefits in terms of repetition rates for coverage, spectral characteristics of sensors, spatial resolution characteristics of sensors, time-of-day for coverage, data throughput needs and tradeoffs between data quality and timeliness of delivery. In the continuing development of this technology, there will have to be a continuing exchange of data from Department of the Interior facilities and NASA facilities so that the development of the technology of user evaluation and application are well meshed. There are probably inherent economies in using a combination of NASA and Interior facilities to accomplish the mission objectives.

We feel that the Department of the Interior should continue its role in processing and disseminating experimental data to Government agencies and to the public at large. This is an area where interest is growing. In fiscal year 1973, which was less than a full year of operations, the EROS Data Center sold \$186,762 worth of ERTS data. This figure grew to \$468,614 in fiscal year 1974. We expect the sales of ERTS data to reach a figure between \$700 to \$900,000 in fiscal year 1975. It is also interesting to note that during fiscal year 1974 satellite items shipped from the EROS Data Center amounted to 61 percent of shipments, and aircraft items, 39 percent. The data base for aircraft pictures has about 5 million entries. The data base for ERTS images has about 500,000 entries. We attribute the relatively large customer demand for ERTS data to the widespread interest in evaluating what actual and potential uses could be made of the combination of unique data characteristics obtainable from this

spacecraft. Several major oil companies order data frequently and are using the repetitive coverage obtainable from ERTS in combination with data from other sources for their geologic analyses.

We are interested in making the user potential base as broad as possible. To help accomplish this objective, we have established the Experiments and Evaluation Office at the National Space Technology Laboratories in Mississippi. This office serves as a contact point for the States in the Southeast, and it has been most effective in helping users in that area evaluate data and potential benefits from remotely sensed imagery. The EROS Data Center in Sioux Falls serves as the data source and as a central location where research results are being adapted for possible operationally oriented applications. These results are made available to the field offices for training and user assistance purposes. Formal training courses and short workshops are conducted at nominal costs to participants at Sioux Falls and other locations to make the skills that are necessary for the use of remote sensing data available to potential users.

In the further development of this technology, NASA would need to conduct continuing analyses of the experimental spacecraft and sensor performance characteristics, possible improvements in techniques and equipment for meeting current and future user requirements and for proper interfaces with activities conducted by Interior and other agencies. If an operational ERTS-type system were to be developed, joint system studies between NASA and Interior would be essential so that the characteristics of space-ground systems would provide for using the types of data that would be acquired on time scales commensurate with the schedule for future spacecraft.

Joint programs between agencies such as Interior and NASA make it possible to utilize the high technology capability of NASA to meet the needs of resource agencies as identified and defined by the decision-makers needing data. The relative roles of each agency must be clearly understood and agreed to. We feel that this has been and can be accomplished through appropriate memoranda of understanding.

In conclusion, Mr. Chairman, we feel that NASA, Interior and the other Federal agency users of ERTS data have already achieved a high measure of success in this experimental program, in the design and operation of ERTS-1, in the development of uses for the data it has supplied, and in helping the broad spectrum of potential users of ERTS data to experiment themselves in the use of ERTS data and enjoy the benefits already obtainable from ERTS imagery.

As you know, EROS is a Department of the Interior program and I am pleased to report that experimentation in the use of ERTS data has involved most of the bureaus of the Department. In several of them—including the Bureau of Reclamation, the Bureau of Land Management, the Bureau of Indian Affairs, the Fish and Wildlife Service, and the Geological Survey—we believe this experimentation will evolve into demonstrations of useful application of ERTS imagery. We are pleased also that our work in EROS has led to good working relations with several other Federal agencies, including the Corps of Engineers, the National Oceanic and Atmospheric Administration, the Department of Agriculture, and the Agency for International Development, as well as many state and local organizations. There are many, many potential users of ERTS data in government

and in the private sector as well, and we feel we have already accomplished much in exposing them to ERTS data and making ERTS imagery available for effective use.

That concludes my statement, Mr. Chairman, and I appreciate the opportunity to appear before you.

Mr. SYMINGTON. Thank you, Dr. McKelvey. I want you to know that the committee feels very strongly that the Department of the Interior, in its view of earth resources activities, is of extreme importance to the proper implementation of that program.

This committee has a certain desire to see space science utilized, that's true, and NASA wants to go forward with improvements in their technology, which it's really the user community interest, at the money source, the encouragement to go forward, by saying, "Yes, we need these things to help us to save money. It's going to cost something to save a lot more." Now, we can, and do, depend very much on your Department, preeminently in this regard, so we're very encouraged by your testimony.

For example, your testimony on page 2, where you refer to the kinds of things that ERTS satellite-sensed data collection is doing in discovery of water and resource inventories, and rangeland management, and so forth.

Now, the OMB maintains that this sort of data is "marginally useful" to resource management. That's a rather negative sounding expression to us. It almost indicates that, "Well, why bother if it's under way or let's not do it at all."

What do you think? Is that data marginally useful, or is it quite useful?

Dr. MCKELVEY. Mr. Chairman, I have no reservations personally, and I don't think that the Geological Survey users in general and others in the Department would hesitate in saying that, indeed, these data are proving useful.

We are still in the learning process as to just how they can be used most effectively, but I think that our reaction has really been one of pleasant surprise over the potential uses that appear to be developing. Some that we had not anticipated are showing up and others that we had perhaps some doubts about appear to be firming up in their application.

Mr. SYMINGTON. I think you were here during Dr. Petrone's testimony, in which he responded to questions concerning the need for continued experimentation in order to improve the sensing process and data analysis, and indicated that the way to improve the system is to use the system.

Dr. MCKELVEY. Exactly.

Mr. SYMINGTON. Do you agree with that?

Dr. MCKELVEY. Yes, I do.

Mr. SYMINGTON. And again, specifically, the Federal Task Force on Mapping and Charting surveys concluded ERTS data, or they seemed to conclude, that there was little value to the functions of the Department, such as mapping, and so forth.

How would the Department of the Interior respond to that finding, and what was the response, and what is your response now?

Dr. McKELVEY. Mr. Chairman, I've forgotten exactly the details of the Interior response. Perhaps Dr. DeNoyer remembers it, and I will ask him in a moment.

But I might just give my own personal impression and view on the matter. I think that the Mapping Task Force was addressing the question of mapping per se, and, of course, much of their interest, much of the interest of the mapping community, focuses on large-scale mapping. An enlarged aerial photograph or a standard U.S. quadrangle map is at a scale of 1,000 or 2,000 feet to the inch, and without doubt ERTS imagery is not as useful at this stage in making such products as are some other kinds of imagery.

But I would call the committee's attention that it has been possible with ERTS to map some parts of the globe that have never been mapped before, simply because of the very large regional coverage and essentially planimetric accuracy of the image, and so in certain kinds of mapping applications there clearly is a use in these data that is almost unique.

I would ask Dr. DeNoyer if he recalls the specifics of the Interior response.

Dr. DENOYER. Yes, Mr. Chairman, I do.

In general we agreed with many of the recommendations of the task force. However, in the case of ERTS, the departmental position, signed by Assistant Secretary Clark, took exception to the task force conclusions.

Mr. SYMINGTON. Is it possible to get a statement of the exceptions that you took?

Dr. DENOYER. I believe that could be supplied, Mr. Chairman.

Mr. SYMINGTON. I wish you would do that and supply it for the record.

[The information to be supplied is as follows:]

U. S. DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D.C., February 2, 1974.

Mr. FRANK G. ZARB,

Associate Director for National Resources, Energy and Science, Office of Management and Budget, Washington, D.C.

DEAR MR. ZARB: We appreciate the opportunity to comment on the findings and recommendations of both the classified and the unclassified versions of the July 1973 "Report of the Federal Mapping Task Force on Mapping, Charting, Geodesy and Surveying." The Task Force obviously made a very comprehensive study, the results of which can have significant impact on the various programs of this Department. We were pleased to be represented on the Task Force and to provide the facilities and support for the conduct of this valuable probe of civilian mapping, charting and geodesy (MC&G) activities.

We agree with the general conclusion of the Report that various aspects of Federal mapping, charting and geodesy programs could be improved. We also agree with, and have taken steps to implement, most of the specific operational recommendations in the Report. Comments on the operational recommendations are attached. Comments on the classified recommendations were sent to you previously.

While the operational recommendations are important and their implementation will improve MC&G efficiency in the Federal Government, a major conclusion of the study and its findings has to do with the way the Federal MC&G community is organized.

The proposal to create an MC&G agency within the proposed Department of Energy and Natural Resources (DENR) is most attractive. That arrangement

brings together the important MC&G functions while continuing the vital association these functions have to other missions in DENR. Our planning and preparation for DENR will include the treatment of MC&G functions within the structure of the proposed new Department.

We recognize that it may be some time before DENR is established, and that response to some organizational issues pointed up in the Report can be acted on at this time. We feel that Interior can and should act now where it can. Where the MC&G functions overlap in other Departments we will work with those Departments and with OMB to further realize the benefits outlined in the Report.

One area where Interior can act is with respect to the National Geodetic Network. While this program is a primary responsibility of NOAA we agree with the Report that the surveying activities of this Department can contribute to the development and maintenance of this network. Through existing relationships between Geological Survey and NOAA, and with OMB's approval, the survey activities of GS's Topographic Division have already been notified so the National Geodetic Network is expanded in the course of our topographic surveys.

We will expand this cooperation to all Departmental surveys that fit the criteria outlined on page 59 of the unclassified report. The Interior member of the Federal Geodetic Control Committee (FGCC) will be responsible for working with NOAA in establishing the guidelines for such cooperation, for securing Interior compliance, and for coordinating relationships between Interior and NOAA. All bureaus with plans for surveys fitting the page 59 criteria will be required to report such surveys to this representative, and where practical, modify their surveys to contribute to the National Geodetic Network.

The size of the Department's surveying program in Alaska is such that we feel that special attention needs to be given to that area. The Bureau of Land Management (BLM) has been working with NOAA to accelerate the development of the primary Geodetic Network in Alaska and is contributing toward the expansion of the network. Surveys of the Geological Survey similarly are being coordinated with NOAA.

We feel, however, that the three survey programs need further coordination, so we propose to include BLM, at the Associate Director level, in the present NOAA/USGS Interagency Committee for Program Coordination (ICPC). The ICPC already has a substantial record of achievement in coordinating the activities of NOAA and GS. We believe it can also obtain an effective coordination for the National Geodetic Network among BLM, GS, and NOAA.

While the report deals very broadly with Federal mapping activities, the core of the land mapping comments and recommendations, relate to the National Topographic Map Series produced by the Geological Survey. This series is basic to much of the mapping activity in the country. Maps produced by other Federal agencies, by States and local governments, and the private sector are commonly based on the National Topographic Map Series.

The MC&G agency proposed in the Report would pull together the Federal cartographic programs so all maps built on the National Topographic Map Series could be produced by the one mapping unit. GS has been working with a number of Federal agencies to improve the utility of its maps. Noteworthy here is its work with the Federal Highway Administration with respect to the County Highway Series; the Department of Housing and Urban Development with respect to urban maps; with the Census Bureau's Metropolitan Map Series; and with BLM with respect to land management requirements.

GS will move forward aggressively to develop its ability to respond to the variety of Federal mapping needs that are based on the National Topographic Map Series. We question, however, the advisability of the GS assuming the responsibility for additional mapping functions until it can do so without detriment to the agency's primary program. The soils maps of the Department of Agriculture and the flood insurance maps of the Department of Housing and Urban Development fit this concern. We are now working with these agencies on the production of these maps.

It is very important to move systematically when expanding Interior's mapping responsibilities. The preparation of thematic maps, dependent upon the availability of base maps, requires a substantial effort associated with mission-oriented data gathering, as well as cartographic reproduction and distribution efforts. Interior will work with each Federal agency to assure that services consistent with the needs of that agency are provided. OMB will also have to support In-

terior in its budget and personnel ceiling increases that go with the expanded responsibility.

On page 160 of the unclassified version of the Report, it is recommended that a map and chart library, photo repository, and MC&G data files centers be established. The practical step, in our view, is to create a central one-stop information system consisting of several components. These centers would have information on maps, photo coverage, survey data and other information.

The Department of the Interior is developing such an information system—the National Cartographic Information Center. Additional work is necessary to complete this job, particularly in developing and establishing the reporting systems and associated equipment. Continued OMB support is requested for funding this program.

We already have made significant progress in this area at our classified mapping center at Reston where we are using equipment and methodologies developed by the military. Some of this is noted in our specific responses to the Report's recommendations.

The Geological Survey has well established relationships with the Department of Defense. It has also pioneered in the development of surveying, mapping and data information systems. We, therefore, are charging the Geological Survey with the responsibility for MC&G research and development and its transfer to the surveying, mapping and related data information systems of the Department of the Interior.

As noted earlier, we believe that creation of DENR will facilitate development of the proposed MC&G agency because most of the components will be in the new Department. The core of the proposed MC&G agency now is divided between Geological Survey and NOAA. The public land surveys and records responsibilities of BLM are less central but also need to be recognized and where appropriate, incorporated into the MC&G framework, i.e. statute and cadastral boundary inputs.

It is not practical for Interior to separate all its survey and mapping functions from their parent bureaus at this time. This would create a truncated office without a full mission. We also would have to develop an overhead structure for management, administrative, and support services.

Our experience with the ICPC indicates that progress can be made toward the objectives of the report within the present allocation of functions. We propose that this Committee be charged with the responsibilities for integrating the MC&G function of Interior and NOAA along all practical operational and organizational lines. Part of this charge should include encouragement of organizational innovations such as mutually funded and managed units, and one-stop information services.

We have deliberately refrained from stressing the negative in preparing this reply, but are concerned about the Report's treatment of the Earth Resources Technology Satellite (ERTS). The Report creates the impression that spectral imagery is in competition with panchromatic photography when, in fact, these data are complementary. Further, it fosters the concept that with sufficient photographic resolution nearly all features are detectable and interpretable. For resource studies a variety of spectral data is needed, as well as sun-synchronous, synoptic, and repetitive coverage. This has been amply demonstrated in numerous applications of ERTS data by geologists, agriculturists, hydrologists, land planners, and resource managers. We will exert every effort to assure that both ERTS imagery and other source data be intensively investigated by a broad spectrum of scientists to achieve maximum utilization of all data.

We see the Report as a broad guideline of possibilities in the MC&G area. The building of any MC&G agency, however, will have to occur systematically. The various missions of the surveying community will have to be integrated in compatible ways. The mapping responsibilities of GS will have to be enlarged systematically so its capabilities, funds, and manpower equal its service responsibilities.

We have, in this response, sought to outline a framework of actions that will, in our judgment, move toward the benefits outlined in the Report. We will work directly with other Federal agencies on the opportunities that lie between us. We will, however, need OMB support in meeting our budget and manpower needs for expanded programs and in the transfer of functions where this is desirable.

Sincerely yours,

JAMES T. CLARKE,
Assistant Secretary of the Interior.

Attachment.

DEPARTMENT OF THE INTERIOR COMMENTS ON THE OPERATIONAL RECOMMENDATIONS
OF THE FEDERAL MAPPING TASK FORCE REPORT

The Department of the Interior agrees with the operational (nonorganizational) recommendations in the report, though implementation may require some support by OMB for additional funding and ceilings. Some recommendations also require the cooperation of other Departments and Agencies. Each recommendation is identified by the number of the page (and line, if necessary) on which it appears in the unclassified report.

Page 18 (line 7). *Agree*. NOS is rewriting geodetic control standards in which third order control will be monumented and made part of the National Horizontal Network. We will monument and document third-order surveys when the new standards are promulgated.

Page 18 (line 34). *Agree*. We will continue to inform NOAA/NOS annually of our high-priority geodetic control needs.

Page 25. *Agree*. The transfer of funds requires an OMB initiative.

Page 30. *Agree*. The transfer of funds requires an OMB initiative. Reprogramming of land survey funds beginning in FY 1976 should be conditional on the demonstration of savings as predicted in the Report.

Page 42. *Agree*. We would be appreciative of any OMB initiative in this direction.

Page 58. *Agree*. The facility of the GS Special Mapping Center at Reston is being used increasingly by GS and other civil mapping agencies. Production research is being actively conducted with newly acquired AS-11 plotters to demonstrate the applicability of all materials to quadrangle and other mapping operations. For specific details on expanded GS activity, see comment on recommendation No. 142.

Page 68. *Agree*. We are studying ways of increasing public awareness of current indexes and the advanced topographic map copy they advertise, as well as adding map dealers and map libraries to mailing lists. Also under consideration is a proposal to symbolize on our sales indexes those quadrangles in production for which advanced map copy is available. A proposed GS Map Information Office brochure will announce the availability and explain the usefulness of advanced map materials and reproducible copy.

Page 74. *Agree*. GS expanded its use of advanced technology for interim revision when proper materials became available and operations became cost effective.

Page 79 (line 3). *Agree*. GS has taken steps to develop the greater flexibility recommended by the Task Force. Meetings have been held with the Bureau of the Census to discuss modifications of methods of preparing quadrangles to facilitate preparation of the new Metropolitan Map Extension Series. Meetings will be held with other agencies for similar purposes.

Page 79 (line 7). *Agree*. GS will continue to produce orthophotomaps. It has been our practice to produce them only when the orthophotomap portrays the area mapped better than would a standard topographic map.

Page 79 (line 11). *Agree*. GS will produce 1,500 orthophotoquads in FY 74, and 30 percent of all new 1:24,000-scale mapping to be started in FY 74 is programmed for orthophotoquad treatment. GS has identified \$3,241,000 in the FY 75 budget for production of 3,500 orthophotoquads of the unmapped areas and for areas where standard mapping is out of date. This would have the effect of implementing the first part of this Task Force recommendation. The production of a contoured orthophoto product is in accord with Phase II of the GS "phased mapping" concept. Phase III, the standard line map, is the final product and is produced only when the need is validated.

Page 79 (line 17). *Agree*. Most of the work in digitizing map data has been accomplished by DOD agencies. The implementation of this recommendation on a nationwide basis to a common data base is highly desirable.

Page 79 (line 22). *Agree*. We support the concept of a complete data base of photography. Our efforts to apply this base in standard quadrangle mapping and map revision are given in response to recommendation No. 142.

Page 79 (line 27). *Agree with reservation*. Interim revision is a successful attempt to accelerate revision operations over a period when the constraints of a limited budget base have made it impossible to meet revision needs and at the same time produce new topographic maps. We are shifting more of our effort from new mapping to revision as national coverage increases; however, we must not overlook the importance of new maps in the developing areas or areas of new concern.

Page 82. *Agree.* We will continue to weigh potential cooperative projects against national high-priority requirements before entering into cooperative agreements. It should be noted that State shares have amounted to \$55.9 million in the last 20 years (4,900 man-years or 17 percent of the 7½-minute quadrangle mapping program during this period) and can be expected to continue to advance significantly the national topographic coverage unless or until Federal program funds are increased to replace them.

Page 90. *Agree with reservation.* We believe that such an examination of requirements should have the highest priority. GS already has initiated discussions with land-management agencies to review and consolidate their base-map requirements. Some of the thematic maps needed, however, would be beyond the capability of a mapping agency.

Page 94. *Defer to the Department of Agriculture.*

Page 106 (lines 1 and 22). *Defer to the Department of Commerce.*

Page 106 (line 34). *Agree with reservation.* We would be interested in any automated techniques that might be developed jointly by DMA and NOAA. We do not have a basis for an opinion as to the cost factors involved.

Page 108. *Defer to the Department of Commerce.*

Page 117 (lines 10 and 28). *Defer to the Department of Commerce.*

Page 120. *Agree.* We will notify DOD of our requirements for bathymetric data and charts.

Page 125. *Agree.* Our resource investigations could benefit from greater access to marine survey data. We will initiate clearances for selected personnel to review and use DOD data.

Page 126 (line 8). *Agree.* The termination by NOAA of its marine geophysical survey and mapping program has resulted in the termination of most of its bathymetric mapping of the continental shelves. These bathymetric maps are essential as bases for our resource investigations. The generalized geophysical maps produced from data acquired during the bathymetric surveys are helpful in the planning of the more detailed surveys needed for our resource investigations. Therefore, we would support the development of a program for the production of bathymetric maps and for maps of geophysical parameters that can be acquired without adversely affecting the bathymetric program.

Page 126 (line 20). *Agree.* We would welcome an annual review of Federal marine survey data-acquisition programs.

Page 132. *Agree.* We would welcome an annual review of Federal programs requiring marine data collection.

Page 136. *Agree.* There is need to coordinate photography requirements of civilian agencies; however, responsibility for such coordination should rest with the operating agencies to assure that collection of photography is fully responsive to program needs.

Page 144 (line 19). *Agree.* The recommended action has been taken and the FY 75 budget presentation of GS includes \$3.0 million for capitalization of advanced techniques equipment.

Page 144 (line 24). *Agree.* Two AS-11A analytical plotters were received—one from DMAAC and the other from DMATC—and installed in the GS Special Mapping Center at Reston.

Page 144 (line 30). *Agree.* The first group of GS trainees on AS-11 operations has completed training at DMATC and DMAAC, and a second group will begin training in October. DMA is assisting the development of software capability, and modification and procurement of equipment.

Page 146. *Agree.* The analysis has begun. Compilation for this purpose will begin this fall on four 1:24,000-scale, 20-foot contour interval quadrangles in Montana. Compilation of Alaskan maps is scheduled to begin early next year.

Page 149. *Agree with reservation.* We agree with that part of the recommendation that treats a common reference system and the development of information systems, and, except as noted in previous comments, agree with centralization of appropriate cartographic functions and skills (see comment for No. 96).

Page 168. *Agree.* Implementation as related to base-map pricing, specifically, should be affected immediately through a Federal Printing Pricing Committee to be established by OMB. However, the Report does not address the subject of returning map sales revenue to the printing agency as opposed to the present policy of returning such revenue to the Federal Treasury. It is recommended that OMB consider recycling revenue gained through sales of map and chart printing as a means of augmenting program budgets.

Mr. SYMINGTON. Dr. McKelvey, you referred to certain kinds of mapping that can only be done by ERTS, and as OMB has mentioned, you're referring to alternative systems as a way of achieving data other than by ERTS sensors.

I'm sure there are some things that can be done, other than through ERTS, but are there some things that only ERTS can do, and some things that it does better than any other method?

Dr. McKELVEY. At this stage I think that is true, Mr. Chairman.

I would refer particularly now to the multispectral data that ERTS supplies in digital form. I think that is a characteristic that presently is unique to the ERTS system.

I would point to other things, such as the repetitive capability of the ERTS system.

Now, of course, on a case basis repetitive coverage could be attained in many other ways, and at shorter or longer intervals, that might be desirable, with aircraft acquisition as an example. I'm thinking of. But still, to have it nationally and for the world on a systematic repetitive basis—that is really unique and tremendously valuable.

Mr. SYMINGTON. It would seem to be of value to the user community if you could make inputs.

Going to your testimony at the bottom of page 4 and going on to page 5:

... during FY 1974 satellite items shipped from the EROS Data Center amounted to 61 percent of shipments, and aircraft items, 39 percent.

That would seem to indicate at least a lively curiosity on the part of the user community in using ERTS data.

Dr. McKELVEY. I'm sure the lively curiosity is a part of what accounts for that. These are new kinds of data, and I'm sure that many of the orders we received are stimulated by the desire to simply have a look and see what sort it is. But it's impressive though that so many of these users are regular customers, they're continually putting in orders. So they're using it.

Mr. SYMINGTON. Then you go on to say that several major oil companies order data frequently, so it would seem that that ERTS data has matured at a steady rate of interest.

Dr. McKELVEY. That's right.

Mr. SYMINGTON. And yet OMB claims that the users need just one look, one cloud free image. That doesn't seem to be the conclusion of the Geological Survey. We've had testimony from geologists that repetitive images are very useful.

Dr. McKELVEY. Yes, it is true, and, of course, at least for most geological features they are not changing that rapidly, but the lighting changes, and the vegetation changes, and so that one look is not enough in many instances to gain what can be gained from ERTS imagery.

Mr. SYMINGTON. The committee was intrigued a year or so ago to hear some testimony to the effect that the size and progress of the geological faults would be studied in this fashion.

Is that true?

Dr. McKELVEY. Yes. It's one of the things that is really remarkable about the broad synoptic coverage of ERTS imagery, and it's one of

the things, I think, that surprised us some, although we had anticipated value in this aspect of ERTS.

But really, when you stop to think about it—and it made me stop to think about it a couple of years ago when we began to see these results—nearly all of the maps of the kinds that we had been using up until now are made from ground observations. They are made from what can be seen with the eye, in a relatively small area. A geological map, for example, is built up, and even the geologic maps of the United States, at scales of 1 to 2½ million and 1 to 5 million, are built up from observations that are essentially made on the ground and at the outcrop, and I might say that's even true to a degree with aerial photographs, because they cover only a square mile, or a few square miles, of ground.

But with the ERTS imagery covering a very large area at one time, you see features that are too subtle in their expression to observe on the ground. These features have continuity such that in some way or other they do show up on a view that covers a very large area of country at one time, and so, lo and behold, we are seeing geologic features on many ERTS images that simply were not known before. That's one of the very important applications of ERTS data.

Mr. SYMINGTON. And doesn't information of that kind have a high relevance to the plans of man with respect to laying pipelines, building cities, and almost everything we do that rests on certain assumptions concerning the land which might be erroneous?

Dr. McKELVEY. Indeed. It's not that ERTS images will replace all other sources of geologic data. That would be far from the truth. But adding this capability—this very capability to identify some of these regional tectonic features—is a very important contribution to the task of building geologic knowledge of the Earth's surface and subsurface, and a myriad of applications that knowledge has.

Mr. SYMINGTON. Some of the dominant changes that have developed, even over centuries, and there comes a point in time when quick changes are about to occur, quick in terms of a lifetime, and it would be extremely valuable to anticipate those within the time frame that something could be done about them, is that not true?

Dr. McKELVEY. Yes, that's true. I think that we really don't know the capability that may evolve for the detection and anticipation of changes in the Earth's surface that may occur.

But I think you can already see, and particularly with the data collection platforms and their use, with the continuous recording of tiltmeters, for example, that measure the change in the inclination of the ground surface. That phenomenon in particular is one that we think has precursory significance in relation to earthquakes, and also with respect to volcanic eruptions, in certain types of earthquakes and certain types of volcanoes.

So I think we can look ahead and anticipate that there may be important applications in this general area, and certainly ones that have a potential significance and that deserve further exploration.

Mr. SYMINGTON. With the increasing growth in population, we need to exploit even more intensively both the developed and less developed areas of the world. It would seem almost irresponsible not to take

advantage of the technology that exists of that kind in making good judgments about the kind of exploitations you wish to make.

Dr. McKELVEY. I heartily agree with that, Mr. Chairman.

Mr. SYMINGTON. The promise is there, so that leads us into a discussion of ERTS-C, which is something which I believe NASA has testified to. They requested an authorization for it. Does the Department of Interior support ERTS-C and subsequent satellites?

Dr. McKELVEY. Yes, we do, Mr. Chairman. We agree heartily with what Dr. Petrone has said in his testimony about the evolutionary nature of the systems that we're dealing with, and we feel that it's very important to pursue this development with its very promising applications, and, at the same time, we recognize that at this point it's not advisable to become locked into any particular aspect of the system.

There are operational uses that are nearly in hand now, are in hand in some respects, and still there are other features that need to be explored and undoubtedly are going to be, and are going to change as time goes on.

Mr. SYMINGTON. Mr. Downing?

Mr. DOWNING. Thank you, Mr. Chairman. I just have one.

Dr. McKelvey, you did not specifically refer to the bills under consideration.

Is it your opinion that this proposal should be deferred, or enacted, or just what do you think about it?

Dr. McKELVEY. Yes. We feel that the bills are premature at this stage, and we feel that the arrangements we have now, and under which we have been working, have been very effective, and ought to be allowed to continue on into the future, until at least there is clear recognition of the need for other arrangements.

Mr. DOWNING. Thank you very much.

Mr. SYMINGTON. Dr. McKelvey, the Sioux Falls Center uses data from NASA ground stations. Would the establishment of direct reception capability at the Sioux Falls Center speedup processing and dissemination of this information. What costs would that entail, in your opinion?

Dr. McKELVEY. I'll ask Dr. DeNoyer to speak to the matter of costs.

I think undoubtedly the acquisition of the reception capability would enhance the overall capability and usefulness of the Sioux Falls Center to the general public. It would shorten the time in which data could be made available.

Mr. SYMINGTON. Before we go to Dr. DeNoyer on that, in time we've had some complaints from various users that it takes too long to get some of the data.

Dr. McKELVEY. Oh, and they're so right.

We are doing our best to shorten that, and I am pleased to report that we have made really big strides in that in recent months. We were literally snowed for a period.

Mr. SYMINGTON. How did you catch up, or how are you trying to catch up?

Dr. McKELVEY. Well, I think the main secret was that, first of all, we made a crash effort to add additional hands to help reduce this

mountain of requests, and then on a continuing basis through improvement in our staff at Sioux Falls and the systems they were developing to handle and expedite requests.

Mr. SYMINGTON. You've added personnel to this effort?

Dr. McKELVEY. In total amount. I'm not sure that on a continuing basis, we have more people. But we have people better trained and able to cope with the problem as our staff has been developing.

Mr. SYMINGTON. I'll turn to Dr. DeNoyer then, to followup on my last question.

Dr. DENOYER. Mr. Chairman, as to your first question, a "quick look" type of capability in the United States similar to what Canada has would certainly speed up data availability. It's something we are studying very hard now. We are working with NASA in this, and looking at several alternatives.

I'd rather not quote the costs because it would depend on what alternative would prove the most appropriate.

We all recognize the need to get at least some sort of data to the user much more rapidly than has been possible in the past.

Mr. SYMINGTON. Thank you, Doctor.

Dr. McKelvey, still looking ahead and wondering what your thoughts are, do you think that an operational system could some day monitor worldwide grain production, giving forecasts that would render surprises in the international grain market less likely?

Dr. McKELVEY. Mr. Chairman, of course that is not my field, but simply expressing my impression of the capability of the system as it might be applied to data of those kinds, I would be optimistic that such a work would be possible, and useful.

Mr. SYMINGTON. That could almost justify the entire program.

Dr. McKELVEY. In itself, yes.

Mr. SYMINGTON. I wonder, does your department have a spokesman or an observer attending the World Food Conference in Rome—from November 5 through 16? Secretary Butz is heading a delegation, and I wondered if you folks were having a representative or spokesman attending that conference.

Dr. McKELVEY. I simply am uninformed on that, Mr. Chairman.

Mr. SYMINGTON. I'm intending to go myself. I thought we would stimulate some interest in these capabilities at the conference. The NASA team has been really helpful to me in that regard, and I'm sure they've done a lot for you.

We may have further questions in writing for you, Dr. McKelvey.

We're very grateful to you for this extremely valuable testimony. The committee's going to have a lot to work with and to work on, and no small part of which is what you've provided this committee.

Dr. McKELVEY. Thank you very much, Mr. Chairman.

Mr. SYMINGTON. Thank you very much, Doctor.

This concludes the hearings of the Subcommittee on Space Science and Applications on the ERTS program.

The meeting is adjourned.

[Whereupon, the subcommittee hearing was closed at 11:56 a.m.]

ADDITIONAL MATERIAL FOR THE RECORD

OSU

CORVALLIS, OREGON 97331

OREGON STATE UNIVERSITY

OFFICE OF THE VICE PRESIDENT FOR
RESEARCH AND GRADUATE STUDIES
Telephone 503 754-3437

October 1, 1974

Mr. Frank R. Hammill, Jr., Counsel
Committee on Science and Astronautics
House of Representatives
Suite 2321 Rayburn House Office Building
Washington, DC 20515

Dear Mr. Hammill:

I am pleased to have your invitation to write and evaluate legislation to establish a federal office to manage and to plan continued development of Earth Resources Satellite Survey Systems. My interests in such systems began in the late 1950's when I participated as a plant pathologist in a National Research Council study on methods for improving accuracy in information on losses in economic crops occasioned by plant pests. From 1961-1969 I served as chairman of a committee of the NRC-Agricultural Board on Remote Sensing in Agriculture-Forestry and participated in research with other members of the committee in proving out the then militarily classified multispectral scanner for collecting data over agricultural crops. Our committee also aided the U.S. Department of Agriculture and NASA in establishing four national laboratories for remote sensing at the University of Michigan at Purdue, at Weslaco, Texas and at the University of California at Berkeley.

More recently I have served as the Oregon member of a Task Force on Land Resource Inventory of the Northwest Regional Commission (comprised of the governors of Idaho, Oregon and Washington). Upon special request of the Governors we have proposed to incorporate information from the Earth Resources Satellite data as the principal basis for determination and quantification of land resources and land use and for monitoring and quantifying land-use change and land management practices in our three states.

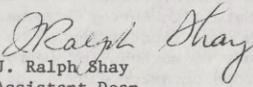
I am enclosing a copy of the proposal approved in principle on September 18 by the Governor's alternates. I am doing this with permission of Mr. Dale Mallicoat, alternate for Governor Tom McCall. The proposal will be enlarged at the alternates request to include land use map products and submitted to the Governors October 27-28 at a funding level of \$375,000 through December 31, 1975.

As indicated in this proposal we in the Pacific Northwest are investing a significant sum in initiating a quasi-operational Earth Resources Information System with planning toward a fully operational system by the time the second generation EOS satellites are proven out in the late 1970's. We have confidence from the ERTS experiments supported by NASA since 1972 that the satellite platform,

electronic sensors and computer-assisted data interpretation represented by the ERTS system is a powerful impersonal source of repetitive data that can help us identify need for and gain adoption of land use practices that will help us preserve and manage as wisely as we know how, the highly valued agricultural, forest and recreational resources of the Pacific Northwest. The Oregon Land Conservation and Development Commission in its first year in 1974 collected Land-related concerns of Oregon citizens. They found the three main concerns were 1) preservation of prime agricultural and ranch lands, 2) planned orderly growth and development, and 3) conservation of natural resources. We believe the ERTS type system will provide an accurate, ongoing, non-biased information source on which our people can rely to serve these basic concerns.

An early decision by the Congress on Federal Management of an operational Earth Resources Satellite program is vital to the orderly progress and ultimate success of our Pacific Northwest program. Delays in this decision as the Office of Management and Budget continue to recommend (statement of Frank G. Zarb dated August 8, 1974) will only discourage states and regions from initiating actions such as we are undertaking. It is only through such actions that we will get true answers to questions on cost-benefits and information improvement for decisions in the management of our food, forest, recreation and wildland resources. The stresses on these resources are obviously of increasing concern to all citizens.

Sincerely yours,


J. Ralph Shay
Assistant Dean
of Research

db
Enc.

LAND RESOURCE INVENTORY
SATELLITE INFORMATION SYSTEM
PHASE I

PROPOSAL

To develop and demonstrate the operational capability to provide and maintain by means of satellite remote sensing the necessary current information base on natural resources and the use of the land by people to city, county and state government in the Pacific Northwest Region.

BACKGROUND

The successful proving-out since 1972 of the Earth Resources Technological Satellite (ERTS-1) and the continued interest of Congress in the Federal Earth Resources Satellite program (3 bills currently under discussion) makes it feasible to begin the development of a regional system in the Pacific Northwest. Federal grants for the direct support of regional operational centers are expected to be slow and meager for the next 3 years but we can expect to get limited help from current level federal (NASA and USDI) remote sensing support to our region for research and training. This support is now \$150,000 annually. Direct federal support might, in pertinent areas, also be sought.

BASIC CHARACTERISTICS OF THE SYSTEM

The satellite platform for remote sensing is advantageous because of its dependable repetitive coverage of large areas allowing for routine detection and quantification of change and for continuously increased accuracy in identification. However, these same capabilities dictate the use of computer storage of the data. Manual interpretation of images on which we have relied for years in our use of low altitude aerial photography, will support and supplement the present ERTS Satellite System.

MAJOR JOBS WE CAN DO WITH THE CURRENT (present through 1978) ERTS SYSTEM

1. Classification and quantification by acreage of land areas into Level 1 land use categories as urban, agricultural, rangeland, forestland, coastal zones, water, barren land, etc.
2. Detection and monitoring of land use and environmental quality changes in land areas listed above.

3. Classification and monitoring of land areas into certain Level II land use categories as urban areas into Commerce-Industry, older and newer residential and forestlands into forest types (deciduous vs. evergreen, etc.). In some cases even greater detail can be monitored as progress of clearcutting and status of regrowth. Similarly in agriculture, the particular crop can be rather accurately identified where fields are 20 to 40 acres or larger and in rangelands where forage conditions can be determined and used in scheduling grazing control programs. Other special tasks include monitoring irrigated acres, monitoring snow pack extent, etc.
4. Detection and/or monitoring of some types of disaster such as insect and disease damage, and flood, draught, freeze or wind damage.

IMPROVEMENT IN UTILITY IN THE FUTURE (1978 ON)

Current federal plans for EOS (Earth Observational Satellite) to be launched in 1978 call for more frequent coverage (every 5 to 9 days vs. present 18 day cycle for ERTS), and the addition of a thermal infrared channel (8-13 microns) to allow sensing of emitted infrared energy from terrestrial objects. The projected EOS will have much greater power for identification and monitoring so many more tasks can be performed. However, it will result in even greater quantities of data and need for greater computer and data storage and retrieval capacities.

FEASIBLE NEAR TERM DEVELOPMENT PLANS OF A N.W. REGIONAL SATELLITE REMOTE SENSING INFORMATION SYSTEM

Rationale and Purpose

As mentioned above, the main reason for considering an integrated regional system is to share high capital costs of computational equipment and the services of highly trained technicians. Further obvious advantages will include development of a common data base for natural resources and simplify coordination with the developing Federal Earth Resources Satellite system.

Experience has shown that successful transfer of this technology must involve user participation from the outset. This will require full cooperation from state agency administrators and key personnel who will make the newly derived information an integral part of their day to day information gathering system. It would seem that a significant amount of Regional Commission funds might be spent for released time from assigned duties so the key personnel of the agencies can work on the development of the system. This budgetary commitment will then limit the funds available for computational and data processing equipment. However, it would be wise at the outset to make use of any existing

and available digital analysis equipment and staff and retain title to whatever equipment must be purchased so it can be used later in a fully operational regional system.

PROPOSED PLAN

1. Each state might select an area in which efforts toward a regional satellite information system would be concentrated in the first 2 years. Candidate areas might include: Oregon--north sections of the Willamette Valley--or selected coastal areas; Washington--Puget Sound Area; Idaho--Snake River Valley; and other areas within the 3-state region, such as the Spokane-Kellogg and the Portland-Vancouver areas.
2. Each state should identify up to 8 state and local agencies interested in ERTS remote sensing information in the region selected for concentrated effort. Within each agency, personnel should be identified who will be responsible for interpreting the ERTS data and working it into their information system. Among these personnel at least one person should be named to engage actively in computer-assisted interpretation of the ERTS data. As the project progresses, workshops will be conducted for the purpose of involving local planning personnel.
3. Current computer-assisted interpretation capabilities and experienced staff exist in the region at Oregon State. We should make full use of this asset by supplementing their support and asking them to help by actively engaging in cooperative work with state agency personnel selected in item 2 above. Assigned state and local personnel should work with remote sensing data in OSU laboratories on their own agency problems in the region of their state selected for early concentrated effort. OSU staff (with qualified staff from other agencies and universities in the region as consultants) will work with the state and local agency personnel to help them extract information from the ERTS data and with incorporating the information extracted into their agency's information system.
4. The participating agency personnel as they gain experience and define problems will be a strong asset to the Land Resource Inventory Task Force in planning the second and third year of the development of a Regional Operational Remote Sensing Information System. Their recommendations on kinds of data processing equipment needed within each state and the feasibility of considering establishment of a central regional facility to serve all 3 states might be expected to be pertinent and cogent.
5. Release a request for proposals for consultant evaluation based upon review of state and local agencies' experience and an overall evaluation of the informational needs of local and state land use

planning and management agencies in the region. The objective of this is to get an impartial evaluation of usefulness of information to state and local government.

MANAGEMENT RECOMMENDATION

The Land Resource Inventory Task Force should retain management responsibility to enable continuous monitoring and evaluation throughout the study period.

TENTATIVE FIRST YEAR BUDGET
THROUGH DECEMBER 31, 1975

I. Personnel Costs		
1.	Released time for state agency personnel; payable direct to state agency --Personnel estimated as 1 person from each of 8 agencies in 3 states or 24 persons with each person spending one-quarter time. This gives a total of 4.5 F.T.E. at an estimated salary rate of \$16,000--	\$ 84,000
2.	Indirect cost to state agencies (15% of salaries)	12,600
3.	Subsistence of state agency personnel while at OSU interpreting ERTS data. Estimated each person would spend \$15/day, 3 days/wk. for 3 weeks/mo. of his 3 months of activity. Cost would be \$405/person x 24 persons	9,820
4.	Travel of state agency personnel to Corvallis	8,070
5.	OSU, personnel, released time for staff to guide state agency personnel 4 staffs, 0.5 F.T.E. @ \$16,000 and 1 staff 0.75 F.T.E. @ \$18,000	45,500
6.	OSU, student wages	2,400
7.	OSU, secretarial time	2,000
8.	Indirect costs to Oregon State University (15% of salaries and wages)	7,500
II.	Computer Time (estimated)	33,000
III. Supplies		
1.	ERTS Computer Compatible tapes (to be purchased from NASA) plus formatting costs	8,600
IV.	Travel for Consultants from Regional Universities	6,510
V.	Consultant Evaluation	30,000
	TOTAL	\$250,000



ARIZONA RESOURCES INFORMATION SYSTEM

3500 N. CENTRAL SUITE 118

PHOENIX, ARIZONA 85012

(602) 271-4061



CARL C. WINIKKA, P.E.
Project Director

October 9, 1974

Frank R. Hammill, Jr., Counsel
Committee on Science and Astronautics
House of Representatives
Suite 2321 Rayburn House Office Building
Washington, D. C. 20515

Dear Mr. Hammill:

Thank you for your letter of September 24th concerning hearings of the Subcommittee on Space Science and Applications of the Committee on Science and Astronautics, US House of Representatives.

The State of Arizona has a high interest in Earth Resources Survey Systems, both from the standpoint of our electronics industry and from the standpoint of being a user of the products of the Earth Resources Survey Systems. This letter will concern itself with the latter.

Arizona is conducting, together with the National Aeronautics and Space Administration and the US Department of the Interior, a continuing experiment in the application of high altitude aircraft and space imagery to matters relating to land and resources. Under this experiment, known as the Arizona Land Use Experiment, NASA has photographed the State using U-2 aircraft. Numerous uses and applications of this photography have been made in a variety of fields including transportation, natural vegetation and agriculture. Although primary emphasis is placed on high altitude photography, the experiment includes the use and evaluation of space imagery, particularly from the Earth Resources Technology Satellite (ERTS) and Skylab. An objective of the experiment is to develop a plan for the use of space, high altitude, low altitude and ground information in a combined program to apply such information.

It is with this background that the following comments are submitted in response to your letter.

Under the Arizona Land Use Experiment, our limited experience to date would indicate that information of the type detected from space will

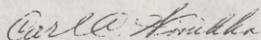
have a particular application in Arizona. We have a sizeable state with large, relatively uninhabited areas being managed under a variety of Federal, State, Indian, Local and private programs. The comprehensive multi-spectral synoptic view of these areas from space is affording Arizona an unprecedented opportunity to view the seasonal changes in such items as natural vegetation, agricultural activity and snow cover over broad areas. The continuance of ERTS-1 type coverage is especially important since one of the primary applications of this imagery is to monitor large areas for the purpose of detecting and recording changes.

As of this date we are experimentally applying ERTS imagery by combining the monitoring capability of ERTS with particular base maps and photo information of our State. Of course, this has been an "after the fact" type application since there has been a considerable time gap between the date of imagery and the date of our use. We have therefore concerned ourselves with seasonal changes and are currently in contact with numerous agencies on this type application on an experimental basis. Although we feel a number of potential applications exist, actual users in an operational sense have not been identified.

Continuity, resolution and timeliness of data would be critical in an operational program. The current experimental program has performed very well within the constraints of the program and its responsiveness is continually being improved. Imagery quality has often surpassed expectations and we, among other users, tend to utilize this in an operational mode comparing it to high resolution photography. We believe that a greater resolution would indeed be most useful, however we also feel that ERTS imagery in particular can or should be used in conjunction with existing maps and photography. ERTS is capable of monitoring particular changes which, when compared to the base material, can be identified in a manner not possible utilizing only ERTS.

To summarize, our experience to date would indicate a number of potential applications of ERTS imagery, some possible in an operational mode. We feel however, that additional experience with the continuing experimental coverage is essential to arrive at a valid evaluation since this is a new technology to most operational agencies.

Sincerely,



Carl C. Winikka,
Project Director

CCW:jh

IOWA GEOLOGICAL SURVEY,
Iowa City, Iowa, October 15, 1974.

HON. JAMES W. SYMINGTON,
The House Committee on Science and Aeronautics,
Washington, D.C.

DEAR CONGRESSMAN TEAGUE: We are furnishing our Remote Sensing Laboratory newsletter in the hope that it will increase awareness of how states are utilizing remotely sensed data, particularly remotely sensed data from the ERTS Satellite System. We are particularly concerned that no provisions exist to insure that ERTS data will continue to be made available to users on the state and federal level. "Operationalizing" the ERTS system should allow the development of the organizational framework for analysis of our earth resources from spacecraft, satellites, and aircraft, as cost-effectiveness dictates.

The major contribution of the ERTS System will be in the area of rapidly updating digital land use and resource information in state and federal data banks. No aircraft underflight program can better provide, at lower costs, the synoptic, repetitive, and multispectral digital data required for rapid and effective updating of land use and resource information in our state data bank. The proposed formal establishment of an operational ERTS System should provide the organizational framework for application of new digital processing technology as it evolves.

If you have further questions regarding any aspect of our program, or desire additional publications, do not hesitate to contact me personally.

Sincerely,

James V. Taranik,
Chief of Remote Sensing.

IOWA REMOTE SENSING LABORATORY

Iowa Geological Survey
 16 West Jefferson Street
 Iowa City, Iowa 52240
 319-338-1173

Samuel J. Tuthill
 State Geologist

James V. Taranik
 Chief of Remote Sensing



Raymond R. Anderson
 George R. Hallberg
 Bernard E. Hoyer
 Logan K. Kuiper
 James R. Lucas
 Jean C. Prior

 NEWSLETTER Vol. 4, Number 1

 26 August 1974

AMANA OAK WILT SURVEY

Iowa Geological Survey Remote Sensing Laboratory (IGSRSL) has recently joined with the Iowa Conservation Commission in a multi-year study of the occurrence and development of Oak Wilt in the forests surrounding Iowa's historic Amana Colonies. Oak Wilt (*Ceratocystis fagacerum*) is a vascular wilt that affects oak trees much in the same manner that Dutch Elm Disease has affected the American Elms.



Oak Wilt has been in Iowa since the 1930's when it first appeared at Pilot Knob State Park in northeastern Iowa. Mechanisms governing the spread of the disease are not completely understood, however, apparently it can spread by root grafts, insects, and possibly by squirrels. According to Daniel Brown, pathologist for the Division of Forest Pest Control, U.S.D.A., St. Paul, Minnesota, unlike Dutch Elm Disease, Oak Wilt only affects small stands of timber, seldom over an acre in size.

The Amana Colonies were founded in 1854 and the seven colonies cooperatively own 25,000 acres of land, of which 10,000 acres are forested. Amana forest land is one of the best timber stands in the state of Iowa and this timber is used in the manufacture of world famous Amana furniture.

Iowa Conservation Commission and Iowa Geological Survey Remote Sensing Laboratory jointly acquired color and color infrared imagery of the Amana timberland on 23 July 1974. A joint imagery analysis team was formed and has met in Iowa City to view the imagery at IGSRS. The imagery is being evaluated by Roy Hatcher, John Beamer and Bob Hibbs of the Iowa Conservation Commission; Don Linsey, the Amana Society Forester; Dan Brown and Keith Hanson of the U.S. Department of Agriculture; and Ray Anderson of IGSRS.

Preliminary evaluation of the imagery and field checks showed that trees affected by the wilt were easily discernible on both color and color infrared imagery. The U.S. Forest Service is sending experts to sample the diseased trees and will produce Oak Wilt cultures from the trees to confirm detection of the disease. Image interpretation keys are being developed by this ground sampling approach and also by ground based photography. Once this phase of the study is complete then the extent of the Oak Wilt will be mapped. Yearly flights will be conducted to study spread of the disease and for development of containment procedures.

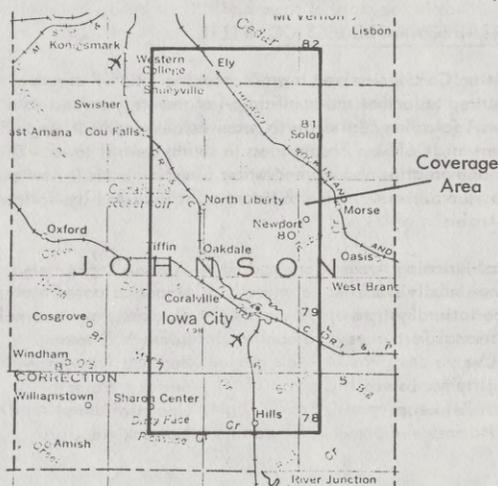
GUIDE TO AERIAL IMAGERY OF IOWA TO BE PUBLISHED

During the deliberations of the Iowa Map Advisory Council over the past two years the problem of duplication of effort in the area of imagery acquisition became apparent. The Map Advisory Council established an Air Photo Subcommittee, chaired by Mr. Richard Riley, of Iowa Power and Light Company. This committee requested that IGSRS compile an index of Iowa imagery so the problem of redundant data acquisition could be analyzed. This index is now available to the public. After analyzing the index, the Iowa Map Advisory Council recommended to Governor Ray that IGSRS be designated as a clearing house for state remote sensing acquisition, data analysis, and for the maintenance of an atlas of available imagery.

IGSRS expects to publish the first edition of this atlas as "A Guide to Aerial Imagery of Iowa" in September 1974. The guide has short discussions on aerial photography and remote sensing including: The electromagnetic spectrum, aerial cameras, films, platforms, scale and coverage, and times of imagery acquisition. The index is arranged around 15 planning regions in Iowa. Coverage of these areas by government acquired imagery is plotted on one page while private industry coverage is plotted on a separate page. The "guide" includes illustrative samples of all common imagery types utilized in Iowa.

JOHNSON COUNTY SOIL MAPPING MISSION

On 3 May 1974 Iowa Geological Survey Remote Sensing Laboratory (IGSRL) flew portions of Johnson County for landuse and soils analysis. This was a cooperative venture between IGSRL, and the U.S. Soil Conservation Service located in Johnson County. The SCS is completing a comprehensive soils survey of Johnson County and has been conducting soils mapping with 1:40,000 black and white imagery, enlarged to 4 inches to the mile. Soil teams have now been provided with color and color infrared imagery at the same scale for purposes of comparison.



The aerial mission was flown two days after a moderate rain, in clear and cold weather and the imagery acquired was judged excellent. Mission design included utilization of a 6-inch focal length metric camera flown at 8,000 ft. above mean terrain. Kodak 2448 (color) and 2443 (color infrared) films were processed to positive transparencies and positive prints were contact printed, 4 inches to the mile, for comparison with black and white imagery. False color infrared imagery sharply delineated poorly drained and well drained soils. However, differences in soil coloration were not as apparent on color infrared film as with normal color film. The SCS mapping teams found that the color films contained more soils data than black and white film. The major limitation in using color prints for soils mapping was the glossy finish which would not permit soils field mapping, except with plastic overlays. This is a serious limitation which restricts the use of color prints in field work. Field mapping requires a matte surface, which will take pencil and which will be moisture and dust repellent. High quality, clear

matte spray finishes are available which accept a pencil line without obscuring details of the photographs. Use of this spray appears to make even high gloss photographs acceptable bases for soils mapping. The SCS will test this approach to field mapping in October.

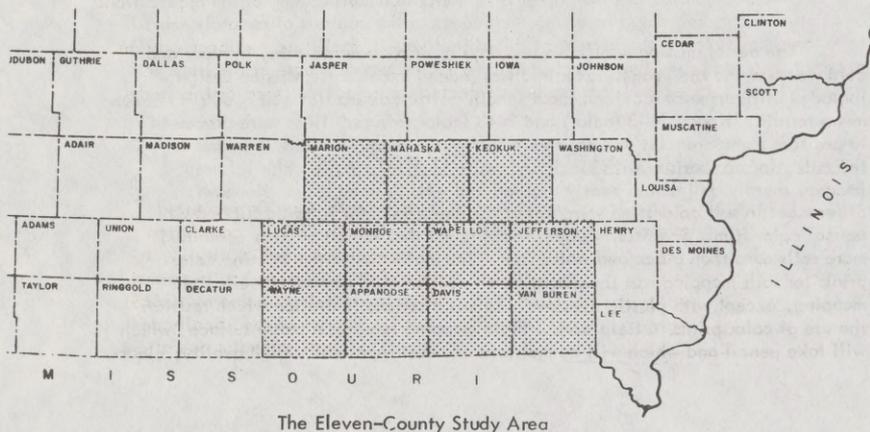
In general, color infrared film was found to be best for soils mapping and for landuse analysis. Complete results of this investigation will be reported in a public information circular.

SOUTH-CENTRAL IOWA PROJECT COMPLETE

Last year IGSRL received a grant from the EROS Program of the U.S. Geological Survey to further the application of remotely sensed data from the Earth Resources Technology Satellite to resource development land- and water-use management of an eleven county area in south-central Iowa. This project is now complete and an atlas of land and water planning maps is now available as Miscellaneous Map Series 4. The published atlas included the following maps at 1:125,000 scale:

Critical Planning Areas
Political Subdivisions
Transportation Systems
Recreational Resources
Land-Use
Suitability for Landfill
Mineral Resources
Flood Hazards

Surface Topography
Unconsolidated Materials
Thickness of Unconsolidated Materials
Bedrock Geology
Bedrock Topography
Surface Water
Unconsolidated Aquifers
Bedrock Aquifers



The final technical report was submitted to the EROS Program Office for review in January 1974 and when returned will be published as a public information circular. This report summarizes the multistage sampling approach utilized in evaluating the utility of ERTS imagery. Imagery utilized in this analysis included low-altitude, black and white photography acquired by the U. S. Soil Conservation Service, U. S. Agricultural Stabilization and Conservation Service, and U. S. Geological Survey; multispectral photography acquired by IGSRL; NASA high-altitude color infrared imagery; and Skylab imagery. The purpose of the study was to determine what scales, accuracies, and formats of imagery would be most applicable to land cover inventory at the city, county, regional, state, and national levels. A secondary objective was to determine the planning relationships between remotely sensed information and surface and subsurface information.

ERTS-1 FOLLOW-ON PROPOSAL SELECTED BY NASA

On 25 January 1973 IGSRL submitted an ERTS-B proposal to the National Aeronautics and Space Administration. This proposal has now been tentatively approved pending contract negotiations. James V. Taranik, Chief of Remote Sensing for Iowa Geological Survey, was selected as principal investigator and Frederic C. Billingsley, Supervisor of the Science Data Analysis Development Group of the Jet Propulsion Laboratory of the California Institute of Technology, will be co-investigator. Both IGSRL and JPL propose to apply existing automated data processing techniques to ERTS-B digital tapes to produce enhanced satellite images of the Iowa landscape. These enhanced images would have land classifications related to sufficiently separated, discrete density levels. Computer enhanced single-band and multiband products derived from ERTS-B digital tapes will be used to produce color thematic maps of land classifications of south-central Iowa for their evaluation and use. The long-term objective of this project is to increase understanding of the applications of existing automated data processing techniques to the analysis of remotely sensed data from satellites. Achievement of this objective will facilitate the incorporation of remotely sensed data into an enhanced, computerized data base at the state and national level. James R. Lucas has been selected as project manager for this study.

ELEVEN COUNTY ENVIRONMENTAL QUALITY INVENTORY

In May, 1973, the Iowa Department of Environmental Quality requested from the U. S. Environmental Protection Agency, Region VII Office, completion



of an environmental quality inventory of the 11-county south-central Iowa area, being studied by IGSRL. This inventory was specifically designed to identify feedlot operations,

sewage lagoons, and other waste disposal sites. EPA Region VII was able to arrange, through the EPA office of Research and Development in Washington, D.C., a high-altitude overflight of the eleven county area last October. The mission was flown from an altitude of over 70,000 feet with an Itek 24-inch optical-bar camera, and the imagery acquired allowed detection of small animals in feedlots.

The EPA Environmental Photographic Interpretation Center (EPIC) at Vint Hill, Virginia, prepared county mosaics from the imagery and inventoried nine categories of land cover having environmental quality significance. EPIC staff have been preparing a variety of products for use by Iowa state agency personnel. Each of the eleven Iowa counties has been divided up into five or six areas and a photo-mosaic has been produced at 1:34,000 scale. The photo-mosaics are annotated showing locations of feedlots, etc. and are printed on mylar masters, so inexpensive reproductions can be rapidly manufactured in Iowa for field work. The results of this state and federal cooperative effort were reported to the Interagency Resource Council meeting last July 19th. If your agency has questions about these products, contact IGSRL for additional information.

RECENT ENVIRONMENTAL QUALITY REMOTE SENSING INVESTIGATIONS

The U. S. Environmental Protection Agency has been monitoring power plants in Iowa for thermal discharges. In April, 1974 twenty-two Iowa electric power plants were monitored by EPA Remote Sensing aircraft based out of Las Vegas, Nevada. These plants include the following:

Cordova, Illinois
 John Deere
 Dubuque
 Ft. Calhoun
 Iowa Power and Light, Des Moines
 Corn Belt Power Coop, Humboldt
 Iowa Electric Light & Power, Iowa Falls
 Interstate Power Company, Willow Creek & Mason City
 Iowa Public Service, Waterloo
 Central Iowa Power Coop, Cedar Rapids
 Brownsville, Nebraska
 North Omaha, Nebraska
 --and several plants in the Sioux City - Council Bluffs areas.

Thermal data was acquired with a Texas Instrument RS 310 Scanner which operates in the 8-14 micron portion of the electromagnetic spectrum. Imagery is being analyzed at the EPA-NERC Laboratory in Las Vegas and the results are being furnished to EPA Region VII personnel for enforcement purposes.

The Iowa Department of Environmental Quality recently requested that IGSRL acquire low-altitude color infrared imagery of feedlots in northwest Iowa for enforcement purposes. This imagery was acquired in August and is now

being analyzed by DEQ and IGSRL staff. Because of the large number of feedlots in this area of Iowa, the Department of Environmental Quality will also request from the U. S. Environmental Protection Agency Region VII office that a complete inventory of 15 northwest Iowa counties be conducted utilizing NASA high-altitude aircraft, color infrared film, and the 24-inch optical bar system. This inventory should be complete in the fall of 1975.



POLK COUNTY LANDUSE STUDY

IGSRL staff recently conducted an evaluation of the utility of NASA high-altitude color and color infrared imagery for land cover (landuse) inventory. The study included an evaluation of the adequacy of existing landuse classification schemes as well as the rate at which interpretation could be accomplished. The test

site included Polk County and the city of Des Moines. The imagery was acquired at 1:120,000 scale by NASA, as a part of the ERTS-1 underflight program. Land cover mapping was accomplished using a B & L zoom transfer scope to produce maps at 1:62,500 scale. Polk County, (594 sq. miles) was analyzed in 15 man hours. This short analysis time is encouraging because this indicates that all of Iowa could be inventoried in 3/4 man months.



Two land classification schemes were compared: (1) the U. S. Geological Survey scheme developed by Anderson, Roach, and Hardy (1972), as outlined in U.S.G.S. Circular 671; and (2) an adaptation of the Standard Land Use Coding Manual used by the Department of Commerce. The USGS system proved most usable with color infrared imagery, however, this classification scheme did not meet the requirements of the local and regional planning agencies. The U. S. Department of Commerce system was too specific for use with remotely sensed data, and a ground survey would be mandatory for inventory of many categories using this system. Two products are available from IGSRL:

1. A 1:62,500 scale map of Polk County landuse which can be reproduced from a mylar master. This map was produced using the U.S.G.S. system and color infrared imagery.
2. A 1:24,000 scale map of a portion of Des Moines, made from imagery using the Standard Land Use Coding Manual system.

EPA REMOTE SENSING REORGANIZATION

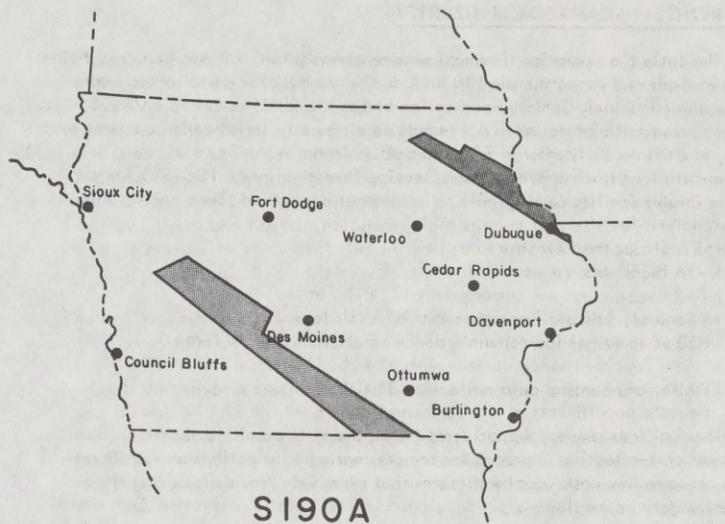
Recently the operational remote sensing arm of the U. S. Environmental Protection Agency was restructured to include the Vint Hill facility in the National Environmental Research Center organization at Las Vegas. The EPA Las Vegas NERC Facility has been the center of EPA's remote sensing activities for the past several years, and until recently most of EPA's activities in the remote sensing field have dealt with acquisition of low-altitude data. Development of the EPA Photographic Interpretation Center facility at Vint Hill, Virginia, has now given EPA a sophisticated imagery analysis facility that permits high-resolution aircraft and spacecraft to be interpreted. Under the new structure the Vint Hill laboratory will be an associate laboratory to NERC Las Vegas.

In general, EPA staff envision that high-altitude aircraft and satellite imagery will be utilized to target low-altitude documentation missions for enforcement purposes.

EPA Remote Sensing data collection missions are best arranged by working through the state departments of environmental quality to the EPA Region office. EPA regional offices request support from NERC Las Vegas and the staff there defines the optimal cost-effective approach for remote sensing data collection. Coverage of large areas at low costs usually dictates that synoptic high-altitude aircraft or satellite imagery be employed.

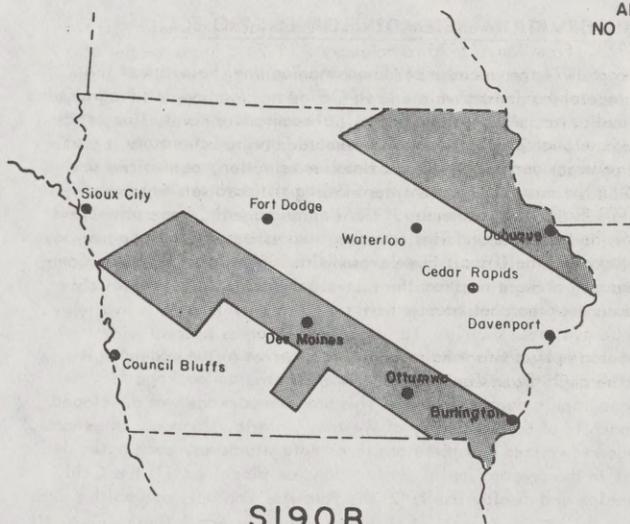
SKYLAB COVERAGE OF IOWA

Skylab, the world's first manned orbital workshop, was inhabited by its first crew on May 25, 1973. From May, 1973 to February 8, 1974, a large number of photographs of the earth were produced. Because of spacecraft system malfunctions not all planned photographic missions were completed. Also problems with use of improper filters, cloud cover, etc. rendered many of the photographs useless. Of the six Skylab tracks, whose photography would have included portions of Iowa, only four actually produced useful imagery. There were two camera systems aboard the Skylab used for photographing the earth. These are the S190A Multispectral Photographic Facility and the S190B Earth Terrain Camera. The map on page 9 shows statewide coverage for each of the two systems. This coverage (the white areas on the maps) is a composite of images returned by all three crews with 30% or less cloud coverage. To date, the photography brought back by the second crew mission is not available in its entirety, and none of the photography from the third crew mission is available. All imagery should be available shortly. To identify those areas in Iowa with available Skylab photography, contact Ray Anderson at the Iowa Geological Survey (319) 338-1173 or the EROS Data Center (605) 594-6511.



S190A

AREAS OF
NO COVERAGE



S190B

Skylab Coverage of Iowa

CONSERVATION COMMISSION AIRCRAFT

The Iowa Conservation Commission recently acquired a Piper Aztec-E, twin-engine aircraft and fitted the aircraft with a 22-inch port for aerial photography. Iowa Geological Survey Remote Sensing Laboratory (IGSRSL) acquired an A-28 Aeroflex Gyrostabilized mount to accommodate K- and T- series aerial cameras in this aircraft, and the U.S. Air Force has provided, on loan to the State of Iowa, two T-11 aerial cameras for use in applied remote sensing investigations. IGSRSL also has available other aerial camera systems for state agency use and these systems include:

I²S Multispectral Camera

- K-17 Reconnaissance camera with 6" F.L. lens
- KA-2 Reconnaissance camera with 12" F.L. lens
- K-22 Reconnaissance camera with 36" F.L. lens
- K-38 Reconnaissance camera with 24" F.L. lens (9 x 18 format)
- KA51A Reconnaissance camera with 6" F.L. lens (4½ x 4½ format)
- KA62A Reconnaissance camera with 3" F.L. lens (4½ x 4½ format)

Metric photography, for topographic plotting, is usually acquired through private aerial contractors. Reconnaissance photography for earth resources investigations by state agencies can be arranged, at relatively low costs, using the cooperative data collection system developed by the Iowa Conservation Commission and Iowa Geological Survey. If your agency has further interest please contact, Iowa Geological Survey Remote Sensing Laboratory or the Iowa Conservation Commission.

LAND-RESOURCE INFORMATION SYSTEM, DEVELOPMENT PROJECT

In the spring of 1974 the Institute of Urban and Regional Research of the University of Iowa received a grant from the Iowa Office of Planning and Programming to develop a pilot land information system that will accommodate point, line, and polygon types of data. Iowa Geological Survey Remote Sensing Laboratory is participating, under subcontract and has assisted in data set selection, definition, and documentation. IGSRSL is assembling and preprocessing the data sets to be computerized. The data sets being furnished by IGSRSL include; soils, vegetation (and landuse), topography, political boundaries, streams, watersheds, subsurface geology, and transportation links and facilities. The Johnson County Regional Planning Commission is assembling a land ownership map for non-subdivided areas and the City of Des Moines is digitalizing preprocessed data sets.

Storage and retrieval of this land resource information in the computer is being accomplished through the utilization of a modified program package for handling selected geographic data structures. This program package was developed by Michael F. Goodchild of the University of Western Ontario, Canada. In general, this program package recognizes that there are three data structures, each optimal at a particular stage in the preparation of data for landuse planning: (1) the Grid, optimal for the planning and display itself; (2) the Parawise Contact, optimal for data storage; and (3) the Image Center, optimal at the encoding stage. A final report will be submitted to the Iowa Office for Planning and Programming in September.

REMOTE SENSING PROGRAMS IN OTHER STATESMissouri

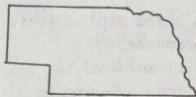
A statewide agency reorganization in Missouri has created a Remote Sensing and Cartographic Data Center. This center was established within the new Division of Research and Technical Information in the Missouri Department of Natural Resources. The Division of Research and Technical Information also includes the Office of the State Geologist, and the new Remote Sensing Center is located in the Missouri Geological Survey Building in Rolla, Missouri. The organizational structure of the new program has been created, however, actual funding will not be approved until 1 July 1975. The U. S. Geological Survey, Topographic Division Office in Rolla, Missouri is developing a user assistance center, which will operate in close cooperation with the Remote Sensing Center. For additional information contact:



Mr. David Rath
Missouri Remote Sensing and
Cartographic Data Center
The Buehler Building
Rolla, Missouri
(314) 364-1752

Nebraska

In September, 1973 the State of Nebraska formed a Remote Sensing Center. This center is within the Conservation and Survey Division, of the Institute of Agriculture and Natural Resources, located at the University of Nebraska in Lincoln. The Conservation and Survey Division also includes the Nebraska Geological Survey. The purpose of the Remote Sensing Center is to provide service and information to state agencies, the general public, and industry. Recently the remote sensing center published an ERTS-1 state photo map and state landuse map derived from ERTS-1 data at a scale of 1:1,000,000. The center publishes a newsletter; for additional information contact:



Dr. Rex Peterson
Remote Sensing Coordinator
Conservation and Survey Division
113 Nebraska Hall
University of Nebraska
Lincoln, Nebraska
(402) 472-3471

"OPERATIONAL" ERTS SYSTEM?

The U. S. Senate Committee on Aeronautical and Space Sciences is currently studying two bills (S. 2350 and S. 3484) which separately propose to establish an Office of Earth Resources Survey Systems in NASA or an Earth Resources Observation Administration in the Department of the Interior. Currently there exists no provisions to insure that ERTS data will continue to be available to users at the state and federal levels because ERTS is being maintained as a research and development project. Both articles of legislation will probably be combined into one bill that will allow NASA, U.S. Department of Interior and U.S. Department of Agriculture to jointly develop a program to analyze our earth resources from satellites, spacecraft, or aircraft, as cost-effectiveness dictates. The Iowa Geological Survey Remote Sensing Laboratory staff are highly supportive of the proposed establishment of an "operational" ERTS system because formal establishment means development of the organizational framework for application of new earth resources management technology as it evolves. Persons having opinions on this matter are urged to write:

Committee on Aeronautics & Space Sciences
United States Senate Building
Washington, D.C. 20510

DEVELOPMENT OF APPLICATIONS ASSISTANCE BRANCH AT EROS DATA CENTER

The EROS Data Center, located at Sioux Falls, South Dakota, is developing an Applications Assistance Branch for: (1) Evaluation and documentation of current state-of-the-art remote sensing technology; and (2) transfer of technology to user-applicators at the state and federal levels. The Applications Assistance Branch is headed by Gene Thorley and consists of the Applications Section, the Techniques Section, and the Assistance Section.

The Applications Section will be staffing over the next year to support: mineral resources and civil works survey; landuse survey; agriculture, forest and range management; and water resources management. This section will interface with the general user community and will be responsible for transferring knowledge and techniques on the applications of remote sensor data to earth resources problems, to users at the state and federal levels.

The Techniques Section will be responsible for evaluation of the applications for state-of-the-art remote sensing equipment, techniques, and programs. A major focal point of the techniques section is the development of a Data Analysis Laboratory for extracting information from imagery and electronic data. Beginning

about 1 January 1975 the Data Analysis Laboratory will have as principal hardware/software:

1. A GE Image 100 system interfaced to the EROS Data Center (EDC) computer.
2. An Image Interpretation System, imagery analysis system connected to the EDC computer.
3. Data analysis terminal connected to Purdue Laboratory Applications of Remote Sensing (LARS) 360/67 computer and LARSYSS classification software.

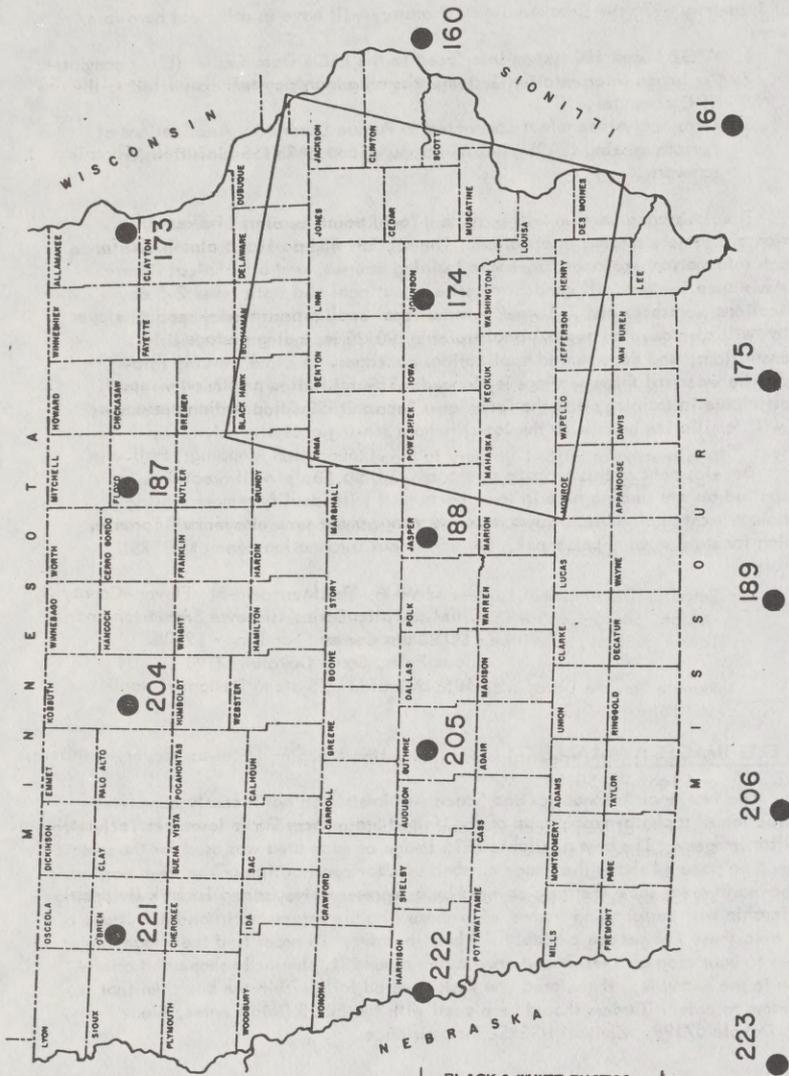
The Assistance Section will provide a focal point for users interested in training and remote sensing information. The section will provide training assistance through information exchange, in-house training courses, and a technical library. The Assistance Section will conduct a series of national and state level 2-5 day applications workshops and 2-3 week international applications workshops. The section will also develop audio/visual training packages, systems capabilities demonstrations, and documented applications packages. A close working relationship between all three sections is planned. This will allow Applications staff to participate in training, and the Techniques Section to develop training packages that will familiarize users with the latest remote sensing analysis techniques.

Development of this program at the EROS Data Center will greatly assist the applied remote sensing here in Iowa because it will identify remote sensing technology most applicable to Iowa resource management problems and will provide training for state agency personnel. For additional information contact IGSRSL staff or:

Dr. Gene A. Thorley
Chief, Applications Assistance Branch
EROS Data Center
Sioux Falls, South Dakota 57198
(605) 594-6511

BEST ERTS IMAGES AVAILABLE

The National Aeronautics and Space Administration has recently completed construction of a photo-mosaic map of the United States from Earth Resources Technology Satellite imagery. The best available ERTS image of each area was used for the mosaic. The map on page 14 shows the image numbers used for construction of the Iowa portion. The boxed in areas show the area covered by a representative frame and its overlapping relationship with surrounding frames. For those who are interested in an ERTS image of their area these images are probably the best to order. To order find the image center closest to your area of interest and draw a box around it, similar in shape and orientation to the example. If the area you wish covered falls within the box then that is the frame to order. Orders should be placed with the EROS Data Center, Sioux Falls, South Dakota 57198. Contact IGSRSL for assistance.



COLOR PHOTOS		
SINGLE PHOTO	9" X 9" (1:1,000,000)	\$7.00
	20" X 20" (1:500,000)	\$15.00

BLACK & WHITE PHOTOS		
SINGLE PHOTO	9" X 9" (1:1,000,000)	\$1.75
	20" X 20" (1:500,000)	\$3.50
COMPLETE SET	9" X 9" (1:1,000,000)	\$7.00

PUBLICATIONS LIST

- _____ Remote Sensing; A Tool for State Planning Management: Tuthill and Taranik, \$0.25.
- _____ Thermal Remote Sensing on the Mississippi River in Iowa: Tuthill, Taranik, and Hoyer, \$0.25.
- _____ Proceedings of the Seminar in Applied Remote Sensing: Parker editor, Public Information Circular number 3, 181 pages, \$0.85 plus \$0.30 for postage.
- _____ Aerial Flood Mapping in Southwestern Iowa, a preliminary report: Hoyer and Taranik. Preliminary Report 1, \$0.25 including postage.
- _____ Flood Inundation Mapping in Southwestern Iowa, a preliminary report: Hallberg and Hoyer. Preliminary Report 2, \$0.25 including postage.
- _____ Application of ERTS-1 Imagery to Flood Inundation Mapping: Hallberg, Hoyer, and Rango, Preprint, 10 pages, \$0.50.
- _____ An Index of Iowa Spacecraft and Aircraft Imagery: Hoyer and Taranik, Preliminary Report 4, \$0.45.
- _____ Resource Development Land- and Water-Use Management, Eleven-County Region, South-Central Iowa: Misc. Map Series 4, Hoyer, Anderson and Taranik, 35 p., \$7.70 plus \$1.30 postage and handling - \$9.00.
- _____ Remote Sensing Data, a Basis for Monitoring Systems Design: Taranik and Tuthill, \$0.35.
- _____ Seasonal, Multispectral Flood Inundation Mapping in Iowa: Hoyer, Hallberg, and Taranik, \$0.50.
- _____ Summary of Multispectral Flood Inundation Mapping in Iowa: Hoyer, Hallberg, and Taranik: (in press).
- _____ Guide to Aerial Imagery of Iowa: Anderson, Hoyer and Taranik (in press).





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