ECON
INCORPORATED

419 NORTH HARRISON STREET
PRINCETON, NEW JERSEY 08540
Telephone 609-924-8778

Copy 6 This copy contains black and white reproductions of color ERTS images shown in Copy 1.

(NASA-CR-141264) THE ECONOMIC VALUE OF REMOTE SENSING OF EARTH RESOURCES FROM SPACE: AN ERTS OVERVIEW AND THE VALUE OF CONTINUITY OF SERVICE. (ECON, Inc., Princeton, N.J.) 85 p HC $4.75 CSCL 05C G3/43

N75-14212

Unclas
06885

☐ ECONOMIC ANALYSES ☐ OPERATIONS RESEARCH ☐ POLICY STUDIES ☐ SYSTEMS ANALYSES ☐ TECHNOLOGY ASSESSMENT

ECON
INCORPORATED

419 NORTH HARRISON STREET
PRINCETON, NEW JERSEY 08540
Telephone 609-924-8778

74-2002-10

THE ECONOMIC VALUE OF REMOTE SENSING OF EARTH RESOURCES FROM SPACE: AN ERTS OVERVIEW AND THE VALUE OF CONTINUITY OF SERVICE

VOLUME VII

NONREPLENISHABLE NATURAL RESOURCES: MINERALS, FOSSIL FUELS AND GEOTHERMAL ENERGY SOURCES

Prepared for the
Office of the Administrator
National Aeronautics and Space Administration
Under Contract NASW-2580

October 31, 1974

NOTE OF TRANSMITTAL

This resource management area report is prepared for the Office of the Administrator, National Aeronautics and Space Administration, under Article I.C.1 of Contract NASW-2580. It provides backup material to the Summary, Volume I, and the Source Document, Volume II, of this report. The interested reader is referred to these documents for a summary of data presented herein and in the other resource management areas.

The data presented in this volume are based upon the best information available at the time of preparation ar' within the resource of this study. This includes a survey of existing studies plus Federal budgets and statutes. Throughout the analysis, a conservative viewpoint has been maintained. Nonetheless, there are, of course, uncertainties associated with any projection of future economic benefits, and these data should be used only with this understanding.

ECON acknowledges the contributions of Keith Lietzke who authored this volume.

Submitted by: Keith R Lietzke
Keith R. Lietzke

Approved by: George A. Hazelrigg Jr.
Dr. George A. Hazelrigg, Jr.
Study Manager

and: Klaus P. Heiss
Dr. Klaus P. Heiss
Study Director

ABSTRACT

This investigation is concerned with the application of remotely-sensed information to the mineral, fossil fuel and geothermal energy extraction industry. Remote sensing has as its major impact an impressive capability in geologic mapping. Of particular importance is the synoptic ability to detect large subtle features such as lineaments and anomalies which control the localization of minerals and fossil fuels. Many features detectable from satellites are not able to be seen from other data sources. Considerable public and private cost savings have been documented in geologic mapping activities. Unquantified benefits also exist from the possibility of using previously undetected features to accelerate exploitation of resources (new capability benefit). Additionally, the repetitive capabilities of an ERS system allow more frequent and less expensive monitoring of hazards and reclamation.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION AND OVERVIEW: NONREPLENISHABLE RESOURCES

This resource area is concerned with the application of remote-sensed information to the minerals, fossil fuels, and geothermal energy extraction industries. Smelting, refining and energy conversion activities are not considered. Data gathered from the Earth Resources Technology Satellite - 1 (ERTS-1) will be the information used to assess capabilities and benefits accruing to an Earth Resource Satellite System.

The non-replenishable resource extraction industry is obviously a crucial one and its importance has been particularly highlighted in the recent times of energy shortage, inflation, and short supplies of raw materials. The annual production value of non-replenishable natural resources is in excess of $25 billion, with as much as 25% or more going to exploration expenses. Any impact which remote sensing might have on cost savings, however small the percentage, would amount to sizable monetary benefits, e.g., an overall .5 percent efficiency increase in exploration in the industry effected by use of remote-sensed information would lead to a benefit, in cost savings alone, of more than $50 million annually.

The overall reaction of geologists to ERTS-1 imagery has been one of pleasant surprise. The small-scale synoptic view has been significant in contributing information about the subtle, large scale features which are so important in this field--structures such as lineaments, folds, faults, anomalies, tectonic province boundaries, and lithological contacts. ERTS has contributed immediately and significantly to upgrading existing geologic maps and providing the basis for maps where they did not exist.

While it seems possible that some large deposits of minerals such as iron ore may be directly detectable, the major impact of ERTS imagery in this area remains in identifying indicators of mineralization. The mapping of lineaments is done almost effortlessly on ERTS imagery. Lineaments have long been felt to be significant geologic features for exploration purposes; they frequently suggest traps for fossil fuels. Fischer and Lathram have concluded that fractures are the primary control in local mineralization. Saunders and Thomas found mining districts to be coincident with some lineaments and have proposed new sites for mineral exploration based on this relationship (see Figure 1). ERTS images in the Adirondacks led to this distribution of linears: previously known, 232; known but not expressed on available images, 297; and new (unmapped), 329. Using image ratioing and false coloring, Goetz and Rowan* showed that iron-rich products showed up in shades of brown. In the immediate vicinity of the

* See REF 5.4.1.

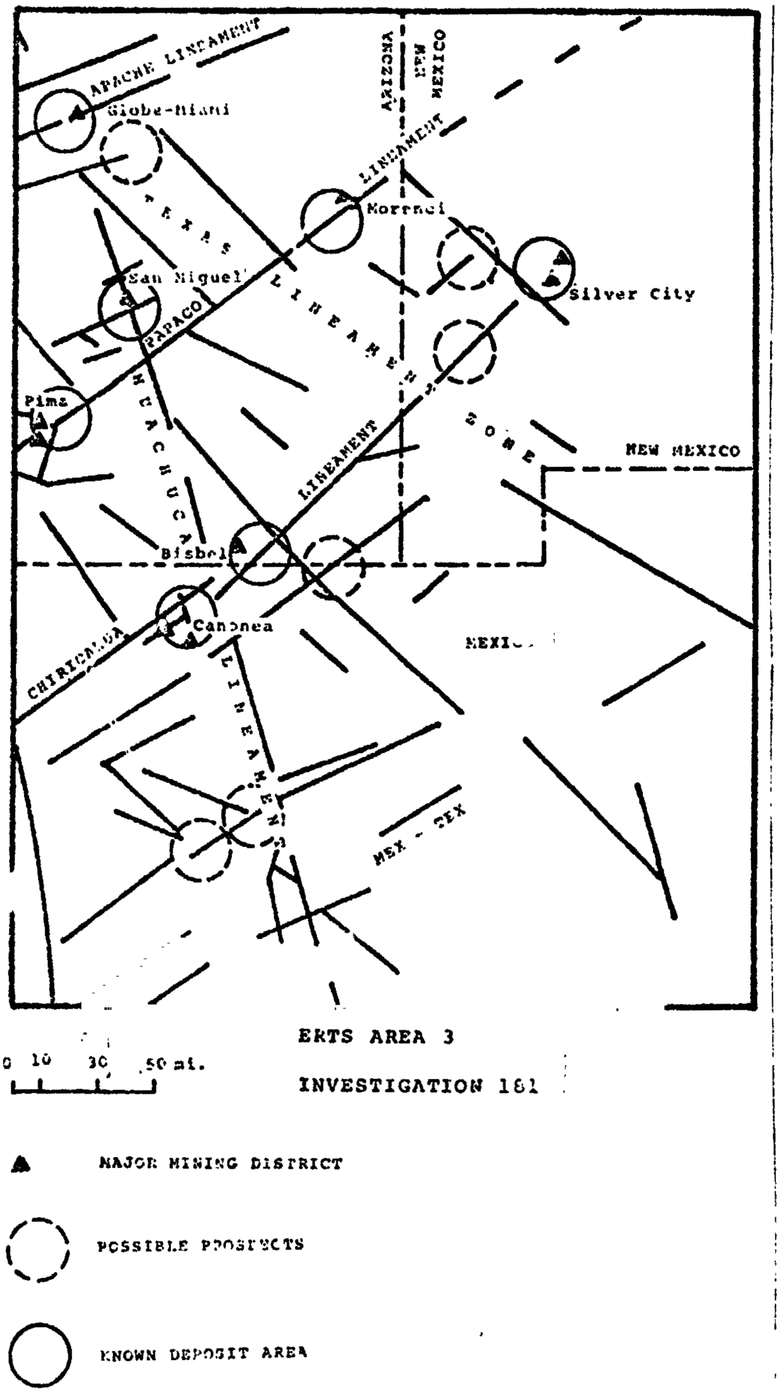


Figure 1 ERTS Lineaments, Major Mining Districts

rich Goldfield, Nevada deposits, the ratioed color composite revealed a distinct circle or halo of brown tones. Work by Knepper and others at the Colorado School of Mines also illustrated that mineralization had a strong correlation with areas of high fracture density and that ERTS imagery was particularly useful in locating these areas. Several ERTS-1 investigators have stated that ERTS images are potentially capable of increasing the rapidity of geologic mapping and reducing its corresponding costs by as much as 30 - 50% in unexplored regions.* As a result of remote-sensed information, Earth Satellite Corporation has participated in an investment venture in some promising-looking mineral sites in Brazil.

Investigators from Eason Oil Company found tonal, "hazy" and closed anomalies in ERTS imagery which had very high correlation with known oil producing areas. In one area 59 of 76 anomalies correlated with producing oil and gas fields and 9 correlated with known but non-producing fields. The "hazy" anomalies, which have had the highest correlation, have only been seen on ERTS-1 imagery; they have not yet been identified on either Skylab or aircraft imagery. However, the nature of some of these anomalies is not yet known; they may be related to hydrocarbon seepage or they may be merely the result of man's activity in the area. Interpretation of the elongation of the lakes shown in the ERTS image of Figure 2 indicates that further oil deposits may be located to the north of the rich Umiat Naval Oil Reserve (See RMF 5.1.1).

Even though the one-time process of geological mapping is the most useful application of ERTS imagery to exploration, the repetitive nature of ERTS has large value here. The presence or absence of vegetation has a real effect on our ability to map geologic boundaries. The detection of geobotanical indicators of mineralization are proving important in this remote sensing application. The seasonal differences in vegetation, therefore, make repetition important. In addition, Wobber and Martin** have effectively demonstrated that light snow cover also aids geologic mapping by suppressing ground cover noise.

Aiding in resource extraction is only one part of the application of remote sensing in this area. Continuity of coverage allows for the monitoring of several dynamic phenomena important to this area, including disturbed lands, reclamation, erosion, glaciation and, with the use of DCP's, volcanic and seismic activity.

---

* Mercanti, "Widening ERTS Applications", Astronautics and Aeronautics, May 1974, p. 31.

** See RMF 5.1.1.

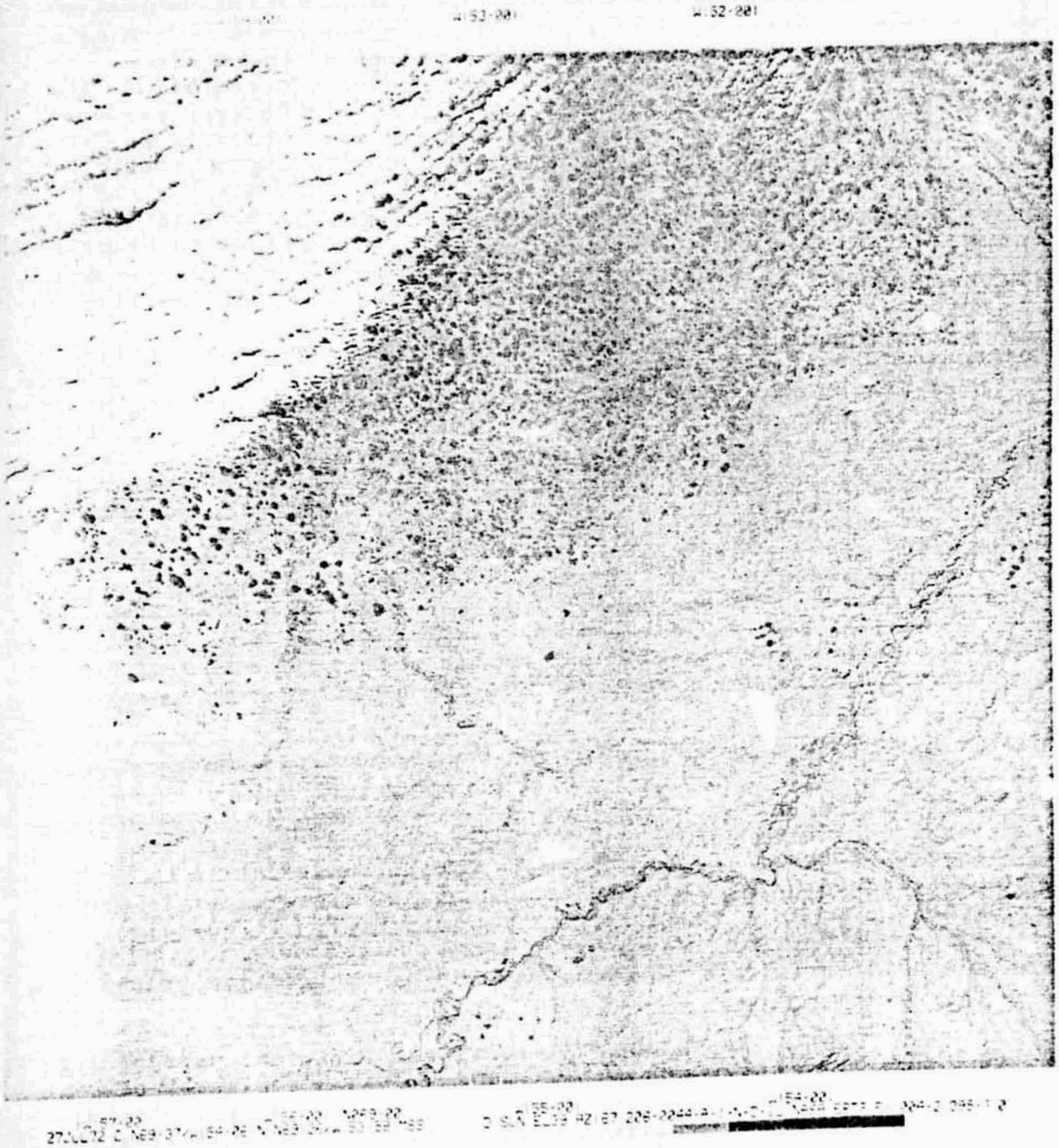


Figure 2 ERTS Image of Lake Structures Near Umiat Oil Field, Alaska

As the demand for energy continues to grow and as the U.S. seeks to become increasingly independent, the large stock of U.S. coal will play a major part in supplying these needs. It will also be likely that this coal will come from strip mines since the man-hour productivity from strip-mined coal is several times the productivity from sub-surface mines. However, the growing environmental awareness has mandated very strict laws about reclamation in several states and threatens to do so in other states and at a federal level, too. All this amounts to a swiftly growing demand for t e monitoring of disturbed lands and their reclamation. ERTS has been shown to be an effective device for this monitoring. Alexander, Dein and Gold have found the imagery useful in determining the location, extent and sub-classification of stripped areas and that it can be used to evaluate the effectiveness of reclamation procedures. Figure 3 illustrates how ERTS-1 imagery has been used to update existing maps of disturbed land. Shown are parts of Pike and Gibson Counties in southwestern Indiana showing strip mine areas previously mapped and that area mapped from ERTS-1 imagery.

By placing tilt meters and seismometers near potentially active volcanoes, the U.S. Geological Survey can gather information of pre-volcanic activity and hopefully help to predict eruption. Similar means are also used to obtain information on earthquakes in remote areas. In this application, ERTS is used as a communications satellite, relaying data gathered by DCP's.

Several investigators including Lattman * and Collins, et al** have expressed the feeling that one of the most valuable contributions of ERTS is that the availability of such imagery has broadened the scale of geological thinking from a local to a more regional format. The investigators discuss in terms of areas of thousands of square miles instead of the customary 15-minute U.S.G.S. quadrangles. Lattman points out that this aspect will be particularly valuable as the demands of problem-solving turn from the local to the regional scale. However, benefits from this adjustment will tend to be evidenced in the long run and probably cannot be fully appreciated at the present.

---

* Lattman, L.H., "Mineral Resources, Geologic Structure and Landform Surveys," Symposium on Significant Results Obtained from ERTS-1, Vol. II (New Carrollton, Md., Goddard Space Flight Center, 1973).

** Collins, et al, "An Evaluation of ERTS Data for the Purpose of Petroleum Exploration," Contract NAS 5-21735, June 1974, p. 8.

This delay in realization of benefits from ERTS is not always the case in this application area, however. Already, remote-sensed data is being used to select regions for exploration and though it is difficult to measure the benefit from the function of choosing a more probable site over a less probable one, the advantage clearly exists. Not so difficult to measure is the benefit of using ERTS imagery to aid exploration within an already-selected region. The Eason Oil investigators have demontrated that as much as 35% of regional geological and geophysical exploration costs can be saved if ERTS imagery is

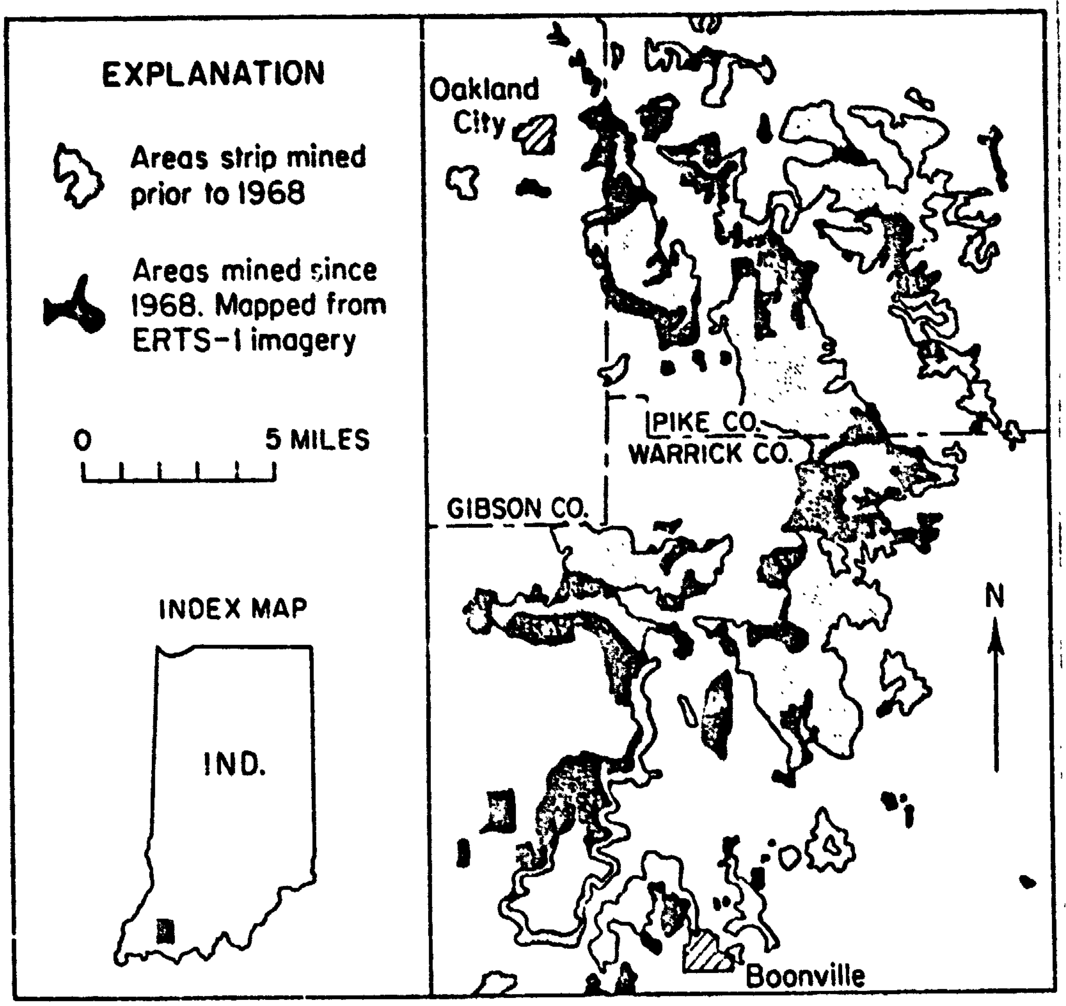


Figure 3 ERTS Strip Mine Inventory. Source: "Fracture Mapping and Strip Mine Inventory in the Midwest by Using ERTS-1 Imagery." Wier, et al, Symposium on Significant Results from ERTS-1, p. 560.

used to aid the study (See RMF 5.4.2). Were the entire industry to apply such data similarly it could lead to an industry cost-savings in onshore G & G of 77 million dollars annually. There is reason to believe that a similar amount could also be saved annually using the imagery for mineral exploration. Immediate cost-savings can also accrue in government G & G operations, annual benefits for the federal sector alone range from .6 to 2.9 million dollars. This estimate assumes the figure of a conservative 7% efficiency increase, estimated by the U.S.G.S. Further benefit could exist from a system with a thermal infrared sensor in the mapping of potential sources of geothermal energy.

It should be noted that these benefits will continue to accrue from only several years, or less, of coverage. A finite amount of imagery, including seasonal changes, will be sufficient for all geologic mapping and exploration purposes, for the information needed concerns static phenomena. Thus benefits in these areas do not justify an operational satellite system.

Benefits for monitoring purposes will be used in justifying the operational system. Disturbed lands and reclamation observations will be the primary functions here; demand will come from both statutory and cost-savings purposes. As these demands are rapidly changing at present, insufficient information is available with which accurate estimates of monetary benefits can be made. Monitoring of mine-related hazards will play a meaningful role for ERTS imagery, and improved resolution will add significantly. The plotting of earthquake epicenters and improved information on erosion, glacial movement and volcanic activity will aid in construction planning and environmental protection.

The actual quantification of potential benefit in this resource area meets with some difficulty for various institutional and technical reasons. Some of these stumbling blocks include:

1) The real possibility that mineral and fossil fuel extraction companies use monopolistic power to suppress competitive supply. Thus the application of ERS information would not be realizing its economic capabilities.

2) The high level of secrecy which exists in these industries for political and economic reasons. The high premium on confidentiality makes information about actual or potential application of remote sensed information somewhat unavailable to the public.

3) The promotion of "break through" techniques in the past which have not proved reliable.

4) The dynamic activity in statutory demand for reclamation monitoring.

Table 1 lists by RMF the benefits in this area. Benefits found in this report are documented in Appendix A, as are the present technical capabilities of ERTS-1. Most of these capabilities are discussed under Geological Mapping (RMF 5.1.1), although other capabilities are considered in RMF's 5.4.2 and 5.5.1. Part of the Eason Oil report is exerpted in Appendix E and relevant federal budget and statutes are found in Appendices B and C respectively. Appendix D contains a partial list of Principal Investigators in this area.

1.1 Cartography, Thematic Maps, and Visual Displays

The use of remote-sensed data allows cost-savings in producing geological maps especially in the case of remote areas and for developing countries which have yet to produce accurate geological maps of their territories. Positive new capability benefits exist through the ability to have dynamic coverage of an area. The dynamic aspects pertain to seasonality, ground moisture, vegetation and climate.

1.2 Statistical Services

Benefits of equal, increased and new capability exist in the detection and inventorying functions. Quantitative measures are difficult to estimate due to the development lag in applying synoptic geological hypotheses and spectral techniques and also because much of the industry applications are considered confidential.

1.3 Calendars

Although much exploration activity exists on the north slope of Alaska, benefits accruing from the development of weather and seasonal calendars are associated with the transportation industry and are covered in resource area no. 8 (Volume X). Positive new capability benefits can be realized from better forecasts of ice formation around drilling rigs, reducing the risk premium on insurance coverage.

1.4 Allocation

This function has the potentially largest benefits. However, capabilities have yet to be demonstrated publicly. However, it should be mentioned that more than 50% of all

Table 1 Magnitudes and Types of Net Annual Benefits by Resource Management Activity - Nonreplenishable Natural Resources: Minerals, Fossil Fuels and Geothermal Energy Sources

Resource Management Function	Benefits, $ millions (1973)		
	Equal Capability	Increased Capability	New Capability
5.1 Cartography, Thematic Maps and Visual Displays			
5.1.1 Geological Mapping	.6 - 2.9		
5.1.2 Map Areas of Potential Geothermal Energy Sources	*		
5.2 Statistical Services			
5.2.1 Detect and Inventory Geographic Areas of Potential Mineral Deposits			
5.2.2 Detect and Inventory Geographic Areas of Potential			
5.4 Allocation			
5.4.1 Manage Mineral Exploration and Extraction	1.0		
5.4.2 Manage Fossil Fuel Exploration and Extraction	(33 - 77)		
5.5 Conservation			
5.5.1 Monitor Strip and Auger Mining Land Reclamation			
5.6 Damage Prevention and Assessment			
5.6.1 Mine Fire Damage Assessment			
5.6.2 Prevent Mine Tailing Studies			
5.6.3 Detect Fractures in Mining Areas			
5.8 Research			
5.8.1 Develop New Methods of Locating Minerals			
5.8.2 Develop New Methods of Locating Hydrocarbon Fuels			
5.9 Administrative, Judicial and Legislative			
5.9.1 Establish and Enforce Mine Safety Regulations			
5.9.2 Establish Policies for and Administer Offshore Oil and Gas Lease Sales			
TOTAL:			
Hard Benefits documented in ECON Case Studies..	1.6 - 3.9		
Soft Benefits..	(33 - 77)		

* A one time benefit of $1 million would be possible from an ERTS-like satellite with a thermal infrared sensor

() - indicates "soft" figures

requests for information from Sioux Falls can be traced to mining and petroleum exploration corporations. The extreme secrecy of bids on Federal and Indian leaselands demands confidentiality of any information derived from remote-sensed images.

1.5 Conservation

Remote-sensed imagery can provide an objective monitoring function for reclaimed strip and auger mining lands. If the legislative requirements become too great and reclamation too costly, underground mining will be substituted for the now economical strip and auger mining. Furthermore, the extent of the use of coal will depend on desulferization technology. Positive benefits are claimed for equal, increased, and new capabilities.

1.6 Damage Prevention and Assessment

Increased capability benefits are claimed since remote-sensed imagery can be incorporated into inspection and mine planning procedures. Given the numbers of inspections claimed and the staffs to perform the inspections more thorough procedures could be developed.

Mine tailings cover large areas and many are in remote areas on federal lands. Remote-sensed imagery can be useful in constructing a complete inventory of mine tailings.

1.7 Unique Event Recognition and Early Warning

Earthquake prediction is not deemed necessary for mining and fuels extraction resource planning, and early hurricane warnings for offshore drilling platforms is assumed covered by other satellite systems.

1.8 Research

While it is known that private mining and fuels exploration companies are by far the largest users of remote-sensed imagery from Sioux Falls the extent of the payoffs obtained from this information appears to be closely guarded.

Academic research, on the other hand, is readily available, but a consensus as to the impact of new satellite information upon received geological theory is not yet forthcoming.

1.9 Administrative, Judicial, and Legislative

Although the federal government has a large hand in the nonrenewable resource area through their leasing operations no benefits are measured here since they would be captured in the other resource management functions, especially, allocation.

Mining profitability can be impacted by mine safety regulations and reclamation laws. If regulations and reclamation procedures become too severe marginal mines will be forced to close or coal extraction can move from strip to underground mining with increasing danger to miners from falls, fires, and black lung disease.

Mine safety and regulation unfortunately is an economic factor in profitability.

APPENDIX A :

DETAILED EXAMINATION OF BENEFITS BY RMF

Appendix A contains the detailed examination of each of the Resource Managment Functions of this resource area. Firm benefit estimates verified by this report may be found in RMF's 5.1.1 and 5.4.1. Benefits that can be attributable to an ERS system but not verified by this in-depth study may be found in RMF's 5.4.2 and 5.1.2.

RMF No. 5.1.1

GEOLOGICAL MAPPING

Rationale for Benefit

Geologic maps are the basic tools for mineral and fossil fuels exploration. They serve two necessary exploratory functions: (1) directly, they show surface features of interest to the geologist, such as faults and lineaments, which have been previously (or may yet be) correlated with subsurface finds and (2) less directly, they provide the basis from which further exploration, such as seismic surveys or drilling, can be planned.

Since one of the goals of federal economic policy is to promote foreign trade along with maintaining long run equilibrium in the balance of payments, U.S. foreign investments can be made more productive with the use of more and better information about the geologic structure of foreign countries. More equitable agreements will be made between foreign investors and local governments when both parties have access to better information. Geologic maps do not exist for much of the territory of developing countries, that are present and potential raw materials exporters.

Federal Government Activities and Responsibilities

The U.S. government maintains a comprehensive mapping program for a variety of earth science purposes. Table 2 outlines FY1972 geophysical expenditures. This type of activity is mandated by several federal statutes, among them are 30 USC 641, 33 USC 883E, and 43 USC 31.

Non-Federal Activities

Many states participate in substantial geologic mapping and information processing beyond that which is supplied federally. Whereas, not all states' activities were surveyed for this report, Table 3 represents a sample of such state activities.

Functions of Remote Sensing

Satellite sensing offers many advantages over conventional mapping activities: (1) cost effectiveness -- satellite imagery is obviously less expensive than ground surveys and has already been demonstrated more cost effective than high altitude aircraft in the ECON Land Cover Case Study; (2) timeliness -- using satellites, an area can be covered much more

Table 2 Federal Geologic and Geophysical Operations (Fiscal Year 1972)

Agency	Federal Expenditures, $ thousands (1972)			
	Geologic	Land Survey & Mapping	Marine Mapping	Marine Scientific Surveys
Department of State				
Agency for Internat. Develop.	(553)			
Department of Defense				
Defense Mapping Agency		1,186		
Navy Operations			1,888	2,500
Department of Interior				
Geologic Div (GS)	(1,163)	930		3,290
Conservation Div (GS)				3,243
Publications Div (GS)	1,163			
Department of Commerce				
National Ocean Survey (NOAA)		227	1,950	
Environ. Data Service (NOAA)		490	125	
Environ. RSCH. Lab. (NOAA)		25		3,377
Department of Trans.				
U.S. Coast Guard				550
Independent Agencies				
Atomic Energy Commission	66	357		
National Science Foundation			7,800	12,500
Tennessee Valley Authority	52	57		
TOTAL	2,997	3,272	11,763	25,460

( ) indicates expenditures contracted to outside agencies

Source: Report of the Federal Mapping Task Force on Mapping, Charting, Geodesy and Surveying. July 1973, Office of Management and Budget. pp. 15, 63, 111.

Table 3 State Mapping and Information Expenditures		
	Expenditures, $ thousands (1973)	
State Activity	Current Year	Recommended
Michigan		
Oil and Mineral Utilization	302.8	319.6
Topographical Mapping (435 sq. mi.)	50.0	50.0
New Jersey		
Geology-Topography	262.6	281.7

Source: Executive Budget, State of Michigan, FY ending 6/30/75 and Executive Budget, State of New Jersey, FY 1975.

quickly than by ground crew; the large-scale image processing operations involved in using an earth resource satellite will also prove more expedient than the more occasional processing of HA aircraft imagery; (3) greater coverage -- for cost and logistics reasons, use of satellites will permit coverage at low marginal cost of larger area than would otherwise have been possible -- this will prove particularly beneficial in undeveloped areas where satellite coverage will be much of the only information available; this could lead to finds which would not otherwise have been uncovered until years later; (4) more frequent coverage -- the way in which the changing seasons affect vegetative ground cover can point out geobotanical indicators of mineralization; this additional frequency, and the information gained, might not prove cost-effective with other survey methods; (5) discovery of large scale features -- space observers have the capability of pointing out large-scale features such as linears and fault zones which have proven undetectable using the limited perspective of other methods.

RMF No. 5.1.1

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

The U.S. Geological Survey has estimated that an earth resources observation satellite (EROS) would contribute a 7 percent efficiency increase to their geologic and geophysical operations.* This efficiency would be effected because the gross distribution of many geological and geomorphological indicators would be apparent. Thus ground traverses could be more effectively used to sample the area. From this estimate, a simple cost savings model can be developed. Referring back to Table 2, the Geological Survey spent $8,626,000 on these operations in 1972 (excluding that amount spent by the Publications Division). This presents a cost savings of $605,000 in U.S.G.S. mapping and surveying operations. Were an increased efficiency of 7 percent possible in all government geologic and geophysical operations, totalling $42,329,000, using remote sensed data, a total cost savings of $2,963,000 would be possible. Cost savings accruing to private industry will be considered in RMF 5.4.2.

Current ERTS Activities

Considerable NASA-funded research has been done in this area. Since a synoptic view can do little more than provide the basis for, or improvement of geologic maps, most of the work by the principal investigators will be summarized in this section.

Although several other investigators found some or all of these results, the following are findings summarized by Isachsen, Fakundiny and Forster:**

1. Boundaries between major tectonic provinces

2. Lithological contacts within tectonic provinces

3. Foliated trends within massive gneisses (a laminated metamorphic rock structure)

---

* Useful Applications of Earth-Oriented Satellites--geology, National Academy of Sciences, 1969, p. 47.

** Isachsen, Fakundiny, and Forster, "Evaluation of ERTS-1 Imagery for Geological Sensing over the Diverse Geological Terranes of New York State", Symposium of Significant Results Obtained from ERTS-1, Volume 1, p. 226.

4. Faults and topographic lineaments

5. Mine dumps and tailings ponds

6. New linear and curvilinear elements, and highly speculative linears

Almost all investigators remarked upon the ability of ERTS to detect new linears and the possible importance of this single function. Table 4 provides a sample of how ERTS imagery can improve on linear sighting. Using new linear maps developed through ERTS-1 imagery, Saunders and Thomas found in their study area that: *

> Invariably, the major mining districts are near coincident with the prominent northeast-trending lineaments... The districts appear to occur along the northeast lineaments where the subtle east-west, east-southeast lineaments intersect the northeast features. Just based on this relationship for prominent new lineaments and mining districts it is possible to postulate other prospective sites in the area where this linear relationship occurs. (See Figure 1.)

Table 4 Linear and Curvilinear Elements Found in ERTS-1 Test Area in New York State

Category	Number	Combined Length
Known lineaments and faults seen on ERTS-1 imagery	234	1890
New and anomalous linears seen on ERTS-1 imagery	329	3060
Total linears seen on ERTS-1 imagery	561	4950
Known lineaments and faults not discernible on ERTS-1 imagery	297	1750

Source: Isachsen, Fakundiny and Forster, "Evaluation of ERTS-1 Imagery For Geological Sensing Over the Diverse Geological Terranes of New York State."

* Saunders and Thomas, "Evaluation of Commercial Utility of ERTS-A Imagery in Structural Reconnaissance for Minerals and Petroleum," op. cit., p. 527.

RMF No. 5.1.1

Bechtold, Liggitt and Childs* have also found that the new understanding of a previously valuable mining area, largely inactive at present, made possible by ERTS data merits consideration in future mineral exploration programs. Vincent** found that ERTS image ratios contained geochemical information, generally superior to aerial photos, which will prove useful in minerological exploration.

One of the most significant finds using ERTS-1 imagery was achieved in a study of northern Alaska near the rich Umiat oil field. An explanation of this image by Lathram, Tailleur, and Patton follows.*** Figure 4 provides some explanation of Figure 2.

> Lakes in the Artic Coastal Plain are dominant elongate, with their long axes parallel and trending about N 9° W. On ERTS-1 image 1004-21395 [Figure 2], an additional strong east-trending regional lineation, not previously recognized on aerial photographs or in field study, is expressed by elongation of some lakes, alignment of others, and by linear interlake areas [Figure 4]. The trend of this lineation is parallel to the trend of deflections in contours of the magnetic and gravity fields in the area and parallel to westerly deflections in the northwest ends of northwest-trending folds mapped to the south. In addition, the alignment of many small lakes forms a large and a small ellipse super-imposed on the regional lineation. Sparse seismic profiles show periodic reversals in dip and regional arching in shallow strata beneath the lineated area. These data suggest that heretofore unsuspected structures may be concealed beneath the Quaternary mantling Gubik Formation in the area of the

---

* Bechtold, Liggett, and Childs, "Regional Techtonic Control of Tertiary Mineralization and Recent Faulting in the Southern Basin-Range Privince, an Application of ERTS-1 Data," op. cit., p. 427.

** Vincent, "Ratio Maps of Iron Ore Deposits Atlantic City, District, Wyoming," op. cit., p. 384.

*** Lathram, Tailleur, and Patton, "Preliminary Geologic Application of ERTS-1 Imagery in Alaska," op. cit., p. 259.

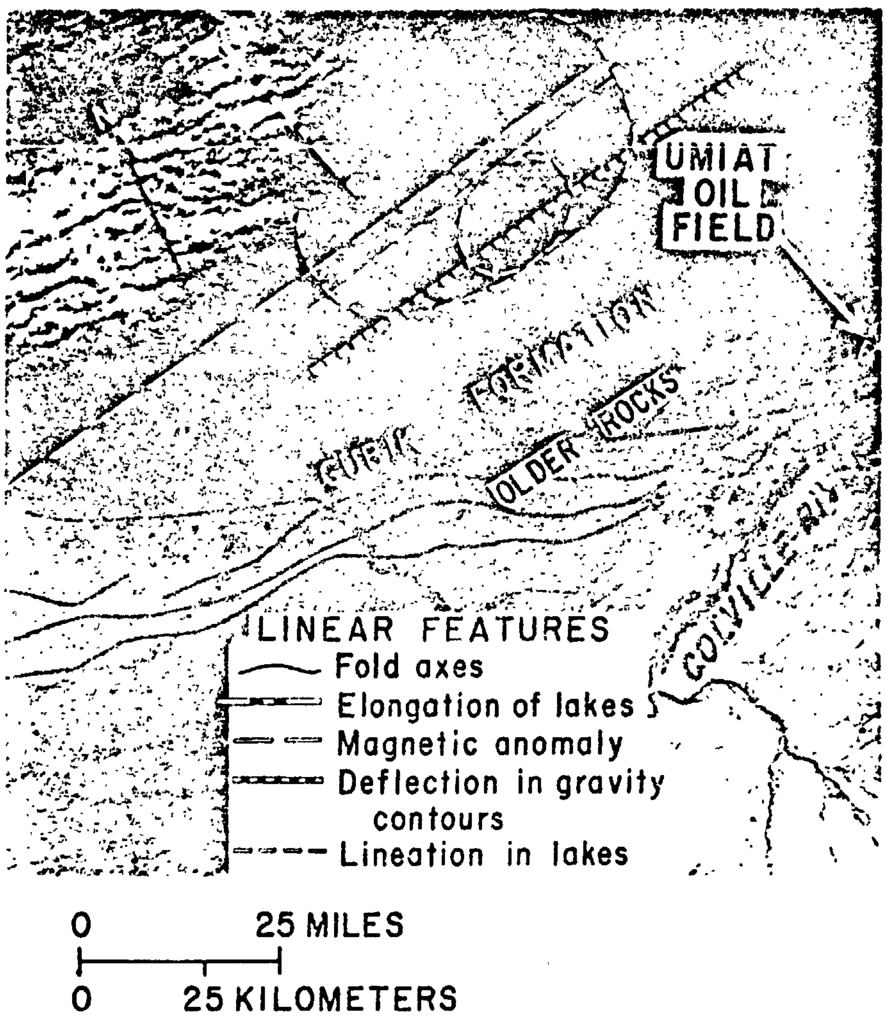


Figure 4 Alaskan Lakes Near Umiat Oil Field (Reference· ERTS-1 Image 1004-21395, see figure 2)

image. The strata in shallow folds are younger than those tapped by the oil wells of the Umiat field to the south, and favorable reservoir beds may occur in the area. Furthermore, the folds in the shallow rocks in this area may reflect structural conditions conducive to oil accumulation in older strata at or near basement.

Several investigators have cited potentially active faults knowledge of which could be used in construction planning and location of highways and nuclear power plants. Abdel-Gawad and Silverstein* have found that seismicity pattern alone is inadequate in defining areas susceptible to earthquakes. Research in this area has already led to much improved knowledge about the location, occurrence and dangers of earthquakes. Bechtold, Liggett and Childs**also found ERTS imagery useful for geologic hazards study, civil engineering, and land-use planning.

Wobber and Martin*** found imagery of snow-covered terrain suppressed ground cover (vegetative) noise and gave new fracture detail which did not appear on available maps. They found that "snow enhancement is a simple and no-cost form of edge enhancement."

Estimate of ERTS Economic Capabilities

Using the U.S.G.S. estimate, annual cost savings of $60",000 is possible in public sectors due to increased efficiency in geologic and geophysical operations. Were the estimate of 7 percent efficiency increase realized in all government geologic and geophysical operations, a total cost saving of $2,963,000 would be effected.

Benefits:

Cost-Savings: $.6M - $2.9M

---

* Abdel-Gawad and Silverstein, "ERTS Applications in Earthquake Research and Mineral Exploration in California," op. cit., p. 433.

** Bechtold, Liggett, and Childs, "Regional Tectonic Control of Tertiary Mineralization and Recent Faulting in the Southern Basin Range Province, An Application of ERTS-1 Data," op. cit., p. 427.

*** Wobber and Martin, "Exploration of ERTS-1 Imagery Utilizing Snow Enhancement Techniques", op. cit., p. 350.

RMF No. 5.1.2

MAP AREAS OF POTENTIAL GEOTHERMAL ENERGY SOURCES

Rationale for Benefits

Geothermal energy sources offer a unique opportunity to capitalize upon the vast thermal energy contained within the earth, possible with a low environmental impact. Some geothermal energy sources are near the surface but are not obvious to earth-based observers. Better understanding of the extent and basic physics of this resource is necessary before widespread use can be safely made of it.

Federal Government Activities and Responsibilities

Prior to 1971, the USGS had no specially funded geothermal resources program, although most investigations of hot springs and geothermal phenomena were carried out as part of the Geological Division's investigations of energy and mineral resources.

The Panel on Geothermal Energy Resources in a report delivered to the Committee on Interior and Insular Affairs - U.S. Senate* stated that more than 75,000 MW of generating capacity would probably be installed by the year 2000 granted a successful research and development program of moderate size where mounted. One of the main components of the R & D program is for "better knowledge of the nature, magnitude, quality, and location of geothermal resources." Legislation for this activity is contained in the Geothermal Steam Act of 1970.

Functions of Remote Sensing

Remote sensing by satellite allows a synoptic overview of sizeable land areas, however, on a scale of resolution that permits detection of relatively fine linear features. Sources of geothermal energy can show up directly in thermal IR maps or indirectly through events such as differential snow melt. Earth resource satellites provide the unique economic opportunity of repeated coverage of large land areas and thus improve the chance of detecting geothermal sources. Also, the process of photo interpretation and map drafting has been simplified because there does not exist the photo mosaicking problem with synoptic satellite images.

---

* Hearings before the Committee on Interior and Insular Affairs, U.S. Senate, June 15 and 22, 1972.

RMF No. 5.1.2

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

"The Geothermal Steam Act of 1970 defines the public lands potentially available for geothermal leasing. These include principally (1) public, withdrawn and acquired lands administered by the Secretary of the Interior, approximately 451 million acres in 25 states; (2) national forests and other lands administered by the Forest Service, Department of Agriculture, approximately 187 million acres in 45 states and Puerto Rico, and (3) lands containing a reservation to the United States of the geothermal resources."*

This yields a potential 1.0 million square miles which needs to be mapped for geothermal resources. From ECON's evaluation of Level II mapping costs by high altitude aircraft and satellite** there is a savings of $1.07/ sq mile between the average cost of aircraft imagery and the marginal cost of satellite imagery. This yields a one-time $1.0 + million equal capability benefit.

Current ERTS Activities

Williams found that, under optimum conditions, the ground resolution capability of the ERTS-1 MSS can distinguish a small geothermal area (2.5 km^2) having a heat output of 25-125 X 10^6 cal/sec by its snow melt pattern.

Estimate of ERTS Economic Capability

From the above considerations, an ERTS-like system with a thermal IR sensor would have a one-time benefit of $1 M, "annualized" at a 10% discount rate to $.1 M.

---

* Hearings before the Committee on Interior and Insular Affairs: United States Senate; June 15 and June 2, 1972; Serial No. 92-31, pp. 117-118.

** "The Role of ERTS in the Establishment and Updating of a Nationwide Land Cover Information System," (Draft) ECON report prepared for NASA, 5 August 1974, III-19.

RMF No. 5.2.1

DETECT AND INVENTORY GEOGRAPHIC AREAS OF POTENTIAL MINERAL DEPOSITS

Rationale for Benefits

While the detection and inventory of mineral deposits is not immediately connected with physical stocks of refined metals, knowledge of the location and measurement of potential future supplies affects present and future prices. Improved knowledge leads to more economical pricing and resource price stabilization. Greater accuracy in detection and inventorying mineral deposits can have an immediate return to the federal government and Indian people through the issuance of further mineral leases. The private industrial sector will benefit as mineral resources in the ground can be "borrowed" from future generations to meet what are called "metal shortages" and "raw materials crises."

Federal Government Activities and Responsibilities

The U.S. government, because of its large land holdings and its needs for the stockpiling of strategic and critical materials, demands accurate information regarding prices and supplies (present and potential). This information is necessary for optimal resource allocation and pricing within both the private and public sectors, and to prevent large redistributions of income from one group to another, such as the transfer of potential income from one country to another which can arise from inadequate supply and price information.*

Table 5 and Table 6 exhibit the stockpile figures as of December 31, 1972. Approximately 82% is made up of 14 materials: aluminum, metallurgical grade bauxite (Jamaica), metallurgical grade chromite, cobalt, industrial diamond bort and stones, lead, magnesium, manganese, molybdenum, quartz crystals, tin, tungsten, and zinc. During 1972, $547 million was received from Receipts, and Rotation Sales and Reimbursements. Redistributing excess inventories to the private sector without creating undue market disturbances requires accurate information about present and future supplies. Present prices reflect both present and future demands and supplies.

---

* E.g., U.S. - Soviet Wheat Transaction

Table 5 Summary of Government Inventories of Strategic and Critical Materials, December 31, 1972

Inventory Type			Costs and Values, $ thousands (1973)	
			Acquisition Cost	Market Value*
A.	I.	Inventories Reserved for Objectives		4,021,506.1
	II.	Uncommitted Excess Inventories		2,356,924.1
		Total		6,378,430.2
B.	I.	Total Inventories in Storage		
		National Stockpile	3,947,856.0	4,893,774.3
		Supplemental Stockpile	1,359,907.6	1,438,417.1
		Defense Production Act	649,171.4	362,112.8
		Total on Hand	5,956,935.0	6,694,304.2
	II.	Inventories Within Objective (in Storage)		
		Total	3,288,522.5	4,023,742.1
	III.	Excess Inventories in Storage		
		Total	2,668,412.5	2,670,562.1

*Market values are computed from prices at which similar materials are being traded; or, in the absence of current trading, at an estimate of the price which would prevail in commercial markets. Market values are unadjusted for normal premiums and discounts relating to contained qualities, or for inherent materials-handling allowances. *Market values do not necessarily reflect the amount that would be realized at time of sale.*

The Uncommitted Excess excludes the unshipped sales; the Inventories in Storage include quantities that have been sold but not shipped. The inventories within Objective (in Storage) include quantities of unshipped commitments of castor oil and feathers and down under the rotation program.

Source: General Services Administration
*Stockpile Report to the Congress, July - December 1972.

Table 6 Summary of Government Inventories, Objectives, Excesses and Balance of Disposal Authorizations* December 31, 1972

Commodity	Unit	Objective	Total Inventory	Market Value	Uncommitted Excess	Market Value+	Balance of Disposal Authorization
1. Aluminum	ST	0	1,269,138	$634.6	1,269,138	$634.6	819,138*
2. Aluminum Oxide, Fused	ST	300,000	420,585	69.2	120,585	16.3	120,585
3. Antimony	ST	40,700	46,676	52.4	5,976	6.0	5,976
4. Asbestos, Amosite	ST	18,400	58,084	14.3	39,684	9.8	39,684
5. Asbestos, Chrysotile	ST	13,700	11,846	5.9	903	0.2	890
6. Bauxite, Metal, Jamaica	LDT	5,000,000	8,858,881	120.3	3,858,881*	52.4	914,000
7. Bauxite, Metal, Surinam	LDT	5,300,000	5,300,000	54.3	0	0	0
8. Bauxite, Refractory	LCT	173,000	173,000	8.8	0	0	0
9. Beryl	ST	28,000	37,582	69.7	9,582***	25.8	0
10. Bismuth	LB	2,100,000	2,101,061	8.4	1,061	0.004	1,061
11. Cadmium	LB	6,000,000	9,213,358	27.6	3,213,358	9.6	3,213,358
12. Castor Oil	LB	50,000,000	22,643,709	8.0	24,242	0.007	10,119,367*
13. Chromite, Chemical	SDT	250,000	568,853	12.2	319,553	6.8	318,853
14. Chromite, Metallurgical	SDT	3,086,800	5,330,336	584.5	2,243,536*	241.9	930,339
15. Chromite, Refractory	SDT	368,000	1,162,201	34.3	794,201	23.4	762,241
16. Chromium Metal	ST	3,775	8,012	19.5	4,237	9.7	4,237
17. Cobalt	LB	38,200,000	68,175,127	166.6	29,975,127	73.0	29,975,126
18. Columbium	LB	1,176,000	7,317,846	12.2	3,743,105*	4.5	3,743,105
19. Copper	ST	775,000	258,659	266.0	0	0	0
20. Cordage Fibers, Abaca	LB	0	33,389,007	8.5	33,389,007	8.5	8,262,120
21. Cordage Fibers, Sisal	LB	0	113,298,897	16.4	113,298,697	16.4	13,065,136
22. Diamond Dies, Small	PC	25,000	25,473	1.0	473	0.02	0
23. Diamond, Industrial Bort	KT	23,700,000	41,316,479	87.6	17,616,479	36.6	17,616,479
24. Diamond, Industrial Stones	KT	20,000,000	23,401,634	177.1	3,401,634	31.0	3,401,634
25. Feathers and Down	LB	3,000,000	2,780,608	13.9	0	0	2,780,608*
26. Fluorspar, Acid Grade	SDT	540,000	890,000	69.9	0*	0	0
27. Fluorspar, Metallurgical	SDT	850,000	411,788	28.2	0	0	0
28. Graphite, Natural, Ceylon	ST	5,500	5,499	1.0	0	0	0
29. Graphite, Natural, Malagasy	ST	18,000	18,023	2.2	83	0.01	83
30. Graphite, Other	ST	2,800	2,800	0.6	0	0	0
31. Iodine	LB	7,400,000	8,011,814	16.5	611,814	1.3	0
32. Jewel Bearings	PC	57,560,000	61,643,858	19.9	14,726,698**	0.4	0
33. Lead	ST	530,000	1,077,615	323.2	547,615	164.3	547,615
34. Manganese, Battery, Natural	SDT	135,000	308,350	27.3	173,350	14.5	173,350
35. Manganese, Battery, Synthetic Dioxide	SDT	1,900	15,758	7.4	13,858	6.5	13,858

* Ibid.

\+ Market Value - $ Millions

Table 6 Summary of Government Inventories, Objectives, Excesses and Balance of Disposal Authorizations* December 31, 1972 (Continued)

Commodity	Unit	Objective	Total Inventory	Market Value	Uncommitted Excess	Market Value+	Balance of Disposal Authorization
36. Manganese Ore, Chemical A	SDT	35,000	146,914	$ 10.3	111,714	$ 7.8	111,914
37. Manganese Ore, Chemical B	SDT	35,000	100,838	7.1	65,838	4.6	65,838
38. Manganese, Metallurgical	SDT	4,000,000	9,931,589	367.1	5,985,214	179.0	5,985,214
39. Mercury	FL	126,500	200,105	56.0	73,605*	20.1	0
40. Mica, Muscovite Block St/Better	LB	6,000,000	11,932,674	43.7	5,172,174**	13.6	5,173,174
41. Mica, Muscovite Film, 1st & 2nd quality	LB	2,000,000	1,469,166	16.5	640	0	640
42. Mica, Muscovite Splittings	LB	19,000,000	35,300,439	42.1	16,300,439	19.3	16,293,535
43. Mica, Phlogopite Block	LB	150,000	153,519	0.05	137,217	0.03	137,217
44. Mica, Phlogopite Splittings	LB	950,000	4,307,294	5.2	3,357,294	4.0	3,357,022
45. Molybdenum	LB	0	42,597,968	76.9	42,597,968**	76.9	6,096,857
46. Nickel	ST	0	0	0	0	0	0
47. Opium	AvLB	143,000	141,602	19.3	85	0.005	0
48. Platinum Group, Iridium	TrOz	17,000	17,176	2.6	184	0.03	164
49. Platinum Group, Palladium	TrOz	1,300,000	1,254,994	85.3	0	0	0
50. Platinum Group, Platinum	TrOz	555,000	452,545	38.8	0	0	0
51. Pyrethrum	LB	63,375	0	0	0	0	0
52. Quartz Crystals	LB	320,000	4,659,240	50.6	4,339,240	45.9	4,338,577
53. Quinidine	OZ	2,000,000	1,800,377	4.9	0	0	0
54. Quinine	OZ	4,130,000	3,548,161	7.2	0	0	0
55. Rubber	LT	200,000	255,982	126.1	55,982	27.6	55,982
56. Rutile	SDT	160,000	56,525	9.9	0	0	0
57. Sapphire & Ruby	KT	18,000,000	16,305,502	0.2	0	0	0
58. Shellac	LB	1,000,000	2,826,222	1.6	1,826,222	1.0	1,826,222
59. Silicon Carbide, Crude	ST	30,000	196,453	38.1	166,453*	32.3	0
60. Silver	(fine) TrOz	139,500,000	139,500,000	281.8	0	0	0
61. Talc, Steatite Block & Lump	ST	200	1,180	0.4	980	0.3	980
62. Tantalum	LB	3,400,000	4,093,897	35.0	879,917**	6.5	0
63. Thorium Oxide	ST	40	40**	0.3	0	0	0
64. Tin	LT	232,000	250,523	1,001.7	18,523	73.1	18,505
65. Titanium Sponge	ST	33,500	35,862	87.9	8,514	18.0	8,511
66. Tungsten	LB	60,000,000	129,409,483	457.2	69,410,300	242.5	69,410,300
67. Vanadium	ST	540	1,740	12.9	1,200	10.1	1,200
68. Vegetable Tannin, Chestnut	LT	9,500	24,630	8.1	15,130	5.0	15,130
69. Vegetable Tannin, Quebracho	LT	50,500	183,459	58.1	132,859	42.1	132,559

* Sold.
\+ Market Value - $ Millions

As of June 30, 1972 the U.S. government had 2,647 mineral leases covering 5,924,076 acres on land of which 939 leases on 3,352,318 acres were Indian lands, and 9 offshore mineral leases comprising 15,073 acres.*

For 1971 the value of this mining was $302 million with royalty payments to the Indian nations and the U.S. government of $14.8 million of which $5.1 million went to the Indian nations.**

Table 7 Federal Statutes Pertinent to RMF 5.2.1

No.	Name of Statute	Reference	Federal Agency	Functions
1.	Exploration Program for Discovery of Minerals	30 USC 641-646; P.L. 85-701	DOI	analysis and evaluation of explorations
2.	Geological Survey	43 USC 31; P.L. 87-626	DOI	inventory of mineral deposits
3.	Bureau of Mines	30 USC 1-11; 36 Stat. 370; 37 Stat. 681	DOI	statistical analysis of mineral commodities
4.	Admission of New States	43 USC 857	DOI	survey of public lands in state prior to its admission to the Union

Non-Federal Activities

In 1969 the National Academy of Sciences*** estimated that "mining industry exploration costs run about $200 million for U.S. and Canadian metal exploration, of which geology and geophysics cost about 25% or $50 million."

Functions of Remote Sensing

Remote sensing by satellite provides a significant complementary capability to a multi-level survey. Improved geologic

---

* Federal and Indian Lands, Coal, Phosphate, Potash, Sodium and Other Mineral Production, Royalty, Income, and Related Statistics, U.S. Department of Interior, Geological Survey Conservation Division, June 1973.

** Ibid.

*** Useful Application of Earth-Oriented Satellites--Geology National Academy of Sciences, 1969.

maps result with increased capability to detect and survey mineral deposits. Multispectral image data can be used to indicate the potential presence of certain minerals in an automatic survey process. Thus, satellite images make possible large scale remote mineralogical prospecting surveys that are difficult, at best, using other (e.g., aircraft) data.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Uncovering of unknown stocks will avoid some of the high cost of materials in times of tight supply. Benefits could be measured from the "smoothing out" of prices over time and optimum timing of sales of excess government reserves.

Estimate of ERTS Economic Capabilities

No benefits can be measured due to the research and development lag in applying synoptic geological hypotheses and to the private nature of the industry which considers the application of synoptic remote-sensed information confidential.

Benefits

Equal capability +
Increased capability +
New capability +

+ Possibly significant benefits but not quantified.

RMF No. 5.2.2

DETECT AND INVENTORY GEOGRAPHIC AREAS OF POTENTIAL FOSSIL FUEL DEPOSITS

Rationale for Benefits

The detection and inventory of fossil fuel deposits are not immediately connected with physical stocks of energy resources. However, knowledge of the location and measurement of potential future supplies affects present and future prices. Improved knowledge leads to more economical pricing and resource price stabilization. Knowledge as to producible resources is poor and estimates of actual potential vary widely (see Figure 5). Improved information here will greatly aid national and international energy policy decisions.

Greater accuracy in detection and inventorying hydrocarbon deposits can have an immediate return to the federal government and Indian people through the issuance of further leases.

Further government benefits accrue as better quality inputs are provided to the planning and allocation functions of the agencies described in Appendix C.

Private benefits accrue to the fossil fuel industry by reducing uncertainty as to the extent of proven reserves.

Federal Government Activities and Responsibilities

Presently the U.S. government needs accurate statistical information to oversee its stake in leasing operations. On June 30, 1972 there existed 112,188 oil and gas leases on 72,058,192 acres of land and 1035 leases on 4,419,327 acres on the outer continental shelf. Of this, 9,927 leases on 3,633,049 acres were on Indian lands. The total value of the leases was $3.1 billion which produced royalties of $466 million of which 16.9 million went to the Indian nations. Also on federal lands 19,000 short tons or 3.2% of the nation's coal production was mined. *

---

* Federal and Indian Lands Coal, Phosphate, Potash, Sodium and Other Mineral Production, Royalty, Income and Related Statistics, op. cit. pp. 36 and following.

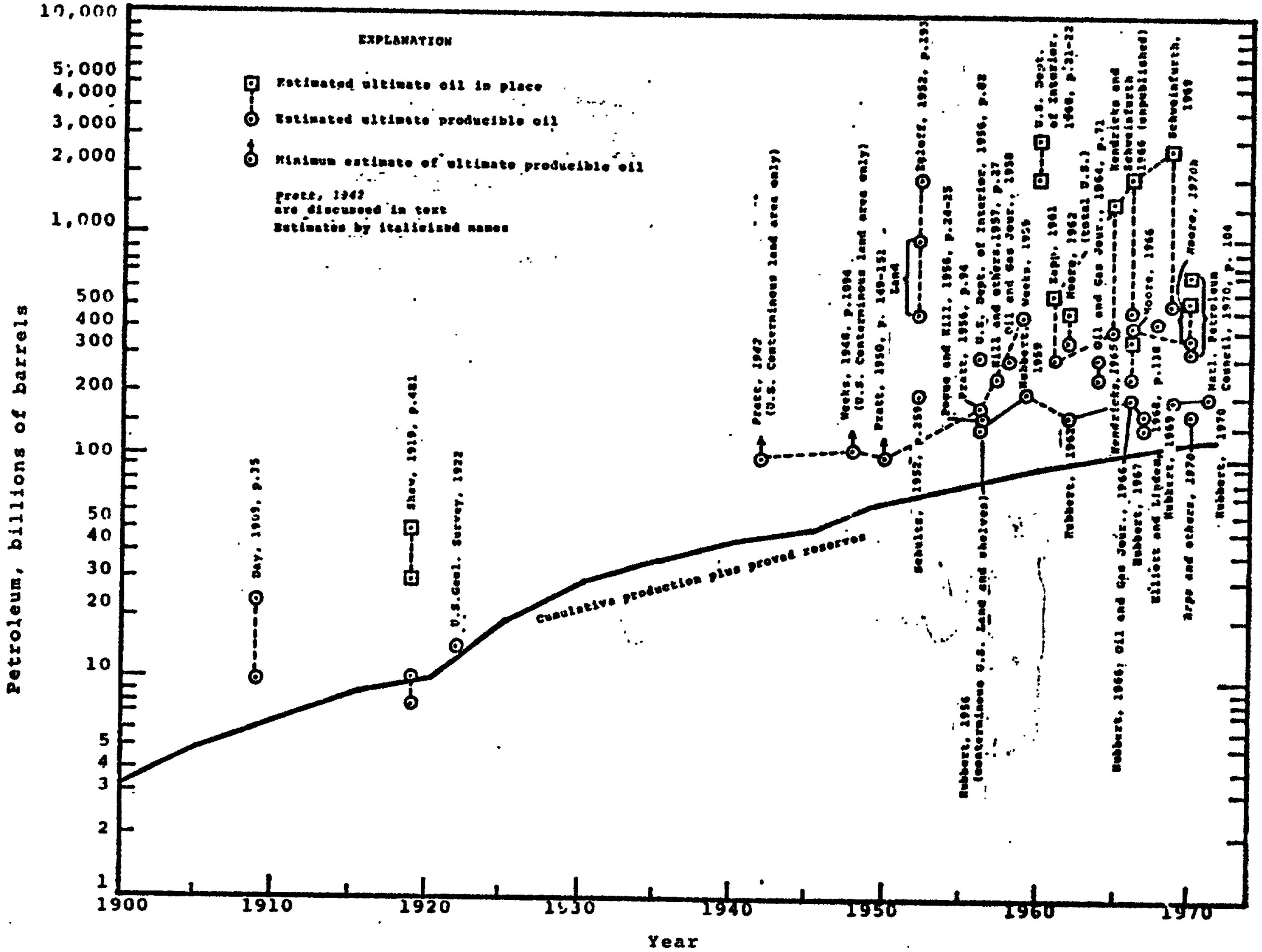


Figure 5 Estimates of Ultimate Producible Oil Resources (and Ultimate Oil in Place) of United States, in Relation of Records of Cumulative Production Plus Proved Reserves from 1900 through 1972.

RMF No. 5.2.2

Non-Federal Activities

In the U.S. alone from 1968 to 1972, $368 million per year, on the average, was expended on geological and geophysical exploration in the private sector.* This is more than 10% of all exploration.

Functions of Remote Sensing

Large area multispectral synoptic images of the earth provide for visual detection and computer analysis of areas of potential fossil fuel sources. Leakages of hydrocarbons in the ocean and lakes provide signatures for analysis. Part of the objectives of geologists using remote sensed information is to distinguish anamolous surface features such as domal features and annular drainage patterns and to identify vegetation characteristics associated with oil deposits. The detection of oil is a science which has several accepted theories as Parke A. Dickey** comments: "We usually find oil in new places with old ideas. Sometimes also we find oil in an old place with a new idea, but we seldom find much oil in an old place with an old idea. Several times in the past we have thought we were running out of oil whereas actually we were only running out of ideas." Earth resource satellites are a new idea.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Uncovering unknown stocks will avoid some of the high cost of fuels in times of tight supply. Benefits could be measured from the "smoothing out" of prices over time and optimum timing of sales of excess government reserves.

Estimate of ERTS Economic Capabilities

The major benefits accrue in the new capability area from the incorporation of information obtained from the synoptic view. A research and development lag in the use of synoptic geological information still exists. This has prevented the demonstration of successful applications in finding fossil fuel deposits. The confidentiality which private industry places on such information further precludes an estimate of benefits at this time.

* World Oil Feb. 15, 1974, pp.86

** Sourcebook for Petroleum Geology, K.H. Dott Sr. and M.J. Reynolds, 1969, p.2.

RMF No. 5.4.1

MANAGE MINERAL EXPLORATION AND EXTRACTION

Rationale for Benefits

The allocation of exploration and extraction resources resulting from the use of better information allows society the opportunity of optimizing over different time horizons, or for the same time horizon at lower cost. Present "mineral shortages" can be alleviated by borrowing mineral deposits from future generations. Benefits accrue to the private sector through higher returns on investment in the mining industry. Lease payments on both Federal and Indain lands will also reflect these higher returns. Since many mineral commodities are extensively traded in foreign commerce benefits will be conveyed directly to owners of mineral deposits in foreign countries and indirectly to the American public through access to continued supplies of minerals. Relatively larger benefits will accrue to the developing countries as the acceleration rate of exploitation will be larger since they are starting from a more primitive information base.

Federal Government Activities and Responsibilities

Activities of the Federal Government are reviewed in Table 8.

Table 8 Federal Statutes Pertinent to RMF 5.4.1

No.	Name of Statute	Reference	Federal Agency	Function
1.	Exploration Program for Discovery of Minerals	30 USC 642	DOI	exploration contracts
2.	Bureau of Mines	30 USC 1-11; 36 Stat. 370; 37 Stat. 681	DOI	economic analysis of mineral commodities
3.	Strategic and Critical Materials Stockpile Act	50 USC 98-98h	GSA	manage critical minerals
4.	Defense Production Act of 1950	50 USC 2061-2166	GSA	manage critical minerals

RMF No. 5.4.1

Non-Federal Activities

While it is diffcult to get accurate figures on exploration and extraction costs it should be noted that domestic mineral production is valued at more than $10 billion per year. This figure includes nonmetallic minerals as well as metals.

Functions of Remote Sensing

As new exploration techniques are developed from remote-sensed information, the probabilities of success in identifying new mineral deposits increases. Remote-sensed images provide synoptic views of geologic structures which are often obscured by higher resolution, lower altitude remote sensing and can lead to the adoption of different models for mineral detection. Saunders and Thomas* have concluded that ERTS-1 imagery is of great value in photogeologic/geomorphic interpretations of regional features, and the simple-shear, block-coupling model provides a means of relating data from remote-sensed images to structures that have controlled emplacement of ore deposits. Remote-sensed imagery provides an alternative link with traditional theories of mineral detection.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

In 1969 the USGS** estimated that the [illegible] system data would contribute a 7% efficiency increase to [illegible]ologic and and geophysical operations. The National Academy of Sciences*** estimated in 1969 that approximately 1% of the total production value can be associated with geophysical and geologic operations. Given a $3.5 billion metal ore industry this implies an annual expenditure of $35 million dollars for these operations.

---

* Saunders and Thomas, "Evaluation of Commercial Utility of ERTS-A Imagery in Structural Reconnaissance for Mineral and Petroleum; Op. Cit

** Useful Application of Earth-Oriented Satellites - Geology, National Academy of Sciences, 1969, p.47

*** Ibid

RMF No. 5.4.1

With a 7% efficiency increase an equal capability benefit of $2.5 million could be realized if this same 7% efficiency increase also applies to private operations and moreover, that learning costs are zero.*

Using the same type of procedure outline in the Economic and Technical Models section of RMF 5.4.2, Figures 6 and 7 represent potential benefits from accelerating production of copper and iron ore.

Current ERTS Activites

See RMF No. 5.1.1 and 5.2.1

Estimate of ERTS Economic Capabilities

From the above considerations, it is felt that one million dollars annually provides a rough, but conservative, estimate of cost savings to metal ore extraction firms due to increased geological and geophysical operations efficiency.**

Speculation has been made as to other benefits from accelerating the discovery rate, but no final estimate of most probable benefits is possible in this area.

Annual Benefits:

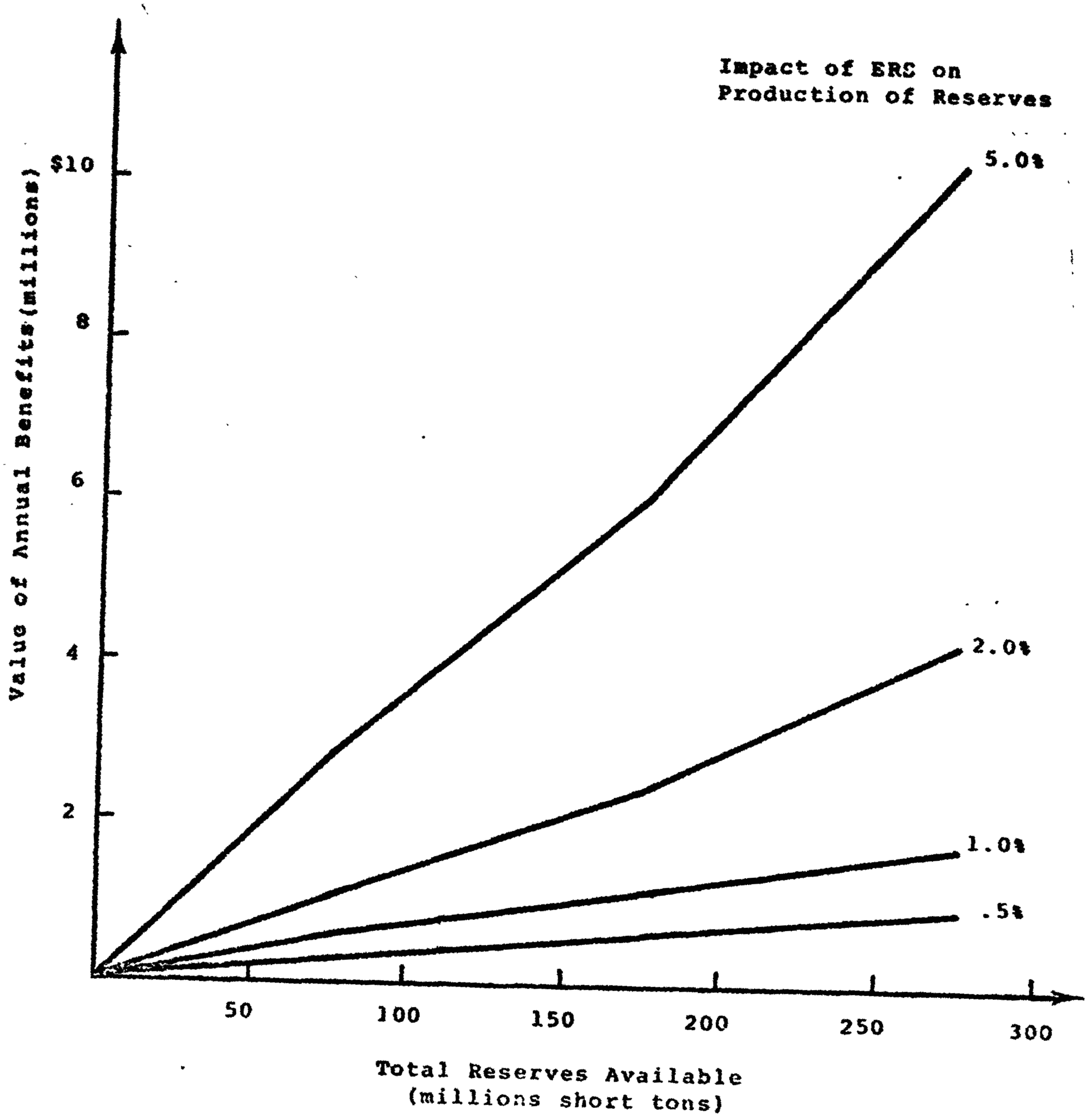
Equal Capability: $1.0 million

---

* However, since private industry is mainly concerned with profitable development rather than detection and inventorying 7% may be too high a productivity increase for private exploration. Then an annual benefit of $1.0+ million may be more realistic.

** However, if the cost efficiency involved is closer to what has been documented in petroleum exploration (see next section), then benefits could range to 35 million dollars annually.

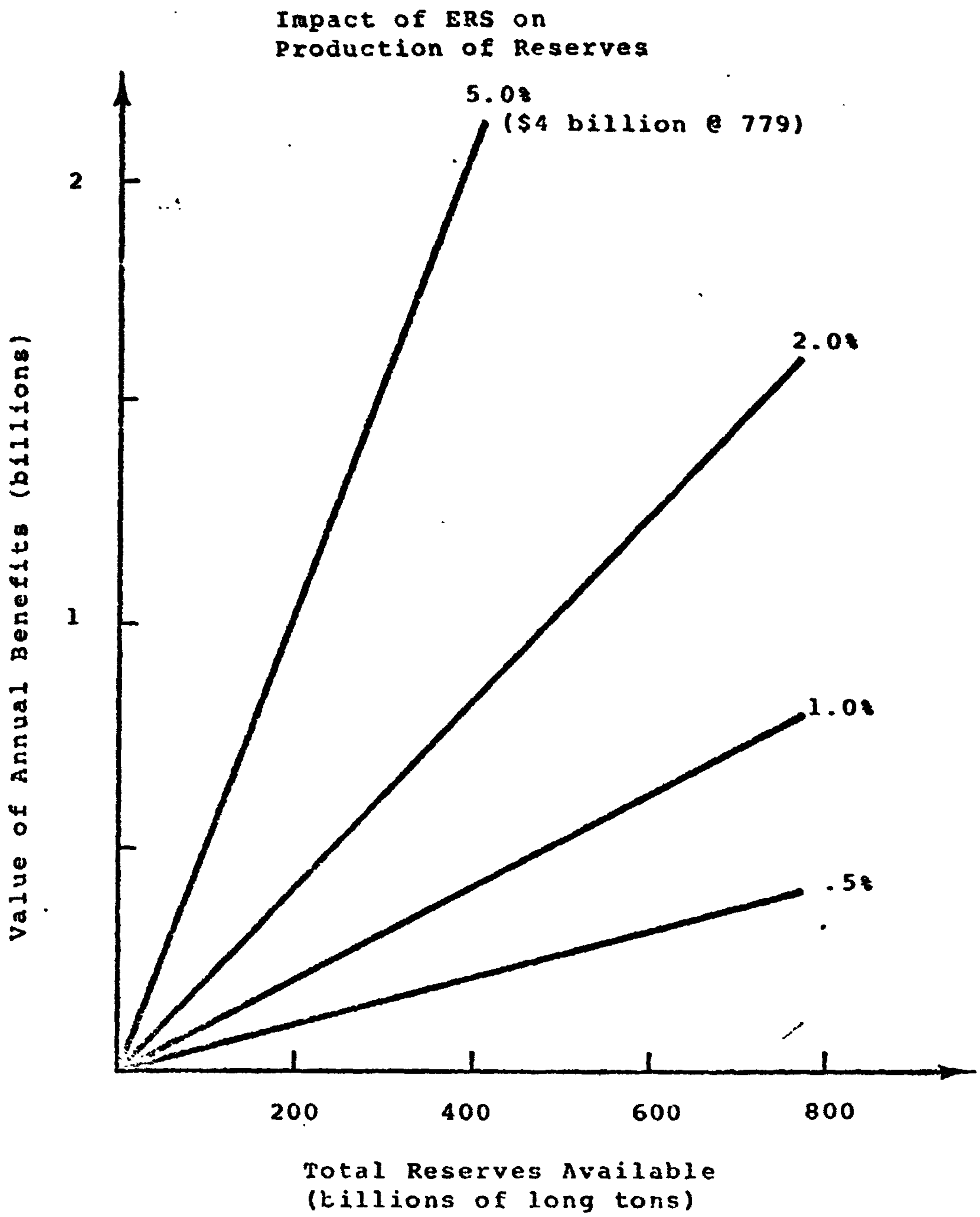
RMF No. 5.4.1



Discount Rate = 10%
Price/ton = $100

Figure 6 Annual Benefits from Increased Production in U.S. Copper Industry

RMF No. 5.4.1



Discount Rate = 10%
Price/ton = $13

Figure 7 Annual Benefits from Increased Production in U.S. Iron Ore Industry

RMF No. 5.4.2

MANAGE HYDROCARBON FUELS EXPLORATION AND EXTRACTION

Rationale for Benefits

Hydrocarbon fuels exploration and extraction will be governed by both supply and demand factors and institutional constraints such as those imposed by the OPEC nations and those to be determined by Congress. Regardless of the fuels scenario assumed, the ability to alter *flows* from the total *stock* of fuels resources will provide more efficient use of exploration and extraction resources. This will result in greater return on investment for hydrocarbon fuels discoveries than would otherwise have existed.

Benefits will accrue to the private sector through increased fuels output and to the U.S. government and Indian nations through higher prices on both land and off-shore leases.

Federal Government Activites and Responsibilities

A large impact from federal policy can be expected if "Project Independence" is implemented. Table 9 lists some of the Federal Statutes impacted by ERS in this area.

Table 9 Federal Statutes Pertinent to RMF 5.4.2

No.	Name of Statute	Reference	Federal Agency	Function
1.	Connally Hot Oil Act	15 USC 715	DOI	encourage conservation of U.S. crude oil
2.	Strategic and Critical Materials Stockpile Act	50 USC 98-98h	GSA	manage critical fuels
3.	Defense Production Act of 1950	50 USC 2061 2166	GSA	manage critical fuels

RMF No. 5.4.2

Non-Federal Activities

In 1972, the fuel industry had a production value of over $22 billion, with oil and gas accounting for $10.7 billion. Table 10 indicates how their expenses have run over the last few years.

Table 10 Estimated Expenditures For Exploration, Development and Production of Oil and Gas in the United States Excluding Income Taxes (Millions of Dollars)

	1968	1969	1970	1971	1972
1. Exploration:					
a. Drilling and Equipping Exploratory Wells	836	944	815	775	910
b. Acquiring Undeveloped Acreage	1,578	1,137	714	642	1,722
c. Lease Rentals and Exp. for Carrying Leases	179	134	138	143	142
d. Geological and Geophysical	373	387	349	361	372
e. Contributions Toward Test Wells	34	33	30	24	35
f. Land Dept. Leasing, & Scouting	82	93	98	100	105
g. Other incl. Direct Overhead	136	168	143	142	147
h. Total Exploration	3,218	2,896	2,287	2,187	3,433
2. Development:					
a. Drilling & Equipping Development Wells	1,539	1,634	1,733	1,573	1,869
b. Lease Equipment	384	442	443	388	497
c. Improved Recovery Programs	222	303	285	323	310
d. Other incl. Direct Overhead	188	180	170	185	160
e. Total Development	2,333	2,559	2,631	2,469	2,866
3. Production:					
a. Prod. Expenditures incl. Direct Overhead	2,094	2,189	2,379	2,504	2,556
b. Production or Severance Taxes	499	525	563	587	615
c. Ad Valorem Taxes	259	271	294	295	269
d. Total Production	2,852	2,985	3,236	3,386	3,445
4. General & Administrative Overhead Not Reported Elsewhere					
a. Allocated to Exploration	204	210	189	206	239
b. Allocated to Development	199	207	220	202	257
c. Allocated to Production	340	369	416	475	467
d. Total G & A Overhead	743	786	825	873	963
5. Drilling & Production Platforms	174				
6. TOTAL EXPENDITURES	9,320	9,226	8,979	8,915	10,677

Source: World Oil, February 15, 1974, p. 86.

RMF No. 5.4.2

Functions of Remote Sensing

Part of the objectives of geologists using remote-sensed information is to distinguish anamolous surface features such as domal features and annular drainage patterns and identify vegetation characteristics associated with oil deposits. There have been no publicly announced oil or gas discoveries as of yet attributable to remote-sensed information. New seismological techniques, for instance, bright spot analysis,* are challenging structural presentations of potential oil and gas traps as the main tools for successful discoveries. Whether remote sensing can be useful directly through the use of the DCP for bright spot analysis or as complementary information has yet to be demonstrated. Figure 8 shows the relationship between different petroleum exploration techniques and production and reserves.

However, an ERS system can be of great advantage in contributing to exploration surveys which must be made before any mining is begun.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Principal investigators from Eason Oil have been using ERTS-1 data in regional exploration studies and have found the information to be "an exceedingly valuable tool for obtaining a rapid geologic assessment of large areas. In particular, ERTS data provide a host of information of lithogolic distribution and structural features, and quickly draw attention to anomalous features and areas that are of interest from the standpoint of petroleum exploration."**

The investigators found that ERTS data were not wholly substituted for aerial imagery; however, they did delineate a program whereby a common point could be reached using conventional methods alone and ERTS imagery along with some conventional methods. Table 11 delineates the comparative costs of the two programs and illustrates that reaching a common point in exploratory operations would probably cost

---

* Bright Spot: "Better Seismological Indicators of Gas and Oil", Science, 9 August, 1974; Vol 185, No. 4150.

** "An Evaluation of ERTS Data for the Purposes of Petroleum Exploration," Collins, McCown, Stonis, Petzel, Everett -- Eason Oil Co., Contract NAS 5-21735, June 1974, p.8.

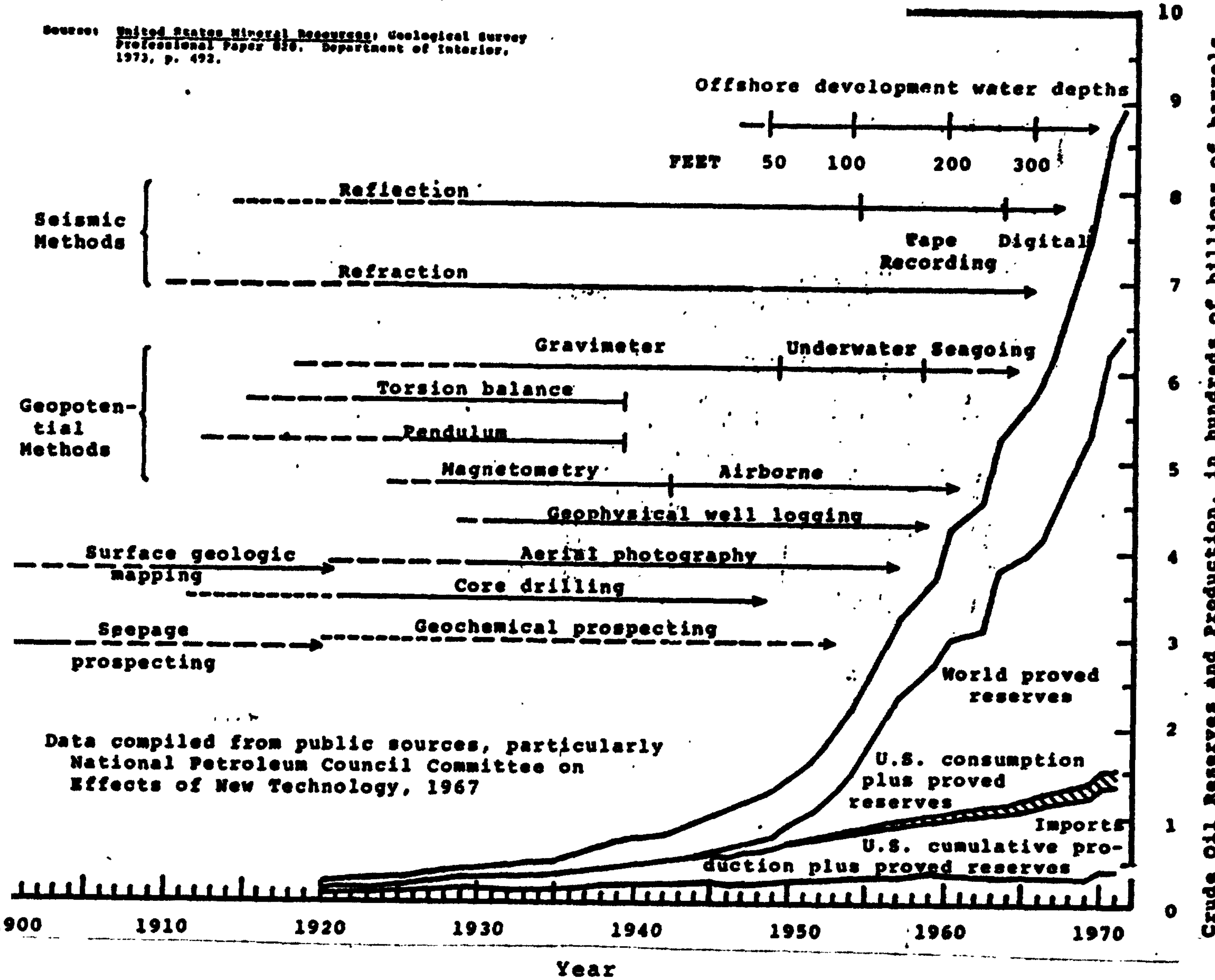


Figure 8 Crude Oil Reserves and Production Related to Exploration Techniques

Table 11 Comparison of Cost of a Regional Petroleum Exploration Program

Conventional Program	Costs by Mode of Acquistion ** $ thousands (1973)		
	Non-Exclusive	Exclusive	Probable
Reconnaissance Seismic Survey (4600 Kilometers)	400.0 *	5,060.0	400.0
Air Photo Interpretation (80,000 Square Kilometers)	64.0 *	160.0	64.0
Reconnaissance Surface Geology	200.0	200.0 *	200.0
Seismic Survey Across Anomalies (900 Kilometers)	76.0	990.0 *	990.0
TOTAL	740.0	$6,410.0	1,664.0
ERTS Program	**Costs by Mode of Acquisition**, $ thousands (1973)**		
	Non-Exclusive	Exclusive	Probable
ERTS Interpretation Including Comparison to Air Photos	25.0	25.0 *	25.0
Seismic Survey Across Anomalies (900 Kilometers)	76.0	990.0 *	990.0
Air Photo Interpretation of Anomalies (14,000 Square Kilometers)	11.2	28.0 *	28.0
Reconnaissance Surface Geology Over Anomalies (14,000 Square Kilometers)	35.0	35.0 *	35.0
TOTAL	147.0	1,078.0	1,078.0

* Indicates probable mode of acquiring the data.

** "Exclusive" and "Non-exclusive" refer to the depth of the program in determining the presence of petroleum.

Source: "An Evaluation of ERTS Data for the Purpose of Petroleum Exploration" Eason Oil Co., Contract NAS 5-21735, June 1975

$1,664,000 using the convential program and $1,078,000 using the ERTS program, thus yielding a 35% cost savings for use of ERTS imagery.

It was found that the activities composing the $1,664,000 figure generally represented all of a company's geological and geophysical onshore operations.* Thus, an estimated cost savings figure of 35% in onshore geological and geophysical operations is derived.

In trying to derive a figure for onshore G & G costs, Table 10 shows that an average of $368M annually was spent by the petroleum industry for all (on and offshore) G & G operations over the last five years. However, it was found in a conversation with Offshore Magazine** that oil companies do not release figures which indicate how much money was spent for strictly offshore or strictly onshore operations. But the publishers did estimate that about 40% of industry costs for G & G would be for offshore operations leaving about 60%, or an average of $220M for onshore G & G. Using Eason Oil's calculation of a 35% cost savings using ERTS Data, this yields an annual benefit figure of $77M due to cost savings in onshore geological and geophyscial operations.

Further benefits exist in the area of acceleration in the discovery rate of the existing petroleum stock. Some of that stock which would have been put into production 20 years from now might be produced within the next few years. Using a 10% rate of discount (which says that we value oil produced next year 10% less than we value oil produced this year because the oil we have now can be used to build capital stock used to produce that many more goods next year), a volume of oil to be produced ten years from now which is presently worth $350,000, would be worth $1,000,000 if produced today, assuming that it would sell at the same rate then and now. Additionally, increasing the supply of known reserves allows for increased production in times of high demand, thus reducing economic losses due to price fluctuations.

Obviously, any benefit deriving from ERTS data due to increased production rate depends upon the impact rate that ERTS data caused. For example, using ERTS imagery, discovery

---

* Personal conversation: Leo P. Stonis, Eason Oil, P.O. Box 18755, Oklahoma City, Oklahoma.

** Personal conversation: Bob Burke, Offshore Magazine, P.O. Box 217, Conroe, Texas 77301.

*** For a discussion of this, see Vol. III, Part II, Distribution Effects, of this report.

may be accelerated at a 10% rate but, due to monopolistic (oligopolistic) power, the companies may not increase production at all, in order to keep prices, and profits high. The benefit also depends upon the future price of oil. If oil prices increase at an annual 10% rate, e.g., due to decreasing supply, then there would be no benefit from accelerating the production rate since the 10% annual price increase wholly offsets the 10% discount rate.

Figure 9 illustrates potential benefit of increasing the rate of production of reserves using ERS data. The different lines represent the different rates of impact on production which ERTS might have. The analysis assumes a constant price of $10 per barrel. The benefit estimates are reached by the difference between the present value of petroleum being produced, e.g., next year, minus the present value of petroleum being produced, e.g., 20 years from now.

Current Activities

In addition to those activities already cited in RMF 5.1.1, Eason Oil investigators found other capabilities from ERTS imagery; the existence of "hazy" anomalies has been found in ERTS imagery that was not apparent in imagery from aircraft or Skylab. The anomalies have a very high correlation with known oil fields. As the investigators report:*

> One method which might be used for locating promising exploration sites is to define sites where two or more anomaly types coincide. On one composite overlay of fall imagery we counted 76 anomalous features. We classified these as geomorphic, tonal and "hazy" areas. Of 76 anomalies, 59 correlate with producing oil and gas fields, 9 are on known but non-producing structures, and the remaining 8 could not be correlated with known features. Twenty-nine geomorphic features are included. Twenty-three correspond with producing areas, 3 with non-productive structures. Three show no correlations. Eight of 12 tonal anomalies correlate with production. One correlates with

* "An Evaluation of ERTS Date for the Purposes of Petroleum Exploration," op cit, p.96.

RMF No. 5.4.2

Impact of ERS on Production of Reserves

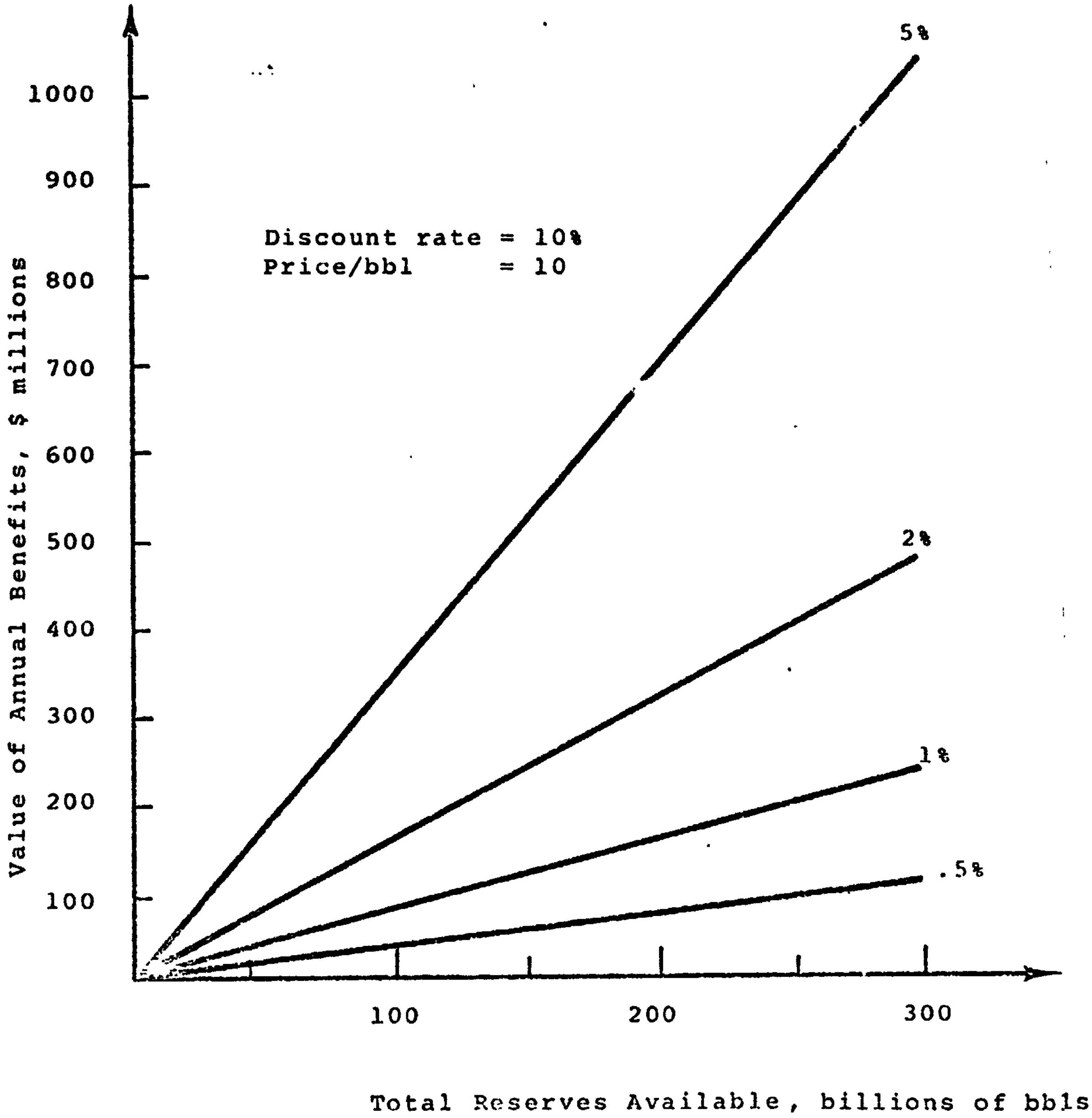


Figure 9 Annual Benefits from Increased Production in U.S. Petroleum Industry

a known structure and 3 correlate with no known features. Of 35 "hazy" anomalies, 33 correlate with producing fields or drilled structures.

The investigation also found the following advantages in using ERTS for lithologic mapping:

- Large areas can be mapped quickly

- Major structural and lithologic features are discernable.

- Existing interpretations of some local areas can be improved.

- Regional relationships among lithologic, strucutral and geomorphic features can be studied.

- Areas for further study or geophysical work can be located.

- Some units can be subdivided on the basis of their reflectivities.

- Interpretation permits evaluation and revision of published information.

- Low resolution and regional coverage suppress or eliminate a large amount of distracting detail permitting subtle large scale differences to be defined and studied.

Estimate of ERTS Economic Capabilities

From the above considerations, an estimate of \$77M annually is dervied for potential cost savings in geologic and geophysical operations. This estimate is considered to be a "soft" benefit due to the extrapolation involved in going from one company's customary procedures to the industry's. Also recognized is the fact that it is unlikely that the industry will shift entirely to use of remote sensed data in the near future. So a range of benefits has been estimated, from \$33.5M for 50% application of remote sensed data, to \$77M for full application.

It should also be pointed out that these figures represent *very* conservatively estimated benefits to the petroleum extraction industry. Not considered here are benefits to: offshore exploration, choosing optimal regions for exploration, time savings, better knowledge of reserves enabling a "smoothing out" of prices over time, and the present value of using newly impacted resources for capital development.

Annual Benefits:

Cost Savings $33.5 - 77M (soft)

RMF No. 5.5.1

MONITOR STRIP AND AUGER MINING LAND RECLAMATION

Rationale for Benefits

Strip mining may be an environmental horror, but it may be essential if the U.S. is to reach the Project Independence target of energy self-sufficiency by 1980. However, Congress recently passed a strip mining bill which, if not vetoed, will make it mandatory for coal companies to reclaim all strip mined land.* In order to insure compliance with the proposed law, constant monitoring of reclamation activities will be necessary. The government agencies involved must be able to quickly determine areas of mining reclamation and progress or viability of replanted vegetation on a total of 2881 existing strip and auger mines.

Federal Government Activities and Responsibilities

On the Federal level, regular inspections of coal mines are estimated to number about 19,400 for FY 1975.** Spot and other inspections for the same period are estimated to number about 54,600.*** For this purpose, the Bureau of Mines employs 1321 field inspection personnel who, as part of their job, monitor reclamation progress. Table 12 lists some Federal statutes to which ERS information would apply.

Table 12 Federal Statutes Pertinent to RMF 5.5.1

No.	Name of Statute	Reference	Federal Agency	Functions
1.	Mining and Minerals Policy Act of 1970	30 USC 21a; P.L. 91-631	DOI	encourage private enterprise in the reclamation of mineral land
2.	Federal Water Pollution Control Act	33 USC 1314e; P.L. 92-500	EPA	control mine discharge pollution

* Newsweek, Vol 84N06, August 5, 1974, p.53

** Federal Budget FY 1975

*** Ibid.

RMF No. 5.5.1

Non-Federal Activities

Ohio and Kentucky are two leading states in mine reclamation activities. The state of Kentucky employs 50 inspectors to cover 1100 surface mines.

Functions of Remote Sensing

The monitoring function of the government can be enhanced through the use of remote-sensed data. In order to determine reclamation progress and vegetation viability, government agencies now rely on ground teams and aerial photographs which rapidly become outdated and given the number of existing strip mining operations, neither method is economically feasible.* Remote-sensed data allows the monitoring federal and state agencies to survey the reclamation progress quickly, repetitively, and more cheaply than existing methods.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

An ERS system will help a great deal in monitoring reclamation processes, particularly if it becomes mandatory for all stripped land to be reclaimed. The benefit here would be the costs saved by using ground inspectors more efficiently, sending them only to suspect areas. Assessing a benefit here would be too tenuous a procedure at this time, until figures on amount of inspection and costs of ground and aerial inspection become known.

Coal industry officials estimate that in order to comply with the proposed strip mining legislation they will incur a cost of $2000 per acre for reclamation and that at the current level of strip mining, this would amount to a more than $500 million a year expenditure on their part.**

Current ERTS Activities

The following is a partial list of Principal Investigators who have done work in this RMF area:

1) Alexander, S.S.; Dein, J.; Gold, D.P.
Concluded that ERTS data can be used to evaluate

* Automated Strip Mine and Reclamation Mapping from ERTS, Robert H. Rogers, Larry E. Reed, Wayne A. Pettyjohn.

** op. cit. Newsweek

the effectiveness of reclamation and pollution abatement procedures. Also found that ERTS imagery can be used to determine the location, extent, and sub-classification of strip mined area.***

2) Rogers, R.H.; Reed, L.E.
Using computer processing techniques, it is possible to produce geometrically-corrected maps of the coal strip mines in East Central Ohio by utilizing ERTS-1 computer compatible tapes.

3) Wier, C.W.; Wobber, F.J.; Russell, O.R.; Amato, R.V.
Concluded that repetitive ERTS-1 imagery is a useful tool for mapping recently mined lands in coal producing areas. Also found that the likelihood of applying ERTS-derived fracture data to improve coal mine safety apperas practical from studies in Indiana.

Estimate of ERTS Economic Activities

Besides increasing mine inspector productivity, the utilization of ERTS imagery will be a cost savings in data collection for the Bureau of Mines. A dollar figure cannot be obtained at this time because of a lack of data on existing data collection methods and the rapidly changing nature of these activities at this time. New capability benefits will accrue through repetitive coverage of reclaimed lands providing the necessary monitoring function to check the continual health of replanted vegetation. The goal of ERTS activities in this RMF will be to provide objective monitoring of reclamation.

*** Alexander, Dein and Gold, "Use of ERTS Data for Mapping Strip Mines and Acid Mine Drainage", Significant Results Symposim, op cit, p. 574

RMF No. 5.6.1

MINE FIRE DAMAGE ASSESSMENT

Rationale for Benefits

The causes of outcrop and abandoned mine fires are many and they depend on specific circumstances. A fire in an abandoned underground mine may, in rare instances, be of past origin, having started and been sealed off when mining was active. Most frequently, however, such fires can be traced to the burning of trash dumped promiscuously into surface stripping pits or old mine openings. The fire then eats its way down into the previously mined coalbed.

In unpopulated areas uncontrolled coal fires can start grass and forest fires, kill vegetation, contaminate nearby water, and become a hazard to people, livestock and wildlife. Near population centers, mine fires menace public health, safety, and property.

In addition to their adverse effects upon the local economy and environment, uncontrolled coal fires destroy fuel resources that may be required for future national needs.

Federal Government Activities and Responsibilities

In August, 1954, Congress enacted P.L. 738, providing an annual appropriation not to exceed $500,000 for DOI, acting to control and extinguish fires in inactive coal formations throughout the United States. In the case of non-federal lands the Act specified that the State or the owner should contribute 50 percent of costs.

A major impetus in the control of abandoned-mine fires in the Eastern United States came with the passage of the Appalachian Regional Development Act of 1965 (P.L. 89-4, as amended). This act removed the appropriations ceiling of P.L. 738 for work within the Appalachian Region, and increased the Federal contribution to 75 percent of costs, with the State contributing the remaining 25 percent.

Outcrop and abandon-mine fire control work in the remainder of the United States continues to be implemented by the Bureau of Mines under the original provisions of P.L. 738.

Federal budget data relevant to this RMF are listed in Appendix B. Some applicable statutes are found in Table 13.

RMF No. 5.6.1

Table 13 Federal Statutes Pertinent to RMF 5.6.1

No.	Name of Statute	Reference	Federal Agency	Functions
1.	Bureau of Mines	30 USC 1-11; 36 Stat. 370; 37 Stat. 381	DOI	increasing safety in mines
2.	Control of Coal Mine Fires	30 USC 551-558; 68 Stat. 1009	DOI	control and extinguish mine fires
3.	Anthracite Mine Drainage and Flood Control	30 USC 571; P.L. 87-818	DOI	seal abandoned mines
4.	Federal Coal Mine Health and Safety Act of 1969	30 USC 801-960; P.L. 91-173	DOI	mine health and safety
5.	Federal Metal nd Non-metal Health and Safety Act	30 USC 721-740; P.L. 89-577	DOI	mine health and safety

The Function of Remote Sensing

Suspected coalbed fires that do not otherwise evidence themselves can be detected by infrared sensing. Using existing aerial infrared sensing, detection has been limited only to a depth of 30 feet.*

If the fire is deep underground, the only known technique to determine its location and extent is exploratory drilling. However, constant, repetitive thermal infrared sensing can aid in determining the detection of new fires thus helping to direct a ground-based control team.

ERS information could reduce the amount of aerial and ground surveillance necessary for monitoring purposes. But such monitoring activities do not regularly take place in an organized fashion and the determination of an impactable budget would be a prohibitive task.

---

* Coal Fires in Abandoned Mines and Inactive Deposits U.S. Department of Interior, Bureau of Mines 1972.

RMF No. 5.6.1

Estimate of ERTS Economic Capabilities

Any program for combatting fires must first start with detection. ERTS-B with a thermal IR band provides periodic monitoring of all coal reserves and mines. Because of this periodic, synoptic coverage, a cost savings on aerial infrared sensing may be ralized. No dollar estimate is possible, at this time, because it is not known how much has been spent for aerial infrared sending, of mining areas and the sensor may not be able to detect deep mine fires.

RMF No. 5.6.2

PREVENT MINE TAILING SLIDES

Rationale for Benefits

After decades of mining, mine tailings exist in various countries of the world. Most are harmless mountains of rubble but others are in precarious locations with potential damage to life and property should they slide. Detection of mine tailings may prevent damaging slides from occurring.

Federal Government Activities and Responsibilities

The Bureau of Mines is responsibile for mine safety and regulations. In addition, the Mining Enforcement and Safety Administration conducts mine inspections and field investigations.

Federal budgets are given in Appendix B.

The government statutes relevant to this RMF can be found in RMF 5.6.1.

Functions of Remote Sensing

Remote-sensed data are useful in detecting mine tailing accumulations of relevant size and hence provide a monitoring function. Once potentially hazardous mine tailings are identified, remedial action can be taken to remove the hazard.

Current ERTS Activities

The following is a partial list of Principal Investigators who have done work in this RMF area:

1) Isachsen, Y;, Fakundiny, R.; Footer, S.
Concluded that ERTS-1 imagery was useful in recognizing known mine dumps and tailings ponds.

Estimate of ERTS Economic Capabilities

An increased capability benefit is difficult to estimate for this RMF because of the infrequency of a mine tailing slide, and inadequate existing inventories of mine tailings. In the last 8 years, tailing slides have occurred in Aberfan, Wales and Buffalo Creek, West Virginia. The Welsh disaster resulted in 131 deaths* and the Buffalo Creek

---

*New York Times, October 22, 1966.

disaster resulted in 37 deaths.** Insufficient inspection contributed to the Welsh tragedy while flood conditions contributed to the West Virginia tragedy.

Benefits:

Increased capability +

**New York Times, February 27, 1972.

+ Possibly significant benefits but not quantified.

RMF No. 5.6.3

DETECT FRACTURES IN MINING AREAS

Rationale for Benefits

A major killer in underground mining operations is falls of roof and rib surfaces. In 1971, roof and rib falls accounted for over 43% or 61 deaths* in coal mines and over 15% or 25 deaths** in other underground mining operations.

One of the major causes of those falls is the lack of proper roof and bracing supports because of the lack of sufficient information on what is being supported -- namely, that many underground mining operations are located under fracture zones. This is especially true in coal mining operations. Over the last several years, however, the coal industry has been moving most towards strip and auger mining with the result that fewer deaths have occureed. This trend is not likely to continue in the coal industry because of the recent passage of the House of Representatives strip mining bill (see RMF No. 5.5.1). Because of the high costs involved in reclaiming strip-mined land (estimates of $2,000 per acre), coal officials predict an increase in underground mining in the East. This increase in underground coal mining could lead to six times*** the fatalities that surface mining does.

In order to minimize the number of fatalities in underground mining operations, more information will have to be known as to the nature of the overlying geologic strata. Once this information is known, proper measures can be taken to prevent roof and rib falls thus reducing the number of fatalities.

Federal Government Activities and Responsibilities

The U.S. Bureau of Mines employes 52 roof and rib surface inspectors.****

The Federal budget expenditures are given in Appendix B. Some applicable federal statutes are found in Table 14.

---

*Moving Forward in Coal Mine Health and Safety, Report of the Secretary of the Department of the Interior on administration of the Federal Coal Mine Health and Safety Act in 1971.

**Metal and Nonmetal Mine Health and Safety, Report of the Secretary of the Interior, 1972.

***Newsweek, Vol. 84, No. 6, 5 August 1974, p. 53.

****Op.cit. Moving Forward in Coal Mine Health and Safety.

Table 14 Federal Statutes Pertinent to RMF 5.6.3

No.	Name of Statute	Reference	Federal Agency	Functions
1.	Bureau of Mines	30 USC 1-11; 36 Stat. 370; 37 Stat. 681	DOI	increasing safety in mines
2.	Control of Coal Mine Fires	30 USC 551-558; 68 Stat 1009	DOI	control and extinguish mine fires
3.	Anthracite Mine Drainage and Flood Control	30 USC 571: P.L. 87-818	DOI	seal abandoned mines
4.	Federal Coal Mine Health and Safety Act of 1969	30 USC 801-960; P.L. 91-173	DOI	mine health and safety
5.	Federal Metal and Non-metal Health and Safety Act	30 USC 721-740 P.L. 89-577	DOI	mine health and safety

Functions of Remote Sensing

Remote-sensed data have proven useful in detecting fracture zones in mining areas. With repetitive, seasonal coverage of mining operations, maps of regional fracture zones can be accurately constructed and used by mining industry officials to better plan their areas of mining operation so as to reduce mine fatalities and thus increase mine productivity by preventing possible mishaps.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Again, there is insufficient impactable budget from which an estimate of cost-savings could be derived. Benefits would come from whatever cave-ins would be avoided through spotting fractures in ERTS imagery; but this figure would be impossible to anticipate.

Current ERTS Activities

See RMF No. 5.5.1.

1) Lowman, Paul

Constructed a fracture map of the northern Sierra Nevada from an ERTS-1 color composite. Numerous photo-lineaments, some of which are probably faults, not shown on existing maps, have been plotted from the ERTS picture.

2) Wier, et al.

Found ERTS fracture data could be used to improve mine safety from studies in Indiana.

Estimate of ERTS Economic Capabilities

The utilization of ERTS imagery to detect fracture zones is estimated to result in positive increased capability benefits.

RMF No. 5.8.1

DEVELOP NEW METHODS OF LOCATING MINERALS

Rationale for Benefits

There exists a need to develop new methods of locating new mineral deposits to keep a balance in production to reserve ratios. As the demand for increased mineral production grows, it becomes necessary to be able to locate and develop new resource deposits. These deposits may lie below the surface and the detection of these deposits becomes a problem of correlating known geologic information with information that may yield a clue as to what is below the surface.

Many theories exist as to how minerals accumulate and how they are best detected. Uncertainty exists and it is the purpose of research to reduce this uncertainty.

It is difficult to predict major breakthroughs in research. Theories, however, need data for testing and the synoptic view which remote sensing provides, will enable the predictive power of geologic theories to be more severely tested.

Benefits accrue to those who can claim a property right to the usefulness of the new research. On one hand, it will be the federal government from increased lease bids and royalty payments from mineral leases, the Indian nations from similar leases and the private mining business sector. Secondary benefits accrue to the public from potentially reduced prices of metals.

A recent study conducted by the National Academy of Sciences, the National Academy of Engineering, and the National Research Council warns that despite the key role of minerals in our society and the vastly increasing worldwide demand for mineral products, mineral technology in the United States is in a declining state, and serious trouble lies ahead for the country unless corrective actions are taken promptly.

Non-Federal Activities

Many major universities have ongoing geological studies where new theories on mineral accumulation are developed and tested. The $10 billion mineral industry is mainly concerned with the application of theories toward economic exploitation of mineral deposits. Table 15 lists some applicable Federal statutes.

RMF No. 5.8.1

Table 15 Federal Statutes Pertinent to RMF 5.8.1				
No.	Name of Statute	Reference	Federal Agency	Functions
1.	Bureau of Mines	30 USC 1-11; 36 Stat. 370; 37 Stat. 681	DOI	mining research
2.	Mining and Minerals Policy Act of 1970	30 USC 21a; P.L. 91-631	DOI	mining research
3.	Resource Recovery Act of 1970	42 USC 3251	DOI	promote national research
4.	National Science Foundation Act of 1970	42 USC 1861-1875; P.L. 90-407	DOI	promote research

Functions of Remote Sensing

Remote sensing allows synoptic coverage of a region that may prove promising for new mineral deposits. Lineaments, faults, folds, and other geomorphological data that are important in the locating of ore deposits are discernible in ERTS-imagery. MSS scanning of vegetation cover may allow geologists to locate below-surface mineral deposits by uncovering mineral signatures in the vegetation. Earth resource satellites provide the unique opportunity of repeated coverage of large land areas and thus improve the possibility of detecting mineral resources.

Economic and Technical Models for Estimating Benefits from Remote Sensed Data

Benefits are probably large in the area of potentially accelerating the rate of recovery of mineral resources (see RMF 5.4.1). Estimation of these benefits is curtailed by lack of information on how much the recovery rate could be impacted and the institutional structures which inhibit maximum production rates for the sake of profits.

Current ERTS Activities

Vincent, Robert K.

Discovered that ratio scattergrammetry (spectral ratio imagery), of ERTS data, a means of determining from laboratory data, what a given material will look like in a particular ratio image. When the laboratory data bank is expanded to include more rock and mineral samples, it may eventually be possible to interpret ratio images over completely unknown terrain with acceptable accuracy.

Estimate of ERTS Economic Capabilities

No benefits are measured here since the applications are performed by private industry who would consider any new methodology proprietary.

RMF No. 5.8.2

DEVELOP NEW METHODS OF LOCATING HYDROCARBON FUELS

Rationale for Benefits

Increasing energy demand necessitates increasing fuel production and proven reserves. Although many of the great structures and larger stratographic traps have been located and are already producing, a great deal of new oil, gas, and coal can be found within known and unknown producing provinces; for example, see the estimates of reserves in Figure 5. As geologists and geophysicists become more sophisticated in applying new geologic knowledge and as traditional tools are improved, these less obvious accumulations have a higher probability of being detected. Development of new deposits will insure increased fuels production.

Federal Government Activities and Responsibilities

The Nixon Administration had recommended an expenditure of $10 billion over a 5-year period beginning with fiscal 1975 as part of "Project Independence." Table 16 lists some applicable federal statutes.

Table 16 Federal Statutes Pertinent to RMF 5.8.2

No.	Name of Statute	Reference	Federal Agency	Functions
1.	Bureau of Mines	30 USC 1-11 36 Stat. 370; 37 Stat. 681	DOI	mineral fuels research
2.	Mining and Minerals Policy Act of 1970	30 USC 21a; P.L. 91-631	DOI	mineral fuels research
3.	Resource Recovery Act of 1970	42 USC 3251	DOI	promote national research
4.	Coal Research and Development	30 USC 661; P.L. 86-599	DOI	develop, through research, new coal mining methods
5.	National Science Foundation Act of 1950	42 USC 1861-1875; P.L. 90-407		

Non-Federal Activities

Many major universities have ongoing geological studies where new theories on hydrocarbon accumulations are developed and tested. The private fuels industry's output is valued at over $23 billion and is mainly concerned with the application of theories towards the economic exploitation of hydrocarbon fuels deposits.

RMF No. 5.8.2

Functions of Remote Sensing

Multispectral images from earth resources satellites can provide data relevant to classification of soil and rock types. Land and rock forms are visually evident in images as are also linements, fractures, and other large scale geologic features associates with mineral and fossil fuel deposits.

Economic and Technical Models for Estimating Benefits from Remote Sensed Data

See RMF 5.8.1.

Current ERTS Activities

See RMF 5.1.1 and 5.4.2.

Estimate of ERTS Economic Capabilities

The theories governing the creation and location of petroleum and gas accumulations, while well developed, are actively debated. They range from those which claim an organic origin to those that support the mild thermal degradation of kerogen as the principal mechanism by which hydrocarbons in natural gas and petroleum are produced.

These theories are then connected to structures which require further geophysical and geologic exploration before hydrocarbon fuel discoveries can be determined.

In 1964, the Energy Study Group claimed that of clear utility would be a method that gives both unequivocal evidence of hydrocarbon accumulations and criteria on their commercial significance. Meager success has rewarded limited efforts over many years to devise a direct surface method of indicating the presence of subsurface deposits of hydrocarbons. The incorporation of the ERTS synoptic view into present theories may lead to refined and new ideas for surface exploration.

New techniques in seismology, namely bright spot analysis, are challenging more traditional methods as the main tool in oil and gas exploration.

RMF No. 5.9.1

ESTABLISH AND ENFORCE MINE SAFETY REGULATIONS

Rationale for Benefits

Destruction of mining resources and the natural resources being mined increases the risk on return on investment. Better mine safety regulation can reduce this risk with benefits accruing to private mine owners, miners, through reduced loss of life and limb, and to the private sector through reduced loss of mineral production.

Federal Government Activities and Responsibilities

Table 17 lists some Federal statutes applicable to ERS information.

Table 17 Federal Statutes Pertinent to RMF 5.9.1

No.	Name of Statute	Reference	Federal Agency	Functions
1.	Bureau of Mines	30 USC 1-11: 36 Stat. 370; 37 Stat. 681	DOI	increasing safety i.. mines
2.	Control of Coal Mine Fires	30 USC 55;-558; 68 Stat. 1009	DOI	control and extinguish mine fires
3.	Anthracite Mine Drainage and Flood Control	30 USC 571; P.L. 87-818	DOI	seal abandoned mines
4.	Federal Coal Mine Health and Safety Act of 1969	30 USC 801-960 P.L. 91-173	DOI	mine health and safety
5.	Federal Metal and Non-metal Health and Safety Act	30 USC 721-740 P.L. 89-577	DOI	mine health and safety

RMF No. 5.9.1

Non-Federal Activities

The states with mining industries all have their own mine regulations. Private mining operators also have a vested interest in providing safe working conditions; however, for the entrepreneurs it is an economic trade-off between safety and profitability. Unions are also active in this area.

Functions of Remote Sensing

Remote-sensed information provides an objective monitoring capability. See RMF areas 5.5 and 5.6

Benefits here are largely unquantifiable; they are based on how much property and lives might be saved through stricter safety regulations.

Current ERTS Activities

See RMF's 5.5, 5.6

Estimate of ERTS Economic Capabilities

No benefits have been quantified for this function.

RMF No. 5.9.2

ESTABLISH POLICIES FOR AND ADMINISTER OFFSHORE OIL AND GAS LEASE SALES

Rationale for Benefits

This activity includes coordination of national energy use and production. The benefits occur by providing a balanced production-to-reserve ratio given the prices for oil and gas. Also liability damages from offshore oil spills need to be traced to their originator.

Benefits accrue to the private sector through increased oil and gas output and to damaged parties of oil spills.

Federal Government Activities and Responsibilities

The Offshore Drilling Act (P.L. 92-500) contains legislation to improve monitoring of offshore drilling lease compliance.

Non-Federal Activities

Private industry leases all offshore areas and looks to offshore drilling as a potential large reserve area. Consider the following excert from the oil and gas report:*

> Much of the United States continental shelf is unexplored. Who can say at this time that another "Los Angeles Basin" doesn't wait for discovery and exploitation beneath the waters of the Southern California Borderland (Emery, 1960)? Who knows that there is not another "Middle East," for example, beneath the continental mar off the southern Atlantic coast of the Unite cates, with another "Ghawar" accumulation (the largest single oilfield yet discovered in the world) containing another "75 billion barrels of producible reserves" (Arabian American Oil Company, 1959; Halbouty and others, 1970)? The onshore-offshore region south of Cape Hatteras has much in common geologically with the onshore-offshore

* Oil and Gas, United States Mineral Resources Ibid, p. 490

region of Saudi Arabia, including a very thick section of structurally similar lithologies beneath a very large area. Prior to discovery by the drill and subsequent development, Ghawar field was not a particularly conspicuous prospect of structure, either from surface geologic mapping or geophysical interpretation (Arabian American Oil Company, 1959, especially p. 437 and p. 440-443).

Functions of Remote Sensing

Remote sensing might be capable of detecting hydrocarbon leakage in offshore areas. This can be useful in directing exploration resources. Furthermore, if the remote sensing capability can detect drilling platforms, this will allow the area geologist to survey offshore rigs and monitor them for oil spills.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Better information and information-dissemination would aid in arriving at a completitive, maximum economic rent for these properties.

Current ERTS Activites

Almost no work has been directed toward realizing capabilities in this area. For assessment of ERTS capabilities in water surface and underwater activities, see Volume IX on Oceans.

Estimate of ERTS Economic Capabilities

No benefits are reported for this RMF.

APPENDIX B:

SUMMARY OF APPLICABLE FEDERAL BUDGETS

Figure 11 shows the Federal Government Agencies and their departments who have legislative responsibility in the nonreplenishable resource area. Along with the departments are the fiscal year, 1975, budgets which are potentially impactable by decisions arrived at using remote-sensed imagery. All RMF activities are also listed along with the budget for each department. Total impactable Federal expenditures are $1,319,135,000.

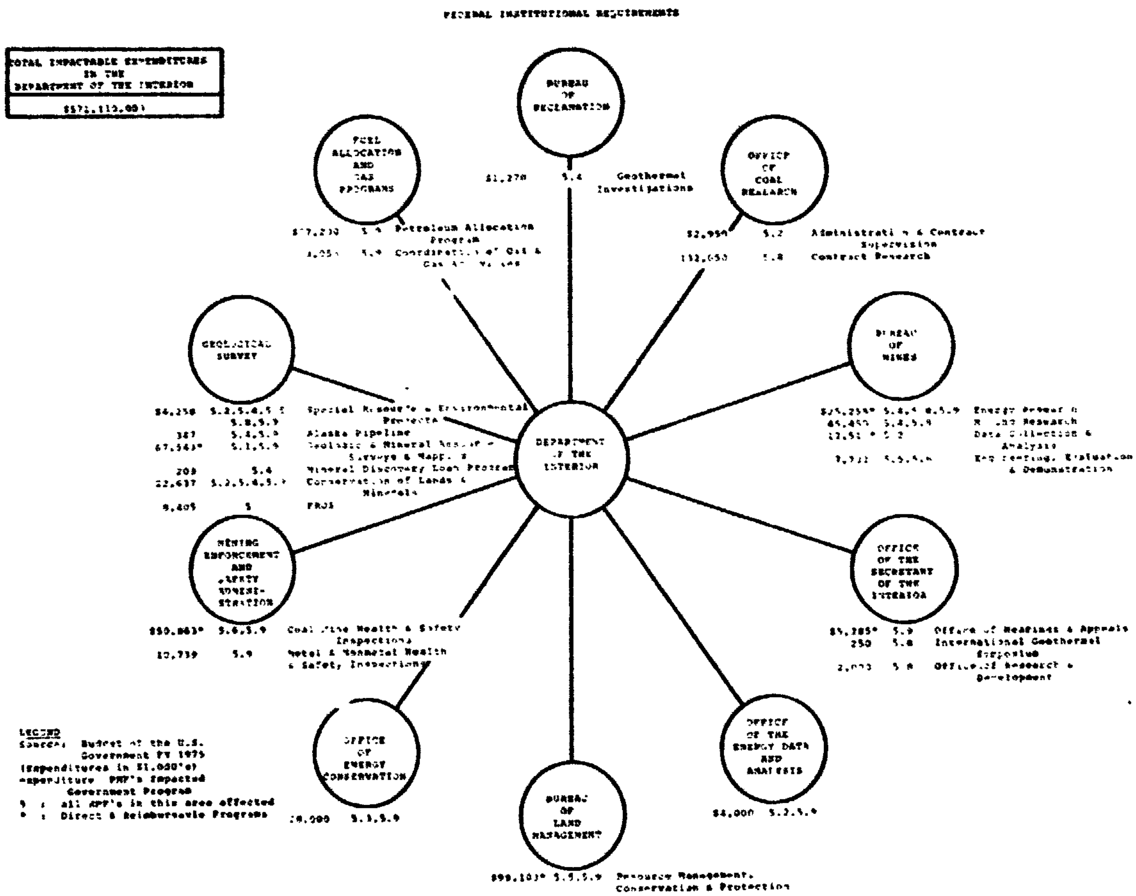


Figure 10 Federal Institutional Requirements

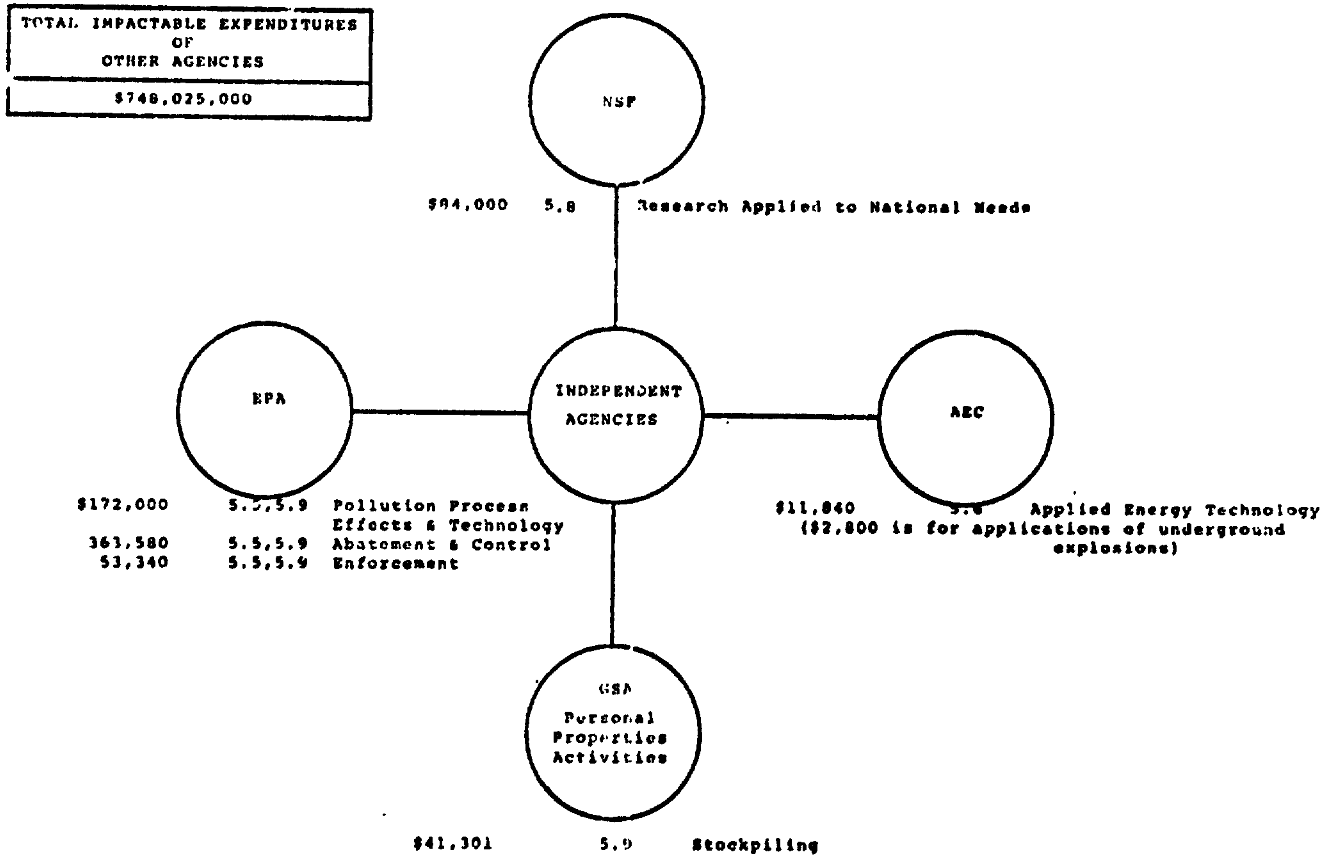


Figure 10 Federal Institutional Requirements (Continued)

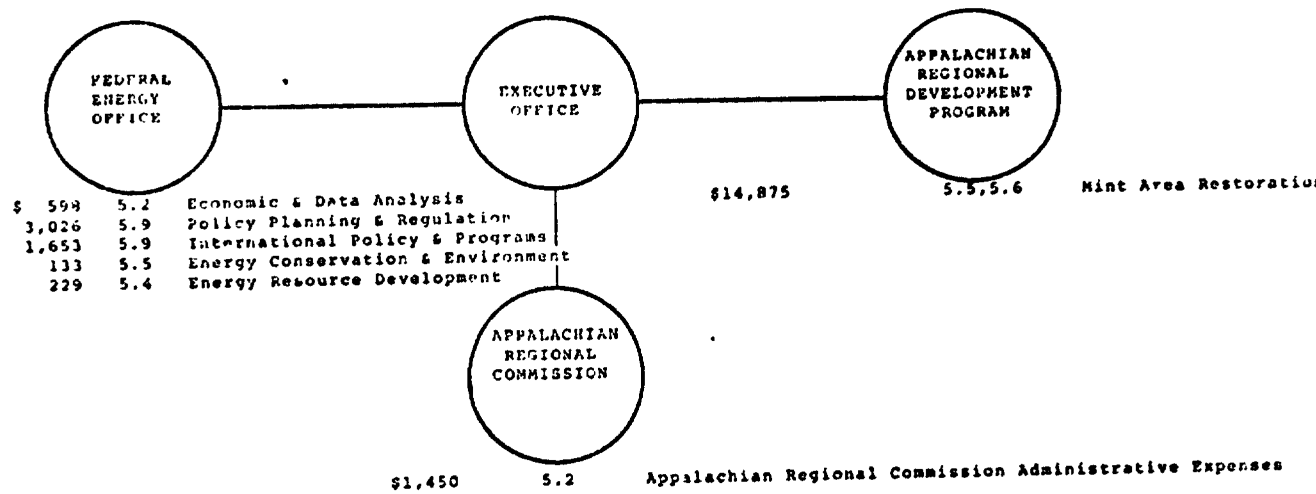


Figure 10 Federal Institutional Requirements (Continued)

APPENDIX C

SUMMARY OF APPLICABLE LAWS AND STATUTES

DEPARTMENT OF THE INTERIOR

U.S. Geological Survey

The USGS was established on March 3, 1879 (20 Stat. 394; 43 USC 31). Its purpose is to provide for the classification of public lands and the examination of the geological structure, mineral resources, and the products of the national domain. By the act of September 5, 1962 (76 Stat. 427; 43 USC 31(b)), this authorization was expanded to include such examinations outside the national domain.

Relevant legislation:

No.	Reference	Name
1)	30 USC 641-646 (P.L. 85-701; 72 Stat. 700)	Exploration Program for Discovery of Minerals
2)	15 USC 715	Connally Hot Oil Act
3)	43 USC 31 (P.L. 87-626)	Geological Survey
4)	40 USC 481(c)	Federal Property and Administrative Act of 1949
5)	22 USC 2357 (P.L. 87-195; P.L. 90-554)	Foreign Assistance Act

Bureau of Mines

The Bureau of Mines was established on July 1, 1910 by the Organic Act of May 16, 1910 (36 Stat. 369; 30 USC Secs. 1, 3, 5-7). The Bureau performs research, provides information to the public, condusts inquiries in accordance with the laws pertinent to the technology of processing, use, and disposal of minerals and mineral fuels. The 1910 act, as amended, has been supplemented by several statutes which allows associated mineral wastes.

Relevant legislation:

No:	Reference	Name
1)	30 USC 1-11 (36 Stat. 370; 37 Stat. 681)	Organic Act of 1910
2)	30 USC 21a (P.L. 91-631)	Mining and Minerals Policy Act of 1970
3)	30 USC 551 (68 Stat. 1009)	Control of Coal Mine
4)	30 USC 571 (P.L. 87-818)	Anthracite Mine Drainage and Flood Control
5)	30 USC 951 (P.L. 91-173)	Federal Coal Mine Health and Safety Act of 1969
6)	42 USC 3251-3259 (P.L. 91-512)	Resource Recovery Act of 1970

Mining Enforcement and Safety Administration

The Mining Enforcement and Safety Administration was established on May 7, 1973 by Secretarial Order No. 2953.

Relevant legislation:

No:	Reference	Name
1)	30 USC 721 note (P.L. 89-577)	Federal Metal and Nonmetal Mine Safety Act
2)	30 USC 801 note (P.L. 91-173)	Federal Coal Mine Health and Safety Act of 1969

Office of Coal Research

The office of Coal Research was established pursuant to the Coal Research Act of July 7, 1960 (74 Stat. 336; 30 USC 661-668). The Office seeks to develop new and more efficient methods of mining, preparing, and utilizing coal to insure abundant supplies of clean energy.

No.	Reference	Name
1)	30 USC 661-668 (P.L. 86-599)	Coal Research Act of 1960

Office of Oil and Gas

The Office of Oil and Gas was established on May 6, 1946 in response to the Presidential Letter of May 3, 1946. The Office develops, evaluates, and coordinates information to provide a sound basis for government oil and gas programs and is the principal channel of communication between the Federal government, the petroleum industry, the oil producing states and the public. It maintains a capability to respond to emergencies affecting the Nation's supply of oil and gas and administers the Mandatory Oil Import Program.

Office of Energy Conservation

The Office of Energy Conservation was established on May 7, 1973 by Secretarial Order No. 2953. The Office promotes efficiencies in the use and development of energy resources; coordinates all Federal energy conservation programs; conducts research on methods to improve the efficiency of energy usage; and develops contingency plans for nationwide power, fuel, and mineral resource emergencies caused by natural disasters, civil defense emergencies, or other interuptions of the Nation's energy and mineral supplies.

Office of Energy Data and Analysis

The Office of Energy Data and Analysis was established on May 7, 1973 by Secretarial Order No. 2953. The office serves as the focal point in DOI for coordinating functions related to gathering and analyzing energy data.

Bureau of Land Management

The Bureau of Land Management was established on July 16, 1946 in accordance with the provisions of Sections 402 and 403 of the President's Reorganization Plan No. 3 of 1946 (5 USC 133y-16). The Bureau classifies, manages, and disposes of the public lands and their related resources according to the principles of multiple-use management. It also administers the mineral resources connected with the acquired lands and the submerged lands of the Outer Continental Shelf.

Relevant legislation:

No.	Reference	Name
1)	43 USC 1	Bureau of Land Management

EXECUTIVE OFFICE

Federal Energy Office

The FEO was established on December 4, 1973 by Executive Order No. 11748. This Office is responsible for assuming that adequate provision is made to meet the energy needs of the nation for the forseeable future and provides the basis for rapid expansion of these activities to deal with an energy emergency.

Upon enactment of pending legislation, the operating programs of this office will be transferred to the Federal Energy Administration.

Appalachian Regional Development Program

This program was authorized by the Appalachian Redevelopment Act of 1965. One of its major programs in the Mine Area Restoration Program under which it is responsible to seal and fill voids in abandoned coal mines; plan and execute projects for the extinguishment and control of underground and outcrop mine fires; and to reclaim and rehabilitate strip and surface mine areas.

INDEPENDENT AGENCIES

Government Services Administration

GSA, under its Personal Properties Activities is responsible for governmental stockpiling.

No.	Reference	Name
1)	50 USC 98-98h	Strategic and Critical Materials Stockpiling Act
2)	50 USC 2061-2166	Defense Production Act of 1950

No.	Reference	Name
3)	68 Stat. 456; 73 Stat 607	Agricultural Trade Development and Assistance Act of 1954

Environmental Protection Agency

THE EPA's efforts are oriented toward producing the scientific knowledge and tools for regulating, preventing, and abating pollution. In the area of non-replenishable natural resources, the EPA is involved in controlling mine pollution.

Relevant legislation:

No.	Reference	Name
1)	33 USC 1314 e (P.L. 92-500)	Federal Water Pollution Control Act

National Science Foundation

NSF initiates and supports basic and applied research, science, and technology policy research, science education improvement activities, and related scientific programs to promote the progress of science and advance the Nation's health, prosperity, welfare, and security.

Relevant legislation:

No.	Reference	Name
1)	42 USC 1861-1875 (P.L. 90-407)	National Science Foundation Act of 1950

APPENDIX D:

PRINCIPAL INVESTIGATORS

Addresses of principal investigators involved in this resource area are given below:

ABDEL-GAWAD, DR. MONEM
North American Rockwell Corporation
Science Center
1049 Camino Dos Riso
Thousand Oaks, California 91360

BAUMGARDNER, DR. MARION F.
Laboratory for Application of Remote Sensors
Purdue University
1220 Potter Drive
Lafayette, Indiana 47907

CARTER, WILLIAM D.
EROS Program, U.S.G.S.
1925 Newton Sq.,E., Rm. 134
Mail Stop 560
Reston, Virginia 22092

COLLINS, DR. ROBERS
Eason Oil Company
5225 N. Shartel Avenue
P.O. Box 18755
Oklahoma City, Oklahoma

GEDNEY, LARRY D.
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701

GUILLEMOT, JACQUES
Institut Francais du Petrole
4 Avenue de Bois-Preau
92-Rueil-Malmaison

ISACHSEN, YNGVAR W.
Geological Survey
New York State Museum and Science Service
Albany, New York 12224

JENSEN, DR. MEAD L.
Department of Geological and Geophysical Sciences
University of Utah
Salt Lake City, Utah 84112

LATHRAM, ERNEST H.
Alaskan Mineral Resources BR. U.S.G.S.
345 Middlefield Road
Menlo Park, California 94025

ROGERS, DR. ROBERT H.
The Bendix Corporation
Aerospace Systems Division
3300 Plymouth Road
Ann Arbor, Michigan 48107

SAUNDERS, DR. DONALD F.
Services Group
Texas Instruments, Incorporated
P.O. Box 5621
Dallas, Texas 75222

STANCIOFF, ANDREW
3516 T. Street, N.W.
Washington, D.C. 20006

SWEET, DAVID C
Dept. of Dev[illegible]ment
State of Ohio
65 South Front Street
Columbus, Ohio 43215

VINCENT, ROBERT K.
Environmental Research Institute
P.O. BOX 618
Ann Arbor, Michigan 48107

WILLIAMS, DR. RICHARD S.
EROS Program, U.S.G.S.
1925 Newton Square
Room 134
Mail Stop 506
Reston, Virginia 22092

WILSON, DR. JOHN C.
Kennecott Exploration, Incorporated
Geologic Research Division
2300 West 1700 South
Salt Lake City, Utah 84104

WOBBER, DR. FRANK J.
Earth Satellite Corporation
1747 Pennsylvania Avenue, N.W.
Washington, D.C. 20006

APPENDIX E:

ROLE OF ERTS-1 DATA IN PETROLEUM EXPLORATION STRATEGY

(The following has been excerpted from "An Evaluation of ERTS Data for the Purposes of Petroleum Exploration," Eason Oil Co. op cit.)

ERTS-1 data are extremely useful during the initial phases of petroleum exploration, and can make significant contributions later in the exploration process. Our work convinces us that by studying ERTS data one can gain an understanding of regional lithologic and structural relationships and rapidly focus attention on areas of exploration interest, even in an area that is as complex and difficult from the standpoint of surface exploration as the Anadarko Basin. Once specific areas of interest are identified one can derive significant detailed information by detailed interpretation of these areas on ERTS imagery. We believe that ERTS imagery will be most important in the exploration of poorly known areas rather than in highly developed exploration provinces such as Anadarko Basin.

Aspects of ERTS interpretation that are important in the regional analysis phase of exploration are: mapping inferred lithology and major structural features, such as the axes of large synclines and anticlines, mapping of major fracture systems (if they can be separated from other linears) and mapping of closed anomalies recognized on the basis of tone, texture, geomorphology or inferred structure. Interpretation of this type can be used to postulate the geologic framework of the region and to focus attention on specific areas. An interpretation of linear features may contribute to overall understanding at this point, but we found it helped little. This preliminary interpretation should be done "blind", that is, without extensive reference to known or published data. Available data should be used to refine and modify the preliminary ERTS interpretation and analysis and to arrive at a regional synthesis of the geology.

Once this preliminary synthesis is complete, areas chosen as interesting or anomalous can be examined in greater detail in order to extract as much information as possible. It is at this level of study that interpretations of linears become important because the linears may coincide with or define alinements of anomalies or may contribute to a greater understanding of specific anomalies. In explored petroleum provinces, features identified as being of interest in petroleum exploration should be carefully examined on the ERTS imagery to see if it is possible to extract additional information or discern regional relationships. These interpretations and analyses can be used to plan regional reconnaissance, geological and geophysical programs, and to begin planning more detailed programs for specific anomalies. Any anomalies identified in the ERTS imagery almost certainly would be checked on normal air photographs before undertaking a seismic survey over them.

In addition to providing the interpretive base for planning regional surveys, ERTS imagery is an excellent map for planning logistics, overflights, the location of operations bases, etc.

Because of small scale and low resolution, ERTS interpretation can contribute relatively little during the detailed phases of exploration. In some instances it could help in choosing a well site (e.g., locating a well on the side of a river near access roads instead of the other side). There may be a few instances where ERTS might be useful in actual selection of a location (e.g., extension of known fracture porosity, extension of known fields, etc.), but these situations are expected to be rare. In all instances, one would want to obtain confirmation with the more customary exploration tools.

It is necessary, at all levels of ERTS interpretation, to continuously integrate ERTS imagery, aircraft acquired imagery, and ground data. This integration enables the interpreter to fully understand the information content of ERTS imagery, to form a geological synthesis and propose the most reasonable hypotheses.

ERTS provides a means of quickly understanding the geology of an exploration province and it rapidly focuses attention on features that may be of exploration interest. We believe these two advantages will be the main contributions ERTS can make to a petroleum exploration program. These types of information can greatly reduce the amount of reconnaissance geological and geophysical work necessary and result in a great saving of time and of manpower.