Pecora VIII

The Eighth William T. Pecora Memorial
Remote Sensing Symposium

SATELLITE LAND REMOTE SENSING ADVANCEMENTS FOR THE EIGHTIES

PROGRAM

October 4-7, 1983
Sioux Falls, South Dakota

Sponsored by:
The National Aeronautics and
Space Administration
The National Oceanic and
Atmospheric Administration
The United States Geological Survey

BACKGROUND

The Pecora Symposium was established in 1975 to foster the exchange of scientific and resource management findings resulting from the use of remotely sensed data. The symposium series honors the memory of William T. Pecora, former Director of the U.S. Geological Survey and Undersecretary, Department of the Interior. Dr. Pecora played a major role in the development and establishment of this country's satellite remote sensing systems.

Pecora VIII broadens the remote sensing applications focus of previous symposia in this series to include discussion of policies and plans for future satellite systems in addition to presentations on data applications and system performance of Landsat 4.

PECORA VIII COMMITTEE

Mr. Raymond A. Byrnes
Chief, Technical Information Office
EROS Data Center

Mr. Daniel Cotter
Chief, User Affairs Unit
National Environmental Satellite
Data, and Information Service

Mr. Donald T. Lauer
Chief, Technique Development and
Applications Branch
EROS Data Center

Dr. John W. Salisbury
Research Geologist
National Mapping Division
U.S. Geological Survey

Dr. Vincent V. Salomonson
Chief, Earth Survey Applications Division
NASA/Goddard Space Flight Center

Dr. Mark Settle
Program Manager
Non-Renewable Resources, NASA

Mr. Pitt G. Thome
(formerly NASA)
President and Chief Executive Officer
The Destek Group, Inc.

Mr. Allen H. Watkins
Chief, EROS Data Center

Mr. Gilbert Weill
Director, SPOT Image Corporation

Mr. Harold W. Yates
Acting Deputy Assistant Administrator
for Satellites
National Environmental Satellite
Data, and Information Service

SYMPOSIUM OUTLINE

Ramada Inn, Sioux Falls

Welcome and Technical Sessions in Roosevelt/Lincoln/Jefferson Room.

Luncheon, Socializer, and Banquet in Washington Room.

Exhibits in Harvest Room (downstairs).

TUESDAY, OCTOBER 4, 1983

8:30-9:30	Registration
9:30-12:00	Welcome and Symposium Overview
Noon-1:30	Luncheon and Keynote Address
1:30-4:30	Invited Papers on Landsat 4 Results
6:00-8:00	Cocktails and Hors d' oeuvres

WEDNESDAY, OCTOBER 5, 1983

9:00-12:00	Invited Papers on Landsat 4 Results
Noon	Luncheon Break
1:30-5:30	Applications and Related Technology

THURSDAY, OCTOBER 6, 1983

9:00-12:00	Future Operational Satellites: Plans and Status
Noon	Luncheon Break
1:30-5:00	Future Operational Satellites: The French SPOT Program
7:00	Pecora Award Banquet

FRIDAY, OCTOBER 7, 1983

9:00-12:00	Future Space Shuttle Experiments

PROCEEDINGS

A bound volume of a Proceedings of all presentations turned in during the Symposium will be distributed to registrants in January, 1984. Additional copies of the Proceedings may be purchased for $15.00 each. Copies can be ordered at the Symposium or by writing to Pecora VIII, P.O. Box 80937.

EROS DATA CENTER TOURS

The EROS Data Center is operated by the USGS as a part of the National Mapping Division. Originally established to receive, process, and distribute Earth image data acquired by satellite and aircraft and to investigate improved scientific uses for the data, the Center now has a broader research and development mission and specializes in the development and operation of advanced, computerized land information systems, in addition to providing products and services related to land and resources map data. The Center employs approximately 350 people.

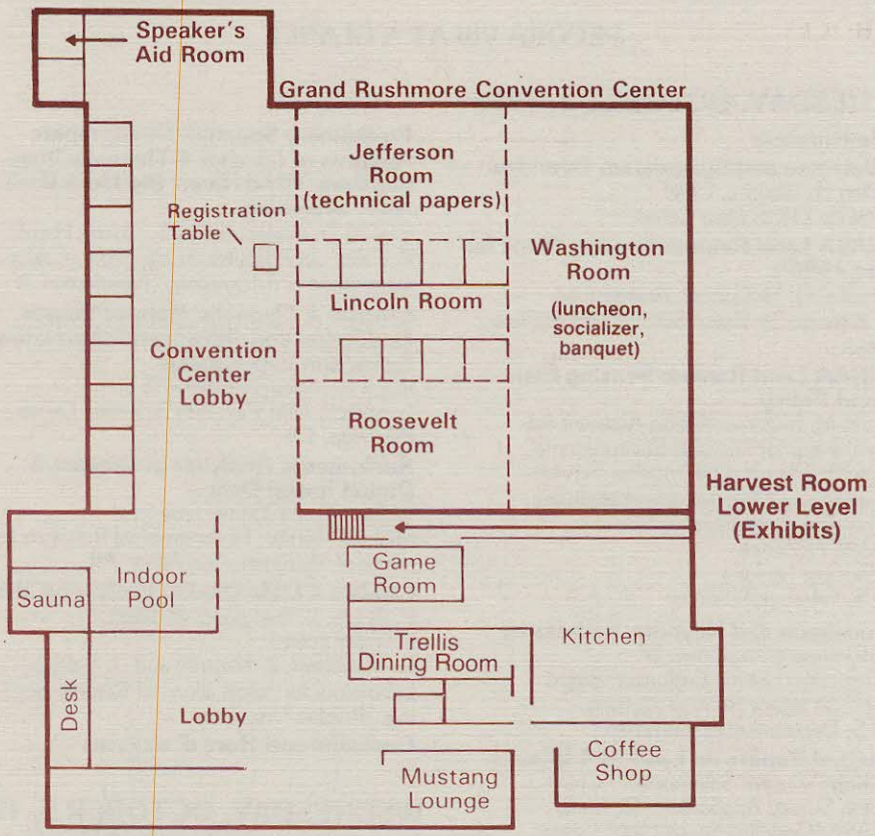
Landsat Products are produced and distributed by the EROS Data Center for the Department of Commerce's National Oceanic and Atmospheric Administration, which manages the operational Landsat system.

BUS SCHEDULE
EROS Data Center Tour

Friday, October 7, 1983

Tour Number	Leave Ramada Convention Center	Arrive EROS Data Center	Leave EROS Data Center	Arrive Ramada Convention Center
1	8:30am	9:00am	10:30am	11:00am
2	9:50am	10:20am	11:50am	12:20pm
3	12:40pm	1:10pm	2:40pm	3:10pm
4	2:00pm	2:30pm	4:00pm	4:30pm

NOTE: Please sign up for the tour of your choice at the EROS Data Center table in the registration area.



EXHIBITORS

Longman & Associates (Australia)
Optronics International, Inc.
Spot Image S.A.
Spot Image Corporation
Barringer Research
Spectral Data Corporation
DIPIX, Inc.
Geosat Committee
United States Geological Survey
National Aeronautics and Space Administration
National Oceanic and Atmospheric Association
Technology Application Center, University of Kansas
Laboratory for Applications of Remote Sensing, Purdue University
American Society of Photogrammetry

PECORA VIII EXHIBIT HOURS:

Harvest Room (downstairs)
Daily 9am to 5pm
Tues. - Thurs.
Coffee Available

PECORA VIII AT A GLANCE

TUESDAY, OCTOBER 4, 1983

Registration

Welcome and Symposium Overview
Allen H. Watkins, Chief
USGS/EROS Data Center

NASA Land Remote Sensing Plans for the 1980's
Dudley G. McConnel, Assistant Administrator for Space Science and Applications

NOAA Land Remote Sensing Plansand Policy
John M. McElroy, Acting Assistant Administrator for National Environmental Satellite Data and Information Services

Geological Survey Land Remote Sensing Activities
Doyle Frederick
Associate Director
U.S. Geological Survey

Luncheon and Keynote Address by
Raymond G. Kammer, Jr.
Chairman, Source Evaluation Board
for Civil Space Remote Sensing
U.S. Department of Commerce

Invited Papers on Landsat 4 Results
Chair: Vincent Salomonson, Chief,
Earth Survey Applications Division,
NASA/Goddard Space Flight Center

The Evolution and Present Status of Landsat 4 Systems
Vincent Salomonson, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD, and Harry Mannheimer, National Aeronautics and Space Administration, NASA Headquarters, Washington, D.C.

Thematic Mapper Image Processing System (TIPS) Performance
Eric P. Beyer, General Electric Company, Valley Forge Space Center, Philadelphia, PA

Landsat 4 Sensor Performance
John Barker, Earth Resources Branch
NASA/Goddard Space Flight Center

Thematic Mapper: Detailed Radiometric and Geometric Characteristics
Hugh Kieffer, U.S. Geological Survey
Flagstaff, Arizona

Preliminary Spectral/Stratigraphic Analysis of Landsat 4 Thematic Mapper Data, Wind River/Big Horn Basin Area, Wyoming
Earnest D. Paylor, James E. Conel, Harold R. Lang, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

Landsat 4 Thematic Mapper Sensor Evaluation and Advanced Information Extraction Experiments
Ralph Bernstein and Jeffry B. Lotspiech, IBM Palo Alto Scientific Center, Palo Alto, CA

Radiometric Analyses of Landsat 4 Digital Image Data
William Malila, Daniel Rice, and Michael Metzler, Environmental Research Institute of Michigan, Ann Arbor, MI

Landsat 4 Data Quality Evaluation Results
P. Anuta, L. Bartolucci, E. Dean, C. Valenzuela, C. McGillem, E. Malaret, and J. Valdez, Laboratory for Applications of Remote Sensing, Purdue University

Cocktails and Hors d' oeuvres

WEDNESDAY, OCTOBER 5, 1983

Invited Papers on Landsat 4 Results

Chair: Vincent Salomonson

Cartographic Quality of Landsat 4 MSS and TM Image Data
R. Welch, Department of Geography
University of Georgia, Athens, GA

Analysis of Landsat 4 Thematic Mapper Data for Classification of Forest in Baldwin County, Alabama
C.L. Hill, National Space Technology Laboratories, NASA/Earth Resources Laboratory

Evaluation of Thematic Mapper Data for Natural Resource Assessment
Robert Haas and Fred Waltz,
EROS Data Center, Sioux Falls, SD

Agricultural Applications of TM Data
David E. Pitts, R. Bizzell, K. Henderson, and D.R. Thompson, NASA/-Johnson Space Center and C. Sorenson and J. Carnes, Lockheed Engineering and Management Corporation, Houston, TX

Evaluation of Landsat 4 Image Quality for the Interpretation of Forest, Agricultural, and Soil Resources
Stephen D. De Gloria, Remote Sensing Research Program, University of California, Berkeley, CA

Contribution of Landsat 4 Thematic Mapper Data to Geologic Exploration
John R. Everett, Jon D. Dykstra, and Charles A. Sheffield, Earth Satellite Corporation, Chevy Chase, MD

Lithologic Mapping Using Landsat Thematic Mapper Data
M.H. Podwysocki, J.W. Salisbury, O.D. Jones, and D.L. Mimms, U.S. Geological Survey, Reston, VA

Lunch Break

Applications and Related Technology

Chair: Donald T. Lauer, Chief
Branch of Technique Development and Applications
USGS/EROS Data Center

Geologic Applications of SideLooking Airborne Radar Data in the Central Appalachians
Howard A. Pohn, U.S. Geological Survey

The National Digital Cartographic Data Base
Eric Anderson, U.S. Geological Survey

New Horizons for the National High-Altitude Photography Program
Peter Bermel,Assistant Division Chief for Plans and Operations, National Mapping Division, U.S. Geological Survey, Reston, VA

Application of Metsat Data in Land Remote Sensing
George Ohring, Michal Matson, David F. McGinnis, Jr., Stanley R. Schneider, National Environmental Satellite, Data, and Information Service, National Oceanic and Atmospheric Administration, Washington, D.C.

The Microcomputer Work Station: An Alternative Hardware Architecture for Digital Image Processing
William Erickson, NASA/Ames Research Center

New Opportunities for the Private Sector in Space Technology
W. D. Carter and A. B. Park, Globex Incorporated, Reston, VA

THURSDAY, OCTOBER 6, 1983

Future Operational Satellites: Plans and Status

Chair: Pitt G. Thome, President
The Destek Group

The Advanced Earth Resources Observations Satellite (AEROS): A Private Sector Remote Sensing Space System
N.H. MacLeod, Chairman,
American Science andTechnology Corporation, Bethesda, Maryland

Commercialization Versus Privatization: A Key Distinction for Future U.S. Civil Remote Sensing
Paul M. Maughan, Timothy M. Alexander, and Dennis J. Burnett
Communications Satellite Corporation, Washington, D.C.

Fairchild-Leasecraft System Providing Complete Service for Commercial and Government Users in Space
John Naugle, Fairchild Space and Electronics Company

The GEOSAT Committee's Current Activities and Plans
Fred Henderson, GEOSAT Committee

The Large Format Camera
Fred Doyle, U.S. Geological Survey

GEO-SPAS, A New Approach for Commercial Remote Sensing Missions
G. Barthel, Hans-Christian Benohr and D.E. Koelle, MBB Space Division, Federal Republic of Germany

RADARSAT
Ed Langham, Radarsat Project Office, Canada

Mapsat
Alden Colvocoresses, U.S. Geological Survey

Multilinear Array Instrument Concepts for Future Land Remote Sensing
Aram Mika, Hughes Aircraft Company

Lunch Break

Future Operational Satellites: The French SPOT Program

Chair: Gilbert Weill, Director
SPOT Image Corporation, U.S.A.

Le Systeme Probatoire d'Observation De La Terre
Michel Courtois, Centre Spatial De Toulouse, Toulouse, France

Flexible Programming for SPOT System
M. Cabrieres and Miss Ponce

Integration of Oblique Space Imagery into Geographic Data Bases
Alain Baudoin, Head of SPOT Project at IGN-France, (Institut Geographique National, Paris, France

SPOT Worldwide Distribution Plans
A. Fontanel, CNES/SPOT Image, France

Testing and Applications Using Simulated Imagery
G. Saint, CNES/Toulouse

The GDTA SPOT Simulation Program
J.C. Cazaux and C. Torres, CNES/Toulouse

The 1983 U.S. SPOT Simulation Campaign
G. Weill, SPOT Image

Pecora Award Banquet and Address
By Senator Larry Pressler
Senate Commerce, Science, and Transportation Committee

FRIDAY, OCTOBER 7, 1983

Future Space Shuttle Experiments

Chair: Mark Settle, Program Manager, Non-Renewable Resources, NASA

Studies of Optical and Biological Properties of Terrestrial Land Cover Using Multispectral Linear Array Technology
W.L. Barnes and V.V Salomonson, NASA/Goddard Space Flight Center, Greenbelt, MD

The Shuttle Imaging Spectrometer Experiment
Alexander F.H. Goetz, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

A Shuttle Thermal Infrared Multispectral Scanner
Anne B. Kahle, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

Orbital Surveys of Solar Stimulated Luminescence
W.R. Hemphill, U.S. Geological Survey, Reston, Virginia, A.F. Theisen, R.M. Tyson, and J.S. Granata, U.S. Geological Survey, Flagstaff, Arizona

Shuttle Imaging Radar Research Facility
C. Elachi, J.B. Cimino, and D. Evans, Jet Propulsion Laboratory, Caltech, Pasadena, CA

Shuttle Digital Topographic Mapper
M. Kobrick and C. Elachi, Jet Propulsion Laboratory, Pasadena, CA

Shuttle Polar Ice Sounding and Altimetry
T.H. Dixon and C. Elachi, Jet Propulsion Laboratory, Pasadena, CA

Integrated Remote Sensing of the Earth from Low Earth Orbit in the 1990's.
Dixon Butler, NASA/Space Sciences and Applications

Program

TUESDAY, OCTOBER 4, 1983

8:30-9:30 **Registration**

9:30-12:00 **Welcome and Symposium Overview**
Allen H. Watkins, Chief
USGS/EROS Data Center

NASA Land Remote Sensing Plans for the 1980's
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NOAA Land Remote Sensing Plans and Policy
John M. McElroy
Acting Assistant Administrator for National Environmental Satellite Data and Information Services

Geological Survey Land Remote Sensing Activities
Doyle Frederick
Associate Director
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Noon-1:30 Luncheon Address
Mr. Raymond G. Kammer, Jr.
Chairman, Source Evaluation Board
for Civil Space Remote Sensing
U.S. Department of Commerce

1:30-4:30 Invited Papers on Landsat 4 Results
Chair: Vincent Salomonson, Chief,
Earth Survey Applications Division NASA/
Goddard Space Flight Center

THE EVOLUTION AND PRESENT STATUS OF LANDSAT 4 SYSTEMS

By Vincent V. Salomonson
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, MD
and
Harry Mannheimer
National Aeronautics and Space Administration
NASA Headquarters
Washington, DC

When the Landsat 4 systems were conceived and designed there were several functional items that departed markedly from the comparable items in the Landsats 1-3. Now, more than one year of performance and data exists with which to evaluate the advantages and disadvantages of the Landsat 4 decisions. The choice of orbital altitude, for example, appears to have had no marked negative consequences. Initial concern about the required wider scan angle on the MSS does not appear to have been manifested. The TM and the associated choices for spatial, spectral, and radiometric resolution all appear to be well founded, with the new spectral bands showing substantial contributions in land cover classification and imagery. Problems resulting from other choices, such as the TM sampling rate per instantaneous field-of-view, edge response characteristics, and attitudinal displacements due to concurrent TM and MSS operation, fortunately appear to have been less severe than initially expected. On the other hand, the loss of X-band transmission capability, loss of solar array power, and difficulties in the placement of the Tracking and Data Relay Satellite System (TDRSS) have resulted in the loss of TM data for a period of many months. It is now hoped that the TDRSS will be available for TM data capture before the end of the operating life of Landsat 4 and that Landsat D' will be launched in 1984.

THEMATIC MAPPER IMAGE PROCESSING SYSTEM (TIPS) PERFORMANCE

By Eric P. Beyer
General Electric Company
Valley Forge Space Center
P.O. Box 8555
Philadelphia, PA 19101

An overview of the performance of the Landsat TM processing system is given, followed by a discussion of image geometric and radiometric correction. Performance is described in terms of: (a) system throughput and data turnaround time; (b) geometric correction accuracy with respect to spectral band-to-band registration, temporal registration, and geodetic rectification accuracy; and (e) radiometric correction with respect to

within-band relative detector accuracy, between-band relative accuracy, and absolute radiometric accuracy.

LANDSAT 4 SENSOR PERFORMANCE

By John Barker
Earth Resources Branch
NASA/Goddard Space Flight Center

ABSTRACT NOT AVAILABLE

THEMATIC MAPPER: DETAILED RADIOMETRIC AND GEOMETRIC CHARACTERISTICS

By Hugh Kieffer
U.S. Geological Survey

Subscenes of radiometrically raw TM data were examined on an individual basis. Areas of uniform radiance were used to characterize subtle radiometric differences and noise problems. A variety of anomalies have been discovered with magnitudes of a few digital levels or less. The only problem not addressable by ground processing is irregular width of the digital levels. The effective resolution in radiance is degraded by about a factor of two by irregular width of the digital levels. Several detectors have a change of gain with a period of several scans, the largest effect being about 4%. Noise with a period of 3.24 samples is pronounced for most detectors in band 1, exists to a lesser extent in bands 2, 3, and 4, and is below background in bands 5, 6, and 7.

The geometric fidelity of the film writer used to expose TM images was assessed by measurement with accuracy better than 3 um of a test grid. Tests indicated that the geometric fidelity of TM images is likely to be higher than the ability of film recorders to reproduce the images.

PRELIMINARY SPECTRAL/STRATIGRAPHIC ANALYSIS OF LANDSAT 4 THEMATIC MAPPER DATA, WIND RIVER/BIG HORN BASIN AREA, WYOMING

By Earnest D. Paylor, James E. Conel, Harold R. Lang
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

A geologic analysis of the Wind River/Big Horn basins, Wyoming, is currently underway utilizing lithologic information extracted from a Landsat 4 TM scene. A major objective of the study is to develop classification schemes that utilize TM data for stratigraphic analysis. Preliminary analysis demonstrates that: (1) Principal component images derived from the correlation matrix provide the most useful stratigraphic information. Components so produced represent linear transformations based on ground reflectance. The separation of unique spectral classes is therefore largely independent of non-random atmospheric and instrumental factors. (2) To extract surface spectral reflectance, the satellite radiance data must be calibrated. Reflectance measurements were not acquired during the overflight, but an empirical calibration based on scatterplots of DN vs. reflectance

for natural and cultural targets of assumed reflectance was carried out. (3) Low instrumental offset and gain settings result in spectral data that utilize less than half of the full dynamic range of the TM system.

LANDSAT 4 THEMATIC MAPPER SENSOR EVALUATION AND ADVANCED INFORMATION EXTRACTION EXPERIMENTS

By Ralph Bernstein and Jeffrey B. Lotspiech
IBM Palo Alto Scientific Center
Palo Alto, CA 94304

An investigation is underway dealing with the analysis and evaluation of Landsat 4 sensor data and assessment of the data radiometric calibration accuracy, geometric correction accuracy, resolution, and quality. Several digital image processing techniques have been applied to the data to improve the data radiometry and quality. In addition, image science experiments are being conducted to develop new information extraction techniques. Inferences about future technologies for image processing and information extraction are being made during the process of carrying out this work.

RADIOMETRIC ANALYSES OF LANDSAT 4 DIGITAL IMAGE DATA

By William A. Malila, Daniel P. Rice, and Michael D. Metzler
Environmental Research Institute of Michigan
Ann Arbor, MI 48107

The results of an analysis of the radiometric characteristics of digital image data produced by the Landsat 4 MSS and TM sensors are reviewed. The MSS analysis found high quality data comparable to the products of previous Landsats, except for a low-level coherent noise effect having a magnitude of about 0.5 counts in each band and a spatial period of about 3.6 pixels. The TM analysis found generally high-quality data, but with low-level banding artifacts associated with the direction of scan (TM employs bidirectional scanning) and expected scan-angle effects for which correction procedures should be addressed by affected applications programs. Procedures for equalizing detector responses appear to be working as intended. However, a very low frequency coherent noise effect has been found which produces banding that is most pronounced in band 1 and which could be a serious problem for water-related applications or others where average signal levels are low. Correction procedures are under investigation.

LANDSAT 4 DATA QUALITY EVALUATION RESULTS

By P. Anuta, L. Bartolucci, E. Dean, C. Valenzuela,
E. Malaret, C. McGillem, J. Valdez

Landsat 4 TM and MSS data were evaluated for radiometric and geometric quality as well as for information content. Geometric

evaluation consisted of band-to-band registration tests. The visible band and reflective IR bands were found to be in accurate registration but between these groups of bands some misregistration was observed. Radiometric evaluation was performed by computing means and variances of individual detectors. Very close agreement was observed. The effect of geometric correction and resampling was evaluated by computing means and variances of uncorrectd and corrected data. Results indicated no significant change.

Information content was first evaluated by performing principal components analysis of the MSS and TM data for Chicago and Iowa data. As expected, two components emerged from the MSS data. In the TM data, three components contained 97% of the variance; however, significant image structure was seen in the fourth component, indicating twice the dimensionality in TM data. Information content was also evaluated by classifying TM and MSS from the Des Moines, Iowa, area. Many more subclasses or corn and soybeans were observed in the TM data compared to the MSS.

WEDNESDAY, OCTOBER 5, 1983

9:00-12:00 Invited Papers on Landsat 4 Results

Chair: Vincent Salomonson

CARTOGRAPHIC QUALITY OF LANDSAT 4 MSS AND TM IMAGE DATA

By R. Welch
Department of Geography
University of Georgia
Athens, GA 30602

Landsat 4 MSS and TM image data in digital formats are being examined for geometric fidelity and image quality as related to mapping requirements. Root-mean-square errors ($RMSE_{xy}$) in whole-scene MSS data sets after rectification with 1st degree polynomials yield values of approximately $\pm$80 m. This figure is reduced to less than $\pm$60 m when 20 or more GCP's are utilized in conjunction with 2nd or 3rd degree polynomials. Rectification of MSS subscene areas of 1024 x 1024 pixels or smaller with 1st degree polynomials, and approximately five GCP's, produced $RMSE_{xy}$ values of about $\pm$40 m.

Thematic mapper data sets of 1024 x 1024 pixels have been fitted to ground control by a simple scaling, rotation, and translation of the image data. The residual errors of $\pm$20 m approximate National Map Accuracy Standards for 1:50,000-scale maps and reflect the advantages of the improved pointing accuracy and attitude control of the Landsat 4 system. The potential for integrating Landsat 4 digital images with other data sets and the possibilities for image and topographic mapping are discussed.

ANALYSIS OF LANDSAT 4 THEMATIC MAPPER DATA FOR CLASSIFICATION OF FOREST IN BALDWIN COUNTY, ALABAMA

By C. L. Hill
National Space Technology Laboratories
NASA/Earth Resources Laboratory, Code HA30
NSTL, Mississippi

The improvements in spatial and spectral resolution of Landsat 4 TM data over previous MSS data have significantly expanded the utility of satellite-acquired remotely sensed data in the field of forest resource management. Because of the diversity and interspersion of vegetative communities in the forest, the 30-meter spot size of the TM offers an opportunity to differentiate forest stands. In addition, the TM samples new portions of the spectrum.

As part of NASA's Test and Evaluation Program, the NASA Earth Resources Laboratory has initiated a research effort to analyze TM data for contribution in the field of forest management. Baldwin County, Alabama, has been established as the study area. A major portion of the county is managed by various products companies with management policies ranging from monoculture plantations to mixed uneven-aged timber stands. These characteristics present a unique opportunity for assessing the capabilities of TM data for forest classification.

EVALUATION OF THEMATIC MAPPER DATA FOR NATURAL RESOURCE ASSESSMENT

By Robert H. Haas and Fred A. Waltz
EROS Data Center
Sioux Falls, SD 57198

A substantial improvement in the information content of TM data over MSS data was shown during an evaluation of TM data for natural resource assessment. The improved spatial resolution of TM data permitted positive identification of locations within land units and allowed efficient manual interpretations of land use, identification of resource types, and assessment of the ecological status of natural vegetation at 1:100,000 scale. Improved spectral resolution of TM data gained from bands 5 and 7 aided in defining water resources, wetland vegetation resources, and other important terrain features.

Results from both TM and TM Simulator data suggest that the coefficent of variation for major land cover types is less for TM data than for equivalent MSS data. This reduction should contribute to improved multispectral classification of land cover types. TM bands 5 and 7 also add a new dimension to multispectral analysis, contributing new information about natural vegetation ecosystems.

AGRICULTURAL APPLICATIONS OF TM DATA

By D. E. Pitts, R. Bizzell, K. Henderson, D. R. Thompson
NASA Johnson Space Center
Houston, Texas
and
C. Sorenson, J. Carnes
Lockheed Engineering and Management Corp.
Houston, Texas

Multitemporal TM data, TM Simulator data, and detailed ground truth data were collected for a 9-by-11-km area in Webster County, Iowa, in the summer of 1982. Data were acquired on three different dates, each, from both the TM Simulator and the TM instruments. The data were then analyzed to determine the effect of the additional TM spectral bands in the middle and thermal infrared and the increased TM quantization levels on corn/soybean separability. A Fisher information measure of separability was calculated using all 7 bands and with the 4 visible-near infrared bands. To evaluate the effect of quantization, the Fisher information measure was calculated using individual bands as a function of the number of quantization levels. The results indicated that there was no significant change in separability when the 256 levels present in the TM data were reduced to 64 levels (as used on MSS).

EVALUATION OF LANDSAT-4 IMAGE QUALITY FOR THE INTERPRETATION OF FOREST, AGRICULTURAL AND SOIL RESOURCES

By Stephen D. DeGloria
Remote Sensing Program
University of California
Berkeley, CA

The performance of both the Landsat 4 MSS and TM sensors is measured through the systematic evaluation of commercially available analytical film products. Natural targets are used to evaluate spectral variability, spatial resolution, radiometric sensitivity, and geometric fidelity of these images. Spectral characteristics are evaluated through the interpretation of image tone and texture variability of known features. Spatial characteristics are evaluated through lineal and areal estimates of similar features, and through the evaluation of residual errors derived from control point processing of relative image coordinates and corresponding ground coordinates. Early results indicate that presently available film products provide adequate spectral and spatial representations of the digital data for mapping and stratifying landscapes in support of resource inventories, improved delineation of boundaries, detecting and identifying changes in land cover, and updating land use maps at 1:24,000 scale and smaller.

CONTRIBUTION OF LANDSAT 4 THEMATIC MAPPER DATA TO GEOLOGIC EXPLORATION

By John R. Everett, Jon D. Dykstra, Charles A. Sheffield
Earth Satellite Corporation
7222 47th Street
Chevy Chase, Maryland 20815

The increased number of carefully selected narrow spectral bands and the increased spatial resolution of Thematic Mapper data over previously available satellite data contribute greatly to geologic exploration, both by providing spectral information that permits lithologic differentiation and recognition of alteration and spatial information that reveals structure. As vegetation and soil cover increase, the value of the spectral components of TM data decreases relative to the value of the spatial component of the data. However, even in vegetated areas, the greater spectral breadth and discrimination of TM data permits improved recognition and mapping of spatial elements of the terrain. As our understanding of the spectral manifestations of the responses of soils and vegetation to unusual chemical environmments increases, the value of spectral components of TM data to exploration will greatly improve in covered areas.

LITHOLOGIC MAPPING USING LANDSAT THEMATIC MAPPER DATA

By M.H. Podwysocki, J.W. Salisbury, O.D. Jones, D.L. Mimms
U.S. Geological Survey
Reston, VA

The Landsat 4 TM, with its new near-infrared bands centered at 1.65 μm and 2.20 μm, and spatial resolution of 30 m, has been used to distinguish rocks containing minerals having ferric-iron absorption bands in the visible and near-infrared and Al-O and CO_3 absorption bands in the 2.1-2.4 μm regions. Digitally processed TM data have been used to differentiate vegetated from non-vegetated areas, limonitic from nonlimonitic rocks, and rocks containing minerals that absorb in the near-infrared from rocks that do not. Specific minerals have been detected in both the humid eastern and semi-arid western United States. These results show that TM data provide a valuable tool for distinguishing several significant geologic materials not distinguishable from space using previous imaging systems. They also show that TM data can be successfully used in a variety of geologic environments.

Noon **Lunch Break**

1:30-5:30 **Applications and Related Technology**

Chair: Donald T. Lauer, Chief
Branch of Technique Development and Applications
USGS/EROS Data Center

GEOLOGIC APPLICATIONS OF SIDE-LOOKING AIRBORNE RADAR DATA IN THE CENTRAL APPALACHIANS

By Howard A. Pohn
U.S. Geological Survey

Side-looking airborne radar has yielded a synoptic view of the central Appalachians sufficiently detailed that the images give an unparalleled representation of the size and nature of the folds within the Valley and Ridge province. The data show that fold wavelengths decrease abruptly south of the region of the Pennsylvania, Maryland, and West Virginia state lines. This decrease in fold wavelength is accompanied by an increase in both frequency and length of disturbed zones (narrow bands of intense folding and faulting, mapped in the field). The disturbed zones are inferred to be surface manifestations of splay faults which are genetically related to the folds.

The model predicted by the combination of the radar images and field observations suggests a broad lateral ramp connecting a deeper decollement north of the Pennsylvania, Maryland, and West Virginia state lines with a shallower decollement to the south. This model appears to be applicable to other areas in the central Appalachians and indicates that abrupt changes in fold wavelengths as seen on radar images may be used to predict changes in depth to major decollements.

THE NATIONAL DIGITAL CARTOGRAPHIC DATA BASE

By Eric Anderson
U.S. Geological Survey

ABSTRACT NOT AVAILABLE

NEW HORIZONS FOR THE NATIONAL HIGH-ALTITUDE PHOTOGRAPHY PROGRAM

By Peter F. Bermel
Assistant Division Chief for Plans and Operations
National Mapping Division
U.S. Geological Survey, Reston, VA

Since the inception of National High-Altitude Photography Program in 1980, black-and-white and color-infrared stereoscopic imagery has been acquired for about 50 percent of the 3,000,000 square miles in the conterminous United States. An additional 40 percent of the 48-State area is under contract to private aerial survey firms. The sixth and final contract to achieve complete once-over coverage will be awarded early in 1985. Extensive use has been made of the newly established data base for mapping, landform studies, land use planning, natural resource inventory, evaluation and management, engineering, and education.

In anticipation of the completion of once-over coverage, the participating agencies have begun studies to define the requirements for a maintenance program which would provide cyclic coverage of the conterminous United States and imagery for specific agency needs. In addition, new applications of the data base to prepare cartographic map and data products are being investigated.

APPLICATION OF METSAT DATA IN LAND REMOTE SENSING

By George Ohring, Michal Matson, David F. McGinnis, Jr.,
Stanley R. Schneider
National Environmental Satellite, Data, and Information Service
National Oceanic and Atmospheric Administration
Washington, D.C.

NOAA's National Environmental Satellite, Data, and Information Service operates two types of meteorological satellies that can be used for remote sensing of the Earth's land surface: the polar orbiting NOAA series and the geostationary GOES series. The two NOAA satellites provide global coverage twice daily; the two GOES satellites provide images of the Western Hemisphere between 55°N and 55°S every half-hour. The Advanced Very High Resolution Radiometer (AVHRR) on the NOAA satellites and the Visible and Infrared Spin Scan Radiometer (VISSR) on the GOES satellites are the instruments that can provide information about land surface parameters. The AVHRR has five channels in the visible, near IR, and thermal IR portions of the spectrum and has a resolution of 1.1 km for local area coverage and 4 km for global coverage. The VISSR has a 1-km-resolution visible channel and an 8-km resolution thermal IR channel. Examples are presented of the application of these satellite observations to agriculture, hydrology, glaciology, volcanology, and land use.

THE MICROCOMPUTER WORK STATION: AN ALTERNATIVE HARDWARE ARCHITECTURE FOR DIGITAL IMAGE PROCESSING

By William K. Erickson
NASA/Ames Research Center

ABSTRACT NOT AVAILABLE

NEW OPPORTUNITIES FOR THE PRIVATE SECTOR IN SPACE TECHNOLOGY

By W. D. Carter and A. B. Park
Globex Incorporated
2404 Paddock Lane
Reston, VA 22091

The proposed transfer of the Landsat operational system to the private sector is certain to create many new opportunities, and a few problems, for those entrepreneurs willing to invest in the future of this program. While there is vigorous conflict of opinion over the worth of the program, we believe the assets of the program are unique in several respects. First, no other resource of the federal government can acquire the same objective information about the natural resources of the earth. Second, the revenue potential of the sale of the data is orders of magnitude smaller than the revenue potential of resource investment decisions

enabled by early access to the raw data. Third, we find it ironic that because the system was designed and administered jointly by and for the resource agencies of the government, it has become an albatross around the neck of the single "responsible" agency. If logic were used as a criterion, the program was a model of how to conduct cost-effective research in the govenment.

This paper discusses alternative strategies for private sector involvement.

THURSDAY, OCTOBER 6, 1983

9:00-12:00 Future Operational Satellites: Plans and Status

Chair: Pitt G. Thome, President
The Destek Group

THE ADVANCED EARTH RESOURCES OBSERVATIONS SATELLITE (AEROS): A PRIVATE SECTOR REMOTE SENSING SPACE SYSTEM

By N. H. MacLeod, Chairman
American Science and Technology Corporation
Bethesda, Maryland

The American Science and Technology Corporation is developing a commercial remote sensing space system known as AEROS. AEROS utilizes a solid-state (CCD) sensor with four pairs of optical and near-infrared stereoscopic arrays at approximately 80 m and 40 m spatial resolution and a swath width of 320 km when flown at 920 km altitude. The selection of sensor and orbital parameters was made to continue the services provided by the Landsat series conducted by NASA since 1972. In addition to the selected Landsat services of some MSS and TM bands, the AEROS system will include some central zone color scanner bands at 80-m resolution as well as stereoscopic data in four spectral regions. The system has no moving parts and is designed to operate in orbit for five years. Planned for launch in 1986, AEROS-A will be the first of a series of increasingly comprehensive, operational Earth observations satellites lasting into the 1990's.

COMMERCIALIZATION VERSUS PRIVATIZATION A KEY DISTINCTION FOR FUTURE U.S. CIVIL REMOTE SENSING

By Paul M. Maughan, Timothy M. Alexander, and Dennis J. Burnett
Communications Satellite Corporation
Washington, D.C. 20024

During the next several months, U.S. industry will be given its first substantive opportunity to propose ways to achieve the commercial transfer of civil satellite remote sensing. Either industry will be able to propose attractive end-to-end commercial

solutions to one or more of the weather/land satellite based systems, or the Government will continue to procure and own the systems, but with increasing reliance on private contracting to support Government operations. In order to be attractive, the first option ("commercialization") must thoroughly address many significant policy, financial, service, and price issues. It must present a technical and business package that holds promise for establishing a succcessful commercial enterprise, while also meeting the continuing public interests in civil remote sensing. If industry is unable to respond successfully to this some form or another of "privatization" is likely to evolve. Privatization will entail continued Government design, ownership, and operation of remote sensing systems into the foreseeable future, with any private involvement continuing to be largely contracting in nature.

FAIRCHILD-LEASECRAFT SYSTEM PROVIDING COMPLETE SERVICE FOR COMMERCIAL AND GOVERNMENT USERS IN SPACE

"time-share condo"

Under a Joint Endeavor Agreement with NASA, Fairchild will design, finance, build, and begin operating in 1987 permanent, mobile, shuttle-serviced space platforms known as Leasecraft. Fairchild will provide services (space, power, communications, data handling, and orientation) from these platforms to government or commercial users of space. Customers will pay for the services as they are provided. Leasecraft is based on the NASA Multi-Mission Modular Spacecraft (MMS) technology and uses the standard modules developed in that program. Its hydrazine propulsion system enables it to move back and forth between the shuttle parking orbit and the orbits required by the missions. Most of the Leasecrafts will be placed in two standard orbits, a 255.6-n.mi., 28.5° orbit from Cape Canaveral, and a 98° Sun-synchronous orbit from Vandenberg. All elements of the Leasecraft are replaceable in space, enabling the platform to remain in space permanently. A technical description of Leascraft is provided together with its status and the process by which a customer can arrange to use the services of a Leasecraft platform. Its particular value to Earth observations is also presented.

THE GEOSAT COMMITTEE'S CURRENT ACTIVITIES AND PLANS

By Fred Henderson
GEOSAT Committee

ABSTRACT NOT AVAILABLE

THE LARGE FORMAT CAMERA

By Fred Doyle
U.S. Geological Survey

ABSTRACT NOT AVAILABLE

GEO-SPAS, A NEW APPROACH FOR COMMERCIAL REMOTE SENSING MISSIONS

By G. Barthel, H. -Chr. Benohr and D. E. Koelle
MBB, Space Division
Ottobrunn, FRG

The SPAS-01 satellite was launched on STS flight number 7. Among other experiments, SPAS carried the first fully electronic camera for Earth observation using linear charge-coupled device arrays for image detection and registration. About 2 million square kilometers of image data were acquired, with a ground resolution (pixel size) of about 20 by 20 m. Based on the SPAS-01 concept, MBB has defined a SPAS derivative, named GEO-SPAS, which is specifically dedicated to commericially viable remote sensing missions to be performed in conjunction with the STS launcher. An improved Modular Optoelectronic Multispectral Scanner (MOMS) will form the nucleus of the payload. Development of this instrument has been initiated by the German space authorities. Principal new features of this camera will comprise infrared channels based on advanced technology and full-scale stereo capability. Additional payload elements complementary to the advanced MOMS system can also be accommodated. This presentation provides an overview of the current status of the program and the medium and long-term aspects of GEO-SPAS commercialization.

RADARSAT

C-band; stepped coverage

By Ed Langham
Radarsat Project Office
Canada

ESA ERS-1 →

ABSTRACT NOT AVAILABLE

MAPSAT

By Alden Colvocoresses
U.S. Geological Survey

ABSTRACT NOT AVAILABLE

MULTILINEAR ARRAY INSTRUMENT CONCEPTS FOR FUTURE LAND REMOTE SENSING

By Aram Mika
Hughes Aircraft Company

ABSTRACT NOT AVAILABLE

Noon **Lunch Break**

1:30-5:00 **Future Operational Satellites: The French SPOT Program**

Chair: Gilbert Weill, Director
SPOT Image Corporation, U.S.A.

(1)

LE SYSTEME PROBATOIRE d'OBSERVATION DE LA TERRE

By Michael Courtois
Centre Spatial de Toulouse
Toulouse, France

Le Systeme Probatoire d'Observation de la Terre (SPOT) is progressing toward an early 1985 launch within the French National Space Program, in association between France, Sweden, and Belgium. The mission objectives, technical characteristics of the system are described. Each of two identical telescopes has a capability for targeting the line of sight to either side of the satellite track, and for operating on a ground sampling step of 20 m (with three color bands) or 10 m (broad band). This flexibility, enhanced by an adequate choice of orbit, will enable more frequent sampling of specific target scenes, and provide for stereo coverage of important areas. The capacity for coverage of large areas, based on meteorological simulations, is presented. Linear arrays of CCD detectors are expected to combine a high data rate (25 megabits/second/data channel) with good radiometric resolution. Data from the satellite will be accessible, either through the central facility in Toulouse or through foreign authorized X-band direct read-out stations.

FLEXIBLE PROGRAMMING FOR SPOT SYSTEM

By Mr. Cabrieres and Miss Ponce

Different SPOT payload programming and acquisition schemes are presented, with the main characteristics of each being discussed. Included are the areas of: (1) technological processing, which is needed to verify that the HRV is working properly; (2) definition by foreign stations of the precise areas they want imaged; (3) requests for global coverage of large areas, which is assumed automatically or manually with graphic support; and (4) programming of the central facility in Toulouse, done in the same was as for foreign stations, for specific needs that cannot be assumed by the main automatic system.

It is shown how revisit flexibility, a key SPOT system capability, will reduce the time needed to obtain coverage of a given area. The key features of the overall process, taking into account all required operations and generating an optimized activity for the payload, are then summarized. Problem constraints are described, as well as the criteria used to choose between possibilities and optimize results.

INTEGRATION OF OBLIQUE SPACE IMAGERY INTO GEOGRAPHIC DATA BASES

By Alain Baudoin
Head of SPOT Project at IGN-France
(Institut Geographique National, Paris, France)

In industrial countries where topographic and thematic data bases exist or are under development, oblique imagery from SPOT will be useful in minimizing the effect of bad weather conditions in order to get useful images when they are required. In order to be compared or combined with other images, or with other geographical data, these SPOT data will be geometrically rectified, taking into account distortions from the satellite and from the relief (with a digital terrain model). In developing countries, oblique views are required to get stereoscopic pairs in order to plot space maps with contour lines (and digital models). Maps derived from space imagery could be easily used to create geographical data bases (with at least relief data and land use data). In both cases oblique and vertical space imagery could be used to update geographical data bases and to study the evolution of some cartographic themes or phenomena.

SPOT WORLDWIDE DISTRIBUTION PLANS

By A. Fontanel

The SPOT system consists of two ground receiving stations and their associated preprocessing centers, namely the Aussaguel station, near Toulouse, France, and the Esrange station, near Kiruna, Sweden. Each of these stations will be capable of receiving some 1,250,000 SPOT scenes per year, corresponding either to real-time transmissions, or to playback-mode transmissions using the two onboard tape recorders. SPOT data will also be received by various foreign receiving stations located around the world.

SPOT data will be distributed by SPOT Image and various distributors. SPOT Image is a private company to which the Centre National d'Etudes Spatiales (CNES) has granted an exclusive worldwide license for the distribution of SPOT data on a commercial basis. SPOT Image is responsible for the granting of sub-licenses to distributors. Any organization that wishes to distribute or sell SPOT data must first obtain a sub-license. SPOT data receiving stations will be automatically granted such a sub-license within the station's distribution zone. In the U.S.A., SPOT Image Corporation, headquartered in Washington, D.C., has received an exclusive sub-license to acquire and distribute SPOT data in the U.S. market.

TESTING AND APPLICATIONS USING SIMULATED IMAGERY

By G. Saint
CNES/Toulouse, France

ABSTRACT NOT AVAILABLE

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THE GDTA SPOT SIMULATION PROGRAMME

By J. C. Cazayx and C. Torres

In the framework of preparations for SPOT, several simulation campaigns have taken place, both in France and in 14 other countries. At this time, coverage of more than 14,000 square kilometers -- including 400 frames of imagery over 80 different areas -- have been made available. More than 50 laboratories and organizations of various types have been associated with the data interpretation and assessment effort.

The technical approaches used for the simulation of SPOT parameters have been (1) geometric and (2) radiometric in their orientation. Early results have been useful in indicating SPOT capabilities in many applications areas, including cartography, geology, land use, coastal studies, forestry, and others. This paper summarizes SPOT simulation activity concepts and gives examples of different thematic applications that might be found for SPOT data when they start being acquired.

THE 1983 U.S. SPOT SIMULATION CAMPAIGN

By G. Weill
SPOT Image

ABSTRACT NOT AVAILABLE

7:00 Pecora Award Banquet and Address
By Senator Larry Pressler, S.D.
Senate Commerce, Science, and Transportation Committee

The Award Banquet will also feature the 1983 winner of the William T. Pecora Award, given each year in recognition of outstanding contributions of individuals or groups toward the understanding of the Earth by means of remote sensing.

FRIDAY, OCTOBER 7, 1983

9:00-12:00 Future Space Shuttle Experiments
Chair: Mark Settle, Program Manager
Non-Renewable Resources, NASA

STUDIES OF OPTICAL AND BIOLOGICAL PROPERTIES OF TERRESTRIAL LAND COVER USING MULTISPECTRAL LINEAR ARRAY TECHNOLOGY

By W. L. Barnes and V. V. Salomonson
NASA/Goddard Space Flight Center
Greenbelt, Maryland

A series of experiments to study the optical and biological properties of terrestrial land cover are planned for late 1987 using a six-channel imaging spectroradiometer based on newly developed multispectral linear array (MLA) detector technology. Data from selected portions of the Sahel and rain forests of Africa and South America will be used to delineate biomass classes and estimate spherical albedos. A spatial resolution of 15 meters in the four visible and near IR channels and 30 meters in the two shortwave IR channels, including a "new" channel centered at 1.24 micrometers when combined with a spectral width of 20 nanometers for all channels, will be used to investigate possible improvements in land cover classification. Technology demonstrations will include a test of the effects of data compression on data quality, the first spaceborne utilization of shortwave infrared Schottky barrier Pd_2Si detector arrays, and the use of close-butted, multiarray modules with attached spectral filters.

THE SHUTTLE IMAGING SPECTROMETER EXPERIMENT

By Alexander F. H. Goetz
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA

A Shuttle-borne imaging spectrometer experiment (SISEX) has recently been proposed that could be orbited by 1988-89. SISEX creates images over a 12-km-wide swath in 128 spectral bands, simultaneously, in the 0.4-2.5 m region. The nominal spectral sampling interval is 10 nm in the 0.4-1.0 m region and 20 nm in the 1.0-2.5 m region. The pixel IFOV is 30 m. The spectral resolution is sufficient to allow identification of a number of surface materials directly, as opposed to discriminating among groups of materials using present-day Landsat data. SISEX portends to revolutionize data analysis and interpretation in remote sensing applications.

A SHUTTLE THERMAL INFRARED MULTISPECTRAL SCANNER

By Anne B. Kahle
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

The thermal infrared portion of the spectral available for geologic remote sensing extends from approximately 3 to 25 μm, with the 8-13 μm region being by far the easiest spectral region to use.

This is also a spectral region containing diagnostic spectral information on the silicates. Recent work with data from the new 6-channel aircraft Thermal Infrared Multispectral Scanner (TIMS) has demonstrated that there is significant geologic information which can be obtained from surface spectral emissivity data acquired by remote sensors. It was shown that in certain cases even minor differences in rock type could be distinguished, i.e., quartz latite/quartz monzonite could be distinguished from latite/monzonite. In order to make data available over a much larger suite of geologic materials and plant communities in a variety of environments, we propose a TIMS-type instrument as a candidate Shuttle experiment. We are evaluating the capability of current technology to produce a 5-10 channel instrument in the wavelengths 8-13 μm and possible also 3-5 μm, with an NEΔT of 0.1 to 0.3K.

ORBITAL SURVEYS OF SOLAR STIMULATED LUMINESCENCE

By W.R. Hemphill, A.F. Theisen, R.M. Tyson, J.S. Granata

The Frauhofer line discriminator (FLD) is an electro-optical device for imaging natural and man-made materials which have been stimulated to luminescence by the Sun. An airborne FLD has been used to detect geochemically stressed vegetation, drought stressed agricultural crops, industrial and residential pollution effluents, marine oil seeps, phosphate rock, uranium bearing sandstone, and bioluminescent ocean plankton. Three-dimensional perspective plots of excitation and emission spectra measured with a laboratory spectrometer graphically depict similarities and differences in luminescence properties between sample materials. The laboratory data also include luminescence intensities at six Frauhofer lines in the visible and near infrared regions of the electromagnetic spectrum. Both the airborne and laboratory data suggest the feasibility of delineating and monitoring at least some of these luminescing materials from orbital altitude, such as a test flight aboard the Space Shuttle using an improved "third-generation" FLD.

SHUTTLE IMAGING RADAR RESEARCH FACILITY

By C. Elachi, J.B. Cimino, D. Evans
Jet Propulsion Laboratory, Caltech
Pasadena, CA

The Seasat Imaging Radar and the Shuttle Imaging Radar (SIR-A) experiments successfully demonstrated that spaceborne synthetic aperture imaging radars provide important geophysical information about the Earth's surface, its cover, and, in some cases, the near subsurface. However, both sensors provided information about the surface using a very limited set of observational parameters. They operated at a wavelength of 25 cm, with an HH polarization and fixed incidence angles (20° for Seasat, 50° for SIR-A). Multi-parameter observations are required in order to extract more

quantitative information about the surface roughness, morphology, and cover.

This is the basis for a multi-year NASA program which consists of an evolutionary Shuttle Imaging Radar Research Facility that will allow Earth imaging with a progressively expanded capability. The first step will be implemented in 1984 as the SIR-B, which will be able to view the surface at multiple incidence angles. This will be followed by SIR-C in 1987 with the capability for acquiring imagery at multiple polarizations and dual frequencies. By the end of the decade the SIR-D will have an additional capability for many frequencies.

SHUTTLE DIGITAL TOPOGRAPHIC MAPPER

By M. Kobrick and C. Elachi
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA

Despite its usefulness and the demand for it, digital topographic data for most of the world are unavailable, and the data bases that have been developed (covering mostly the United States) vary widely in quality. A technical analysis of the methods available for collecting digital topographic data from orbit has been completed. Conventional photographic stereo, imaging radar stereo, radar interferometry, laser altimetry, and radar altimetry, as well as a few hybrid techniques, were evaluated. In general, we find that techniques employing direct altimetric measurement are favored over conventional stereogrammetric methods.

The most promising technique for acquiring a world-wide data base at medium resolution is scanning radar altimetry. A scanning radar altimeter could produce a digital topographic map of the world in only three Shuttle flights. For high resolution data (of the order of TM or SPOT data), laser altimetry is preferred. A scanning laser altimeter could be operated from a long-term orbital platform and acquire targeted data at very high resolution in a manner similar to Landsat.

SHUTTLE POLAR ICE SOUNDING AND ALTIMETRY

By T. H. Dixon and C. Elachi
Jet Propulsion Laboratory
Mail Code 183-701
4800 Oak Grove Drive
Pasadena, CA 91109

Less than half of the Antarctic continent has been remotely sensed with even a coarse grid of airborne radio echo sounding lines. The surface topography of the ice sheet is very poorly known. A synoptic description of the polar ice caps could be

accomplished in one or two Shuttle missions in polar or near-polar orbit, generating a sample grid of 20 km or better.

A 200 MHz (λ = 1.5 m) synthetic aperture radar sounder, capable of mapping bed rock topography through 4 km of ice, is feasible with present technology. Such a sounder could also provide altimetry with 5-10 m precision. However, 1-2 m precision is required to adequately constrain ice flow dynamics. This could be accomplished with a scanning laser altimeter. A laser with 1.0-kHz pulse repetition frequency, 10-ns pulse duration, and 10-mJ pulse energy, would provide the requisite spatial resolution (better than 3 km), height resolution (better than 1.5 m), and signal-to-noise ratio. Existing lasers, including the copper vapor laser, provide this capability and consume less than 2 kW of power, making Shuttle deployment feasible.

INTEGRATED REMOTE SENSING OF THE EARTH FROM LOW EARTH ORBIT IN THE 1990's

By Dr. Dixon M. Butler

Remote sensing instrument technology is advancing, and new capabilities to use lasers and solid-state detection devices may enable sensors of more general capability to be developed. The ability to operate in space now permits consideration of spacecraft that are larger and more versatile for use in Earth remote sensing. Servicing sensor systems in orbit may radically change our approach to long-term, sustained observations of our planet. Key questions in earth science increasingly demand a multidisciplinary approach and focus on connections among the atmosphere, oceans, and continents. These trends have prompted NASA to undertake a study of the needs for an integrated low earth-orbiting observing system. The preliminary findings of this study are presented.

THE WILLIAM T. PECORA AWARD, presented annually in recognition of outstanding contributions of individuals or groups toward the understanding of the Earth by means of remote sensing, is sponsored jointly by the Naitonal Aeronautics and Space Administration and the Department of the Interior. The award was established in 1974 to honor the memory of Dr. William T. Pecora, former Director of the U.S. Geological Survey, and later, Under Secretary, Department of the Interior. Dr. Pecora was a motivating force behind the establishment of Earth resource sensing from space. He was a Government leader with broad vision and deep appreciation for the use of satellite system programs in continually inventorying and managing our national resources.

PREVIOUS RECIPIENTS

1974-1st Award:	Dr. William A. Fischer, U.S. Geological Survey
1975-2nd Award:	Dr. William Nordberg, NASA, and Dr. Carlos Brockman, Director, Landsat-Bolivia Project Pecora I-American Mining Congress
1976-3rd Award:	Jointly, ERIM, accepted by Dr. Mile Holter, and LARS, accepted by Dr. David Langrege Pecora II-American Society of Photogrammetry
1977-4th Award:	Michel T. Halbouty, Consulting Geologist and Petroleum Engineer, and Dr. Robert N. Colwell, University of California, Berkley Pecora III-American Association of Petroleum Geologists
1978-5th Award:	Dr. David S. Johnson, NOAA NESS, Department of Commerce Pecora IV-National Wildlife Federation
1979-6th Award:	Dr. John DeNoyer, USGS, and Virginia T. Norwood, Senior Scientist, Hughes Aircraft Pecora V-American Water Resources Association
1980-7th Award:	Dr. Verner E. Suomi, University of Wisconsin Pecora VI-Society of Exploration Geophysicists
1981-8th Award:	Dr. James R. Anderson (Posthumously), USGS, and Leonard Jaffe, Computer Sciences Corp. (formerly with NASA) Pecora VII-Association of American Geographers
1982-9th Award:	Alexander H. Goetz, California Institute of Technology, JPL, and Lawrence C. Rowan, USGS No Pecora Symposium