

XVI
Pecora
XVI
SYMPOSIUM

Satellite Land Remote Sensing:
Current Programs and a Look to the Future

May 5-7, 1987
Holiday Inn City Centre
Sioux Falls, South Dakota

ABSTRACTS

The Pecora 11 abstracts are supplied as a reference for participants attending symposium technical sessions. This collection is not to be cited as a reference to any Pecora 11 paper or presentation. The symposium proceedings will be published soon after the conference as the official reference document.

TABLE OF CONTENTS

<u>Session</u>	<u>Page</u>
Applications of Satellite Remote Sensing in the Biosciences	1
Applications and Developments in Geologic Remote Sensing.	12
Technique Development and Data Processing	23
Current Remote Sensing Topics and Initiatives	32
Future Remote Sensing System Plans and Programs	43
Poster Session.	52

SESSION: APPLICATIONS OF SATELLITE REMOTE
SENSING IN THE BIOSCIENCES

Wednesday, May 6, 8:30-12:00 a.m.

CO-CHAIRPERSONS: KEVIN P. GALLO
CHRIS J. JOHANSEN

- J.-P. Malingreau, The Joint Research Center of the European Communities, and
C. J. Tucker, NASA, Goddard Space Flight Center
The Unique Contribution of AVHRR Data for Measuring and Understanding
Global Processes: Large Scale Deforestation in the Amazon Basin
- D. Reilly and J. Olsson, U.S. Agency for International Development
Current U.S. Agency for International Development Needs for the Famine
and Early Warning System (FEWS)
(Abstract not available)
- J. R. Vande Castle and T. M. Lillesand, University of Wisconsin-Madison
The Utility of AVHRR Data for Monitoring Large-Scale Temporal Changes in
Great Lakes Water Quality
- C. G. Justus, Georgia Institute of Technology
Sensitivity of Vegetation Index Estimates to Proposed AVHRR Filter
Changes
- T. L. Haithcoat, University of Missouri-Columbia, and D. L. Hallett, Missouri
Department of Conservation
Computerized PATREC Assessment of Landsat Derived Land Cover Data to Aid
Planning of Pheasant Management in Missouri
- E. A. Cook and L. R. Iverson, Illinois Natural History Survey, and
R. L. Graham, Oak Ridge National Laboratory
The Relationship of Forest Productivity to Landsat Thematic Mapper Data
and Supplemental Terrain Information
- D. J. Wheeler and A. A. Jayasekara, Utah State University
Monitoring Agricultural Productivity in Developing Nations Utilizing
Landsat Data and GIS Technology
- W. Weaver, H. G. Fisser, J. K. Lewis, and R. W. Marrs, USDA/SRS
Range Site Reflectance Characteristics Measured by Landsat MSS and Color
Infrared Low Altitude Aerial Photography in South Dakota Mixed Prairie
- R. Murphy, NASA, Land Processes Branch
International Satellite Land-Surface Climatology Project (ISLSCP)
(Abstract not available)

THE UNIQUE CONTRIBUTION OF AVHRR DATA FOR MEASURING AND UNDERSTANDING
GLOBAL PROCESSES: LARGE SCALE DEFORESTATION IN THE AMAZON BASIN

By J.-P. Malingreau and C. J. Tucker

ABSTRACT

Tropical deforestation is a major environmental issue of our time. It is indeed believed that the transformations taking place in the forest canopy of large regions of Asia, Africa and South America will have important repercussions on biological diversity and global climate. However, the uncertainty affecting current estimates of the magnitude and rates of tropical deforestation still prevent the formation of a scientific consensus on these possible impacts. The low resolution 1 km data provided by the NOAA AVHRR instrument is shown here to offer various advantages to survey this dynamic phenomena over large areas. Data have been collected over the southern part of the Amazon Basin daily during the dry season of 1982, 1984, 1985, and 1986. The analysis of the vegetation index and thermal data documents an accelerating deforestation trend in that very sensitive portion of the world's largest tropical forest biome. The approach developed here relies upon the delineation of disturbance areas in the forest canopy--the bounded area within which deforestation activities are taking place--and the measurement of the forest/non-forest cover within those regions. An analysis of the distribution and frequency of fires in the forest or at its fringes leads to the delineation of active fronts which call for attention; the same data illustrate the role of fire as a major agent of deforestation even in the wet tropics. The same data set further documents the close relationship between the building of roadways and the deforestation process. This analysis which was done over an area of more than 1.3 million km² demonstrates the relevance of the approach for studying global changes in the tropics.

CURRENT U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT NEEDS
FOR THE FAMINE AND EARLY WARNING SYSTEM (FEWS)

By D. Reilly and J. Olsson

ABSTRACT

(Abstract Not Available)

THE UTILITY OF AVHRR DATA FOR MONITORING LARGE-SCALE
TEMPORAL CHANGES IN GREAT LAKES WATER QUALITY

By. J. R. Vande Castle and T. M. Lillesand

ABSTRACT

The AVHRR sensor system aboard the NOAA series of polar orbiter satellites has been used extensively for large-scale observations of temporal changes in vegetation. This sensor system is also a valuable source of information for surface observations of large water bodies such as the Great Lakes. The overpass frequency, spatial resolution, and cost of the data combine to form an excellent tool for monitoring changes in water quality variables such as surface temperature patterns, coastal upwelling, and turbidity. Seasonal AVHRR images of Lake Michigan show dramatic circulation patterns and instantaneous whole-lake temperature measurements which are cost-prohibitive to obtain using other technologies. These observations provide information needed to develop a fundamental understanding of the horizontal variability in water temperature and transparency on a temporal basis. The monitoring of upwelling events also aids in the prediction of nutrient availability and the subsequent potential increases in phytoplankton production.

This paper highlights the role AVHRR observations (coupled with Thematic Mapper, SPOT, and "sea truth" data) can play in developing an operational satellite-based water quality monitoring system for the Great Lakes.

SENSITIVITY OF VEGETATION INDEX ESTIMATES TO
PROPOSED AVHRR FILTER CHANGES

By C. G. Justus

ABSTRACT

Currently AVHRR channels 1 (0.55-0.7 μm) and 2 (0.7-1.0 μm) are used to determine a normalized vegetation index $\text{NVI} = (\text{Ch2} - \text{Ch1})/(\text{Ch2} + \text{Ch1})$. The sensitivity of proposed new filters (with channel 2 narrowed to 0.84-0.87 μm) for measurement of NVI is examined. A version of the spectral model of Justus and Paris (*J. Clim. Appl. Met.*, 24, 193-205, 1985) is used to simulate radiances along an AVHRR scan line for various surface directional reflectances and satellite viewing angles. Comparisons are made of NVI values computed from top-of-atmosphere exitance values modeled for a clear, dry case (aerosol optical depth $\delta = 0.1$, precipitable water $\text{PW} = 0.5$ cm), and a turbid, moist case ($\delta = 0.5$, $\text{PW} = 4$ cm). Surfaces with the spectral reflectances of eight different vegetation types were used, as represented by Bowker et al. (1985, NASA Reference Publication 1139). These results show that, for the proposed channels: (1) The NVI values are larger in the mean; (2) Effects on NVI of aerosol and water vapor interference are less severe; (3) On average the range of NVI values across the vegetation types is as great, or slightly greater, as for the current channel filters; and (4) In some individual cases the discrimination between two vegetation types is somewhat decreased, while for other vegetation type pairs the discrimination is improved.

COMPUTERIZED PATREC ASSESSMENT OF LANDSAT DERIVED LAND COVER DATA
TO AID PLANNING OF PHEASANT MANAGEMENT IN MISSOURI

By T. L. Haithcoat and D. L. Hallett

ABSTRACT

Ring-necked pheasants are expanding their range in northeastern Missouri. The land cover components utilized by them in this expansion have not been thoroughly evaluated. Habitat parameters and their spatial relationships as related to pheasant life requirements should be understood prior to continuing a pheasant release program in Missouri.

Land cover in five counties (569,000 ha) in northeastern Missouri was quantified by analyzing two dates of LANDSAT imagery within the 1982-83 growing seasons. Reflected wavelengths of pixels (0.45 ha) were classified into land cover classes by computer-aided techniques. Habitat classes delineated included: high and low density forests, savannah, pasture - trees, fescue pasture, old field - mixed pasture, red clover - bluegrass pasture, soybeans, corn, and water.

A pattern recognition (PATREC) model was developed for use with the LANDSAT imagery data to qualify the habitat within each sampling unit and assess its potential for supporting pheasant populations. Model parameters included: percent composition of various land cover classes, overall habitat and crop diversity, and distance measures to specific classes. County maps of PATREC values were then generated showing the spatial relationships of these potentials.

Accuracy of these maps was tested against indexed pheasant populations as determined by spring crowing cock counts. PATREC model precision was enhanced by revising parameters according to the results of these tests. The final maps will be used to select future release areas for pheasants in northeastern Missouri.

THE RELATIONSHIP OF FOREST PRODUCTIVITY TO LANDSAT
THEMATIC MAPPER DATA AND SUPPLEMENTAL TERRAIN INFORMATION

By E. A. Cook, L. R. Iverson, and R. L. Graham

ABSTRACT

Research is being done to examine spectral data sensitivity to forest productivity. Several study sites across the major forest regimes of North America are being studied. Two intensive study sites are located in southern Illinois and the Huntington Wildlife Forest in the central Adirondack Mountains, New York. The southern Illinois site consists of eastern deciduous and introduced conifer forests on level to rolling uplands and bottomland. Huntington Forest is a transitional boreal/northern hardwood forest in rugged, mountainous terrain.

Landsat Thematic Mapper (TM) data have been incorporated with spatial terrain information, such as soils, slope, vegetation types, and landforms, in a geographic information system (GIS) for each site. Also included in the data bases are the locations of ground forestry plots and their associated productivity measurements. Correlation and regression techniques are used to test the relationships of spectral values, band ratios, and vegetative indexes to productivity indexes.

This paper will discuss project methodology and results from the two sites. Discussion will focus on the value of TM data alone and with accompanying GIS information for predicting relative forest productivity. Consistency of results from multitemporal analysis at Huntington Forest and between the two sites will be discussed as an indication of the temporal and regional transferability of potential predictive models using TM data.

MONITORING AGRICULTURAL PRODUCTIVITY IN DEVELOPING NATIONS
UTILIZING LANDSAT DATA AND GIS TECHNOLOGY

By D. J. Wheeler and A. A. Jayasekara

ABSTRACT

Irrigation specialists in developing nations are challenged by the problem of planning the distribution of water to agricultural project areas. The feasibility of rehabilitation or expansion of an irrigation project is aided by reliable monitoring of crop productivity within various regions of that project. In developing nations, where extensive onsite field surveys by consultants are not feasible, remotely sensed data and geographic data bases of irrigation networks are marketable alternatives. This allows many agricultural factors to be modeled in the laboratory, keeping ground investigation and costs at a minimum.

The Galoya Irrigation Project in eastern Sri Lanka was used as a test case for this system under the co-sponsorship of Utah State University and U.S. Agency for International Development. Extensive networks of canals, reservoirs, and drainage systems were digitized into a geographic data base. Unsupervised multispectral classification of MSS data were merged into the GIS. Several factors analyzed with this data base included: 1) uniformity of water distribution throughout the project area; 2) crop productivity of irrigated rice in relation to distance from particular canals or reservoirs; 3) extent of crop disease, pest damage, or drainage related problems; 4) surface water storage of reservoirs; and 5) modeling of temporal changes in land use and agricultural patterns using multitime imagery.

RANGE SITE REFLECTANCE CHARACTERISTICS MEASURED BY LANDSAT MSS
AND COLOR INFRARED LOW ALTITUDE AERIAL PHOTOGRAPHY
IN SOUTH DAKOTA MIXED PRAIRIE

By W. Weaver, H. G. Fisser, J. K. Lewis, and R. W. Marrs

ABSTRACT

A 1982-1984 study using least square linear prediction model was made to determine the relationships between range biomass (the response variable) and digital reflectance information (the regressor variables) from Landsat MSS and CIR photography. The study sites were located in the continental climate of the mixed prairie of the northern Great Plains (U.S.A.). Elevations ranged from 702 to 778 meters above sea level. Temperatures varied from -34°C to over 38°C . Long term precipitation averaged 39.73 cm (1982-1984 equalled 46.26 cm).

Ground truth collection (biomass of total, live, and dead components) were made during (1) peak cool-season grass growth (June), (2) peak warm-season grass growth (August), and (3) early winter dormancy (October). Biomass samplings were scheduled within ten days of Landsat and aerial photography overpasses.

Selection of regression equations involved a test criteria of; first, an F-ratio significance at 0.05 probability level or higher, and second, a coefficient of determination, R^2 , equal to or greater than 50 percent. The Landsat MSS June data best fitted the test criteria.

The response variable was the live biomass (BLVSQ and BL) components. The regressors with the higher R^2 s were the near infrared (LS6, LS7) and red band (LS5) ratios from Landsat MSS. The prediction models best fitted to the data were:

- (1) $\text{BLVSQ} = -56668 + 44697 \text{ LS6/LS5}$ ($R^2 = 61.0\%$),
- (2) $\text{BLVSQ} = -43856 + 37042 \text{ LS7/LS5}$ ($R^2 = 62.0\%$),
- (3) $\text{BL/BD} = -12.9 + 7.95 \text{ LS6/LS5}$ ($R^2 = 53.5\%$), and
- (4) $\text{BL/BD} = -10.0 + 6.30 \text{ LS7/LS5}$ ($R^2 = 49.6\%$).

The square root of the solution to either equation (1) or (2) produces the live biomass (BLV) component (g/m^2) related to the June sampling period in western South Dakota. Substitution of that component (BLV) into either equation (3) or (4) yields the dead biomass component. The sum of live plus dead components produces total biomass (g/m^2). Total biomass multiplied by 10.00 converts into kg/ha , a managerial unit.

INTERNATIONAL SATELLITE LAND-SURFACE
CLIMATOLOGY PROJECT (ISLSCP)

By R. Murphy

ABSTRACT

(Abstract Not Available)

SESSION: APPLICATIONS AND DEVELOPMENTS
IN GEOLOGIC REMOTE SENSING

Wednesday, May 6, 8:30-12:00 a.m.

CO-CHAIRPERSONS: MICHEL T. HALBOUTY
G. BRYAN BAILEY

- M. Abrams, Jet Propulsion Laboratory
Mapping in the Oman Ophiolite with Thematic Mapper Data
- M. Settle, J. McKeon, and M. Crawford, ARCO Oil and Gas Company
Hydrocarbon Microseepage Detection Using Remote Sensing Techniques
- L. C. Rowan, U.S. Geological Survey, C. Anton-Pacheco, Institute of Geology
and Mines of Spain, D. W. Brickey and M. J. Kingston, U.S. Geological Survey,
and A. Payas, Institute of Geology and Mines of Spain
Mapping Contact Metamorphic Aureoles in Extremadura, Spain, Using Landsat
Thematic Mapper Images
- M. H. Podwysocki, W. J. Ehmann, and D. W. Brickey, U.S. Geological Survey
Application of Combined Landsat Thematic Mapper and Airborne Thermal
Infrared Multispectral Scanner Data to Lithologic Mapping in Nevada
- J. V. Taranik and M. X. Borengasser, University of Nevada-Reno
Application of SPOT Data to Geological Investigations in Nevada
- J. Chorowicz, G. Vidal, and P. P. Rudant, Pierre et Marie Curie University,
Paris, and J. C. Rivereau, SPOT Image, Toulouse
SPOT Capability in Geological Mapping: The Rift Valley Case
- C. M. Trautwein and L. C. Rowan, U.S. Geological Survey
New Techniques for the Quantification and Modelling of Remotely Sensed
Alteration and Linear Features in Mineral Resource Assessment Studies
(Abstract not available)
- A. F. H. Goetz, University of Colorado
AVIRIS: The New Future in Geologic Remote Sensing

MAPPING IN THE OMAN OPHIOLITE WITH THEMATIC MAPPER DATA

By M. Abrams

ABSTRACT

Ophiolite terrains, considered to be the on-land occurrences of oceanic crust, host a number of types of mineral deposits: volcanogenic massive sulfides, podiform chromite, and asbestos. Thematic Mapper data for the Semail Ophiolite in Oman were used to separate and map ultramafic lithologies hosting these deposits, including identification of the components of the extrusive volcanic sequence, mapping of serpentinization due to various tectonic processes, and direct identification of gossans. Decorrelation stretching was used to process the three infrared bands, channels 4, 5, and 7. These channels were selected based on analysis of reflectance spectra of ophiolitic rocks. The resulting color pictures allowed separation of two different mantle sequence units, mafic and less mafic cumulate gabbros, dikes with gabbro or lava screens, and three units of extrusive lavas. One of the mantle units was found to have a spatial correlation with known chromite deposits; altered and gossanous areas in the dike and extrusive units were also identifiable. Thematic Mapper data were found to be extremely effective for mapping in this terrain due to the excellent spatial resolution and the presence of spectral bands which allow separation of the pertinent mineralogically caused spectral features associated with the rock types of interest.

This work was performed at the Jet Propulsion Laboratory, California Institute of Technology under contract to the National Aeronautics and Space Administration.

HYDROCARBON MICROSEEPAGE DETECTION USING REMOTE SENSING TECHNIQUES

By M. Settle, J. McKeon, and M. Crawford

ABSTRACT

Remote sensing techniques have been used extensively within the oil and gas industry to detect folds, faults, and fractures that may have influenced the accumulation of hydrocarbons at depth. They have also been used to map lithologic variations in geologic formations exposed at the edges of major sedimentary basins. More recently, these techniques have been employed to map surface alteration effects associated with hydrocarbon microseepage. This paper presents the results of two remote sensing studies conducted at Cement, Oklahoma and Mist, Oregon which were designed to detect surface evidence of hydrocarbon microseepage.

The Cement oil and gas field is situated in south-central Oklahoma near the axis of the Anadarko Basin. A reddish brown sandstone known as the Rush Springs Formation outcrops in and around the Cement field. In the vicinity of the field this sandstone is altered to a buff white color. Landsat Thematic Mapper (TM) imagery was used to map the regional extent of this alteration phenomena and its relationship to the known limits of production of the Cement field. A band ratio image constructed from TM bands 5 and 2 proved to be effective in discriminating altered exposures of the Rush Springs from unaltered exposures. The band ratioing technique was applied to TM images acquired on three separate dates. A mask was constructed for each image which effectively obscured those portions of the scene that did not contain soil or rock exposures of the Rush Springs Formation. Merging the band 5/2 images constructed from the three TM images reveals the presence of a subtle alteration halo along the northern edge of the Cement field.

The Mist gas field is situated in northwestern Oregon near the Columbia River. Gas is produced from a number of small, structurally isolated pools situated at an average depth of 1,500 feet. The dominant form of surface vegetation is Douglas fir trees. Ground based reflectance measurements were performed on samples of native Douglas fir trees. These measurements revealed that trees growing over gas pools are characterized by lower overall reflectance in the near infrared. In addition, a prominent absorption feature situated at 1,200 nanometers is generally less well developed in samples extracted from "on-field" trees.

These results suggest that remote sensing techniques could prove to be effective in detecting surface evidence of hydrocarbon microseepage as the spatial and spectral resolution of imaging sensor systems continues to improve.

MAPPING CONTACT METAMORPHIC AUREOLES IN EXTREMADURA, SPAIN,
USING LANDSAT THEMATIC MAPPER IMAGES

By L. C. Rowan, C. Anton-Pacheco, D. W. Brickey,
M. J. Kingston, and A. Payas

ABSTRACT

In the Extremadura region of western Spain, Ag, Pb, Zn, and Sn deposits occur in the apices of late Hercynian granitic plutons and near the pluton contacts in late Proterozoic slate and metagraywacke that have been regionally metamorphosed to the greenschist facies. The plutons generally are well exposed and have distinctive geomorphological expression and vegetation; poor exposures of the metasedimentary host rocks and extensive cultivation, however, make delineation of the contact aureoles difficult.

Landsat Thematic Mapper (TM) images have been used to distinguish soil developed on the contact metamorphic rocks from soil formed on the stratigraphically equivalent slate-metagraywacke sequence. The mineral constituents of these soils are similar, except that muscovite is more common in the contact metamorphic soil; carbonaceous material is common in both soils. Contact metamorphic soil have lower reflectance, especially in the 1.6-micrometers-wavelength region (TM 5), and weaker Al-OH, Mg-OH, and Fe³⁺ absorption features than do spectra of the slate-metagraywacke soil. The low-reflectance and subdued absorption features exhibited by the contact metamorphic soil spectra are attributed to the high absorption coefficient of the carbonaceous material caused by heating during emplacement of the granitic plutons.

These spectral differences are evident in a TM 4/3, 4/5, 3/1 color-composite image. Initially, this image was used to outline the contact aureoles, but digital classification of the TM data was necessary for generating internally consistent maps of the distribution of the exposed contact metamorphic soil. In an August 1984, TM scene of the Caceras area, the plowed, vegetation-free fields were identified by their low TM 4/3 values. Then, ranges of TM 4/5 and 3/1 values were determined for selected plowed fields within and outside the contact aureoles; TM 5 produced results similar to TM 4/5. Field evaluation, supported by X-ray diffraction and petrographic studies, confirmed the presence of more extensive aureoles than shown in published geologic maps; few misclassified areas were noted. Additional plowed fields consisting of exposed contact metamorphic soil were mapped digitally in an August 1985 TM scene.

Subsequently, this approach was used to map two 1-km-wide linear zones of contact metamorphosed rock and soil in the San Nicolas Sn-W Mine area, which is located approximately 125 km southeast of the Caceras study area. Exposures of granite in the San Nicolas area are limited to a few altered granitic dikes in the mine and a small exposure of unaltered pegmatite-bearing granite in a quarry about 1.5 km west of the mine. The presence of coarsely crystalline biotite and beryl in the granite in the quarry and of contact metamorphosed slate up to 2.5 km from the nearest granite exposure suggest that only the apical part of a pluton is exposed in the quarry and that a larger, shallowly buried body is probably present.

These results indicate that potential application of TM image analysis to mineral exploration in lithologically similar areas that are cultivated in spite of poor rock exposures.

APPLICATION OF COMBINED LANDSAT THEMATIC MAPPER AND AIRBORNE
THERMAL INFRARED MULTISPECTRAL SCANNER DATA TO
LITHOLOGIC MAPPING IN NEVADA

By M. H. Podwysocki, W. J. Ehmann, and D. W. Brickey

ABSTRACT

Future Landsat satellites are to include the Thematic Mapper (TM) and also may incorporate additional multispectral scanners. One such scanner being considered for geologic and other applications is a four-channel thermal-infrared multispectral scanner having 60-m spatial resolution. This paper discusses the results of studies using combined Landsat TM and airborne Thermal Infrared Multispectral Scanner (TIMS) digital data for lithologic discrimination, identification, and geologic mapping in two areas within the Basin and Range province of Nevada. Field and laboratory reflectance spectra in the visible and reflective-infrared and laboratory spectra in the thermal-infrared parts of the spectrum were used to verify distinctions made between rock types in the image data sets.

TIMS collects data in six relatively broad channels in the emitted-infrared (8-11.6 μm) part of the spectrum. Within this region, many minerals display diagnostic molecular vibration bands related to their molecular structure and the force constants between their atoms. These bands include the strongest molecular vibration band of silicate minerals, the silicon-oxygen stretching fundamental. A carbon-oxygen bending mode also occurs within the TIMS bands.

The Nelson test site lies within the Mojave Desert, approximately 60 km southeast of Las Vegas, Nevada. Precambrian gneisses, Tertiary intrusive and extrusive rocks, Quaternary alluvium, and minor occurrences of Tertiary sedimentary rocks are the dominant lithologic units. Late Tertiary hydrothermal activity altered some of the Precambrian and Tertiary crystalline rocks to produce minerals characteristic of propylitic, argillic, and phyllic alteration; several small base- and precious-metal deposits also formed at this time.

TM band-ratio images were used to distinguish rocks based upon the presence or absence of ferric iron-bearing minerals, clays, sulfates, carbonates, zeolites, and desert varnish. Within the crystalline rocks, hydrothermally altered and potentially mineralized rocks were identified by the presence of absorption features related to clays, micas, and sulfates.

Inverted principal component (IPC or decorrelation stretch) images of TIMS data allowed distinction between felsic, intermediate, and mafic crystalline rocks. Limestone, which appears spectrally flat in five of the six TIMS bands, was used to normalize the TIMS channels to one another. Thus, granites and granodiorites were identified as a result of their high quartz and feldspar content, which gives them distinctive signatures in the TIMS data. Crystalline rocks that were hydrothermally altered to a quartz-kaolinite-sericite assemblage were uniquely identified on the basis of combined TM and TIMS information, as was desert varnish. Zeolitized tuffs and bleached

hydrothermally altered rocks, which gave similar spectral signatures in the TM bands, could be distinguished by using TIMS data. Limestone was separable from all other rocks. TIMS spectral signatures conformed well to the shapes of the laboratory-measured spectra for the rock types examined.

The Carlin test site lies within the grass and scrub brush land of the northern Great Basin, approximately 50 km northeast of Elko, Nevada. Sedimentary rocks predominate and consist of Paleozoic deep-water quartzites, cherts, and shales that were overthrust eastward onto a shallow-water shelf sequence of carbonates and quartzites. Small late Mesozoic intrusives and Tertiary volcanic flows occur locally. Tertiary hydrothermal activity produced replacement jasperoids in the sedimentary rocks; associated with the jasperoids are sediment-hosted disseminated gold deposits. The dominant mineralogy of the altered rocks is quartz, accompanied by minor kaolinite, sericite, and rarely, alunite.

TM band ratios in this terrane were not useful for distinguishing among the sedimentary rocks or distinguishing between sedimentary and hydrothermally altered rocks. Areas that do appear anomalous are the result of firescars that are being revegetated. Laboratory spectra in the visible and near-infrared parts of the spectrum show that most of the rocks that contain hydroxyl-bearing minerals tend to be quite dark; hence, absorption features that do exist are quite subdued. Rocks that are bright, such as quartzites, lack features in the visible and near-infrared parts of the spectrum.

When TIMS data were processed as IPC images, they showed more apparent lithologic variation than the TM data did. Quartz-rich rocks were readily distinguished from other rocks. Moreover, Eureka quartzite, which has the typical mid-infrared absorption features of quartz, could be distinguished from hydrothermal jasperoids and the western-facies cherts, which display unusual quartzlike spectra. These differences appear to result from sericite in the cherts and some of the jasperoids. This sericite is produced by either a regional metamorphism of sedimentary illite or an enrichment due to hydrothermal processes. The unusual shape of the spectral curves appears to result of particle size differences between quartz and sericite within the cherts and jasperoids. Jasperoids located along faults were identified where they cut across the sedimentary host rocks. After the TIMS data were calibrated internally and adjusted to known signatures of ground targets, they could be correlated with the shapes of spectral curves for laboratory-derived spectra.

TIMS data, when they are used in conjunction with TM data, provide additional spectral information for mapping lithology in arid terranes. Units that could not be distinguished by using TM data alone were separable on the TIMS imagery because of its capability to detect spectral differences between silicate and carbonate rocks.

APPLICATION OF SPOT DATA TO GEOLOGICAL INVESTIGATIONS IN NEVADA

By J. V. Taranik and M. X. Borengasser

ABSTRACT

The first French earth observations satellite, Systeme Probatoir d'Observation de la Terre (SPOT-1) was launched on February 21, 1986, into a near-polar, 820km nominal orbit. SPOT-1 utilizes two High-Resolution Visible (HRV) linear-array sensors that view a 60km swath-width. Data can be acquired in a single panchromatic band having a 10 meter Ground Instantaneous Field of View (GIFOV) or in three multispectral bands having GIFOV's of 20 meters. Panchromatic and multispectral data may be recorded on two 50 megabit per second tape recorders or may be transmitted directly to the ground. Data acquisition began over Nevada in May 1986, after the engineering tests had been completed on the system.

The Mackay School of Mines was selected by CNES and SPOT Image to investigate SPOT data under PEPS (Program to Evaluate SPOT). That investigation was to include an evaluation of SPOT data acquired at five different viewing angles over the Candelaria Region in west-central Nevada. SPOT multispectral data were also provided over the Johnnie District in southern Nevada. In addition, Mackay School of Mines is coordinating SPOT studies over the Goldfield test site as a part of the Geosat Committee's PEPS investigation. This paper summarizes the significant results of those investigations.

SPOT panchromatic data were first analyzed over the Candelaria test site in Central Nevada. This test site is located near the boundaries between Mineral and Esmeralda Counties in Nevada and adjacent to the California-Nevada Border. Mina, Nevada is centrally located in the 60 by 60km area covered by the SPOT data. Panchromatic SPOT data were found to support geologic field investigations at 1:12,000 scale, although photointerpretation could be accomplished at 1:24,000, or even 1:48,000 scale. Analysis of stereoscopic data is only preliminary, but the images appear to be comparable to 1:48,000 scale stereo aerial photography. Although SPOT multispectral data have only been recently received, preliminary analysis indicates high sensitivity to variations in iron-oxide abundance have been recorded in SPOT-1 band 2. Registration of SPOT panchromatic data to Landsat-TM data was accomplished with some difficulty for terrain in relief. The best co-registered product utilized SPOT panchromatic data for intensity and Landsat-TM bands 5 and 4 for hue and saturation.

SPOT multispectral data were analyzed over Goldfield, Nevada and compared to Landsat Thematic Mapper data and SPOT aircraft simulator data. SPOT multispectral data were found to be superior to Landsat TM data in resolving roads, buildings and geological contacts. However, the additional spectral resolution of the TM data provided better discrimination of alteration patterns than the SPOT data when ratios and principal components analysis techniques were utilized.

SPOT CAPABILITY IN GEOLOGICAL MAPPING:
THE RIFT VALLEY CASE

By J. Chorowicz, G. Vidal, P. P. Rudant, and J. C. Rivereau

ABSTRACT

The purpose of the study was to assess SPOT capability in geological mapping over a selected area in the Gregory Rift in Kenya, using 20-m resolution multispectral data. Various standard and special processing techniques have been used to provide optimum information. These include stretching, anamorphosis, filtering, and spectral band decorrelation. The decorrelation technique proved to be particularly useful in geological mapping as it gives a good discrimination between image textural elements linked to rock types and geomorphic features associated with the structural pattern. In addition, stereo capability improves the confidence and reliability in image analysis and mapping as altitude differences as small as three meters can be detected.

Main results of the study included perfect delineation of the two major regional structural trends, which are the submeridian faults belonging to the Cenozoic main rift trend and the NW-SE transform faults from the Aswa lineament family. In addition, still unknown tensional fractures with an orthogonal direction have been detected. Mapping of volcanic units has also been improved. The study demonstrates that resolution is sufficient for standard 1:50,000 mapping scale. The map interpreted from SPOT data is compared with other documents already available, and results are discussed.

NEW TECHNIQUES FOR THE QUANTIFICATION AND MODELLING
OF REMOTELY SENSED ALTERATION AND LINEAR FEATURES
IN MINERAL RESOURCE ASSESSMENT STUDIES*

By C. M. Trautwein and L. C. Rowan

ABSTRACT

Linear structural features and hydrothermally altered rocks that were interpreted from Landsat data have been used by the U.S. Geological Survey (USGS) in regional mineral resource appraisals for more than a decade. In the past, linear features and alteration have been incorporated into models for assessing mineral resource potential by manually overlaying these and other data sets. Recently, USGS research into computer-based geographic information systems (GIS) for mineral resource assessment programs has produced several new techniques for data analysis, quantification, and integration to meet assessment objectives.

Digitally encoded geological, geophysical, geochemical, and mineral resource occurrence data that were incorporated within a GIS were used to evaluate the spatial significance of linear features and alteration in the Butte 1°-by-2° quadrangle, Montana. The density and distribution of azimuthal trends and the intersections of rasterized linear features that were mapped in Landsat images and a side-looking radar image mosaic were analyzed for 16 geologically defined subdomains. An automated procedure was developed for quantifying the spatial relations between known mineral occurrences and linear features within six azimuthal ranges; a similar procedure was used for evaluating the hydrothermally altered rock exposures. The quantitative index developed, termed the normalized density (ND), is the percent mines per percent area encompassed by the linear features, intersections, or altered areas. The ND value was used to select the linear feature trends and intersections that are most closely associated with known mineralization of several types.

A composite mineral resource model that incorporates several types of deposits was developed by integrating submodels defining favorable geologic, geophysical, geochemical, and remote sensing characteristics. The GIS was used in evaluating the relative importance of these submodels by iteratively overlaying them and in comparing the ND values for areas described by their combination. Linear feature and alteration submodels were assigned numeric values that were proportional to their spatial definition of known mineral occurrences. The addition of all submodels developed in this manner resulted in composite models that spatially describe known (historic) and inferred mineral potential within the quadrangle.

The application of a GIS to efficiently display, analyze, and model complex spatial relations between remotely sensed and other geologically descriptive variables allows the user to develop and test many more hypotheses regarding the significance of remotely sensed data in mineral resource investigations than would be possible using manual techniques alone.

*This abstract is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards or nomenclature.

AVIRIS: THE NEW FUTURE IN GEOLOGIC REMOTE SENSING

By A. F. H. Goetz

ABSTRACT

The Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) is now becoming operational. Imaging spectrometry allows the acquisition of images in hundreds of contiguous spectral bands simultaneously such that for each pixel a laboratory-like spectral reflectance curve is available. AVIRIS collects data in 208 spectral bands in 20-m pixels over an 11-km swath from U-2 altitude. Data with this spectral dimensionality makes it possible to identify minerals, the state of stress in vegetation, and constituents of suspended matter in water. The ability to identify materials, rather than just discriminate among classes of materials, will revolutionize the application of remote sensing to a variety of discipline problems. This advance is unfortunately accompanied by a surfeit of data to be analyzed, requiring new approaches to image processing.

SESSION: TECHNIQUE DEVELOPMENT AND DATA PROCESSING

Wednesday, May 6, 1:30-4:30 p.m.

CHAIRPERSON: RICHARD MROCYNSKI

- M. P. Buchheim and T. M. Lillesand, University of Wisconsin-Madison
Semi-automated Training Sample Selection for Classification of High
Resolution Multispectral Imagery
- J. W. Merchant, University of Kansas
Characterization of Landscape Complexity in Digital Satellite Images
- T. Chu, University of Kansas
A Paradigm of an Expert System Prototype for Semantic and Syntactic
Land-Use/Cover Classification
- S. C. Ahearn, University of Minnesota
Multi-frequency Image Analysis: Beyond the Per-point Classifier
- Y. Lu, NASA/Goddard Space Flight Center, M. H. Story and D. A. Klemas,
Science Applications Research
Multi-temporal Application of the Tasseled Cap Transformation for General
Land Cover Classification
- H. Maitre, Ecole Nationale Supérieure des Telecommunications, Paris, France,
and A. Anglade, Etablissement Technique Central de l'Armement, Arcueil,
France
Dynamic Method for Search of Control Points for the Registration of Two
Pictures
- B. K. Quirk, TGS Technology, Inc., and L. R. Oleson, U.S. Geological Survey
Overview of the Land Analysis System (LAS)

SEMI-AUTOMATED TRAINING SAMPLE SELECTION
FOR CLASSIFICATION OF HIGH RESOLUTION MULTISPECTRAL IMAGERY

By M. P. Buchheim and T. M. Lillesand

ABSTRACT

A semi-automated training sample selection technique has been developed in response to problems encountered in the application of traditional supervised and unsupervised image analysis techniques to high resolution, multispectral imagery.

The procedure automatically compiles training sample fields for an image based only upon the coordinates of a user identified "seed pixel" for each training field and the value of a homogeneity criterion (maximum summed variance) for the field. Pixels are added to a training field sequentially, based upon the amount of variance that each pixel will add to the training data for that field. Processing for a given field terminates when either the homogeneity threshold is exceeded or a user-specified maximum field size is reached.

Implementation may be in either supervised mode, wherein the seed coordinates and homogeneity thresholds are manually selected by an image analyst, or unsupervised mode, in which seeds are randomly or uniformly located throughout an image.

Use of the procedure greatly reduces the amount of analyst time required for training field delineation and extraction. It also overcomes some other more general problems with certain traditional classification techniques as applied to high resolution imagery.

Results of preliminary testing of the procedure in both supervised and unsupervised mode will be discussed.

CHARACTERIZATION OF LANDSCAPE COMPLEXITY
IN DIGITAL SATELLITE IMAGES

By J. W. Merchant

ABSTRACT

Edges partition the landscape into "patches" of homogeneous land cover. Visual image interpreters rely heavily upon analysis of edge and patch characteristics, the expression of spatial structure in the landscape, to demarcate and identify landscape regions. A technique for classifying and analyzing spatial structure in digital images is described. Edges are categorized by origin, configuration and contrast; patches are classified by composition, size, shape and context. Landcover is classified using an unsupervised clustering algorithm. Windows of varying dimensions are superimposed on the classification. These windows are clustered in multi-dimensional data space defined by measures of edge/patch configuration, diversity, and composition. Such clusters identify windows possessing similar spatial structure. Windows within individual clusters which are also located contiguously in geographic space are identified as regions of similar spatial structure. Edge/patch structure measured in processed Landsat TM data of northeast Kansas is shown to be well correlated with land use. Potential application of these results is discussed.

A PARADIGM OF AN EXPERT SYSTEM PROTOTYPE FOR SEMANTIC
AND SYNTACTIC LAND-USE/COVER CLASSIFICATION

By T. Chu

ABSTRACT

The results of per-pixel-based spectral interpretation are visually noisy and often exhibit low accuracy for most high-level land use categories. Possible reasons for the noisy appearance and low accuracies are suggested by comparison with human interpretation. It is shown that human image interpretation is often founded more upon spatial information than upon spectral data (color). Secondly, reference information and knowledge are used by human interpreters. Expert systems techniques may help correct such drawbacks by providing the more sophisticated classification logic needed to handle both more complicated data and the knowledge to use those data. The principal objective of this research is to demonstrate a sophisticated classification scheme by developing a prototype expert system for general purpose land use/cover classification using Landsat Thematic Mapper data. The classification procedure in this study consists of several stages: identification, conceptualization, formalization implementation and testing. The process is not a one-path process, but is iterative in order to refine the system incrementally. The expert system approach provides not only a powerful interpretation tool, but also a means to inspect and understand the knowledge and procedures employed by human image interpreters.

MULTI-FREQUENCY IMAGE ANALYSIS: BEYOND THE PER-POINT CLASSIFIER

By S. C. Ahearn

ABSTRACT

Advancements in the SPOT and TM satellite remote sensing systems have not been matched by equivalent strides in automated image analysis. Human interpretation is still superior to automated techniques for comprehensive analysis of the new satellite data. The problem with present automated satellite image analysis techniques is their reliance on multispectral reflectance from a single pixel to differentiate between objects. This ignores the spatial characteristics of the image which are critical for a complete interpretation of it.

In an attempt to re-examine image analysis techniques, research is underway that treats analysis as an analogue to human processes of image interpretation. At the heart of this approach is the development of techniques for image analysis that are guided by general principles that govern the relationship between the image and the objects it represents. An example is a principle that states that intensity changes occur in the image over a broad range of frequencies that relate to different size objects. A technique which has been successful in detecting the intensity changes is called the Difference of two Gaussian filters (DOG). One of the principles developed in this research permits the transformation of intensity changes at different spatial frequencies to the detection of different size objects. This is done by combining the DOG images derived with different sized Gaussian filters. The combined images called multi-frequency images, enable the analysis of: an object's components, at the higher frequencies; the object, at the frequency that matches it; and the context of the object, at the frequency of a larger object that may contain it (i.e., the branches of a tree, the tree and the forest stand). This technique is in effect using the spatial structure at different frequencies to derive an interpretation of an image, a process that is arguably used by the human interpreter. While this approach is still in its initial stages of development it marks a fundamental shift in the way high resolution satellite imagery is analyzed that may provide the capability to obtain detailed information from the new satellite remote sensing data with automated techniques.

MULTI-TEMPORAL APPLICATION OF THE TASSELED CAP
TRANSFORMATION FOR GENERAL LAND COVER CLASSIFICATION

By Y. Lu, M. H. Story, and D. A. Klemas

ABSTRACT

Preprocessing of digital image data through spectral transformations can enhance the imagery by increasing the separability of spectrally similar features. The Tasseled Cap transformation was originally developed by Kauth and Thomas (1976) to aid in the extraction of agricultural information from Landsat Multispectral Scanner (MSS) imagery. It is a linear information that results in components related to soil brightness, greenness, and wetness. This transformation has recently been expended to Thematic Mapper (TM) data (Crist and Ciccone, 1984) and applied to areas other than agriculture with some success (Goward and Wharton, 1984).

This paper reports on findings of research conducted at Goddard Space Flight Center (GSFC) concerning the applicability of the Tasseled Cap transformation for enhancing classification of general land-cover features from TM imagery. Imagery from three seasons was collected for the same study site and classified on GSFC's Land Analysis System (LAS). This multi-temporal approach allows for the monitoring of signatures that change significantly from season to season. Both transformed and untransformed data were classified using Bayesian technique and classification results were compared for accuracy. The results indicate that the Tasseled Cap transformation increases class accuracies for certain land cover classes. The most appropriate season for developing each land-cover signature is also determined from the analysis.

DYNAMIC METHOD FOR SEARCH OF CONTROL POINTS
FOR THE REGISTRATION OF TWO PICTURES

By H. Maitre and A. Anglade

ABSTRACT

Our aim is to provide an automatic method for the registration of two pictures, by propagation of control points. Starting with n existing pairs of control points (one point on each image), we automatically add one by one new control points, simultaneously matching their images on both views. A new control point is at the same time globally optimal in position and locally optimal in quality.

The elementary steps are: (a) choice of the ideal position as suggested by the n existing pairs of control points, (b) detection of k salient features in the vicinity of this ideal position in each picture, and (c) matching the best k' features ($k' < k$) with respect to both geometrical and photometrical criteria.

Step (a) is solved using an iterative propagation based on Voronoi's tessellation; it guarantees that the $(n + 1)^{\text{th}}$ control point will be the farther away from any other.

Step (b) makes use of any classical feature point detector available in the literature, the choice depending essentially on the kind of picture to process. It provides two lists of salient pixels, candidates for a possible matching.

Step (c) is solved by extracting two sublists from these lists, each element of the first one being paired to one of the second. This is a problem of assessment which is solved as a tree search problem (A* algorithm). The optimization is driven by a cost function taking into account the quality of each pairing with respect to: the coherence to the topographic model of deformation suggested by the n existing points, the radiometric similarity between the two neighborhoods, and the geometrical internal coherence of the sublists.

Very good results have been obtained with several different pictures from: high resolution aerial image, Landsat TM, Landsat RBV, and SPOT.

OVERVIEW OF THE LAND ANALYSIS SYSTEM (LAS)

By B. K. Quirk and L. R. Oleson

ABSTRACT

The Land Analysis System (LAS) is a fully integrated digital analysis system designed to support remote sensing, image processing, and geographic information systems research. The system is being developed through a cooperative effort between the National Aeronautics and Space Administration Goddard Space Flight Center and the U.S. Geological Survey Earth Resources Observation Systems (EROS) Data Center.

LAS will have over 300 analysis modules capable of performing input and output, radiometric correction, geometric registration, signal processing, logical operations, data transformation, classification, spatial analysis, nominal filtering, conversion between raster and vector data types, and display manipulation of image and ancillary data.

LAS is currently implemented using the Transportable Applications Executive (TAE). While TAE was designed primarily to be transportable, it still provides the necessary components for a standard user interface, terminal handling, input and output services, display management, and intersystem communications. With TAE the analyst uses the same interface to the processing modules regardless of the host computer or operating system.

LAS was originally implemented at EROS on a Digital Equipment Corporation VAX 11/780 computer system under the Virtual Memory System operating system with DeAnza displays and is presently being converted to run on a Gould Power Node 9050 and Sun workstation under the Berkeley System Distribution UNIX operating system.

SESSION: CURRENT REMOTE SENSING TOPICS AND INITIATIVES

Wednesday, May 6, 1:30-4:30 p.m.

CO-CHAIRPERSONS: PEGGY HARWOOD
BILL BISHOP

- R. A. Pohl, U.S. Geological Survey
Landsat Data Distribution Trends from 1973 through 1986
- C. Sheffield and O. R. Russell, Earth Satellite Corporation, and P. Harwood, NOAA/NESDIS
Creation of the National Archive for Land Satellite Remotely Sensed Data
- J. V. Taranik, University of Nevada-Reno
Aerospace Science and Terrestrial Applications in Nevada: A New NOAA Cooperative Institute in Mineral Resources Applications
- J. Spiller, University of New Hampshire, and R. W. Birnie, Dartmouth College
The Cooperative Institute for Remote Sensing of Biogeophysical Processes
- F. B. Henderson, III, The Geosat Committee, Inc. on behalf of D. Stearns, University of Oklahoma
CIARS, A NOAA Cooperative Institute for Applied Remote Sensing in Energy Resources
- D. Way, Ohio State University
Ohio State University's Center for Mapping and NASA Center for Commercial Development of Space
(Abstract not available)
- C. F. Schueler, Institute for Technology Development, NSTL
ITD SRSC Remote Sensing Commercialization Strategy
- P. M. Maughan, Space Development Services
NASA/Industry Relationship for Commercial Remote Sensing
- M. S. Talbett, University of Indiana/Purdue University at Indianapolis
Remote Sensing and the Law -- Balancing the Need to Know and Privacy Rights

LANDSAT DATA DISTRIBUTION TRENDS FROM 1973 THROUGH 1986

By R. A. Pohl

ABSTRACT

With the launch of the first Landsat satellite in 1972, and the start of data distribution operations, it was estimated that annual worldwide data sales would amount to tens of millions of dollars, and some projections predicted annual revenues in excess of 50 million dollars. In fact, as the use and applications of satellite remote sensing technology grew in the 1970's, the worldwide marketplace expanded to the point where, in 1980, gross data sales reached \$3,800,000. By 1985, worldwide sales were approximately \$10,000,000.

While data demand is cyclic and dependent upon many parameters such as price, data availability, sensor resolution, and processing techniques, the data market, as it is currently known, is probably near saturation for Landsat-type data.

Worldwide Landsat data revenue trends for Landsat digital and imagery data from 1979 through 1985 are described and their causes and implications discussed. Primary emphasis is on United States data distribution revenues from 1982 through 1986. During this period, the program management was transferred from the National Aeronautics and Space Administration to the National Oceanic and Atmospheric Administration, then to a commercial operator in late 1985.

CREATION OF THE NATIONAL ARCHIVE
OF LAND SATELLITE REMOTELY SENSED DATA

By C. Sheffield, O. R. Russell, and P. Harwood

ABSTRACT

Recent legislation calls for the creation of a U.S. archive of data from U.S. and foreign earth resources satellites for historical, scientific, and technical purposes, including global environmental monitoring. Such a data base offers the unique opportunity to develop an historical record of worldwide surface conditions at different seasons and epochs. However, technical and cost limitations will impose practical constraints on data acquisitions, volumes, formats and storage media needed by such an archive.

This paper addresses the logic for constructing an archival data base with both a global and historical perspective. In a six-month design study performed for the National Oceanic and Atmospheric Administration, Earth Satellite Corporation reviewed all known, existing and planned sensors and data types and surveyed industry, academia, and state and local government for scientific and programmatic long-term uses for this historical data base. Results indicate that the value of this archive will be most readily apparent to scientists conducting research in global land processes and environments, but that statisticians and program managers are expected to find increasing value in the ability to document trends and assess impacts from natural disasters and other changes. Evolving needs for this historical record and improved technology must be factored into the definition of a logical structure, acquisition strategy, storage methodology, and access techniques applicable to a national archive of space remotely sensed data from the 1970's into the 21st century.

AEROSPACE SCIENCE AND TERRESTRIAL APPLICATIONS IN NEVADA:
A NEW NOAA COOPERATIVE INSTITUTE IN MINERAL RESOURCES APPLICATIONS

By J. V. Taranik

ABSTRACT

The Nevada Legislature made major commitments toward advancing education and research in mineral engineering and the geological sciences in the 1980's through appropriations totaling \$8.1 million for a new building and equipment for the Mackay School of Mines. That state commitment, allowed the UNR Foundation to acquire over \$3 million in state-of-the-technology equipment for laboratories in the new building. The W. M. Keck Foundation provided \$2 million in funding for these laboratories and one Keck Foundation grant was specifically awarded for the purpose of supporting the development of an aerospace remote sensing program. The School acquired a VAX11/780 computer with Gould DeAnza IP8500 image display and TRW-Electromagnetic Systems Laboratories Interactive Digital Image Manipulation System (ESL-IDIMS) software in 1984. In 1986 the School developed a multipurpose microcomputer classroom that can be utilized for training in computer analysis of aerospace remote sensing data. This classroom utilizes 16 IBM Personal Computer-Advanced Technology (PC-AT) workstations, high-resolution color monitors, monochrome monitors and MacDonald-Dettweiler Meridian software. The classroom is linked to the VAX11/780 computer by an ethernet.

Development of these aerospace remote sensing research facilities allowed the School to secure over \$1,100,000 in remote sensing grants from NASA, NOAA and State Office of Nuclear Waste Management. Research is currently underway that involves: evaluation of Shuttle Imaging Radar and aircraft quad-polarization radar data; JPL Airborne Imaging Spectrometer data; NASA Thermal Infrared Multispectral Scanner Data; Landsat Thematic Mapper data; and French SPOT data.

In 1985 the Mackay School of Mines received a \$9.5 million federal appropriation for construction of the Paul Laxalt Strategic Minerals Research Center. In 1986 the School received a second federal grant of \$5 million to establish the Center for Strategic Minerals Policy Research. These federal grants were made on the basis of an Office of Technology Assessment report published in 1985 entitled, "Strategic Materials: Technologies for Reducing U.S. Vulnerability." A major thrust of that report was a recognized national need for developing new global aerospace remote sensing technology and would allow the U.S. industrial economy to explore for and develop new independent domestic and international sources of strategic minerals. In 1986 Mackay School of Mines sent an unsolicited proposal to the National Oceanic and Atmospheric Administration to establish a NOAA Cooperative Institute for Aerospace Science and Terrestrial Applications which would focus on the application of developing aerospace technology to the acquisition of strategic minerals needed by our industrial economy. This paper describes that new NOAA Cooperative Institute at the University of Nevada-Reno.

THE COOPERATIVE INSTITUTE FOR THE
REMOTE SENSING OF BIOGEOPHYSICAL PROCESSES

By J. Spiller and R. W. Birnie

ABSTRACT

The University of New Hampshire and Dartmouth College have combined with the National Oceanic and Atmospheric Administration (NOAA) to form The Cooperative Institute for the Remote Sensing of Biogeophysical Processes. The Cooperative Institute will employ remotely sensed data to monitor Earth resources and analyze the processes underlying global, continental, and regional change in the Earth's environment. When joined with processor-oriented modeling and *in situ* field studies, the remotely sensed data, primarily Landsat and AVHRR, will provide a comprehensive basis for understanding the effects of natural and human-induced perturbations on the Earth.

Working in a collaborating way, The Cooperative Institute seeks to:

- foster collaborative research between NOAA and the Universities to improve the information content derived from remotely sensed data,
- expand use of these data in both global and finer scale investigations of various biogeophysical processes and phenomena,
- promote collaboration between scientists and engineers from federal, state, academic, and industrial organizations and diverse disciplines to develop appropriate techniques for
 - analyzing and interpreting satellite remotely sensed data and
 - applying data to global and finer scale studies, and
- stimulate the education of scientists and engineers and assist in the transfer of methods and techniques to researchers and operational users for the use of satellite remotely sensed data through
 - academic programs,
 - on-site training of collaborating foreign materials, and
 - presentations at scholarly meetings and symposia.

CIARS, A NOAA COOPERATIVE INSTITUTE FOR APPLIED
REMOTE SENSING IN ENERGY RESOURCES

By F. B. Henderson, III

ABSTRACT

NOAA and the University of Oklahoma established the Cooperative Institute for Applied Remote Sensing (CIARS) for Energy Resources in Norman, Oklahoma August 1986. The purpose of this center is to promote industry-government academia cooperative research into applications of satellite remote sensing technology to practical geological problems with an emphasis on structural and basin geology for energy resources.

While recently delayed by uncertainties over continued NOAA funding, the search for a first class remote sensing geologist to serve as permanent Director of CIARS is being completed. Dr. David Stearns is presently interim Director. Facilities for the Center are initially based on the remote sensing capabilities of the Department of Geography under Dr. Lee Williams. Present projects include comparisons of SPOT and Landsat data for stereoscopic applications in structural geology. Other projects are being solicited from industry which will be encouraged by the recent decision of the Geosat Committee considering the undertaking an in-depth evaluation of how far the user community has progressed in developing standard methods of applying remote sensing technology to and integrating remote sensing data into information systems to solving geological problems. Those interested in participation are invited to contact CIARS/GEOSAT.

OHIO STATE UNIVERSITY'S CENTER FOR MAPPING AND NASA CENTER
FOR COMMERCIAL DEVELOPMENT OF SPACE

By D. Way

ABSTRACT

(Abstract Not Available)

ITD SRSC REMOTE SENSING COMMERCIALIZATION STRATEGY

By C. F. Schueler

ABSTRACT

The Space Remote Sensing Center (SRSC) is a Division of the Institute for Technology Development (ITD). ITD SRSC has a grant from the National Aeronautics and Space Administration (NASA) Office of Commercial Programs to develop commercial applications of space remote sensing technology, and ITD created SRSC to help stimulate economic growth in the State of Mississippi. This paper summarizes the SRSC program scope and status and describes specific efforts that may be of interest to developing nations.

ITD was created in early 1985 under a \$20 Million Department of Commerce appropriation and a \$16 Million State of Mississippi appropriation as a demonstration project for development of various technologies to assist Mississippi in creating new industry and jobs. In 1985, ITD won an award from the NASA Office of Commercial Programs (OCP) to establish a Center for Commercial Development of Space (CCDS) in remote sensing technology. The OCP program has established eight other CCDS programs in the United States in various areas, including materials processing, robotics and automation, and remote sensing. NASA expects the various CCDS programs to become self-sustaining within seven years and provides interim seed funding with the expectation that the various Centers will establish synergistic programs with academia and private sector industry to support Center operations beyond the initial seven-year period.

The ITD SRSC program includes three major areas: 1) joint projects with industry and academia; 2) project management for remote sensing application; and 3) training and consultation. Several joint commercial projects are now underway, including projects with International Paper Company, DuPont, and the Massachusetts Computer Corporation (MASSCOMP). Several joint research projects are also in motion, including projects with the University of Arkansas, the University of Mississippi, Boston University, and the University of Florida.

SRSC's primary goal is to stimulate commercially profitable ventures based on remote sensing. The strategy to do this is based on bringing remote sensing down to the land ownership level and integrates with ancillary information to pursue commercial market opportunities. Our private sector partners provide a key element in this effort by keeping SRSC's efforts focused on satisfying market needs. All our R&D efforts are also focused on solving technical problems that block market penetration. Finally, the training program provides a key communication link to the market.

SRSC's training program began in late 1986 with a joint training course in remote sensing applications for archaeologists conducted at Boston University (BU) under contract to BU. This year seven additional training courses have been established. Three are at BU: one of these is similar to the one that was taught last year; one is on desert hydrology funded by the Agency for International Development (AID); and the third is on microwave remote sensing. Four others are to be taught on site at SRSC on applications of geographic information systems (GIS) for archaeology and for major facilities planning. The latter two courses will be taught using a MASSCOMP 5600 super minicomputer, and will concentrate on applications of the Geographic Resource Analysis Software System (GRASS), a raster-based public domain GIS. SRSC has recently been designated the National Center for GRASS training and support.

NASA/INDUSTRY RELATIONSHIP FOR COMMERCIAL REMOTE SENSING

By P. M. Maughan

ABSTRACT

Recent actions by the Government to "privatize" the current and next generation Landsat systems and the stated intent to "commercialize" future Landsat systems has raised an important issue as to the appropriate relationship between a private entity and NASA with respect to Government funded remote sensing R&D. NASA asked its Space Applications Advisory Committee (SAAC) to study this issue and define an appropriate working objective between the private sector and NASA. SAAC recommended the following objective:

NASA shall conduct the necessary R&D to maintain effective and efficient operational satellite observing systems and to keep the U.S. in the forefront internationally. Specifically, NASA should advocate that the government should assure the continuity of land observation data.

Specific recommendations with regard to EOSAT and other private space ventures and the roles and relationships with other Government agencies are discussed. An implementation strategy is presented taking into account two overriding policies: the National Space Policy on Commercial Use of Space and NASA Commercial Use of Space Policy.

REMOTE SENSING AND THE LAW --
BALANCING THE NEED TO KNOW AND PRIVACY RIGHTS

By M. S. Talbett

ABSTRACT

The United States Supreme Court has recently decided whether or not the use of high resolution aerial photography constitutes a search in violation of the Fourth Amendment. In deciding that issue, the Court intimated that the use of sophisticated remote sensing techniques might be an illegal search, but it offered little guidance for making that determination. Although in certain instances sensory enhancement devices have been held to be permissible, the use of satellite imagery has yet to be tested. This paper focuses on the controversy between privacy rights and satellite surveillance, and it provides an overview of the evolving legal standard which applies to remote sensing -- an individual's reasonable expectation of privacy.

SESSION: FUTURE REMOTE SENSING SYSTEM PLANS AND PROGRAMS

Thursday, May 7, 8:30-12:00 a.m.

CHAIRPERSON: HOWARD W. WARRINER

- W. J. Hussey, NOAA
Landsat Program Status
(Abstract not available)
- C. P. Williams, EOSAT
Landsat Status and Future
- S. Tilford, NASA
NASA's Advanced Plans for Land Remote Sensing
(Abstract not available)
- K. N. Joshi, N. S. Rathore, and V. B. Bhatt, Birla Institute of Scientific
Research, India
Indian Remote Sensing Satellite (IRS-1): A Step Ahead, Indian Space
Programme
- Y. Horikawa, NASDA
Current and Future Earth Observation Programs in Japan
- P. Bescond, SPOT Image Corporation
The SPOT Program: Commercialization of Remote Sensing
- M. Arnaud, CNES
The SPOT 4 Program

LANDSAT PROGRAM STATUS

By W. J. Hussey

ABSTRACT

(Abstract not available)

LANDSAT STATUS AND FUTURE

By C. P. Williams

ABSTRACT

The Land Remote-Sensing Commercialization Act of 1984 (PL 98-365) and the September 27, 1985, contract award by the Department of Commerce created an environment for the Earth Observation Satellite Company (EOSAT) to operate, market, and privatize the Landsat program. The annual U.S. Government budget cycle, Graham-Rudhman-Hollings, the Shuttle Challenger disaster and other U.S. launch vehicle losses have all combined to effect the stability of the EOSAT program.

Since December 1985 the Congress and the Administration have openly disagreed about the intent of PL 98-365 and the appropriate level of capital investment by the U.S. Government in Landsat. Once again the House of Representatives have initiated restoration of Landsat commercialization funds, specifically for a two spacecraft program, consistent with the intentions of PL 98-365. We are awaiting Senate Appropriations Committee action and the release of FY 87 funding for a program restart.

With the release of FY 87 funds, spacecraft and sensor construction will again move forward toward a September 1990 launch for Landsat 6. We estimate continued operations of Landsat 5 through 1988 and possibly beyond, thereby reducing any data gap to a year-and-a-half or less. Landsat 6 will operate with an Enhanced Thematic Mapper at 15 and 30 meter spatial resolution, and options including 4-band TIR capability and an ocean color instrument called SEA-WiFS. The new Landsat ground station, located in Norman, OK, together with the new product distribution facility in Lanham, MD, will be able to deliver a wider range of user products with a faster turnaround time. In addition the users will be offered data in a wider array of options and media, including geocoding and PC level products.

NASA'S ADVANCED PLANS FOR LAND REMOTE SENSING

By S. Tilford

ABSTRACT

(Abstract not available)

INDIAN REMOTE SENSING SATELLITE (IRS-1): A STEP AHEAD,
INDIAN SPACE PROGRAMME

By K. N. Joshi, N. S. Rathore, and V. B. Bhatt

ABSTRACT

In the wake of growing demand for timely and accurate information on various subjects viz., geology, agriculture, ecology, geomorphology, landuse, environment, soil, hydrology, India is all set to launch its IRS series of satellites. During seventies much experience has been gained from the previous satellites, i.e., Bhaskara 1 and 2 (1976-82) and this experience has led to the concept of launching the IRS series. It is supposed that with the better capabilities Indian Remote Sensing satellite system will make a direct contribution to the efficient resource management system for the country.

Previously the IRS-1A was to be launched in the year 1986, but due to some unavoidable reasons, the launch has been postponed. Now the possible date of launching is October, 1987. IRS-1A is the first of a series of operational remote sensing satellites and will certainly serve user's need in natural resource sensing. The IRS-1 satellite system constituted of a 950 Kg. Polar sun-synchronous 3 body stabilized satellite and carries one low spatial resolution and two medium resolution, four channel multispectral electro-optic 'Push broom' scanners operating in the visible and near infra-red (IR) bands (0.4 - 0.9 μm). The orbital altitude proposed for this system is 904 km., where sensor will provide the image of 150 km., wide strip of earth's surface at resolutions of 72.5m and 36.25m and it has a repetivity of 22 days. These specifications could be made much more usable in the future for example - the possibility of a high resolution camera with a spatial resolution of 15-20m (very near to SPOT - i.e., 10m) in IRS-1B is being considered.

The IRS - data product system would give both digital and analog data in the form of quicklook, CCT, special and standard products. Utilization programme of this IRS series is considered to be achieved through the establishment of a National Natural Resource Management Systems (NNRMS) which will be based on a hybrid information system consisting of an optimum mix of remote sensing systems and conventional system.

CURRENT AND FUTURE EARTH OBSERVATION PROGRAMS IN JAPAN

By Y. Horikawa

ABSTRACT

National Space Development Agency of Japan (NASDA) successfully launched the first Japanese Earth Observation Satellite, MOS-1 (Marine Observation Satellite-1, named MOMO-1, whose meaning is Peach Blossoms) on February 19, 1987. The earth images which were sent from MOMO-1 were of good quality and satisfactory. NASDA is now performing tests of the satellite's function and performance. After completing this test, test operation will start from the end of May. Then, routine operation will actually start from November of this year.

NASDA would contribute to the development of remote sensing from space through this data utilization. I will briefly touch on this matter including MOS-1 function, ground system capability, data utilization plan, data verification program and so on.

Further as a successor of MOS-1, MOS-1B program which is identical to MOS-1, will be explained.

As for the Land Remote Sensing Program, NASDA is now developing JERS-1 (Japanese Earth Resources Satellite-1) whose launch date will be early 1991.

This program is a joint program with the ministry of International Trade and Industry who is responsible for the development of observation system including synthetic aperture radar and optical systems. This program status will be presented at the Symposium.

In the future, NASDA will participate in International Polar Orbiting Platform Program by the provision of some on-board sensors such as advanced microwave scanning radiometer or ocean colour and temperature sensor. This program status will be presented with planned Japanese future contributions to remote sensing.

THE SPOT PROGRAM: COMMERCIALIZATION OF REMOTE SENSING

By P. Bescond

ABSTRACT

The transition of remote sensing from a government research and development program to an international commercial industry raised several issues requiring programmatic solutions. SPOT's response to these legal, institutional, technical and marketing issues became cornerstones for the SPOT space and ground station system design and operational philosophy.

Development of the system is initially backed by multinational investment, though it is designed to support its own commercial operation, technical research and the launch of future satellites. SPOT operates according to the generally accepted international guidelines of "open skies" and "nondiscriminatory access to data."

The state-of-the-art technology produces the most detailed image data available and includes advanced capabilities designed to expand the benefits of remote sensing to existing users and to inspire development of new applications. SPOT is working with all components of the industry to make the entire technology more accessible and affordable.

Solutions implemented by SPOT are establishing standards for existing systems and for planned future systems developed in the international arena of commercialized remote sensing.

THE SPOT 4 PROGRAM

By M. Arnaud

ABSTRACT

This paper describes the configuration of the SPOT 4 system which is a follow on of the SPOT 1-2-3 spacecraft.

It begins with a brief introduction of the SPOT 1 system and results of one year of in orbit operation. The modification of the system is described in some detail, mainly the implementation of a new infrared band on the High Resolution Visible Radiometer and registration of the panchro and multispectral band.

A description of the new payload in terms of characteristics is given, this new payload - VEGETATION - provides a wide coverage (2200 km - 1 km pixel) of the earth and is complementary of the HRVIR.

Brief description of the new ground segment technical structure, evolution of the HRVIR products and new vegetation products is given.

