Landsat DATA USERS NOTES

ISSUE NO. 32 DECEMBER 1984

NOTICE TO READERS

The September 1984 issue of the Landsat Data Users NOTES was cancelled, causing a departure from our quarterly publication schedule. We resume our regular schedule with this, the December 1984 issue, which includes most of the material that would have appeared earlier. The next issue of the Landsat NOTES is scheduled for publication in March 1985.

IMAGING RADAR: A COMPANION FOR LANDSAT

Space Shuttle Mission 41-G, which was launched October 5, carried as part of its scientific payload a synthetic-aperture radar experiment known as SIR-B.

The Shuttle Imaging Radar-B (SIR-B) experiment is the third in a series of spaceborne radar experiments conducted by NASA that began with the 1978 launch of Seasat and continued in 1981 with the launch of SIR-A.

Like Seasat and SIR-A, SIR-B operated in the L-band (23 cm) and was horizontally polarized. However, SIR-B was to allow **digitally processed imagery** to be acquired at **selectable incidence angles between 15 and 60 degrees**. Seasat and SIR-A were both fixed-parameter sensors, acquiring images at constant look angles.

Imaging radar is a relatively new tool for acquiring synoptic coverage of the Earth's surface, and much is not understood yet, especially in the area of specifying optimum illumination geometries. The potential is great, though. It was from SIR-A images, for example, that ancient river beds buried 1 to 3 meters under the sands of the Sahara Desert were first discovered. Such features are not visible in Landsat images, nor can they be observed from the ground.

This capability for penetrating certain materials on the surface (dry sand, in this case) combines with other advantages. Radar sees through cloud cover, for one thing. Also, because it is an "active" type of sensor, providing its own illumination power, it makes no distinction between night and day, time of day, or seasonal angle of the sun.

In general, the response of radar is controlled by the characteristics of the terrain being illuminated. Sand, for example, will alter a radar signal differently than will a rocky surface, or vegetation. This combines with the fact that radar image intensity is a function of incidence angle. Topography is revealed best at lower incidence angles; higher incidence angles provide more information on surface roughness (the average size of the rocks, for example). Being able to image a specific area at a variety of incidence angles on successive days would give one an excellent means of characterizing the terrain below quite fully.

This is one central objective of the SIR-B experiment — to study the effect of different illumination geometries on the data acquired in order to make more informed decisions about future imaging radar system designs. Forty-five investigations, in all, spanning almost every Earth science discipline, are planned with the 73 hours of data that were to be acquired.

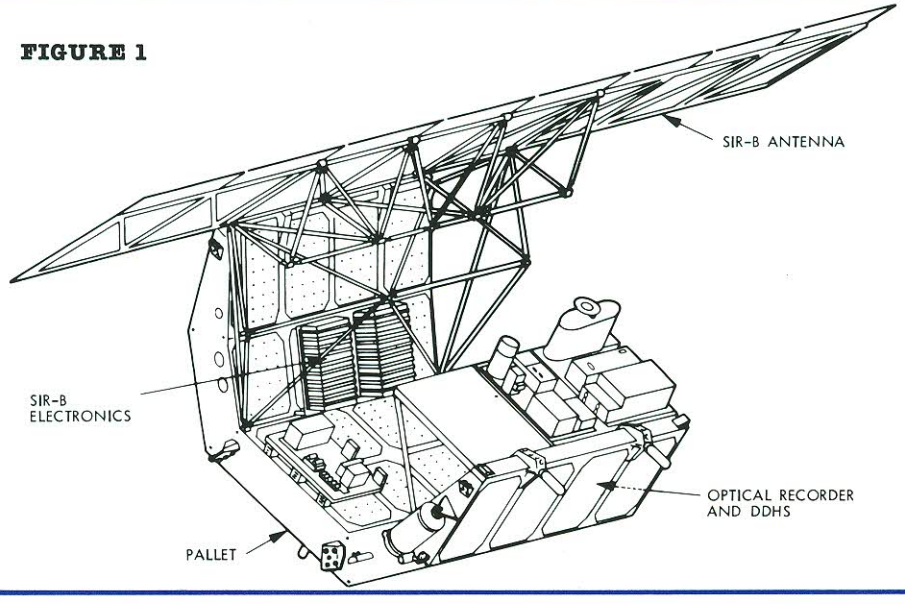
SIR-B Instrument

The SIR-B instrument (fig. 1) is an upgraded version of its predecessor, SIR-A, with several new features having been incorporated. These enhancements include the addition of antenna electronics that allow selectable look angles, a somewhat increased bandwidth, a calibrator, and a digital handling subsystem. The antenna and radar sensor have been carried over from SIR-A with only slight modification. The optical recorder has remained unchanged. Table 1 is a list of SIR-B's operating characteristics.

The sensor works by generating microwave pulses at 1.28 GHz (L-band) in the transmitter portion and radiating them outward through the antenna. The signals reflected from the earth are then collected by the antenna and sent to the receiver portion of the sensor where they are broken down to baseband to form an offset video output. This output is then sent to either the optical recorder or the digital data handling subsystem, or both.

The optical recorder is equipped to

FIGURE 1



store about 8 hours of data on film. The digital data handling subsystem is designed to handle about 65 hours of digital data, a large majority of which (more than 95%) were to be routed to the Shuttle's Ku-band antennna system for transmission to the Tracking and Data Relay Satellite (TDRS) and retransmission to the ground receiving station at White Sands, New Mexico. From White Sands, the data were to be transmitted via Domsat to the NASA/Goddard Space Flight Center in Greenbelt, Md., and recorded there on high-density digital tapes (HDDT's). A limited amount of onboard storage capacity for the digital data was provided for those times when the Shuttle would be out of range of the TDRS.

After recording at Goddard, all data will be sent to the Jet Propulsion Laboratory (JPL) in Pasadena, Calif., where the HDDT's will be processed into digital imagery with a software correlator. SIR-B digital images will feature a range resolution two times better than that of either the SIR-A or SIR-B optically correlated images because of the increased SIR-B bandwidth. An end-to-end system block diagram for SIR-B is shown in figure 2.

The Shuttle itself was launched into a nominally circular orbit at an inclination of 57 degrees and an average altitude of 225 km (141 mi.) for most of the mission. The mission was to last 8 days, starting on October 5 and ending on October 13. At an altitude of 225 km, the ground track was to repeat on a 1-day cycle, but with a westward drift. This would allow SIR-B to image a given site at several different incidence angles, one angle each day.

> It is known that Mission 41-G experienced difficulty pointing its Ku-band antenna in the direction of the TDRS relay. This led to a significant limitation in the amount of data acquired by SIR-B. Only 20% of the originally planned coverage was actually acquired. However, this still corresponds to an areal coverage of more than 6 million square kilometers.

Optical Processing

The raw echo data collected during the SIR-B mission were to be of two general types: optical and digital. The optical data were to be recorded onboard via film by an optical recorder exactly like that used with SIR-A.

From the optical data, two types of imagery are to be produced. One will be products processed directly from the 8 hours of optical recorder data collected in-flight. They will be of same quality and resolution as those from SIR-A (40 meters, 6 looks).

The second type of optical product will be a degraded "survey-mode" image produced from the digital data after conversion to signal film by a laser beam recorder. Survey-mode images will be produced from all digital data collected during the mission in order to allow the SIR-B investigators to validate the digital data acquired over their sites and to accurately locate the swaths. Minor ambiguities will not be corrected and the image quality will be inferior (50 meters, 4 looks) to the onboard recorder products.

The bandwidth limitations of the optical correlator (used during ground processing) will reduce the range resolution by a factor of two relative to that of the corresponding digital data. Thus, SIR-B optical imagery will have a ground range resolution of 30 to 100 meters depending on incidence angle. All optical products will be annotated with date and time of acquisition, but no image location or radiometric calibration will be performed. The imagery will be in a slant-range presentation with a scale of about 1:500,000.

Digital Processing

The SIR-B digital processor will be capable of handling data of 3, 4, 5, or 6 bits per second with the full range of synthetic-aperture lengths that results from the variable look angles (15 to 60 degrees). As a result of the instability of the Shuttle as an imaging platform, and because of the high look angles (up to 60 degrees), the possibility of range migration of the target across multiple range bins during the imaging period required incorporation of an azimuth-compression algorithm to maintain required signal-to-noise ratios.

The data will be both geometrically and radiometrically corrected, and a determination of the absolute location of the image center will be made.

The geometric correction will convert the slant-range presentation to a ground-range presentation (exclusive of local terrain distortion) and will remove the skew due to Earth rotation. Output image size is to be 25 to 60 km across-track and 90 to 110 km along-track, depending on imaging mode (look angle, data rate, etc.).

Radiometric compensation will be performed to produce a relative uniformity in the image presentation that will be independent of imaging mode or target location across the swath. No attempt will be made to relate the image gray level to the backscatter coefficient. The SIR-B digital processor will use pre-launch test data in conjunction with in-flight sensor data to compensate for such variations as: (1) transmitter output power variation; (2) elevation antenna modulation; (3) variable slant range both across-swath and at different look angles; (4) receiver gain fluctuation; and (5) along-track

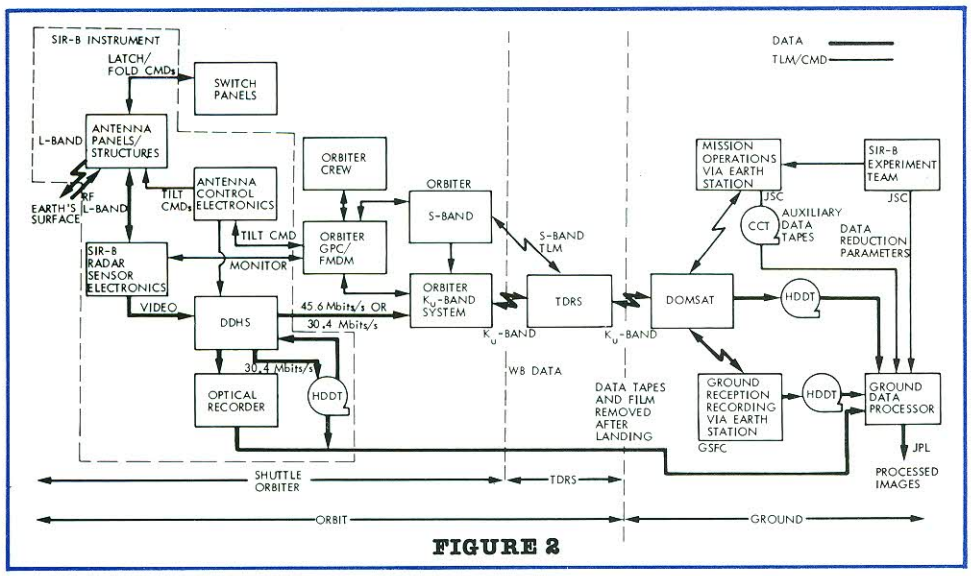


FIGURE 2

Doppler shift. It is estimated that a relative calibration of approximately 2 dB will be maintained over the digital data set produced.

Table 1
SIR-B Operating Characteristics

Description	Value
Orbital altitudes	352, 274, 225 km
Orbital inclination	57 deg
Mission length	8.3 days
Wavelength	23.5 cm
Frequency	1.28 GHz
Polarization	HH
Pulse length	30.4 ms
Bandwidth	12 MHz
Optical recorder bandwidth	6 MHz
Minimum peak power	1.12 kW
Antenna dimensions	10.7 x 2.16 m
Antenna gain	33.2 dB
Look angles	15 to 60 deg
Swath width	20 to 50 km
Range resolution	14 to 46 m
Azimuth resolution	30 to 30 m (4-look)
Digital data rate	45.6 and 30.4 Mbits/s
Total digital data	65 h
Total optical data	8 h

Investigation Plan

Forty-five separate investigations, conducted by scientists in 14 countries, will use the unique capabilities of the SIR-B sensor to answer basic questions such as:

(1) What role can radar imagery play in fulfilling the scientific or applications objectives for remote sensing data in a given discipline?

(2) What is the potential contribution of SIR-B and what performance parameters should be specified on future missions?

(3) What data are needed that are ancillary to SIR-B and how can SIR-B be used synergistically with other sources of data such as the Landsat thematic mapper (TM)?

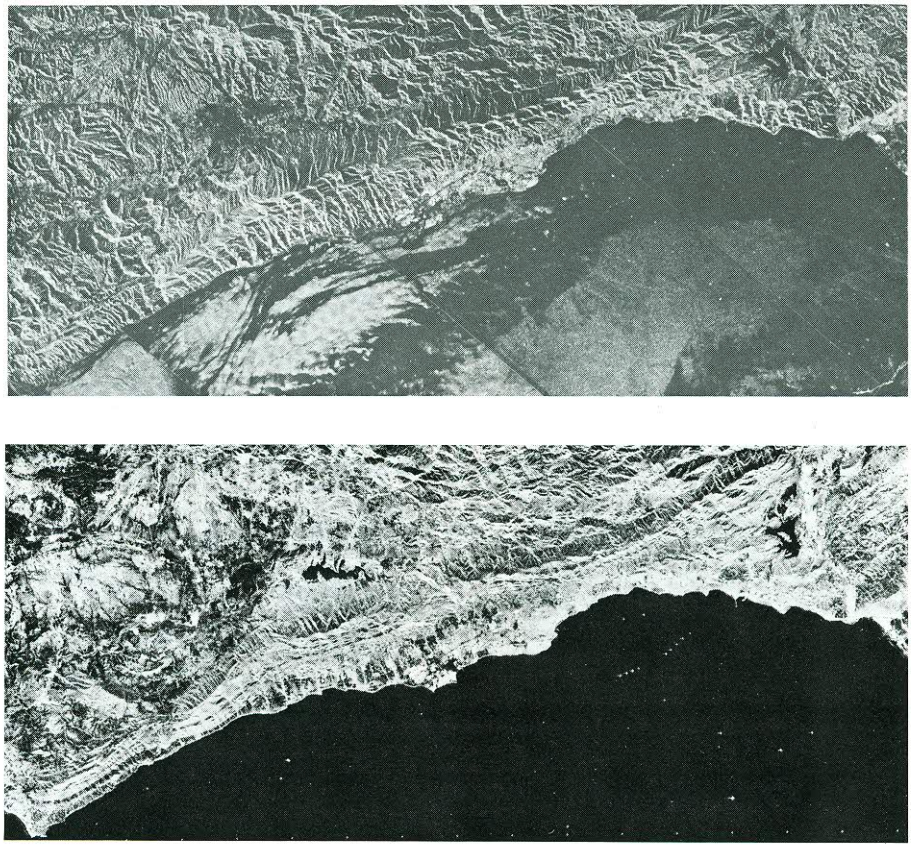
The SIR-B investigations touch most areas of geoscience, including geology, forestry, agriculture, oceanography, hydrology, and cartography, as well as studies of the characteristics of the radar system itself. Thirteen of the investigation plans originated in other countries, including Japan, Australia, Sweden, New Zealand, the Netherlands, the Federal Republic of Germany, the United Kingdom, and Canada. In addition, many of the experiments will be carried out as international cooperative efforts with collaborators in both the U.S. and such countries as Egypt, Indonesia, Turkey, Argentina, Bangladesh, Botswana, India, Peru, Brazil, and Saudi Arabia.

Geology

In the investigations having a geologic emphasis, a number of experiments will be conducted to assess the capability of multiple-incidence-angle radar data for lithologic mapping and the delineation of textural and structural features. Geologists have made extensive use of airborne radar imagery in the past for purposes of terrain analysis and structural mapping, as radar can be very sensitive to subtle changes in surface slope which, in turn, can be related to the presence of underlying crustal structures such as folds and faults.

The ability to discriminate geological boundaries and the composition of surficial materials will be extensively investigated. Previous attempts to relate tonal and textural variations in aerial radar imagery to surface geologic boundaries have been difficult, but work with Seasat imagery has shown that variations in the lithology of surficial rocks and soils can be detected successfully. Orbital radar imagery can even be used to detect lithologic boundaries between different geologic materials in certain types of environments.

The discovery, with SIR-A, of buried dry river channels in Egypt has focused interest on radar's penetration capabilities. The SIR-B experiment will place great emphasis on extending such coverage to more of the western deserts of Egypt and Sudan, as well as other hyperarid areas including southwest Africa, India, and the western coasts of Peru, Chile, and Central Australia. The penetration studies will extend east of the Nile to the Precambrian Shield where frequent outcrops of basement rocks will provide landmarks for co-registration of SIR-B data with Landsat data.



The way topography is represented in radar imagery depends greatly on local incidence angle, as demonstrated by these two photographs of the Santa Ynez Mountains along the California coast. The top photo is a Seasat SAR image. The bottom photo is a SIR-A image. Both are at the same scale, with Point Conception at the far left and the city of Ventura at the far right. The higher incidence angle of the SIR-A instrument is responsible for the mountainous regions in the bottom photo looking more geometrically correct.

Forestry/Agriculture

Investigations in the area of vegetation will include studies of both forests and agriculture. Equatorial rain forests in Sumatra, Kalimantan, and Columbia will be imaged in an attempt to geologically map these cloud-shrouded, inaccessible areas. Multiple-incidence angle data will also be used to quantify the signatures of tropical rain forests as a function of imaging geometry and to assess the penetration of dense vegetation canopies.

Experiments with both scatterometers and imaging radars have shown that the entire microwave spectrum (1 to 30 GHz) is useful for discrimination of vegetation. Longer wavelengths (10 to 30 cm) appear to be preferable for larger plants such as trees, and shorter wavelengths (2 to 6 cm) for smaller crop plants (corn, soybeans, wheat, etc.). Several SIR-B experiments will therefore be concerned with identifying and characterizing the types and conditions of both forest canopies and agricultural crops.

Hydrology

The presence of water in the top few centimeters of soil can be detected in radar imagery, and this capability will be exploited to test SIR-B as a soil moisture mapper in the Central Valley of California. Other hydrologic investigations will examine the dynamics of floodplains in wet tropical ecosystems, river channel morphologies over such areas as the Amazon River basin in Brazil, and land/water interfaces of various deltaic areas over the entire tidal cycle.

Oceanography

Oceanography experiments will be conducted in the waters around Europe in the North Atlantic, the North Sea, the Mediterranean, and off the coasts of Chile and South Africa. Ocean features such as internal waves, currents, bathymetric features, and surface gravity waves will be studied. Radar images often show wave structures, and recent work has indicated that the correct wavelength and direction of wave crests can be extracted from the imagery in many cases. Ocean wave directional spectra as a function of incidence angle will be monitored in the Agulhas Current off the southeast tip of Africa in one study. This region has long been noted for extremely high waves that reach amplitudes of 20 meters and more.

Two experiments are designed to determine the radar signatures of oil spills. Some others will look at the potential of spaceborne imaging radar for monitoring sea ice.

Geography

The investigations to be conducted with SIR-B are not limited to the surface of the Earth. The utility of SIR-B data for the detection and measurement of rainfall events and the potential for improving existing rainfall models will be investigated.

Multiple-incidence-angle radar imagery can be used in a stereo mode for cartographic, topographic, and thematic mapping, too. Two investigations will assess the optimum radar illumination geometry for stereoscopic analysis and for future radar stereo mapping missions. High-resolution elevation measurements can also be made using radar to emulate interferometric techniques. The surface relief of featureless plains and gentle slopes of alluvial fans are difficult to detect using stereo techniques, but they could be easily observed if radar signals from separate passes were allowed to cross at very shallow angles, providing what would be the equivalent of a spaceborne interferometer.

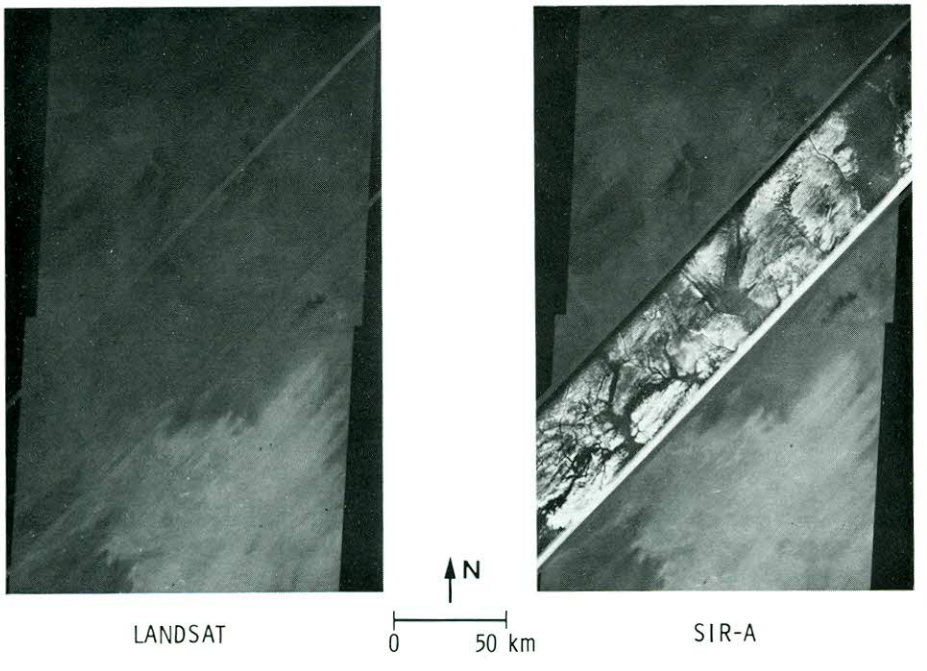
Sensor Experiments

Finally, SIR-B will offer an opportunity to conduct a number of controlled sensor experiments that will provide valuable information for future sensor designs. As part of one experiment, a calibrator will provide a reference signal to allow evaluation of such variables as antenna pattern, spacecraft attitude, transmitter power, receiver gain, and system linearity. Other, similar kinds of work to characterize SIR-B operating parameters will take place, all aimed at putting this sensor technology to work in the future.

Distribution of Products

SIR-B data products will be available to the general public through the National Space Science Data Center. Orders, questions about availability, price lists, and other information can be obtained by contacting:

National Space Science Data Center (NSSDC)
Request Coordination
NASA/Goddard Space Flight Center
Code 601.4
Greenbelt, Md. 20771
Telephone: (301) 344-6695



A Landsat MSS image taken over the Sahara Desert in the vicinity of Egypt and Sudan has been overlaid with a strip of SIR-A imagery (right part of photo). Landsat imagery alone (left side) appears almost featureless in an area like this. Radar imagery, however, penetrates the sand cover to reveal underlying land forms.

COMMERCIALIZATION PROCESS UPDATE

Following the enactment last July of legislation authorizing the transfer of U.S. land remote sensing capabilities from the Federal Government to the private sector, negotiation with the two remaining competitors in the proposal process — Eastman Kodak and EOSAT — continued.

At meetings held in early July, both firms were informed that although their technical approaches were acceptable, their overall proposals were not comparable. Both were asked to revise and resubmit their proposals in accordance with the baseline established by the Source Evaluation Board, which was consistent with the Request for Proposals (RFP) and the legislation as enacted.

Revised proposals were submitted, but these, plus the results of additional financial analysis by the Office of Management and Budget, still indicated that the Government's liability over the life of the program was not being held to an acceptable level. The Administration subsequently decided to put a cap on the amount of financial support that would be given to the establishment of a commercial Landsat system. Secretary of Commerce Malcolm Baldridge and the Director of the Office of Management and Budget, David Stockman, both agreed (with Presidential concurrence) that the cost to the Government should not be permitted to exceed: (1) the run-out cost for operating Landsats 4 and 5, plus (2) a maximum of $250 million of new budget authority for the commercial follow-on system.

Both firms were notified of this decision and, once again, were asked to revise their proposals. Only EOSAT responded with the changes necessary. Kodak declined to compete.

EOSAT, or the Earth Observation Satellite Company, was formed as a company earlier this year for the express purpose of addressing land remote sensing in Commerce's original Request for Proposals. Technically, it is a joint venture of two companies, RCA Corporation and Hughes Aircraft Corporation, with four major subcontractors having been identified as team members. All are recognized, experienced companies in space-related commercial activities, and three are principal participants in the current Landsat 4/5 program. They are as follows:

- Santa Barbara Research Center (SBRC), a subsidiary of Hughes Aircraft Corporation, which would be responsible for the sensor systems on any new land remote sensing satellites. SBRC developed both the multispectral scanner (MSS) and the thematic mapper (TM) instruments currently flying aboard Landsats 4 and 5.
- Computer Sciences Corporation (CSC), which is the current contractor operating the NOAA Landsat system control and processing facilities at NASA's Goddard Space Flight Center. CSC would perform the same function for the commercial program when implemented.
- Earth Satellite Corporation (EarthSat), which is a data analysis, processing, and value-added service organization that has been a major supplier to the Landsat user community for more than 14 years. EarthSat would be responsible for setting up and directing EOSAT's applications and marketing support activities.
- RCA Astro-Electronics, a division of the RCA Corporation, which would provide the Landsat 6 and 7 spacecraft. An advanced TIROS-N platform, or derivative thereof, is contemplated. This would be the fifth generation of a polar-orbiting weather satellite that RCA has had experience in building.

EOSAT's proposal provides for: (1) the construction, launch, and operation of two additional Landsat satellites; (2) the development and installation of a supporting ground system; and (3) the sale and distribution of remote sensing data to the world user community. A significant international market development effort and assurance of data continuity in keeping with all current agreements, both national and international, are included as requirements.

Products

Products and services from a future commercial system will be similar to those provided now. Standard products will be in the form of film (both black-and-white and color) and computer-compatible tapes (both geometrically corrected and uncorrected). A variety of non-standard products will also be available. At a minimum, these will be compatible with and functionally equivalent to the products furnished by Landsats 4 and 5.

Certain advancements in sensor design have already been identified and are expected to be included on Landsat 6. One of these is to be an additional panchromatic band on the TM, which will provide a means of achieving 15-meter resolution in the image data provided. An option planned on Landsat 7 is a thermal infrared (TIR) capability which could provide four 60-meter-resolution bands in the 8.0- to 11.5-micrometer portion of the spectrum. Such capabilities carry new and interesting implications for cartographers, agriculturists, and mineral explorationists.

EOSAT will maintain an ongoing R&D effort while the Administration, in accordance with legislation, pursues methods to parallel these improvements in an attempt to advance multilinear array (MLA) technology, which currently represents the next-generation capability in multispectral Earth observation. A place, in fact, exists on Landsat 7 for an MLA sensor which would have selectable very-near and short-wave infrared channels, a 41-km ground swath, stereo imaging, and cross-track pointing.

At the present time, Landsat 6 is planned for launch in the first quarter of 1988. Landsat 7 would be launched in the second quarter of 1991.

Market Development

EOSAT's marketing organization will be responsible for expanding the current market as well as finding new markets for Landsat products. The strategy calls for the establishment of such elements as:

- An EOSAT data center
- An expanded computer access system
- An office network
- Franchises to value-added firms and to foreign ground stations
- Direct sale of data to volume users.

Both domestic and international users are to be approached, to whom improved data processing capabilities, new products, and a wider variety of products will be offered.

The success of the marketing plan will be a key measure of the success of the entire commercialization experiment. Certain rates of return must be met, and rather early on, to establish a commercially viable land remote sensing industry.

Ground Facilities

Until EOSAT can build and occupy its new ground facilities in 1987, it has proposed to utilize existing Government facilities for satellite

control, data acquisition, data processing, product distribution, and archiving. Some parts of this arrangement may remain in effect after 1987 under terms mutually agreeable to EOSAT and the Government. EOSAT's prime objective is to establish a state-of-the-art capability through whatever means necessary to provide high quality products and timely delivery.

At this writing, a final draft of the contract that would govern the Landsat commercialization process was being circulated both within the Department of Commerce and at EOSAT headquarters in Arlington, Virginia. Neither organization is obligated at this time, and no funding has been appropriated by Congress.

TDRSS STATUS

NOAA management has learned that restrictions on use of the Tracking and Data Relay Satellite System (TDRSS) are scheduled to remain in effect at least through the first week of December 1984. It had previously been stated by NASA that internal TDRSS testing, which has been the reason for a restricted mission since last May, could continue through September.

The TDRSS is currently available for use by NOAA between the hours of 0700 and 1300 (Greenwich mean time) daily. High-priority TM data from Landsat 5 are collected during these times.

Specific questions on TDRSS availability for Landsat acquisitions can be directed to NOAA Landsat Customer Services, Mundt Federal Building, Sioux Falls, SD 57198. Telephone: (605) 594-2261.

HISTORICAL MSS CCT's: QUALITY INDICATOR

An evaluation of past inspection records at NASA/Goddard has shown that the vast majority of Landsat 1, 2 and 3 CCT-X scenes (MSS data) that have been cancelled in recent years were so handled because of anomalies in the digital data which were classed as uncorrectable. Testing conducted during the past year has proven that most of these errors are, in fact, irrecoverable due to a variety of reasons (wideband videotape deterioration, recording station problems, missing or incorrect annotation data, etc.), but this does not necessarily mean that the scenes have been rendered unusable in every case.

In June 1984, specification changes were agreed upon between NASA and NOAA that will eliminate the unnecessary cancellation of usable data and thereby make more historical data available to the user community while reducing the frequency of costly reprocessing attempts. These changes provide that all scenes meeting the following criteria will be shipped to NOAA's Landsat archive facility in Sioux Falls, South Dakota, where they will be available to the user community on a permanent basis:

- Correct format (that is, correct quantity, arrangement and types of files, records, bytes and end-of-file marks).
- Free of tape errors (that is, free of read errors, parity errors, etc.)
- Proper labelling and packaging.
- Of good, marginal, or best possible data quality, as specified in Table 2, and flagged as such.

As referred to in Table 2, sensor striping and/or bit slips are, by far, the most frequent and visible cause of image degradation, and they provide a reliable and easily measurable indication of digital quality. After correlating visual inspection and digital histogram data for hundreds of scenes, the level of striping and/or bit slips in an image has been defined as the range of detector mean values in each spectral band, as calculated from a 40-pixel by 2340-line sample in each of the four image swaths. The lowest rated band in each swath determines the rating for the entire swath. Similarly, the lowest rated swath in a scene determines the overall rating for the entire scene. In addition, any scene which is "saturated" (that is, which has a mean digital value of 127 for bands 4-6 and 63 for band 7) will be cancelled. Any scene which exhibits 25 or more levels of striping and/or bit slips will be individually evaluated and either cancelled, reprocessed, or reclassified as "best possible" and shipped.

Figure 3 provides examples of three scenes that were rated "good", "marginal", and "best possible."

Table 2

Quality Rating	Level of Striping/Bit Slips Minimum	Maximum
Good	0	3 (or 5*)
Marginal	4 (or 6*)	12
Best Possible	13	24

*Applies to high radiance data for (in-band mean digital value greater than 80 for bands 4, 5, and 6; 40 for band 7)

LANDSAT 4 MAJOR ANOMALIES

Standard Telemetry and Command Components Central Unit (CU-B)

Function: Provides direct command, telemetry, and clock interface to the command and data handling components and to all other spacecraft subsystems via the multiplexed data bus.

Failed: 29 October 1982

Impact: Failure of CU-A would terminate the mission.

Wideband Communications System X-Band Transmission Link

Function: Receives digital data from the TM and MSS sensors and transmits to ground stations.

Failed: X-Band Unit B 22 September 1982
X-Band Unit A 14 February 1983

Impact: Unable to receive TM data except through TDRSS.

Solar Array Panels

Function: Provide power to the spacecraft and batteries during spacecraft daylight periods.

Failed: Solar Panel 4 22 May 1983
Solar Panel 3 26 July 1983

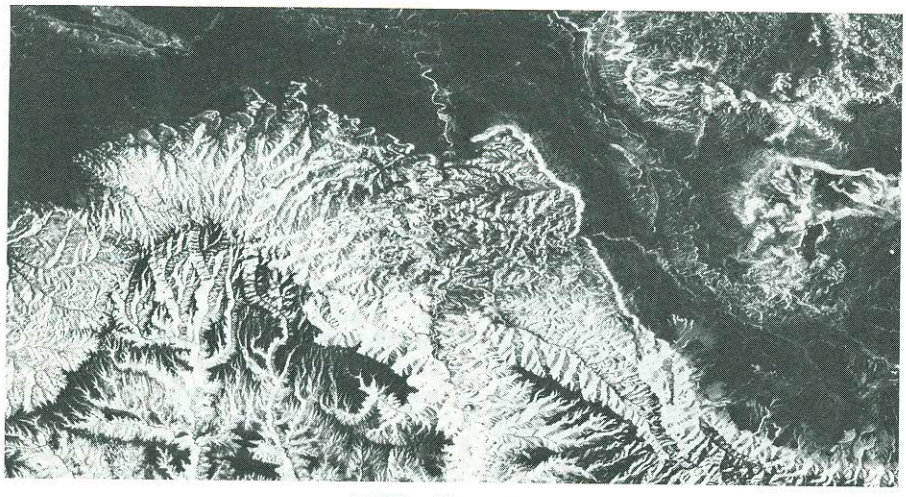
Impact: Not enough power available to support the MSS mission and also send TM data through TDRSS.

Narrowband Tape Recorder

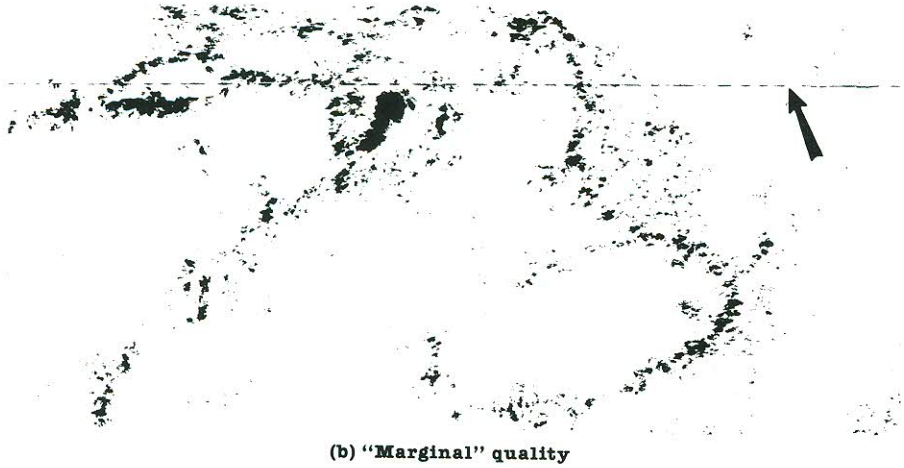
Function: Record telemetry throughout the orbit.

Failed: Narrowband recorder No. 1. Numerous servo errors cause the data to be unreliable for MSS scene processing. Recorder No. 2 is now used for areas where MSS processing is requested.

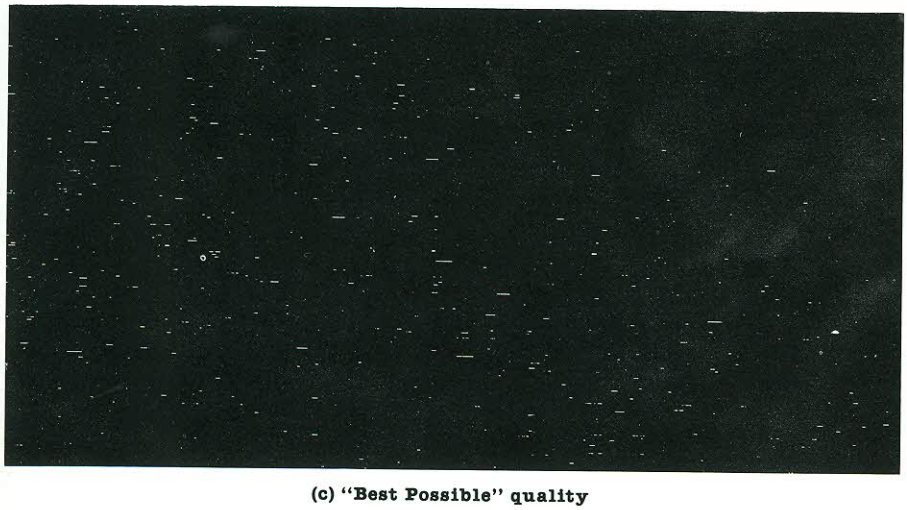
Impact: Loss of Narrowband recorder No. 2 will cause loss of capability to process foreign scenes for domestic use.



(a) "Good" quality



(b) "Marginal" quality



(c) "Best Possible" quality

Figure 3. The first scene above is free of noise of any kind. The second has a bit slip visible in the upper right portion of the image. The third scene illustrates a severe case of bit slipping and was classified as the "best possible" data that could be produced (image detail has been suppressed in order to illustrate the bit slips better).

TM COLOR COMPOSITE PRODUCTS UNDER SCRUTINY

NOAA wishes to inform the user community that it is currently investigating the radiometric correction applied to TM data by the Thematic Mapper Image Processing System (TIPS). Some users of Landsat TM data have noted a tendency in TM false-color composites toward cyan color saturation. The reason for this is a lack of adequate response in the infrared component (represented by the color red) of the band 2-3-4 composite. As a result, some applications of the imagery may be affected. Renewable resource planners, for example, may experience difficulty in assessing plant vigor.

In view of the extensive experience of the Landsat user community with MSS data, NOAA now plans to alter the TM product so that it will be similar in appearance to the MSS color composite. The changes being researched will be incorporated in such a manner that no information from the TM sensor will be lost. The final product, however, should lend itself more readily to renewable resource interpretation.

An additional concern expressed by users centers around TM black-and-white scenes over areas with very low or very high reflectance. Users believe that these images lack the contrast or definition that they should have. Although several causes are possible, including exceeding the dynamic range of the sensor, it is expected that a solution lies in finding and applying more optimum look-up table values during ground processing. The investigations currently underway are concerned in particular with the impact of both this and the aforementioned problem on the final TM color composite image.

Questions, comments, or requests for further information can be directed to: NOAA Landsat Customer Services, Mundt Federal Building, Sioux Falls, SD 57198. Telephone: (605) 594-2261.

PUBLISHED PRICES EFFECTIVE FEBRUARY 1, 1985

The Landsat price schedule shown below has been published here before. It is reprinted at this time to confirm that prices will remain stable through September 30, 1986. It should also serve to remind users of the minor increases that will become effective on February 1, 1985. These have been planned for some time.

NOAA PRICES FOR LANDSAT PRODUCTS AND SERVICES

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
WASHINGTON, D.C. 20233
Effective through September 30, 1986

TYPE OF PRODUCT/SERVICE	RETURN BEAM VIDICON & MULTISPECTRAL SCANNER		THEMATIC MAPPER	
	Current	Effective February 1, 1985	Current	Effective February 1, 1985
Image Products				
10-in. film (b/w, pos)	30	35	50	75
10-in. film (b/w, neg)	35	40	60	80
10-in. paper (b/w)	30	35	50	75
20-in. paper (b/w)	58	65	95	140
40-in. paper (b/w)	95	105	150	200
10-in. film (color, pos)	74	80	140	190
10-in. paper (color)	45	50	115	170
20-in. paper (color)	90	110	200	235
40-in. paper (color)	175	195	275	290
Digital Products				
MSS CCT, full scene (1600 or 6250-bpi, 1 tape)	650	730	—	—
RBV CCT, single subscene (1600 or 6250-bpi, 1 tape)	650	730	—	—
RBV CCT, full scene (1600 or 6250-bpi, 4 tapes)	1300	1460	—	—
TM CCT, full scene (1600-bpi on 12 tapes, or 6250-bpi on 4 tapes)	—	—	3400	4400
TM CCT, quarter scene (1600-bpi on 3 tapes, or 6250-bpi on 1 tape)	—	—	925	1350
Services				
Color Composite generation*	195	220	305	325
Special Acquisitions				
Delivery of MSS/TM HDT via communications satellite — per scene	790	885	1200	1600
Delivery of standard MSS/TM imagery (not color composite) — per scene	880	985	1460	1995
Delivery of MSS/TM CCT or HDT — per scene	1000	1120	4000	5200
Surcharge for color composite* generation for customer ordering acquisition — per scene	150	170	250	275
Surcharge for specified maximum cloud cover — per scene	250	275	250	275

*Color sequence is blue, green, red.

PECORA AWARD WINNER NAMED

In ceremonies held at the Pecora IX Symposium in Sioux Falls, South Dakota, October 3, the 1984 William T. Pecora Award went to a man who was one of the very earliest workers in satellite remote sensing.

Dr. Archibald B. Park, pictured below, is this year's recipient. He was cited for working closely with NASA, the Department of the Interior, and other agencies in developing the concepts and parameters of the original Landsat 1 mission. In particular, the presence of the multispectral scanner (MSS) on the Landsat platforms can be directly attributed to his foresight. This technology would have been delayed until a later mission had Dr. Park not been able to demonstrate that such a data acquisition system was needed and that the data could be processed to provide important resource and environmental information.

Archibald B. Park
Winner, 1984 Pecora Award

A former employee of the Department of Agriculture, NASA, and private industry, Dr. Park currently consults in the Washington, D.C., area.

Dr. Park's vision and leadership in the development of programs to use multispectral scanners and analyze the data digitally formed the basis for most of the successful applications from the Landsat program. He was able to apply his exceptional talents to the construction of concep-

tual and quantitative models of the biosphere, hydrosphere, and lithosphere, and to include in these models remote sensing data as a source of missing information or as a way of obtaining needed information more efficiently.

Many more achievements were listed in the award citation. We extend our warm congratulations to Dr. Park on this occasion and recognize that his contributions to the field have been exceptional and continuing.

The William T. Pecora Award is presented annually in recognition of outstanding contributions of individuals or groups toward the understanding of the Earth by means of remote sensing. Sponsored jointly by the National 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, Undersecretary, Department of the Interior. Dr. Pecora was a motivating force behind the establishment of Earth resource sensing from space in this country.

NEW PUBLICATIONS

The National Space Science Data Center has acquired a 16-mm motion picture entitled **The SIR-A Movie** which is available on loan to institutions as well as to individual requesters. Produced by the Jet Propulsion Laboratory, the 11-minute film begins with footage of the Space Shuttle launch and continues with examples of the imagery acquired during the 1982 Shuttle Imaging Radar-A (SIR-A) mission. The narrator is Dr. Charles Elachi, SIR-A Principal Investigator. The imagery shown includes the coast of southern California, villages and tectonic features in China, river patterns in Borneo, and buried drainage patterns in the Eyptian/Sudanese desert. To borrow this film, contact the National Space Science Data Center, Code 601.4, Goddard Space Flight Center, Greenbelt, MD 20771. Telephone: (301) 344-6695.

The **Proceedings of the VIIIth Canadian Symposium on Remote Sensing**, held last year from May 3-6 in Montreal, are now available from the Association Quebecoise de Teledetection, C.P. 10047, Ste-Foy, Quebec G1V 4C6, Canada. The theme of this symposium was the integration of remote sensing in resources management by removing discipline barriers and using multisource geographic information systems. Of the 82 papers presented in the proceedings, 58 deal with methods and applications relative to the new generation of satellites that include SPOT, Radarsat, and Landsats 4 and 5 with the thematic mapper. Papers are in either French or English depending on author preference. The price is $60.

The **U.K. National Remote Sensing Centre** has produced an introductory slide set showing examples of several types of remote sensing data that are available, listing their sources. The 18 slides, in color, are accompanied by a commentary in pamphlet form. Shown are images and information on color infrared aerial photography, Meteosat, GOES, Landsat, HCMM, Nimbus-5 and -7, SIR-A, Skylab, and Seasat. A comprehensive picture of what remote sensing can offer — using aircraft, spacecraft, and low-orbit shuttles — is thus presented. For information regarding the purchase of this slide set, please contact ERSAC Scientific Publications, Peel House, Ladywell, Livingstone, West Lothian EH54 6AG, Scotland, U.K. The price is £ 6.85.

The **Proceedings of the 9th William T. Pecora Symposium** are now available from the Institute of Electrical and Electronics Engineers (IEEE) Computer Society, one of the principal sponsors. The theme of this conference was "Spatial Information Technologies for Remote Sensing Today and Tomorrow." The 424-page volume presents 65 papers on an unusually broad variety of spatial data handling problems as seen from several points of view or disciplines. To order a copy, contact the IEEE Computer Society, P.O. Box 80452, Worldway Postal Center, Los Angeles, CA 90080; or the IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854. The price is $28 for IEEE members, $56 for nonmembers.

The **Proceedings of the Landsat 4 Scientific Characterization Early Results Symposium**, held February 22-24, 1983, at the NASA Goddard Space Flight Center, are now available. This multi-volume set of documentation reports the initial work that was in progress by the Landsat 4 principal investigators, especially in relation to early assessments of the TM sensor, being flown for the first time. A two-volume set of summaries, and the complete four-volume set of actual papers, are available through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. Telephone: (703) 487-4650.

A bibliographic periodical listing sources on remote sensing theory and applications is published quarterly by the University of New Mexico's Technology Application Center. Entitled **Remote Sensing of Natural Resources: A Quarterly Literature Review**, each issue of this publication contains a collection of remote sensing abstracts and citations in fields such as: geology, environmental quality, hydrology, vegetation, oceanography, regional planning and land use, data manipulation, instrumentation, and geographic information systems. Sample copies are available at $20 each. For further information contact the Technology Applications Center (TAC), University of New Mexico, Albuquerque, NM 87131. Telephone: (505) 277-3622.

A collection of interesting aerial and satellite pictures of the Earth has been published in the form of a calendar by International Mapping Unlimited, the U.S. map distribution agent for the World Bank. Entitled **Flying Camera 1985**, this publication provides a technical explanation (in several languages), complete with geographic data, next to each image. For further information, contact International Mapping Unlimited, 4343 39th Street, N.W., Washington, DC 20016.

The second edition of a rather useful book entitled **Eye in the Sky**, by Dorothy Harper, has recently been published by Multiscience Publications Limited in association with the Canadian government's Department of Energy, Mines and Resources. It describes in non-specialist's terms the principles of remote sensing, sensors and platforms used, data reception, image correction and enhancement, and uses of remote sensing information for cartography, ice reconnaissance, and resource management. Copies may be ordered from: Multiscience Publications Ltd., 1253 McGill College Street, Suite 175, Montreal, Quebec H3B 2Y5. The book is also available in French under the title "Terre, Mer, et Satellites."

SYMPOSIA

An **International Conference on Advanced Technology for Monitoring and Processing Global Environmental Information** will be held from May 29-31, 1985, in Washington, D.C. This conference was scheduled for August of this year in Boston, Mass., but those plans were cancelled. Sponsored by the North American Section of the Remote Sensing Society and the Center for Earth Resource Management Applications (CERMA), the meeting will focus on (1) space platforms for monitoring natural and energy resources, (2) techniques and procedures for gathering and processing remote sensing data, (3) and integration of remote sensing data with georeferenced data bases. Information regarding this meeting can be obtained by contacting Mr. Yale Shiffman, Center for Earth Resource Management Applications, P.O. Box 2787, Springfield, VA 22152. Telephone: (703) 644-9472. (Those wishing only to obtain the call for papers and registration literature are welcome to use a toll free number if calling from outside the Washington, D.C., area: (800) 424-2733, ext. 9002).

Remote Sensing for Exploration Geology will be the theme of an international symposium to be hosted by the Environmental Research Institute of Michigan (ERIM), April 1-4, 1985, in San Francisco, California. The meeting will feature an industry-oriented program including both conventional plenary sessions and poster presentations on such topics as: advanced sensors and sensor systems; commercial operation of satellite systems; data processing, analysis, and integration; engineering, logistics, and marine applications; image enhancement and feature extraction; photogeology and image interpretation; and a wide variety of discipline-specific remote sensing techniques and applications. Further information on either the technical program or registration details is available from Mr. Donald R. Morris-Jones, Remote Sensing Center, Environmental Research Institute of Michigan, P.O. Box 8618, Ann Arbor, MI 48107. Telephone: (313) 994-1200.

The **11th International Symposium on Machine Processing of Remotely Sensed Data**, sponsored by Purdue University's Laboratory for Applications of Remote Sensing (LARS), will take place in West Lafayette, Ind., June 25-27, 1985. Special emphasis will be given this year to quantifying global processes: models, sensor systems, and analytical methods. A call for papers has been issued with a deadline of December 14. Further information on all aspects of this meeting can be obtained from Douglas B. Morrison, Symposium Coordinator, Purdue University/LARS, 1291 Cumberland Ave., West Lafayette, IN 47906. Telephone: (317) 494-6305.

An **International Workshop on Hydrologic Applications of Space Technology** will be held August 18-24, 1985, in Cocoa Beach, Florida. Sponsored by the International Association of Hydrologic Sciences (IAHS) and the World Meteorological Organization (WMO), this meeting will emphasize both offered and invited papers related to the input of remote sensing and remote data transmission to hydrologic models and geographic information systems. Field trips to NASA's John F. Kennedy Space Center and other points of scientific interest will be part of the program. Information regarding this meeting can be obtained by contacting A. Ivan Johnson, President, IAHS International Committee on Remote Sensing and Data Transmission, 7474 Upham Court, Arvada, CO 80003.

The **1985 ASCM-ASP Fall Convention** will be held September 8-13,

Pecora X

The Tenth William T. Pecora Memorial Remote Sensing Symposium
August 20, 21, 22, 1985. Student Center, Colorado State University,
Fort Collins, Colorado

REMOTE SENSING IN FOREST AND RANGE RESOURCE MANAGEMENT

The Pecora Symposium will focus on research and development in remote sensing of forest and rangeland resources and related fields. The meeting will cover basic research as well as operational uses of sensor technology. Topics will include:

- INTEGRATED RESOURCE INVENTORY
- VEGETATION DAMAGE ASSESSMENT
- FIRE-FUELS MAPPING
- GLOBAL RESOURCE PERSPECTIVES
- LAND USE AND LAND COVER MAPPING
- MAPPING SOIL AND WATER RESOURCES
- CHANGE DETECTION AND MONITORING
- NEW AND EMERGING TECHNOLOGY

Technological and scientific developments will determine how effectively remote sensing will be used in forest and range resource management. The symposium goal is to bring together managers, technologists, and scientists from private, government, and university sectors to display, present, and discuss the most recent research and application developments.

CALL FOR PAPERS

Authors: Submit a summary (500 words or less) or full paper including author's name, address, and office and home telephone numbers before February 1, 1985, to Dr. Haas, Program Chairperson. Submit poster session summaries (250 words or less) to Richard Myhre, Poster Session Chairperson.

SPONSORED BY
Society of American Foresters
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American Society of Photogrammetry

IN COOPERATION WITH
United States Geological Survey
National Aeronautics and Space Administration

SCHEDULE

Abstracts due	Feb. 1, 1985
Notification of Acceptance	Mar. 15, 1985
Camera Ready Papers Due	July 20, 1985
Preregistration Deadline	Aug. 1, 1985
Symposium	Aug. 20-22, 1985
Proceedings Published	Oct. 15, 1985

Symposium Chairpersons:

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3825 East Mulberry
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Program Chairperson:
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SOCIETY OF AMERICAN FORESTERS 1900

Range Management

American Society of Photogrammetry

U.S. Department of the Interior Geological Survey

NASA
National Aeronautics and Space Administration

1985, in Indianapolis, Indiana. Sponsored jointly by the American Congress on Surveying and Mapping (ACSM) and the American Society of Photogrammetry (ASP), the theme of this meeting will be "Racing into Tomorrow." Topic areas include cartography, land surveys, data acquisition, digital processing and photogrammetric applications, control surveys, and other subjects. In conjunction with this symposium, the **Final Landsat Image Data Quality Analysis (LIDQA) Symposium** will take place at the same site. Hosted by NASA, this meeting will present current developments and/or accomplishments over the past two years with respect to the work that has been done by the Landsat 4 LIDQA investigators. A call for papers has been issued for the ACSM-ASP Symposium contributors with a deadline for proposals of February 1, 1985. Complete details on paper requirements, the technical programs, and registration procedures for both symposia can be obtained from: Dr. Paul Mausel, Dept. of Geography/Geology, Indiana State University, Terre Haute, IN 47809, telephone: (812) 232-6311; or Mr. Richard Lomax, 243 S. Sheldon Street, Charlotte, MI 48813, telephone: (517) 373-3237.

Envirosat "85" is the title of NOAA's 1985 environmental satellite conference, scheduled for September 10-13, 1985, in Washington, D.C. The conference theme is to be "25 years of service," with the sessions to focus on future environmental remote sensing programs, availability and sources of products and services, public and private sector interests, and trends in satellite environmental services. Further information regarding Envirosat "85" can be obtained by writing to the Program Committee, 2nd Envirosat Conference, NOAA/NESDIS, Code E/ER-2, Federal Building 4, Mail Stop D, Washington, D.C. 20233.

TRAINING IN REMOTE SENSING

Nov. 26-29
Synthetic Aperture Radar with Remote Sensing Applications (Washington, D.C.) Contact: Darold Aldridge, Continuing Engineering Education program, George Washington University, Washington, D.C. 20052. Telephone: (202) 676-8518.

Dec. 3-7
Spatial Data Analysis for Resource Assessment (Sioux Falls, S. Dak.) Open enrollment. Contact: Chief, Training and Assistance, Technique Development and Applications Branch, U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57198. Telephone: (605) 594-6114.

Dec. 3-7
Geographic Information Systems in Remote Sensing (Brookings, S.Dak.) Contact: Mary E. DeVries, Remote Sensing Institute, South Dakota State University, P.O. Box 507, Brookings, SD 57007. Telephone: (605) 688-4184.

Dec. 10-14
Digital Image Processing in Remote Sensing (Brookings, S. Dak.) Contact: Mary E. DeVries, Remote Sensing Institute, South Dakota State University, P.O. Box 507, Brookings, SD 57007. Telephone: (605) 688-4184.

January 21-25
Hydrology Remote Sensing and Information System Workshop (NSTL Station, Miss.) Contact: U.S. Geological Survey, National Mapping Division, Building 3101, NSTL, Mississippi 39529. Telephone: (601) 688-3541.

Feb. 11-15
Aerial Photography/Aerial Photo Interpretation (Moscow, Idaho) Contact: Dr. Joseph J. Ulliman, College of Forestry, Wildlife, and Range Sciences, University of Idaho, Moscow, ID 83843. Telephone (208) 885-7209.

Feb. 18-22
Thirteenth Alberta Remote Sensing Course (Edmonton, Alberta) Contact: Mr. Cal Bricker, Alberta Remote Sensing Center, 11th Floor, 9820-106 Street, Edmonton, Alberta 75K 2J6, Canada. Telephone (403) 427-7380.

March 25-29
Terrain Analysis: Interpretation of Aerial Photographs and Images (Sioux Falls, S. Dak.) Contact: Coordinator, Continuing Education Program, Harvard Graduate School of Design, Gund Hall, L-37, Harvard University, Cambridge, MA 02138. Telephone: (617) 495-2578. Workshop site: EROS Data Center, Sioux Falls, SD.

April 22-26
Spatial Data Analysis for Resource Assessment (Sioux Falls, S. Dak.) Open enrollment. Contact: Chief, Training and Assistance, Technique Development and Applications Branch, U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57198. Telephone: (605) 594-6114.

LANDSAT OPERATIONAL SUMMARY
SEPTEMBER 1984

ORBITAL CHARACTERISTICS	Landsat 4	Landsat 5
International Designation	1982-072A	1984-021A
Launch Date	16 July 1982	1 March 1984
Date Operations Began: MSS	20 July 1982	6 April 1984
TM	17 August 1982	6 April 1984
Days Operational (this period)	30	30
Orbit Angle	98.2257°	98.2386°
Average Altitude: kilometers	699.60	699.62
miles	434.66	434.66
Precession Rate	−0.264 minutes/month	−0.324 minutes/month
Orbit Nodal Period	98.88 minutes	98.88 minutes
Equatorial Crossing Time: descending	09:37 a.m. (local)	09:42 a.m. (local)
ascending	09:37 p.m. (local)	09:42 p.m. (local)
Last Orbit Adjust	26 July 1984	22 August 1984
Next Orbit Adjust	October 1984	November 1984
Hydrazine Remaining	472.00 lbs	496.17 lbs
SENSOR STATUS		
MSS	Operational	Operational
TM	Operational	Operational
DOMESTIC SCENES ACQUIRED		
MSS	239	2,428
TM	0	3,218
SPACECRAFT STATUS		
Attitude and Orbit:		
Modular Attitude Control System	Operational	Operational
Power Module	Operational	Operational
Communications and Data Handling:		
Communications and Data Handling	Operational	Operational
Narrow Band Tape Recorder No. 1	Marginal	Operational
Narrow Band Tape Recorder No. 2	Operational	Marginal
Signal Conditioning and Control Unit	Operational	Operational
Digital Processing Unit	Operational	Operational
Power and Thermal:		
Modular Power Subsystem	Operational	Operational
Power Distribution Unit	Operational	Operational
Solar Array Drive	Operational	Operational
Solar Panel 1	Operational	Operational
Solar Panel 2	Operational	Operational
Solar Panel 3	Failed	Operational
Solar Panel 4	Failed	Operational
Operational Solar Array Offset	−31 degrees	0 degrees
Transmitters:		
Unified S-band	Operational	Operational
S-band	Operational	Operational
X-band	Failed	Operational
Ku-band	Operational	Operational
Global Positioning System	Off	On (test)

GROUND STATUS AND CAPABILITIES	S-band	X-band	Command	Status
U.S.:				
NOAA Transportable Ground Station, Greenbelt, Maryland	X	X		Operational
NASA Ground Station, Goldstone, California	X		X	Operational
Other NASA Ground Stations			X	Operational
TDRSS (Ku-band), White Sands, New Mexico	X		X	Testing
International:				
Argentina, Mar del Plata	X			Operational
Australia, Alice Springs	X			Operational
Brazil, Cuiaba	X	X		Operational
Canada, Prince Albert	X	X		Operational
India, Hyderabad	X	X		Operational
Indonesia	X			Operational
Italy, Fucino	X	X		Operational
Japan, Tokyo	X	X		Operational
Spain, Maspalomas Island	X			Operational
South Africa, Johannesburg	X			Operational
Sweden, Kiruna	X	X		Operational
Thailand, Bangkok	X			Operational

REMARKS:

1. **Landsat 5:** Landsat 5 continues to support the full MSS and TM missions. No systematic changes were noted in the MSS instrument during this period. Minor changes were made in the radiometric calibration to correct for high radiance striping.
2. **Landsat 4:** Landsat 4 continues to support the current MSS mission. No systematic changes were noted in the MSS instrument during this period.

The Landsat Data Users NOTES is published quarterly in order to present information of interest to the user community regarding Landsat products, systems, and related remote sensing developments. There is no subscription charge; individuals and organizations wishing to receive the NOTES should contact: NOAA Landsat Customer Services, Mundt Federal Building, Sioux Falls, SD 57198, U.S.A., Telephone: (605) 594-6151, FTS: 784-7151.

Comments, corrections and queries of any kind may be directed to: Editor, Landsat Notes, Mundt Federal Building, Sioux Falls, SD 57198.

☆GOVERNMENT PRINTING OFFICE: 1981-564-078/9