Australian Landsat Station

DIVISION OF NATIONAL MAPPING
DEPARTMENT OF RESOURCES AND ENERGY

NEWSLETTER

FOR THE REMOTE SENSING INDUSTRY

CONTENTS

NEXT ISSUE

The next issue of this newsletter will be known as ACRES NEWS. Although we aim to publish biannually, the upgrade decision has generated a great deal of additional activity and made it impossible to achieve the required deadlines. We apologise for the delay but hope that you will find this issue worth waiting for. Organizations and individuals wishing to contribute to the next issue of this publication are invited to present their work in type-written form on A4 paper and ready for publication. Illustrations should be presented in camera-ready form with captions attached. We look forward to receiving your contribution soon !

A GOOD NEWS ISSUE

Government initiatives which have seen the start to implementation of recommendations contained in the Madigan Report - A Space Policy for Australia - constitute very good news indeed, especially where these concern remote sensing. The decision to upgrade the Australian Landsat Station (Now: The Australian Centre for Remote Sensing) for direct reception of Landsat TM and SPOT data ensures the continuation and further development of expertise in the application of remote sensing data in Australia. The successful launch of SPOT and the excellent performance of its operational systems further help make 1986 a vintage year for remote sensing.

COVER STORY

Seeing the Trees from Space

The data for this false colour image of the Wagga Wagga area was recorded by the French satellite SPOT from 835 km altitude, on 23 March 1986 only one month after launch. It was down linked over Europe for archiving at the SPOT Image processing facility in Toulouse (France). The data was recorded in the Multispectral mode with 20 m pixels in visible green, visible red and near-infrared, and was pre-processed by SPOT Image before dispatch to Australia. Further processing and contrast enhancement of this 20 km x 20 km sub-scene at the ALS through its Image Writing Service resulted in this spectacular 1:100 000 false colour image. The red colours correspond to healthy vegetation, green to red soils of fields ready for sowing, and blue indicates water, urban/industrial areas, roads and bare ground.

Throughout the image and particularly along the Murrumbidgee River individual trees can be seen as red dots. In the south-west quadrant, business and industrial areas (blue) of Wagga Wagga contrast sharply with the vegetated (red) urban areas, parks and sportsfields. Fairways and greens of the golf course can be seen as irregular red lines just west of the town. In the country, patterns of ploughing and drainage can be recognised, and individual paddocks, fields, dams and farm buildings can be identified and the status of crops can be assessed. The airport is clearly visible in the south-east corner. Digital and photographic data of this kind and at the resolution shown here are invaluable to resource managers in many disciplines. An example of 10 m resolution panchromatic data is shown elsewhere in this issue.

Produced by:
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Editor: John Bruyn

LATE NEWS

We have changed our name . . .

THE

AUSTRALIAN LANDSAT STATION

is now the . . .

AUSTRALIAN CENTRE FOR REMOTE SENSING

Following the Australian Government's decision to upgrade the Australian Landsat Station's facilities at Alice Springs and Canberra to be able to receive and process data from the new generation of remote sensing instruments, the ALS is to be renamed the "Australian Centre for Remote Sensing". The official acronym for the name will be "ACRES".

The new name more accurately reflects the expanded capabilities planned for the Centre and its role as the Commonwealth Government's principal facility and archive for Earth resources data from satellite remote sensing instruments.

Initial capabilities following upgrade, will allow for the reception, archiving and processing of data from high resolution instruments such as Landsat's Thematic Mapper, and from the French satellite SPOT with high resolution stereo imaging and quick revisit capabilities.

The Australian Centre for Remote Sensing is a Commonwealth Government remote sensing data dissemination and information service provided by the Department of Resources and Energy through the Division of National Mapping.

The name change takes effect as from 1 October 1986.

Advice of this change was received in the post editing phase of this newsletter. Any reference to the Australian Landsat Station or ALS should be read as the Australian Centre for Remote Sensing or ACRES. Subsequent issues of this newsletter will be known as "ACRES News".

ALS UPGRADE!!

The Australian Landsat Station will be upgraded to be able to receive and process data from the new generation of satellite remote sensing instruments, which includes Landsat's Thematic Mapper and the SPOT-HRV sensors.

The announcement was made by the Minister for Resources and Energy, the Hon. Senator Gareth Evans Q.C. on 19 August 1986. Senator Evans said that the Australian Government has agreed to the expenditure of $15 million over the next three years for the upgrading and replacement of equipment at the ALS receiving and processing facilities in Alice Springs and Canberra.

An amount of $1.5 million has been allocated in the 1986 - 1987 Federal Budget for the commencement of the project, which is expected to be completed towards the end of 1988. Reception and archiving of the new data should commence during the first quarter of 1988, with processed products becoming available about six months later.

Following the completion of the upgrade, the ALS will be able to provide the much sought after data from Landsat's Thematic Mapper and from the French satellite SPOT. The Thematic Mapper provides data over the same large area as the current Multi-Spectral Scanner (MSS), but at much higher resolution and a wider range of spectral channels, including a thermal channel. The SPOT sensors provide even greater spatial resolution, albeit over a smaller area, and through off-nadir viewing capability revisit periods of only a few days are possible. Another benefit of off-nadir viewing is that very high resolution stereo pairs can be acquired, for three dimensional viewing of land surfaces and for digital terrain modelling.

While the upgrade of the Australian Landsat Station facilities is in progress, the lower resolution MSS data will continue to be made available and every effort will be made to obtain new high resolution data from overseas sources, albeit in limited quantities.

The decision to proceed with the upgrade of the Australian Landsat Station in a time of severe economic restraint, is a clear indication that the Government recognises that continued access to satellite remote sensing data will significantly benefit all resource related industries and enable more extensive and cost-effective monitoring, management and development of our natural resources.

Geology and mineral exploration, with a long history of effective use of remote sensing data from earlier resource satellites, will benefit greatly from the availability of data from the new generation of remote sensing instruments. The data will enable the detection of specific rock and mineral types and allow for more detailed and complex structural analysis in search of economic mineral and energy deposits.

In agriculture much benefit will be derived from the high resolution data by acquiring the ability to markedly improve crop yield predictions and by the early detection and diagnosis of stresses in crops caused by diseases, drought, rising water tables and land degradation. The new data will also help in the detection and monitoring of infestations by pests and noxious weeds. In rangeland management, the improved data will facilitate better management practices and help optimize the use of natural pasture through the monitoring of grazing pressures. The data will further facilitate more effective pasture improvement programs.

Environment monitoring and land use planning will be greatly assisted by being able to better discriminate between vegetation types, by finer terrain detail and by the ability to carry out moisture content analysis. Fuel load assessments in fire prone areas can help prevent disastrous bushfires through allowing early preventative measures to be taken. The ability to derive multi-level inventories of forest and rangeland resources will assist many government and private environment monitoring agencies.

Mapping applications, which have in the past been constrained by the high cost of conventional methods and the low resolution of earlier satellites, will derive much benefit from the finer detail and the availability of stereoscopic image pairs. The new data will lead to reductions in the time needed to complete the revision cycle for topographic maps and add to a greater completeness and accuracy of thematic maps for the Atlas of Australian Resources.

In narcotics investigation, the improved spectral and spatial resolution of the new satellite systems may contribute to the early detection fo cannabis crops, especially where these are grown in small quantities amongst other crops. Frequent observation of areas under suspicion at the time that illicit crops reach maturity is an important factor in interrupting the drug trade at the source.

Water resources management needs improved accuracy in land use and flood inundation mapping. The monitoring of flood water movement and levee performance at various stages of a flood will enable more effective development of flood mitigation schemes and water storage facilities. The detection and control of pollution of surface water and ground water will be greatly aided by the higher spectral and spatial resolution of the new data.

Marine applications of satellite image data will be significantly enhanced by the better resolution both above and under water in terms of the ongoing work in delineation of land/sea boundaries, charting and classification of reefs, shallow water mapping, sedimentation, and ocean current mapping. The added ability to measure sea surface temperatures and the detection of chlorophyll concentrations, both indicative of fish habitation, should be of great assistance to the fishing industry.

In addition, the upgrade of the Australian Landsat Station will also provide indirect high-technology benefits, by underpinning the continued development of Australia's remote sensing expertise, thereby contributing to marketing of analysis and interpretation systems and skills overseas.

SPOT DATA DISTRIBUTION IN AUSTRALIA

Following the successful launch of the French commercial remote sensing satellite SPOT on 22 February 1986 and the completion of the in-orbit check out and calibration phase, the Division of National Mapping (NATMAP) is negotiating with SPOT Image (the French marketing organisation for SPOT data), for the ALS to become a distributor of SPOT products. Upon the successful completion of the negotiations, it is expected that SPOT products will be available through the existing ALS distribution network. In the interim, the ALS has an informal arrangement whereby SPOT products can be ordered through the station.

The NATMAP license will entitle the ALS to purchase, reproduce, generate and sell SPOT products to the Australian user community on a non-discriminatory basis. However, SPOT products, derivatives and value added products are subject to very strict copyright conditions, protecting the commercial interests of SPOT Image and the French space agency, CNES.

In its role as the national distributor for SPOT products, the ALS will be building up a national archive of digital and photographic masters of SPOT data to facilitate the rapid turn-around of orders the Australian user community is accustomed to from the ALS.

First acquisitions of images however, will be subject to turn-around times that apply at the SPOT Image processing facility in Toulouse in France, or other overseas ground stations if applicable. Although no figures on delivery times can at this point in time be quoted, an initial peak demand for SPOT data may result in some delays. Customers are therefore advised to place their orders well in advance of the date of requirement. Details on the SPOT system and product range are given in the Features section of this newsletter.

For the selection of images, SPOT Image operates a fully computerised catalogue of all images that have been archived world wide. The catalogue is operated and updated continuously on a 24 hour basis. For each scene the following details are recorded: the catalogue and grid reference system identification numbers, acquisition date, spectral mode, viewing configuration, viewing angle, image quality, cloud cover percentage, and the level of processing. In order to be able to provide the best possible service to its customers, the ALS has established direct access to this data base from the Belconnen facility.

If a required image is not available from archive base, or a customer wishes to acquire imagery on a specific date, a request to program the satellite can be made. No extra cost is (at present) involved in making a programming request. However, the customer making the request is obliged to purchase the ordered product, following successful acquisition of the data. The ALS has established an electronic communication link with SPOT Image to facilitate quick and easy service. ALS user services staff will be happy to discuss and assist in making your SPOT programming request.

ELEVENTH DESIGNATED REFERENCE CENTRE

The School of Applied Science at the Canberra College of Advanced Education (CCAE) has become the eleventh institution to be formally recognised as a designated Reference Centre of the Australian Landsat Station. The close proximity of the CCAE to the ALS, the Division of National Mapping and the Australian Survey Office in Belconnen as well as to A.C.T. offices of other government and private users, offers an opportunity for effective co-operation in the area of remote sensing applications. The School has particular strength in techniques for natural resource management and has offered courses in Earth and environmental sciences since 1970, including the use of remote sensing data. Specialist remote sensing courses will be offered at post graduate level in the near future.

Enquiries should be directed in the first instance to Dr Brian Button, Dr Peter Morgan or Mr Eric Best of the Resource Science Division, School of Applied Science, Canberra C.A.E., PO Box 1, Belconnen 2616. Phone (062) 52 2565.

US/AUSTRALIA JOINT SCANNER PROJECT

As a result of the high standing of Remote Sensing in Australia, a unique invitation was received from the National Aeronautics and Space Administration (NASA) and the Jet Propulsion Laboratory (JPL) to participate in a joint research project here in Australia.

Following the acceptance of this offer by a group of participants involving both private enterprise and government agencies (Table 1), the NASA C-130 Hercules aircraft, believed to be the most sophisticated airborne remote sensing facility in existence, arrived in Australia in October 1985.

During its 30 day presence a total of 74 hours and 24 minutes of data was collected over 54 test sites scattered throughout mainland Australia (Fig 1). The outstanding success of the acquisition phase of the two year research project is largely due to the excellent organisation by Dr. Jon F. Huntington and co-workers at CSIRO's Division of Mineral Physics, the excellence and professionalism of the NASA C-130 crew and the fine weather conditions that prevailed over most of the test sites at the time of deployment. These three factors resulted in more data having been collected over Australia than over any other country in the world.

The Joint Scanner Project data will aid research on a diverse range of topics which include geological investigation and the detection of mineral deposits, agricultural applications, forestry, vegetation mapping, wetland and rangeland mapping, conservation, soil salinity and degradation processes, and groundwater hydrology.

LIST OF AGENCIES

Australian Landsat Station
Australian Survey Office
BHP Exploration Pty Ltd
BMR
BP Minerals Australia
BP Petroleum
CRA Exploration Pty Ltd
CSIRO Division of Mineral Physics and Mineralogy
CSIRO Division of Groundwater Research (With CSIRO Maths & Stats, CSIRO Minerals & Geochemistry & WA Department of Lands)
CSIRO Division of Water and Land Resources
Defence Research Centre, Salisbury
ESSO Minerals
NASA/JPL
NERC
NSW Soil Conservation Commission
Placer Pacific Pty Ltd
Qld Department of Mapping and Surveying (With Qld Department of Water Resources)
SA Centre for Remote Sensing
Sumitomo Metal Mining Co Ltd
University of NSW, Centre for Remote Sensing
Western Mining Corporation

Table 1

The Sensors

The sensor package included the NS001 Thematic Mapper Simulator, the Airborne Imaging Spectrometer (AIS), the Thermal Infrared Multispectral Scanner (TIMS) and two aerial cameras, a Zeiss 15/23 with a 153 mm lens and the AIS Nikon 35 mm tracking camera, used for location identification and tracking respectively.

NS001 Thematic Mapper Simulator

The NS001 is a remote sensing instrument with detectors in spectral bands similar to those of Landsat's Thematic Mapper, but with the addition of a 1.2 μm short wave infrared band useful for vegetation discrimination and plant moisture studies. The pixel sizes range from 2.5 m - 25 m and the swath widths from approx. 1.4 km - 14 km at altitudes ranging from 1 km - 10 km respectively. Like the Thematic Mapper, the NS001 uses a scanning mirror to sweep across its 100 degrees field of view and it can do this at variable speeds ranging from 10 - 100 scans per second. The 8 bit data provides for 256 quantization levels in the spectral bands shown in Table 2.

Airborne Imaging Spectrometer (AIS)

The AIS is designed to operate at an altitude of 3 km at which the pixel size is nearly 6 m and the swath width 183 m. It covers a spectral range of 1.2 μm - 2.4 μm (see Fig 2) at a sampling interval of 9.6 nm over 128 spectral channels, which are adjustable over a window of wavelengths. The average data rate of this instrument is 400 kilo-bits per second. With the AIS it is possible to obtain spectral reflectance curves (Fig 3) over a given area and detect the presence of a range of minerals, provided these are present at the surface. Stresses induced in some species of vegetation through the presence of particular minerals (e.g. sulfides) may also be observed as shifts occurring in the absorbtion spectra for those species.

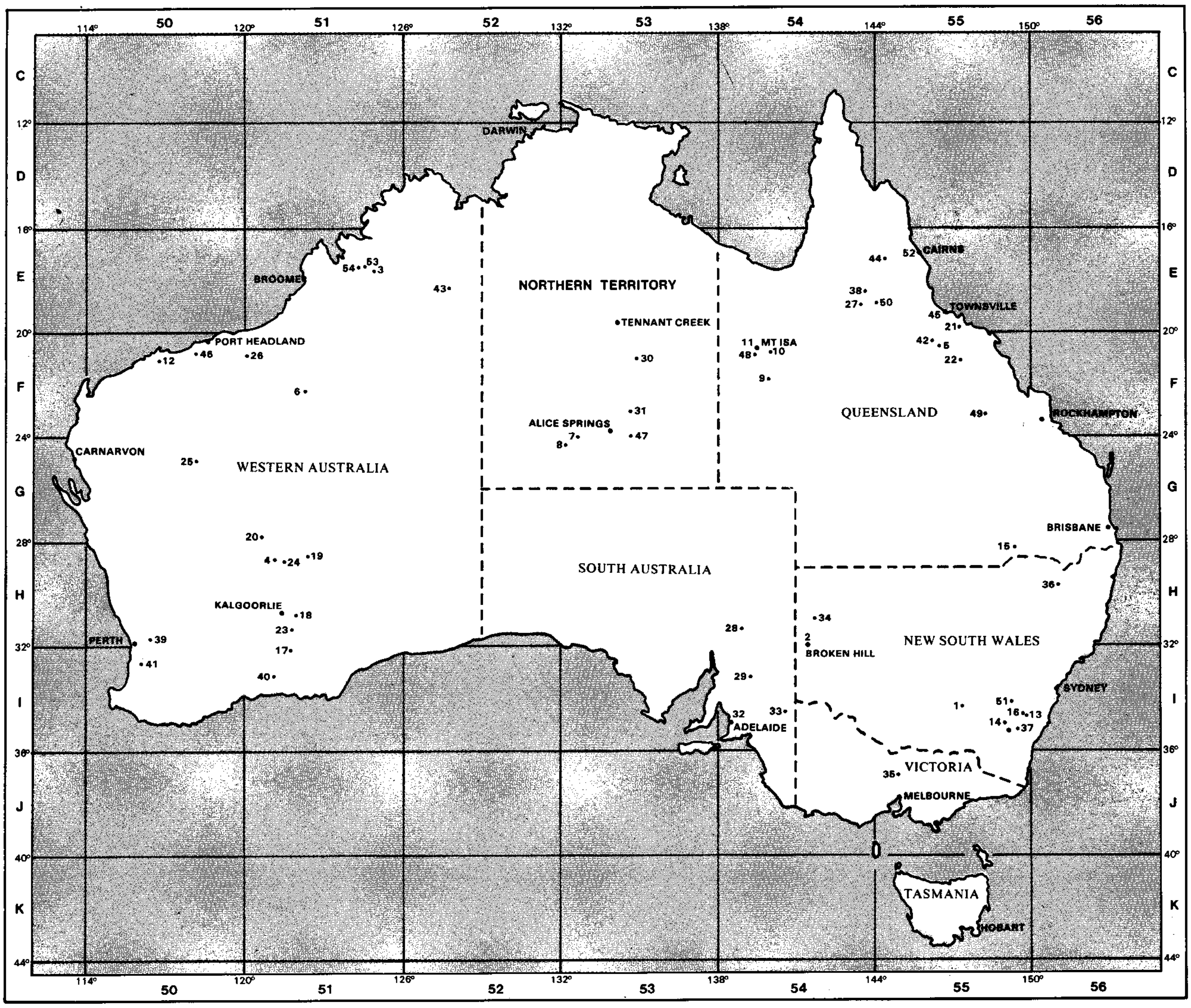

Figure 1 Australian Test Sites

TEST SITES

1 Temora, NSW
2 Broken Hill, NSW
3 Ellendale, WA
4 Leonora, WA
5 Plateau, QLD
6 Broadhurst Range, WA
7 Palm Valley, NT
8 Stairway, NT
9 Phosphate Hill, QLD
10 Mary Kathleen, QLD
11 Mount Isa, QLD
12 Munni Munni, WA
13 Goulburn, NSW
14 Dicks Creek, NSW/ACT
15 Wycanna, QLD
16 Yarralaw, NSW
17 Norseman, WA
18 Yindarlgooda, WA
19 Skull Creek, WA
20 Agnew, WA
21 Burdekin River, QLD
22 Bimurra, QLD
23 St. Ives, WA
24 Murrin Murrin, WA
25 Illawara, WA
26 Coppins Gap, WA
27 Bald Mountain, QLD
28 Wilka Willina, SA
29 Pine Creek, SA
30 Hatches Creek, NT
31 Mt. Riddock/Mordoor, NT
32 Adelaide/Barker, SA
33 Loxton, SA
34 Fowlers Gap, NSW
35 Puckapunyal, VIC
36 Inverell, NSW
37 Braidwood, NSW/ACT
38 Newcastle Range, QLD
39 Yalanbee, WA
40 Cascades, WA
41 Dwellingup, WA
42 Mt. Leyshon, QLD
43 Halls Creek, WA
44 Chillagoe, QLD
45 Townsville (1 & 2) QLD
46 Port Hedland, WA
47 Allambi/Amadeus, NT
48 Gorge Creek, QLD
49 Gregory Mine, QLD
50 Kidston, QLD
51 Junction Creek, NSW
52 Cairns – Green Island, QLD
53 Blina, WA
54 Sundown, WA

NS001 Spectral Characteristics

Band #	Detector	Bandwidth μm	NE∆P %	Region	Use
1	Si	0.45-0.52	0.5	Blue	Iron oxide absorption, some water penetration.
2	Si	0.52-0.60	0.5	Green	Veg. green peak.
3	Si	0.63-0.69	0.5	Red	Veg. chlorphyll absorption, red peak of iron.
4	Si	0.76-0.90	0.5	NIR	High IR plateau of veg.
5	Ge	1.00-1.30	1.0	SWIR	Veg. water stress.
6	Ge	1.55-1.75	1.0	SWIR	Peak for most rocks and soils.
7	InAs	2.08-2.35	2.0	SWIR	Clays, carbonates, micas.
8	HgCdTe	10.40-12.50	NE T= 0.25°K	TIR	Thermal IR.

Table 2 NS001 Spectral Characteristics.

The above bands are similar to those on the Landsat 5 Thematic Mapper with the addition of the 1.2 μm band useful for vegetation discrimination and plant moisture studies.

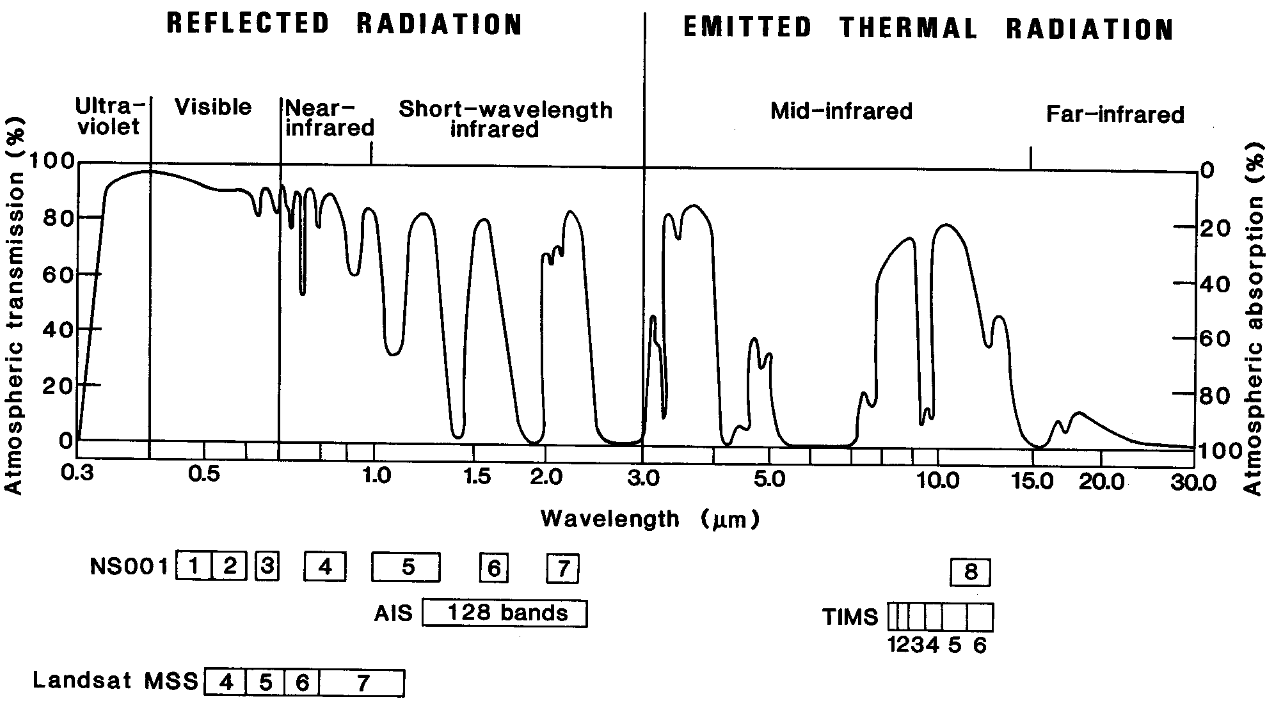

Figure 2 Atmospheric Transmission of Electrical Energy

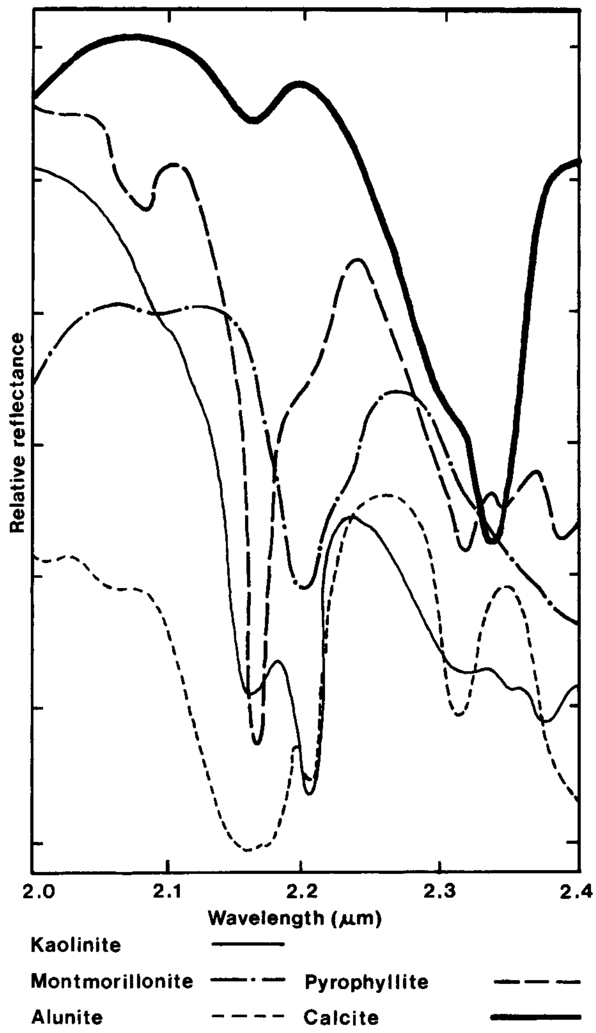

Figure 3 Spectral reflectance curves of several minerals (after 'Imaging Spectrometry: the next step in remote sensing', NASA/JPL Publication).

Thermal Infrared Multispectral Scanner (TIMS)

The spectral characteristics of the TIMS instrument are more aligned with the thermal bands of the Landsat TM and NOAA AVHRR instruments and measure the spectral emittance from the Earth's surface rather than the reflectance as is the case with the AIS. TIMS allows for the first time, the recording of these data in six discrete spectral bands (Fig 3), and makes it possible to differentiate from the air between several rock forming minerals, as well as rock types and weathering products based on their thermal characteristics. Over a field of view of nearly 80 degrees and an instantaneous field of view (IFOV) of 2.5 milliradians the instrument allows for the calibration of each band to within 0.3°C noise equivalent temperature. Because of its high sensitivity both thermally and spectrally the TIMS instrument is superior to earlier thermal scanners.

Data Processing and Analysis

This second phase of the Joint Scanner Project began in Australia with the arrival of the CCTs containing the data from the above instruments and the film products from the two cameras. The tapes are stored at the national archive for the project – the ALS, where some 170 CCTs were copied for safety back-up and off station storage. As part of the ALS contribution, further copies were made and selectively distributed to the participants according to their nominated test sites. As a further contribution, the ALS has also made available free of charge (on a limited basis) the ALS Image Writing Service, to enable participants to present their data as high quality photographic products.

Although, researchers will present their findings at a final meeting at the end of the two year research period in late 1987, CSIRO scientists at the Division of Mineral Physics have already analysed some of the AIS data and discovered that a vegetation filter, which was called for in the design of the system, was not in place at the time of the operation. The absence of this filter causes significant leakage of reflected energy of shorter wavelengths in the near infrared region into the mineral bands, and results in a degradation of the data in terrain containing considerable amounts of vegetation. NASA/JPL managers were unaware of this problem, encountered in the Mary Kathleen data, because previous testing had taken place in much less vegetated terrain in Nevada. Despite this problem however, sophisticated processing techniques employed by CSIRO scientists on the AIS data have shown that much of the information sought can be recovered in all but the severest cases of contamination.

The ALS/NATMAP participation in the Joint Scanner Project concerns the evaluation of the NS001 Thematic Mapper Simulator data. The area chosen is the same as the one selected for the evaluation of SPOT data under the PEPS proposal, the Gregory Mine area just west of Rockhampton in Queensland. The evaluation of the NS001 scanner allows the ALS to obtain processing experience on this type of data ahead of upgrade for the reception and processing of data from the new generation of remote sensing instruments, which includes Landsat's Thematic Mapper and SPOT's HRV. Choosing the same site for both investigations has the obvious advantage of enabling comparison of the quality of both data sets, as well as the quality of our own processing and image generation procedures following an upgrade.

AUSTRALIAN SCIENTISTS PROPOSE DEVELOPMENT OF IMAGING SPECTROMETER

The development of a high spectral resolution imaging spectrometer for Earth resources remote sensing was proposed to the Department of Industry, Technology and Commerce (DITAC) in December 1985. The proposal came from CSIRO's Division of Mineral Physics and Mineralogy in conjunction with the University of New South Wales and the Electronics Research Laboratory of Salisbury, South Australia. The proposal was made in response to the Mirrabooka announcement of opportunity by DITAC, which involved the placement of instrumentation on a Spartan satellite of NASA to be refurbished and enhanced in Australia.

The scientific objectives of the project are to test the capability of acquiring high resolution information from space on the short wave infrared (SWIR) spectra of materials at the Earth's surface in Australia, and to test the influence of atmospheric components on these spectra. The data will also permit the definition and development of processing techniques for both onboard and ground processing of data from the next generation of remote sensing satellites.

Technologically, the objectives of the project are to develop within Australian industry the techniques and skills for manufacturing precision components for future remote sensing instruments. In addition, a demonstrated ability of our industry to produce space qualified precision hardware would put it in a position to bid for and win overseas contracts.

JOINT USA/AUSTRALIAN WORKSHOP ON ARID LAND REMOTE SENSING

In October 1986 the US and Australian governments set up a bilateral exchange program for science and technology. The object of the agreement is to facilitate and foster the exchange of scientists between laboratories and/or the exchange of information and ideas on problems of mutual interest via the medium of seminars and workshops. Funding is provided by the National Science Foundation (US) and the Department of Science (Aust) to a small number of projects that are jointly prepared by US and Australian organizers. Scientific meetings and collaborative research of world class has resulted from this sparingly funded bilateral agreement.

A US/Australian workshop was held in Tucson, Arizona in June this year, as one such project funded under the agreement. The theme of the workshop was "Arid Land Remote Sensing" with an emphasis on the spectral characteristics of arid landscapes. There were a total of fifteen participants: six from Australia and nine from the USA. The Australian contingent consisted of two very experienced operational users of satellite data (H.J. Houghton, D.R. Barber) and four CSIRO applied researchers (N.A. Campbell, B.D. Foran, R.D. Greatz, R. Pech). The American contingent was more diverse but surprisingly contained no operational users from state or federal level.

The workshop ran for five days and included a day of field work. The combined opinion of the entire group was that it was an excellent meeting, successful in achieving all its objectives. From a purely parochial point of view it succeeded well beyond my hopes – the Australians presented very good papers in a spirited manner and we came away with the view that we have come a long way in the world of remote sensing of arid lands and are amongst the best. That is not to say that we had little to learn. Very thought provoking papers were presented by A.R. Huete (Arizona) and M.B. Satterwhite (Virginia), as well as a mind-boggling paper by Jim Tucker of NASA.

Very noticeable too, was how well integrated research groups and users are here in Australia and how advanced our applications were compared with the USA. There seemed to be no application success stories from the USA that were comparable to, say, the activities of the Remote Sensing Applications Centre in W.A. Henry Houghton laid them in the aisles with his presentations. It would seem that the USA – the home of remote sensing – has yet to sell and apply the data well to the rangelands in its own backyard. The site-limiting step appears not to be remote sensing, but rather the state of rangeland science and management in the USA.

The collected papers from the workshop are to be published as a special issue of Remote Sensing of Environment, the first issue of 1987. It should make interesting reading.

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REMOTE SENSING EDUCATION IN QUEENSLAND

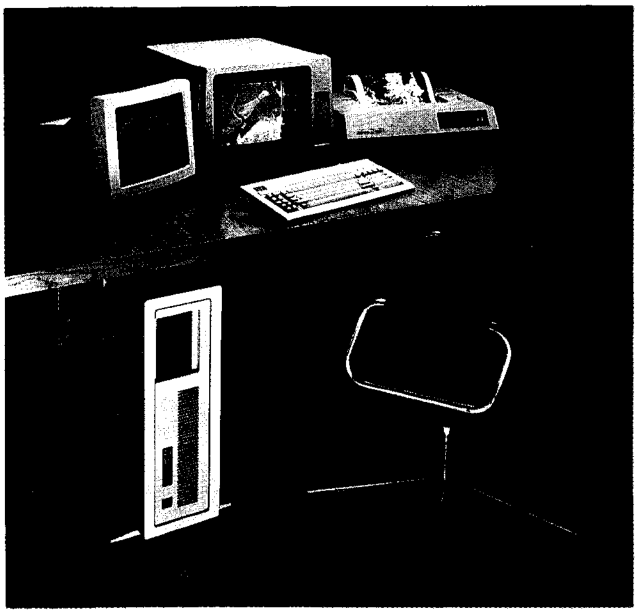
The Queensland Department of Mapping and Surveying in conjunction with the University of Queensland and the Queensland Institute of Technology have jointly formed a centre for surveying and mapping studies called "The Australian Key Centre For Land Information Studies". The Centre offers remote sensing and digital image processing courses for applications in geology, rangeland management, agriculture and shallow water mapping. As an institution of tertiary education, graduate courses and post graduate courses to PhD level, are offered drawing on local expertise and specialists from around Australia. It is anticipated that graduate courses will also be offered to external students in 1987. For hands-on image processing experience the centre relies on a number of IBM-ATs, running on CSIRO developed micro Brian software.

BRIAN BURSTS ONTO WORLD MARKET

Barrier Reef Image Analysis (BRIAN) software, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) has become available for worldwide application. Prior to release, the software was thoroughly tested during extensive reconnaisance of the 348 000 km^2 Great Barrier Reef (see ALS NL, Vol 3, No 4, November 1985). The BRIAN software used for this project is now available for use on micro processors as micro-BRIAN.

The original software was developed by Dr David Jupp and colleagues at CSIRO's Division of Water and Land Research and was subsequently adapted for use on IBM XT/AT hardware by the CSIRO team in conjunction with Micro Processor Applications Pty Ltd (MPA). The micro-BRIAN package resulting from these efforts is a powerful, yet inexpensive software package for the analysis of remote sensing data from space and airborne scanners, digitised photographic data, digital elevation data etc. and permits the integration of these data with other data sets. During the development specific care was taken to simplify the user interface for easy operation. The system is interactive and menu driven, while allowing the experienced user to bypass the menu structure and "help" facility.

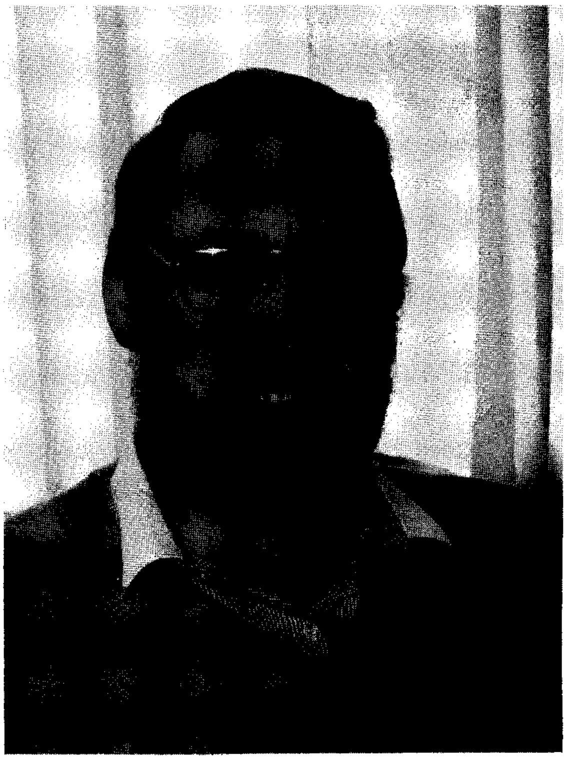
The many orders received by MPA for the software have come from both Australian and overseas users. Applications include shallow water mapping, agriculture, forestry, fisheries, geology, land management, environment monitoring, and education. Marketing in the US began at Siggraph in Dallas in August 1986 and MPA will be demonstrating the micro-BRIAN system at the World Congress on Remote Sensing, Beijing in November this year.



Micro Brian System

Micro Processor Applications Pty Ltd
101-107 Whitehorse Rd
Blackburn, Vic. 3130 Australia.

AUSTRALIAN ACADEMIC AWARDED FULBRIGHT FELLOWSHIP FOR REMOTE SENSING RESEARCH



Dr Brian Button

Dr Brian Button, Senior Lecturer in Applied Science at the Canberra College of Advanced Education has been awarded a Fulbright Post-Doctoral Fellowship by the Australian American Educational Foundation to undertake research on remote sensing applications in hydrology, water management and irrigated agriculture. Dr Button will be attached to the Geoscience Applications Office of the EROS Data Center at Sioux Falls in South Dakota (U.S.A.) for twelve months from August 1986. He will also visit a number of other major U.S. and Canadian institutions involved in the hydrological applications of remote sensing data.

Dr Button's investigations will focus on four main areas of application:

* mapping of floodplains and flood events.
* conducting regional inventories of water usage and storage conditions, particularly with reference to the use of on-farm irrigation storages.
* airborne techniques for irrigation scheduling with crop vigour assessment based on measurements of infrared reflectance,
* locating near surface aquifers and storage beds using microwave systems.

EOSAT POISED TO COME UP WITH NEW LANDSAT SYSTEM

EOSAT (Earth Observation Satellite Company), the commercial operator of the Landsat system since September 1985, is a consortium that was especially formed as a joint venture between the RCA Corporation and the Hughes Aircraft Company, for the purpose of operating the Landsat space and ground segments on a commercial basis. The organisation consists of the four team members.

* RCA - Astro-Electronics Division – Spacecraft
* Hughes - Santa Barbara Research Centre – Sensors
* Computer Sciences Corporation – Operations
* Earth Satellite Corporation – Marketing

EOSAT initially planned to provide data continuity with Landsat 6, a modified version of Landsat 5, which was to be launched during the first quarter of 1988. On 30 May 1986 however, EOSAT announced plans for a new generation platform called OMNISTAR to succeed Landsat 5. The spacecraft would be large enough to accommodate sensors other than those proposed for Landsat 6 and include a sensor with a wide field of view and moderate resolution, akin to the AVHRR aboard the NOAA TIROS-N series of weather satellites, or an Ocean Colour Imager.

RCA is reported to have spent nearly $20 million on the definition and development of OMNISTAR, and the spacecraft could be ready for launch in 1989 by either the Space Shuttle or Atlas rocket. Being a modular platform, it will require some in-orbit assembly and allow for repairs and refurbishment by mission specialists in Space Shuttle orbits, to give it a 20 year life expectancy. Over this period remote sensing instruments can be replaced as the technology or demand changes. The following information was extracted from a recent EOSAT brochure on Landsat missions planned for the next decade.

OMNISTAR

Landsat 6

The Landsat 6 payload is to consist of an Enhanced Thematic Mapper (ETM), generally identical to the one on Landsat 5 but with a new 15 m panchromatic band; a Multispectral-Scanner Emulator (EMSS) to provide 60 m resolution sub-sampled TM data instead of the current MSS data (see editor's comment in this article); and 2 tape recorders to acquire data over areas that are presently not covered by a ground station capable of receiving and processing either Landsat TM or MSS data.

Landsat 7

The design for Landsat 7 called for the same platform as Landsat 6, but in addition to the ETM and EMSS instruments, it will carry the totally new Multi-spectral Linear Array (MLA). This first pushbroom scanner for the Landsat series will eventually provide data in up to 32 spectral bands, of which eight can be recorded simultaneously in blocks of four. Initially however, for Landsat 7 the data will be from the visible and near infrared (VNIR) part of the spectrum and from the short wave infrared (SWIR) only. The system's design allows for acquisition of the data at 10/20 m (IFOV) resolution over a 41 km swath width, as well as for cross-track and stereo pointing. The data acquisition rate is up to 116 MBPS. The proposed launch date for Landsat 7 is the second quarter of 1989.

Landsats 8 & 9

The proposed designs for the Landsat instruments of the 1990s no longer include any of the earlier EMSS and ETM instruments, but focuses completely on MLAs. A new instrument, MLA-2 will replace the ETM to provide essentially the same data, but in addition, like MLA-1 it will have cross-track and stereo pointing capability over the full 185 km swath width. The data rate of MLA-2, at 70 MBPS, is slightly less than that of the current Thematic Mapper which transmits data at 85 MBPS.

The capacity of MLA-1 will reach its full potential when in the mid 1990s the full 32 channels will become available with new spectral bands in the middle infrared (MWIR) and in the thermal infrared (TIR) in addition to those in the VNIR and SWIR regions as proposed for Landsat 7. Other MLA-1 parameters remain unchanged.

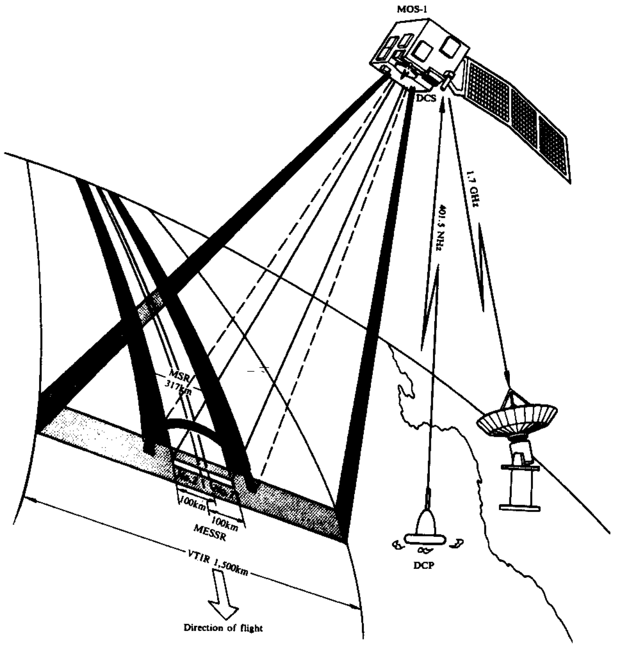
Editor's comment: The EMSS concept results from an early U.S. Government requirement that EOSAT shall fly 2 successive spacecraft with MSS type capability to follow on from Landsat 5. Many highly successful remote sensing programs using MSS data have been set up around the world since the launch of Landsat 1 in 1972 and are tuned to the 80 m resolution, the four spectral bands, and the 185 km x 185 km image area of the MSS instruments. Continuity of the supply of MSS-type data is therefore essential. However, MSS data can easily be provided through sub-sampling of the much higher resolution TM data by ground station operators. The chances for the EMSS ever to be flown in any of the future Landsat missions have always been doubtful and are subject to a decision by the U.S. Government.

The trend towards MLAs is a logical one, following the development of charge coupled devices (CCDs). Although the optics of the scanning instruments of Landsat are extremely good, the solid state CCD arrays do away with the need for the complexity of moving mirrors, and provide more simple data acquisition and processing. Advances in CCD technology in terms of size, sensitivity and band width definition further add to CCD arrays becoming the successors of the scanning mirror technology. Research currently under way with instruments like the Airborne Imaging Spectrometer (AIS) and the Thermal Infrared Multispectral Scanner (TIMS), as used in the US - Australia Joint Scanner Project (see article this issue), is currently providing information as to what channels should be selected for future MLAs.

MOS-1 SET FOR LAUNCH IN JANUARY 1987

Japan's first Earth remote sensing platform MOS-1 (Marine Observation Satellite) is an experimental satellite which was developed with the primary objective of giving Japan the fundamental technologies and experience in manufacture for its own marine and land observation systems. MOS-1 will be flying at an altitude of about 909 km in a sun-synchronous orbit with an equatorial crossing between 10:00 am and 11:00 am, and a repeat cycle of 17 days.

The MOS-1 spacecraft was developed by Japan's National Space Development Agency (NASDA) in association with Nippon Electric Company (NEC) and carries three remote sensing instruments with capabilities in the visible and near-infrared (VNIR), in the thermal-infrared (TIR), as well as in the micro-wave range of the electromagnetic spectrum. The VNIR bands of the instruments are almost identical to Landsat's Multi-Spectral Scanner (MSS) bands, while in the TIR two spectral bands cover Landsat's Thematic Mapper (TM) band 6. A third band in the TIR covers the 6.0 μm - 7.0 μm range, which is a special band to measure the water content of the stratosphere. The micro-wave bands are primarily intended to record



MOS-1 Observation Pattern

information on the atmospheric moisture content at or near the Earth's surface, including precipitation as water, snow and ice.

MOS-1 Instruments

MESSR (Multispectral Electronic Self Scanning Radiometer).

The MESSR is an optical pushbroom type scanner consisting of two identical camera systems, for Earth observation over two 100 km wide swaths on either side of the flight line, to provide an overall swath width of 185 km with an overlap of 15 km. With two optical units per camera system, each system is capable of viewing in four spectral bands of the VNIR part of the spectrum at 50 m (pixel) resolution. The optical units have two arrays of 2048 Charge Coupled Devices (CCDs) each, that are sensitive to data in two spectral bands of either the visible or the near infrared part of the spectrum. The four spectral bands of the MSSR are virtually identical to Landsat's Multispectral Scanner.

VTIR (Visible and Thermal Infrared Radiometer).

For this instrument a rotating scanning mirror is used to collect data over a 1500km wide swath across the ground track. The VTIR has one band in the visible part of the spectrum, covering both green and red (0.5 μm - 0.7 μm), and three bands in the TIR part of the spectrum (6.0 μm - 7.0 μm, 10.5 μm - 11.5 μm, 11.5 μm - 12.5 μm), of which the first is designed to measure the stratospheric moisture content, and the other two, which coincide with Landsat's TM band 6, are designed to measure Earth surface temperatures to an accuracy better than 0.5 K. The pixel sizes for this instrument vary from 0.9 km in the visible to 2.7 km in the TIR bands.

MSR (Micro-wave Scanning Radiometer).

Unlike the other two instruments, the MSR is a Dicke type radiometer and scans the earth in a conical pattern across the satellite's ground track over a swath width of 317 km. The operating frequencies are 23.8 GHz and 31.4 GHz. and with beam widths of 1.89° and 1.31° respectively. surface resolutions of 32 km and 23 km can be obtained. The dynamic range of the MSR is from 30 K to 300 K.

Operations & Data Distribution

The management and operational control of MOS-1, as well as data acquisition and processing, will be handled by NASDA at thes Tsukuba Space Center and thes Earth Observation Center. Processed data will be available, at a cost and on a non-discriminatory basis from Japan's Remote Sensing Technology Center (RESTEC). NASDA will also accept foreign requests for direct reception of MOS-1 data and plans to set up a verification and evaluation program with other organisations. Possible Australian participation is being discussed.

SUCCESSFUL NOAA-G LAUNCH

The (US) National Oceanic and Atmospheric Administration weather satellite NOAA-G was launched by Atlas E booster rocket from Vanderberg Air Force Base, California, on 17 September 1986 at 8:52 am. After successfully reaching its 820 km near polar orbit the spacecraft was renamed NOAA-10. All systems are reported to be operating normally and NOAA-10 is expected to replace NOAA-6 around the middle of October. Apart from the usual AVHRR imaging capability and the transmission of weather data, the new satellite will also be able to locate emergency radio beacons on Earth with its SARSAT (Search And Rescue Satellite Aided Tracking) system, a capability which was lost with the failing of NOAA-8 in late 1985.

SPOT PROGRAM MODIFIED

While SPOT-1 is returning a steady flow of image data from all over the world, following a highly successful launch and commissioning phase earlier this year, new decisions are being made concerning future spacecraft in Europe's Earth observation program. The life expectancy of SPOT-1 and its identical successor and back-up SPOT-2, is between two and three years. If SPOT-1 keeps on performing as well as it is at present, and no major problems are encountered during its design life, SPOT-2 will be launched either late 1988 or early 1989, and SPOT-3 needs to be ready for launch in 1991-92.

In June 1985 during a visit to the Paris International Air and Space Show, the French Minister for Research and Technology, Prof. Hubert Curien, announced the decision that two more spacecraft SPOT-3 and -4 will be succeeding SPOT-1 and -2. The follow-on spacecraft will carry a new generation of HRV Earth observation instruments in which the 10 m pixel size of the panchromatic mode would be replaced by providing this resolution on band 2 (visible red, 0.61 μm - 0.68 μm).

The provision of 10 m pixels in one band of the multispectral mode, will allow for products to be offered as mixed data sets without the need for recording the data in two separate modes and subsequent more complex image registration procedures. Band 2 will provide 10 m resolution with built-in geometric registration for all channels, including a new second short wave infrared band with 20 m resolution at wavelengths between 1.5 μm and 1.7 μm for vegetation interpretation.

In addition to the two HRVs, SPOT-3 and -4 will also carry a new wide field of view instrument with a swath width of around 2000 km. The resolution will be better than 1 km in each of four spectral bands, similar to those planned for the second generation HRVs. This wide view instrument will transmit directly to receiving stations around the world and together with on-board data storage it will permit daily global coverage.

The new generation spacecraft, however, is not expected to be ready for launch until the middle of 1991. If anything should go wrong with either SPOT-1 or SPOT-2, there would be no replacement ready to continue the service. In order to ensure the continuity of the operational service through the 1990s and to allow more time in the development schedule for the second generation of SPOT spacecraft, SPOT-3 has been ordered to be identical to SPOT-1 and -2.

It is hoped that approval will be given still to provide two second generation spacecraft. With the intended four year design life of the second generation spacecraft and the addition of SPOT-5, the SPOT missions could provide Earth observation data until the end of this century.

LANDSAT INTERPRETATION AT THE DIVISION OF NATIONAL MAPPING

Introduction

Since 1975 the Division of National Mapping (NATMAP) in Canberra has been using Landsat satellite imagery in a number of mapping applications, especially in land use and vegetation mapping, and revision of information on small scale topographic maps. Currently a major effort is being made to complete a map of Australia's present vegetation at 1:5 million scale for the *Atlas of Australian Resources* third series. Landsat imagery is a major source of information for this project and routine interpretation of imagery, supplemented by other information, is now proceeding.

Type of Imagery Used

Today, much effort is being directed to digital analysis of imagery from computer compatible tapes, but this technique is at present unsuited to routine thematic mapping on a national scale. The very large area of the Australian continent, combined with the wide range of environment types, renders impracticable digital tape analysis, where every scene is classified pixel by pixel and frequent ground truth calibration is required to preserve the reliability of classification. Visual interpretation of 1:1 million scale false-colour composite transparencies, in combination with other information such as maps and field survey data, has therefore been adopted by NATMAP as the fastest and most practical way to extract information from Landsat at the broad national scale required.

The false-colour composite transparency provides the highest density of data in one image, as it combines information about the land surface from three separate bands of the radiation spectrum. The experienced interpreter can either read this spectral information as it appears in a false-colour image, or mentally separate the contributions made to the colour by each band and make inferences about the land surface or land cover from the way it interacts with the different parts of the spectrum.

Interpretation

Interpretation is done by locating relevant landscape features in the images and recording them on a transparent overlay. To do this the interpreter needs to have not only a clear view over a whole image, or a large part of it, but also the facility to look closely at small details such as roads or individual paddocks, or to detect detailed information about the land surface to allow him to make inferences about land use, land cover, vegetation, etc. over wider areas. For example, within a grassland area the observation of man-made patterns or textures may be combined with more detailed information about the area from other sources to infer the existence of improved pastures.

Experience has shown that there is an optimum level of enlargement for each part of the interpretation process. An area of intensive cropland might best be recognised as such when there is just enough enlargement to render the pattern of paddocks clearly visible without introducing confusion by making individual pixels conspicuous. Extensive grazing land would require less enlargement, however, to bring out its characteristic pattern of fencelines and grazing effects while preserving the overview of the larger area within which they occur.

The smallest unit of information in Landsat MSS imagery, the pixel, represents an area of approximately 75 m x 50 m on the ground, and therefore measures approximately .075 mm x .05 mm at 1:1 million scale. Some magnification is required to fully appreciate detail at this level, but there is nothing to be gained by enlarging the imagery any further once the pixels become noticeable. A maximum magnification of about 20X is adequate.

Equipment

Visual interpretation of Landsat images is often carried out with minimal equipment since very little specialised optical apparatus is available for this application. Much equipment has been developed for working with aerial photographs, but it is usually designed for stereoscopic viewing of pairs of photographs and is therefore unsuitable for viewing Landsat MSS images, which have no stereoscopic capability.

There is a need therefore, for an instrument with a single light-path to a binocular head with a magnification range of about 1X to 20X, that provides an upright, laterally correct image. A wide field of view is essential, no less than about 10 cm diameter, and a zoom or similar magnification change facility is highly desirable.

To meet these requirements, the Division of National Mapping is using a Wild M420 Macroscope which has a zoom ratio of 1:5 which, with 5X/25 widefield eyepieces, gives a magnification range of 4X to 20X. An additional 0.3X objective lens is used when required to give a range of 1.2X to 6X, with a maximum field of view of 14.2 cm. A 0.5X objective lens is also available, and used on occasions, to give an intermediate magnification range and field of view. The macroscope is mounted on a large swinging-arm stand which allows it to be brought out over a light table with plenty of clearance to operate conveniently over large overlays or map-sheets.

Figure 1

Land cover/vegetation interpretation of Landsat 4, WRS 092-085 of 4 February 1984. The code classes used are: eM3Z - medium height eucalypt forest, with shrub understorey; eM3L - medium height eucalypt forest, with low tree understorey; eM3G - medium height eucalypt forest, with grass understorey; eM2G - medium height eucalypt woodland, with grass understorey; Ab - pine plantations.

Example

Some of the principles described above are illustrated in Fig. 1, a land cover/vegetation interpretation of Landsat MSS full scene WRS 092-085 of 4 February 1984, which is centred on the Rutherglen area of Victoria. A wide range of land cover types is shown, ranging from the very extensive native pastures west of Lake Urana in the north west corner of the scene, to the extremely dense pattern of improved pastures (and some crops) in the upper valleys of the Kiewa, Ovens and King Rivers of north eastern Victoria. The visible patterns and textures were first established by close examination of the image under relatively high magnification. The boundaries of the separate land cover types were then drawn at a lower magnification which allows the broad relationships between the different areas to be appreciated. Identification of crop and vegetation types was then assisted by reference to published information such as maps, statistics, etc.

Conclusion

Landsat imagery is currently used in the Division of National Mapping for thematic map compilation, and increasingly for revision of information on topographic maps.

The 1:1 million scale false-colour composite transparencies produced by the Australian Landsat Station, which are extensively used for this purpose, have a much higher information content than can be easily appreciated by the naked eye. Suitable optical equipment is needed to realise the full potential of the imagery. The requirements of equipment for this application of Landsat MSS images are:

(a) a magnification range of about unity to 20X without any significant degradation;
(b) zoom magnification change;
(c) a single light path to binocular eyepieces;
(d) adequate field of view and clearance for pencil work beneath the objective lens;
(e) optics of sufficiently high quality to allow long periods of use without operator fatigue;
(f) convenience of operation.

The M420 Macroscope was found to meet these requirements in all respects.

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INTERNATIONAL EARTH OBSERVING SYSTEM

A multi-disciplinary group of Earth and environmental scientists from the USA, Canada, Europe and Japan are working together on the design requirements for an international Earth Observing System (EOS). With this system, scientists will be able to monitor damage caused to the Earth's natural systems through human activity and through natural forces.

EOS will be operational during the 1990s and beyond and will monitor problems such as the increase in atmospheric carbon dioxide, the anticipated depletion of the ozone layer, El Nino related modifications to weather patterns, and acid precipitation. The EOS derived information will allow scientists to study our planet as an integrated system in which the Earth interacts through fundamental processes, such as the hydrological and biochemical cycles and climatic activities with the atmosphere, cryosphere, biosphere and hydrosphere.

Many of the Earth's natural systems involve both short and long term changes and persistent observations of these dynamic phenomena are needed to build data records stretching over a decade or more. Although current operational land and metereological satellite systems have provided over a decade of data crucial to research addressing environmental problems, and a series of discipline oriented missions are planned or under development, understanding of the global integrated functioning of the earth will require observation and analysis systems that go beyond those that have already been planned or commissioned.

During the 1990s a set of thirteen new measurement capabilities need to be placed in orbit as a series of synergistically related packages involving an automated data collection and location system for "in situ" measurements and three groups of remote sensing instruments in sun-synchronous orbits. Equatorial crossings of around 2:00 pm are preferred, as to coincide with maximum vegetation stresses through solar irradiation and heating, and to provide optimum contrast between day and night passes.

The automated data collection and location system (ADCLS) would service a global range of stationary and freely moving "in situ" monitoring instruments such as current meters and fluoro meters for oceanography, soil moisture detectors for hydrography, ice sheet monitors, and balloons for atmospheric measurements. Locations need to be determined twice daily at accuracies ranging from 1 km for buoys to 1 m for ice sheet packages.

The remote sensing instruments of EOS are arranged to be flown as three separate missions:

* Surface Imaging and Sounding Package (SISP)
* Sensing with Active Microwave (SAM)
* Atmospheric Physical And Chemical Monitors (APACM)

Surface Imaging and Sounding Package

The SISP instruments include both proven technology and instruments that are still in the engineering design phase. Simultaneous and coincident observations with these instruments during the 1990s is expected to considerably enhance their individual usefulness and power to address the problems that Earth scientists encounter today. The SISP imagers will measure both quasi-static and dynamic quantities at or near the Earth's surface through both systematic global and detailed local coverage. The integrated interpretation of these data is greatly facilitated if they are all acquired at the same time and from a common platform.

SISP Instruments

(1) Moderate Resolution Imaging Spectrometer (MODIS)

For meaningful information on land and marine biological systems data from the Coastal Zone Colour Scanner (CZCS) and the Advanced Very High Resolution Radiometer (AVHRR) has proved to be very useful in characterizing biological and physical processes. Repeat observations at spatial resolutions of 1 km pixels over land and 4 km pixels over ocean areas for both visible and infrared images has been appropriate to provide a comprehensive view of global biological activity and thermal states. In order to obtain quantitative data on surface conditions however, atmospheric effects masking these data need to be removed. An increase in spectral information may be of considerable use in defining these effects and correcting the information.

MODIS is envisaged to incorporate new technology that will permit images to be obtained selectively from a much wider and continuous range of spectral information at discrete intervals. The technology proposed for MODIS takes advantage of both the convential mirror scanning technology and arrays of Charge Coupled Devices (CCDs) as used by SPOT to acquire data from up to 64 spectral bands. The different needs for ocean and land monitoring, require MODIS to be implemented as two separate packages. It is expected that these packages will be capable of some on board processing and calibration, as well as automatic channel selection based on predetermined geographic models.

MODIS-T (tilt) will need up to 20° off-nadir viewing capability in the along track scanning direction to minimize specular reflectance from the ocean surface and to study other oceanic and atmospheric properties. The imaging spectrometer proposed for MODIS-T will have a spatial resolution of 1 km (IFOV) over a 1500 km swath width for twice daily coverage. While there is a minimum requirement of 17 spectral bands of 10 nm wide, the proposed optics and 64 x 64 CCD array provide for 64 perfectly registered contiguous spectral bands of 10 nm width in the 0.4 μm - 1.0 μm range.

MODIS-N (nadir) will be required to collect nadir viewing data in at least 35 spectral bands from visible to the thermal infrared range of the spectrum. The band widths will be tuned to the application and range from 10 μm - 20 μm in most of the surface applications to 500 μm for some of the thermal bands. Of the proposed 36 channel array half of the detectors need to be maintained at 300 K and the others at 80 K. Cross track scanning optics similar to those of MODIS-T will be used to collect data over a 1513 km wide swath in 12 channels at 500 m resolution and 24 channels at 1000 m resolution.

(2) High Resolution Imaging Spectrometer (HIRIS)

Whilst MODIS is to provide global coverage at a frequency of at least every two days, the need for a more detailed coverage for ecosystem characterization and specialised investigations will be satisfied through HIRIS. A spatial resolution of 30 m pixels over a 50 km swath is required to detect small changes in boundary conditions of different ecosystems and to study inland aquatic environments, agricultural practices, soil types and geological features. Spectrally there will be very little difference between the two systems and frequent revisits of the same site will be allowed for through an off-nadir viewing capability. In the management and monitoring of global ecosystems and natural resources, same day coverage over a wide spectral range make the MODIS/HIRIS combination a much more powerful tool than what they are individually.

(3) High-resolution Multifrequency Microwave Radiometer (HMMR)

Despite the wide range of applications for images of the visible and infrared part of the electromagnetic spectrum, persistent cloud cover in some areas severely limits the frequency of observations. Microwaves permit an all-weather viewing capability and are particularly useful in the assessment of other water related processes. Applications include sedimentation, ice characterization, assessment of snow properties, soil moisture and atmospheric conditions. The HMMR is to provide passive microwave observations with a global coverage of every two days, to complement the MODIS data. A resolution of 1 km - 2.5 km pixels at a frequency of 36.5 GHz is needed over a swath width of around 1500 km to satisfy the requirements.

(4) Lidar Atmospheric Sounder and Altimeter (LASA)

The prime LASA objectives are to measure both the horizontal and vertical distribution of water vapour through the atmosphere in order to gain an understanding of continental transport and weather systems variation on a large scale as part of the overall hydrological cycle. In addition the Lidar (Light detection and ranging), which will operate in the visible and near-infrared, will take measurements on the atmospheric distribution of temperatures, aerosols and thin clouds to accurately model phase functions for the correction of surface image data. The required vertical accuracy of 1 km can not be achieved with passive systems. With LASA, distance measurements may be performed over a wide baseline at the Earth's surface to provide centimetre scale accuracies for the measurement of continental drift and deformation.

Sensing with Active Microwave

The SAM instrument package is to consist of a group of synergistically related scientific active microwave systems. Most of these are currently in advanced states of development and need to be flown in a high inclination near-polar orbit. The mission is to meet a number of scientific objectives for global and local coverage of dynamic and quasi-static phenomena in geology, agriculture, forestry, land cover determination and monitoring, oceanography, and cryospheric sciences.

Although some phenomena measured by the SAM package will persist for times greater than 12 hours, others, such as the orientation of foliage and plant water status are on time scales in the order of hours. The complementary nature of the SAM package to the SISP instruments therefore requires SAM to be implemented in such a way, as to enable it to measure the same ground locations to within one hour of the SISP observations.

SAM Instruments

(1) Synthetic Aperture Radar (SAR)

SAR is the most demanding instrument of the SAM group in terms of complexity, cost, power, weight and data rate, and follows on from the SIR-A and SIR-B projects aboard the Space Shuttle. The instrument will be operated at dual frequencies in C and L bands, and possibly X band, with HH and VV polarization. Effective look angles will be from 15° - 20° (Low), 30° - 35° (Medium) and 55° - 65° (High). The resolution (4 looks) is 30 m over a 200 km swath width, and pixels can be located to accuracies of within 100 m. Near global coverage can be obtained and revisit times range from almost daily, for some ice and ocean applications, to less than ten days. SAR provides the microwave high resolution complement to the HMMR of SISP and the all weather complement to the HIRIS imager.

With SAR, many land and sea ice features may be located and identified to provide data on ice motion and deformation; ages and stress states of ice may be determined from the radar albedo. Outside the cryosphere, a range of oceanographic and atmospheric phenomena can be measured and interpreted. On land, the distribution of changes in the condition of vegetation may be assessed and characterised. Many geological features of textural and structural nature may be assessed, interpreted and mapped both at the surface and below, to a depth of up to 4 m in arid regions. In the surface hydrological environment SAR has proved to be particularly useful in the estimation of soil moisture content and area estimation of wetland and other ecosystems.

(2) Radar Altimeter (ALT) and Radar Scatterometer (SCAT)

Global modelling of the hydrological cycle requires both qualitative and quantitative information on climatic and oceanographic processes. ALT and SCAT are included in the SAM package to provide quantitative observations of ocean phenomena mapped by SAR. While ALT would measure the time dependent portion of ocean topography, SCAT would measure the vector component. In the cryosphere, ALT and SCAT would complement SAR (and MODIS) by providing information on the extent, type and motion of ice cover, and the surface state of sea ice. For the purpose of calibration of the SAM package, surface verification data on wind and ocean current speed/direction need to be collected in situ at key locations on a continuous basis.

The primary role of ALT and SCAT is to provide information on ocean circulation and surface wind, features that generally persist for periods greater than twelve hours. Simultaneous observation with other instruments is therefore not essential and deployment on other platforms is possible, provided that the same orbital parameters are adhered to. The SAM package can thus be implemented in either an integrated or distributed manner.

Atmospheric Physical and Chemical Monitor

As the name implies, the focus of the APACM is the physics and chemistry of the atmosphere, the most dynamic environment of our planet, with changes occurring over time scales ranging from seconds to decades. The observations of the 1990s will allow for a better understanding of the dynamics of various layers of the atmosphere, their interaction with the hydrosphere and lithosphere, and their role in the distribution and transport of chemical species, particulates, and thermal energy. One of the baseline requirements of EOS is the incorporation of data from existing operational and planned meteorological acquisition systems.

The APACM compliment will primarily provide upper atmospheric and tropospheric wind and chemical information. Although the troposphere and upper atmosphere are coupled, interaction time scales are sufficiently long to permit independent observation. Techniques for measurements in the upper atmosphere are currently being developed as part of the Upper Atmosphere Research Satellite (UARS) project.

APACM Instruments

(1) Doppler Lidar

Low concentrations of specific trace chemical species of the upper atmosphere, require the use of Doppler Lidar to measure their doppler shift in wavelength either passively or following illumination. Because the gases to be measured have individual spectral characteristics ranging from ultraviolet to microwave, a number of instruments operating in different spectral regions need to be deployed. For tropospheric observations, active sensing in vertical mode is required; upper atmospheric observations can be made passively through wide angle off-nadir viewing (limb viewing) of narrow altitude ranges. Global coverage needs to be obtained twice daily, with 2° latitude x 2° longitude resolution and a vertical resolution of 1 km.

(2) Upper Atmosphere Wind Interferometers

The monitoring of wind and temperature in the upper atmosphere from a space platform, can be done by measuring the doppler shift in the absorbtion and emission spectra of certain atmospheric molecules and atoms. The prime spectral features measured at low altitudes result from the absorbtion and scattering of light by molecular oxygen and water vapour. At higher altitudes it is the emitted light from oxygen molecules, -atoms and -ions that can be used to discern wind and temperature. For passive monitoring accurate to a few metres per second, a multiple-etalon Fabry-Perot interferometer is proposed. High spatial resolution of upper atmospheric wind and temperature phenomena may be obtained with a wide angle Michelson array interferometer. Global coverage is required daily at spatial resolutions of 3 km vertical and 2° latitude x 2° longitude.

(3) Upper Atmosphere Composition Monitors

Determinations of the chemical composition of the upper atmosphere involve remote sensing in wavelengths ranging from ultraviolet and the visible part of the spectrum, through to the microwave range. Limb viewing is generally the most effective method because of the black background and the possibility of high vertical resolution. The range considered here is from the tropopause to an altitude of 120 km; global day and night coverage is required daily.

Observations in the ultraviolet and visible wavelengths are primarily to determine the presence of certain atoms and metastable constituents through their emission spectra. Proposed are a set of two-dimensional array spectrometers capable of both nadir viewing and limb scanning. One direction of the arrays would be used to provide the spatial resolution and the other to provide the spectral dispersion. The information could provide global maps of stratospheric ozone, total column content of H_2O, NO_2, O_2, and other minor gases, thermospheric densities of O, N, H, N_2, O_2, NO, and a series of metastable species abundant in upper atmospheric regions.

Monitoring the upper atmosphere in the infrared spectrum over the 2.5 μm - 16 μm range is for quantitative assessments of a wide range of gases, and requires a highly sensitive multi-channel interferometer spectrometer with temperature control of detectors and optics to well bellow 100° K. While the range of observations should be from 15 km - 120 km altitude at 500 km spacing, the vertical resolution required is about 2- 3 km. The gases that could be monitored this way include O_3, H_2O, HNO_3, NO_2, CH_4, N_2O, NO, CO, $CFCl_3$, CF_2Cl_2, HCl, and possibly $ClNO_3$.

The technology for monitoring in the submillimetre range is not as advanced as for infrared observations. Detectors and optics need to be cooled to about 3° K and active scan periods need to be in the order of several seconds.

For observations in the microwave spectrum the Microwave Limb Sounder of UARS (Upper Atmosphere Research Satellite) with 15 variable width channels could be deployed. With this instrument kinetic temperatures and N_2O, H_2O_2, and O_3 can be measured down to 90 km.

(4) Tropospheric Wind Sounding

Due to the high spectral resolving power required to monitor tropospheric winds, a specialised dedicated doppler lidar is needed. The spatial resolution of this instrument will be in the order of 1 km in altitude and about 2° in latitude and longitude, possibly with the option of higher resolution over selected targets. Although a trade-off can be made between velocity accuracy and spatial resolution, the anticipated accuracy is in the order of 1 m per second throughout the troposphere. Global coverage will be required from the surface to 100 mb.

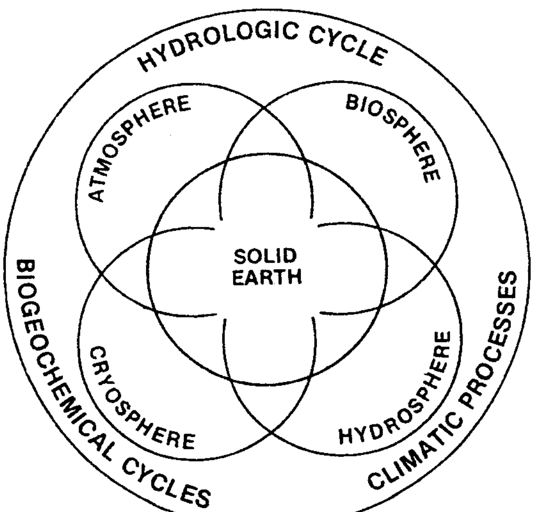
(5) Tropospheric Composition Monitors

Monitoring of chemical species in the troposphere may be done from space or at the Earth's surface. In the latter case, few ground based observations of substances with significant spatial variation is often inadequate to determine the global distribution. Passive monitoring from space using a correlation radiometer can provide information on the total column content of CO, NH_3 and perhaps other species. Active monitoring with nadir viewing lidar using differential absorbtion or resonance fluorescence may provide vertical profiles of OH, O_3, NH_3, NO_2, HNO_3, H_2S, SO_2, CH_4, CH_4, CH_3Hg, and Hg. Global coverage needs to be obtained daily.

(6) Energy Input Monitors

The primary sources driving the major atmospheric currents are of solar and magnetospheric origin. Included in the Earth Observation System should be a series of instruments to measure the solar emissions from 150 nm - 400 nm at 1 nm resolution, total solar irradiance, Earth radiation budget, and magnetospheric electric fields, currents and input of particles into the atmosphere. Sampling should be at least twice daily for solar observations to almost continuous for others.

The foregoing information reflects recommendations and was compiled from, the NASA Science and Mission Requirements Working Group Report (TM86129) dated August 1984 and EOS Report of the MODIS Instrument Panel – Volume IIb (in press). During his September 1986 visit to Australia, Dixon M. Butler, the Chairman of the working group reported on the current state of development of the EOS program.



SPOT – A NEW GENERATION IN REMOTE SENSING

With the successful launch of SPOT by the 16th European Ariane rocket from Kourou in French Guiana on 22 February 1986, a new era in remote sensing by satellite began. The French designed spacecraft, weighing almost 2 tonnes, was placed in Earth orbit at an altitude of close to 830 km. Within five days most of the spacecraft's systems were checked out and reported to be functioning as expected. The first images received and processed at the Toulouse ground station were said to be "simply beautiful".

SPOT was conceived and designed by the Centre National d'Etudes Spatiale (CNES) of France, and was built by French industry in association with the European partners Belgium and Sweden. Although the original meaning of the acronym SPOT was Systeme Probatoire d'Observation de la Terre, the successful entering of the data acquisition phase led to renaming SPOT "Satellite Pour l'Observation de la Terre".

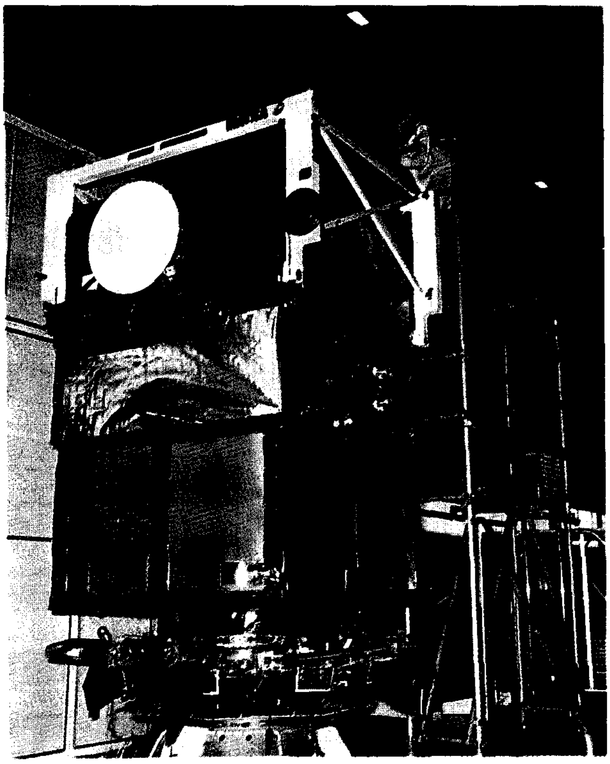
The design of the two HRV (High Resolution Visible) remote sensing instruments aboard SPOT is tuned to the high density of Earth surface features that prevail through much of Europe. It further reduces the gap in spatial resolution that had existed between aerial photography and routine remote sensing from space for more than a decade. In addition, the off-nadir viewing capability of the HRV instruments allows for 3

SPOT Image of Adelaide

dimensional imaging of the Earth's surface and a re-visit capability of only 2-3 days.

Does this imply that the arrival of SPOT means competition for the current Landsats? Certainly not! The French have cleverly designed SPOT to occupy a niche of its own. Instead of competing with other satellite systems, SPOT complements these by providing a whole new data set, that brings with it a new range of applications in the solving of problems that face resource managers today.

SPOT, like most other spaceborne remote sensing systems, allows for the acquisition of the data at a cost far less than is possible by conventional methods. Particularly in countries such as Australia, where the density of surface features is generally significantly less than in Europe, scientists could stand to gain more from SPOT, than the Europeans themselves, and pioneer new methods and new applications of the data from this exciting new generation spacecraft.



SPOT under Construction

The Satellite

The SPOT satellite had a weight at launch of 1959 kg, which included 150 kg of propellant for orbit adjustments during its 3 year design life. The spacecraft consists of two parts, the SPOT "bus", a standard multi purpose platform, and the payload. The bus subsystems perform essential functions such as orbit control, stabilization of the platform, a 1300 Watt power supply, housekeeping telemetry, and the monitoring and programming of the payload through an on-board computer. The payload itself consists of 2 HRV instruments for Earth observation, 2 magnetic-tape data recorders, and a data transmitter.

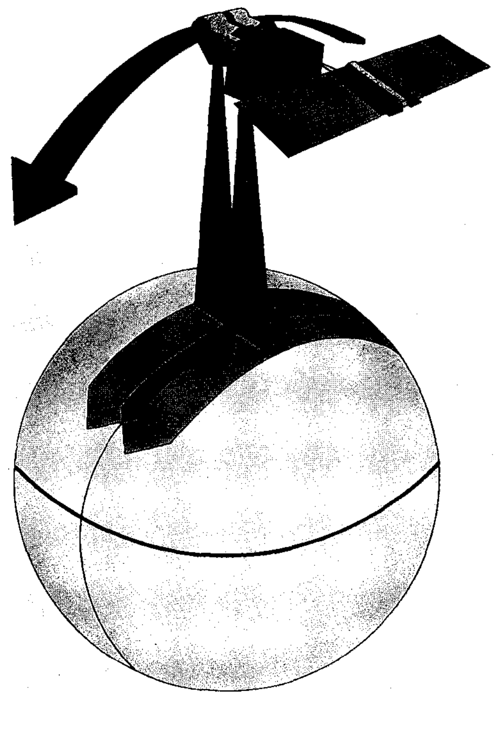
The recorders allow for a limited number of images to be collected over areas where receiving facilities are not yet in place, and for downloading of these data at receiving facilities that are especially equipped to handle the additional load. The Landsat experience shows that substantial delays in getting the images to the end user and other limiting factors are inherent in this method of operation; they were in fact some of the significant reasons for establishing the Australian Landsat Station.

The Orbit

The 830 km orbital altitude and the 99° inclination of the orbit to the Earth's equatorial plane were chosen to allow SPOT to pass over the same image area at the same local time, each overpass. Its sun-synchronous orbit further allows for all images of the same latitude also to be taken at the same local (solar) time. The daytime crossing of the equator for instance is at about 10.30 a.m. for every ground track, even though these tracks are separated by 108.6 km, and successive overpasses are 2823 km (26 tracks) apart. The synchronization of the satellite's motion with the daily rotation of the Earth is such, that successive passes over the same ground track occur every 26 days and adjacent tracks are covered 5 days apart.

The HRV Instruments

There are two identical HRV imaging instruments aboard SPOT, which can operate in either of two modes, a multispectral mode with 3 spectral bands (visible green, visible red, near-infrared) similar to Landsat's MSS bands 4,5,6, and a panchromatic (black and white) mode, which is sensitive over the green and red range of wavelengths.

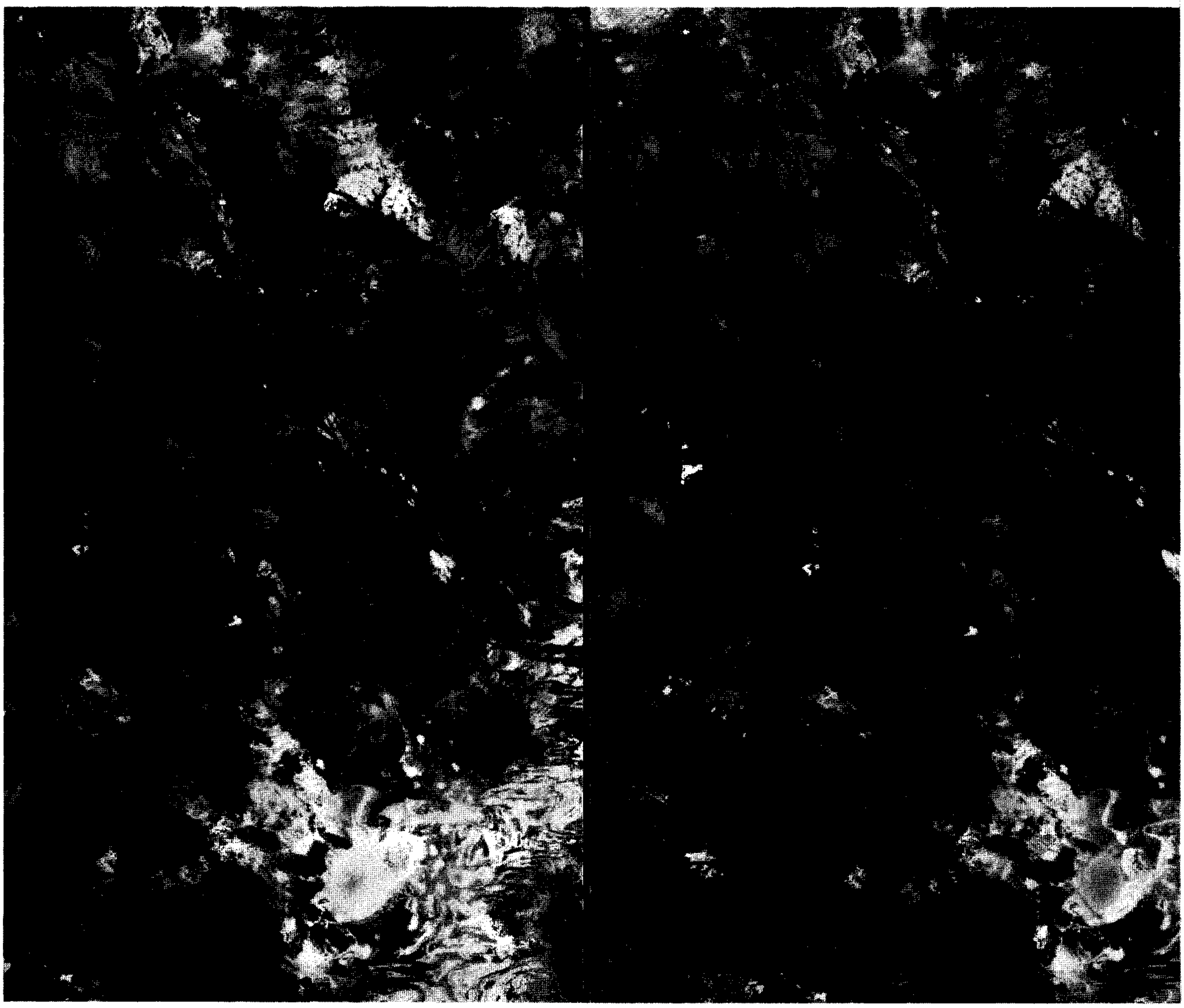


Scanning of the Earth's surface is done through projecting the reflected light onto a linear array of 6000 photo sensitive charge coupled devices (CCDs), to sample complete image lines across the ground track in one look. Scanners of this kind are commonly referred to as "pushbroom scanners", and do not need any moving parts. They contrast sharply with the earlier instruments of Landsat and NOAA, which use oscillating scanning mirrors.

The two HRV instruments are arranged side by side along the direction of flight and can be pointed to image on either side of the ground track. In the nadir viewing "twinning mode", the ground surface can be imaged along 60 km wide strips, that overlap by 3 km to provide a total field of view (FOV) of 117 km. Multispectral viewing of the HRVs is slightly ahead of the spacecraft and panchromatic viewing slightly aft. The offset for the two modes is approximately 15 km on the ground. As a consequence, a small westward offset occurs in the imagery due to the Earth's rotation during the time it takes the spacecraft to advance the 15 km. Users of these data are therefore warned that **images of differing imaging modes obtained simultaneously over the same viewing area do not register unless special processing is requested.**

Off-nadir Viewing

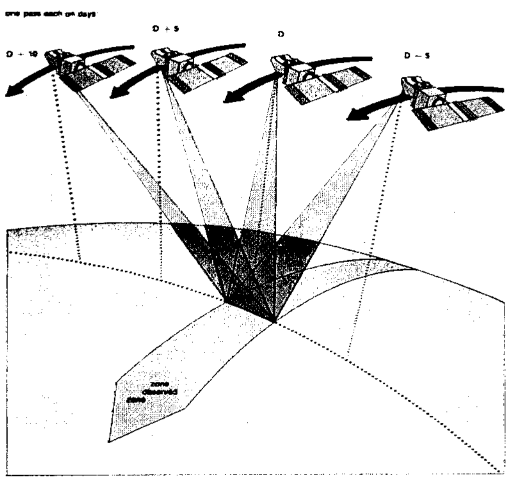
The only moving part of an HRV is a ground controlled steerable mirror, which allows the instrument to look sideways (off-nadir) at angles of up to 27° in 45 steps of 0.6°. The advantage of this mirror is that it allows for images of the same area to be taken at



A SPOT stereo pair taken in the panchromatic mode at 10 m resolution of an area just north of Kalgoorlie (WA), (30°27'S, 121° 12'E). The image on the left was recorded with a 22° view angle on 4 August 1986; the one on the right was taken 17 days later, on 21 August 1986 with a 24° view angle. © CNES—SPOT Image.

opposing view angles, and to be viewed as a stereo pair in 3 dimensions. The steerable mirror further enables SPOT, if need be, to shorten the revisit period of 26 days to only 2-3 days, in the case of monitoring of events with very short period changes such as floods, bushfires, cyclones and other natural disasters. For off-nadir viewing, the area covered by each scene increases in the across track direction with increasing view angles, to a maximum of 80 km at 27°.

revisit capabilities



Resolution

The spatial resolution, is signified by the smallest sample of the ground surface reflectance. This picture element or "pixel" is 20 m x 20 m in the multispectral mode and 10 m x 10 m in the panchromatic mode (nadir viewing). Spectrally, the HRV instruments are able to distinguish 256 different shades (grey levels) in each of the spectral bands and the panchromatic band. In the case of off-nadir viewing, the area covered on the ground by each pixel increases slightly with increasing viewing angles, and the data is resampled to the intended pixel size to give an increased number of pixels per scan line.

SPOT Reference System

The SPOT Grid Reference System (GRS) is designed for the identification of SPOT images by geographic coordinates within latitudinal zones. Five zones are symetrically arranged about the equator, with the equatorial intermediate zone stretching from 51.5°N to 51.5°S. The North and South zones are between latitudes 51.5° and 71.7° on their respective hemispheres, while the North and South Polar zones extend beyond 71.7°.

In the (equatorial) Intermediate Zone, which includes the whole of Australia, the GRS grid consists of lines of constant latitude (rows) and lines that run parallel to the satellite's ground track (columns). Their intersections are designated by coordinates (J,K) respectively, and are in essence similar to Landsat's Path-Row system. The J,K coordinates identify the nominal scene centres at nadir viewing, for each of the two HRVs and occur 58 km apart on either side of the satellite's groundtrack. There are thus twice the number of K coordinates as there are ground tracks.

During a 26 day repeat cycle, SPOT will have completed 369 revolutions over 369 different ground tracks, which are numbered eastward, starting with track 1 being the track that crosses the equator at 330.24° longitude during the descending day time pass. There are then 2 x 369 or 738 K coordinates, with K= 1 being the coordinate immediately West of track 1 and K = 2 being immediately East of track 1. The HRV instruments are correspondingly numbered according to their West, East pointing directions in the twinning mode, HRV 1 and HRV 2 respectively. In summary then, we can say that all odd number K coordinates correspond to images west of the ground track, and all even number K coordinates correspond to images east of the ground track.

Examples: Over Australia, the ground track going through the Exmouth Gulf of W.A. is number 103, and the associated K coordinates are 205 (2N - 1) and 206 (2N). Along the East Coast, ground track 196 hugs the coastline between Ballina and Port Macquarie, and the K coordinates are 391 and 392.

The latitudinal J coordinates for the Intermediate Zone of the Grid Reference System (GRS) are arranged in a much simpler fashion, at close to ½° intervals. Numbering starts with J = 246 at 51.5° North and finishes at 51.5° South with J = 455. The range for Australia starts at around 10°S with J = 370 and finishes at around 45°S with J = 440 just south of Tasmania.

In the North and South zones the convergence of the satellite's groundtracks with increasing latitudes led to the decision to maintain only half the number of longitudinal coordinates (K). Just the odd-numbered reference tracks and corresponding K numbers are continued for scene identification, even though imagery can be acquired on either side of all tracks, with either or both of the two HRV instruments.

Due to the rapidly increasing angle of the spacecraft's ground track with respect to latitudinal geographic coordinates and the fact that images are measured in spacecraft time, the interval for the latitudinal coordinates (J) can no longer be maintained at ½° intervals. There are now 46 rows for each of the two Zones. The numbers range from 200 - 245 (71.7°N - 51.5°N) and from 455 - 500 (51.5°S - 71.7°S).

The GRS in the two Polar Zones is a triangular grid in which adjacent nodes are kept constant at 26 km. In the North Polar Zone the K coordinates are kept parallel to the 120° - 300° meridian and the J coordinates parallel to the 60° - 240° meridian. The South Polar Zone meridians are (K) 60° - 240° and (J) 120° - 180°. The GRS coordinates for the poles are conveniently numbered K= 100, J= 100 for the North Pole and K= 100, J = 600 for the South Pole.

Image Processing

The SPOT Image processing system allows for the processing of image data at four basic levels:

Level 1A: Essentially raw data without geometric corrections, but includes the normalization of detector (CCD) responses in each of the spectral bands. This level of processing is specifically intended for applications that require a minimum level of pre-processing, such as basic radiometric studies and stereo plotting.

Level 1B: The bulk processing level, is suitable for many applications at the photo interpretation and thematic analysis level. It includes full geometric corrections for Earth curvature, Earth rotation, view angle, systematic errors etc., as well as radiometric corrections. The absolute location accuracy is 0.8 km (RMS) for nadir viewing, at this level of processing the internal distortion of an image is around 0.15 percent.

Level 2: The precision processing level, includes all of the level 1B corrections but in addition, it allows for a higher level of image rectification and of pixel location accuracies to within 50m (RMS) for nadir viewing. Ground control points (GCPs) are used to attain this accuracy and provided that the GCPs are sufficiently accurate and that the variation in relief is no greater than 1250 m, this high level of precision can be achieved. For off-nadir viewing, the relief limits reduce from 1250 m to 170 m at the maximum viewing angle of 27° to meet the 50 m standard. Images can be rectified to a number of cartographic projections, including Lambert Conformal, Transverse Mercator, Polar Stereographic and Polyconic, and are oriented to geographic North.

Level S: This is a special level of processing designed for multi-date studies of images that were recorded in the same viewing configuration and for registration of panchromatic mode images to multispectral mode images. A 0.5 pixel accuracy can be achieved for registration of images of different dates. Other products that can be obtained at this level of processing are digital and photographic scene mosaics, non-standard false colour composites and linear combinations of spectral bands.

SPOT Products

Digital: SPOT image data can be supplied on computer compatible tapes (CCTs) at packing densities of 1600 bpi and 6250 bpi. The volume of one SPOT scene ranges from 27 Megabytes for a single band in the multispectral mode to 100 Megabytes for off-nadir viewing in the panchromatic mode. Although an entire scene will fit on one CCT at the 6250 bpi density, at the 1600 bpi density up to 3 CCTs may be required. The following format options are available: band interleaved by line (BIL) and band sequential (BSQ), with coding in either ASCII or EBCDIC. It is anticipated that at some future date the ALS will be in the position to supply subscene data on either floppy disks or CCTs or both.

Photographic: The SPOT photographic products are available from the ALS at a wide range of scales, processing levels and image sizes. Products may be purchased as film positives and positive paper prints. Although at the time of writing a product and price list still remains to be finalised, the listing shown gives a provisional over view of the likely product range, based on the SPOT IMAGE product range. It is anticipated however, that this range will be expanded and adapted to suit the requirements of the Australian user community. There appears to be considerable scope at the urban and district level of application for 1:50 000 and 1:25 000 sub-scene data in a wide range of disciplines.

Scale	Product Sizes Levels 1A, 1B	Product Sizes Levels 2, S	Data Type PAN	Data Type 1 Band	Data Type FCC	Pos. Film Levels	Paper Print Levels
Full scenes (60 km x 60 km)							
1:400 000	240x240mm	300x350mm	v	v	v	1B,2,S	-
1:250 000	480x480mm	600x700mm	v	v	v	1B,2,S	1B,2,S
1:200 000	480x480mm	600x700mm	v	v	v	1B,2,S	1B,2,S
1:125 000	960x960mm	1200x1400mm	v	v	v	-	1B,2,S
1:100 000	960x960mm	1200x1200mm	v	v	v	-	1B,2,S
Quarter scenes (30 km x 30 km)							
1:100 000	480x480mm	600x700mm	v	v	v	1B,2,S	1B,2,S
1: 50 000	960x960mm	1200x1200mm	v	v	v	-	1B,2,S

Note: At the 1A processing level, photographic products are available only as film products at 1:400 000 scale.

USES OF LANDSAT IMAGERY IN WATER ENGINEERING

G. Whitehouse & D. Outhet

Water Resources Commission of New South Wales

Introduction

Landsat images of flood conditions display a number of features which are not readily apparent in conventional photographs of the same scene. With correct interpretation, these images provide a wealth of information to water resource planners and lead to an improved understanding of flood behaviour. This in turn results in the development and operation of more efficient projects for water conservation and flood mitigation. The authors became aware of these benefits to be derived from the imagery soon after seeing some

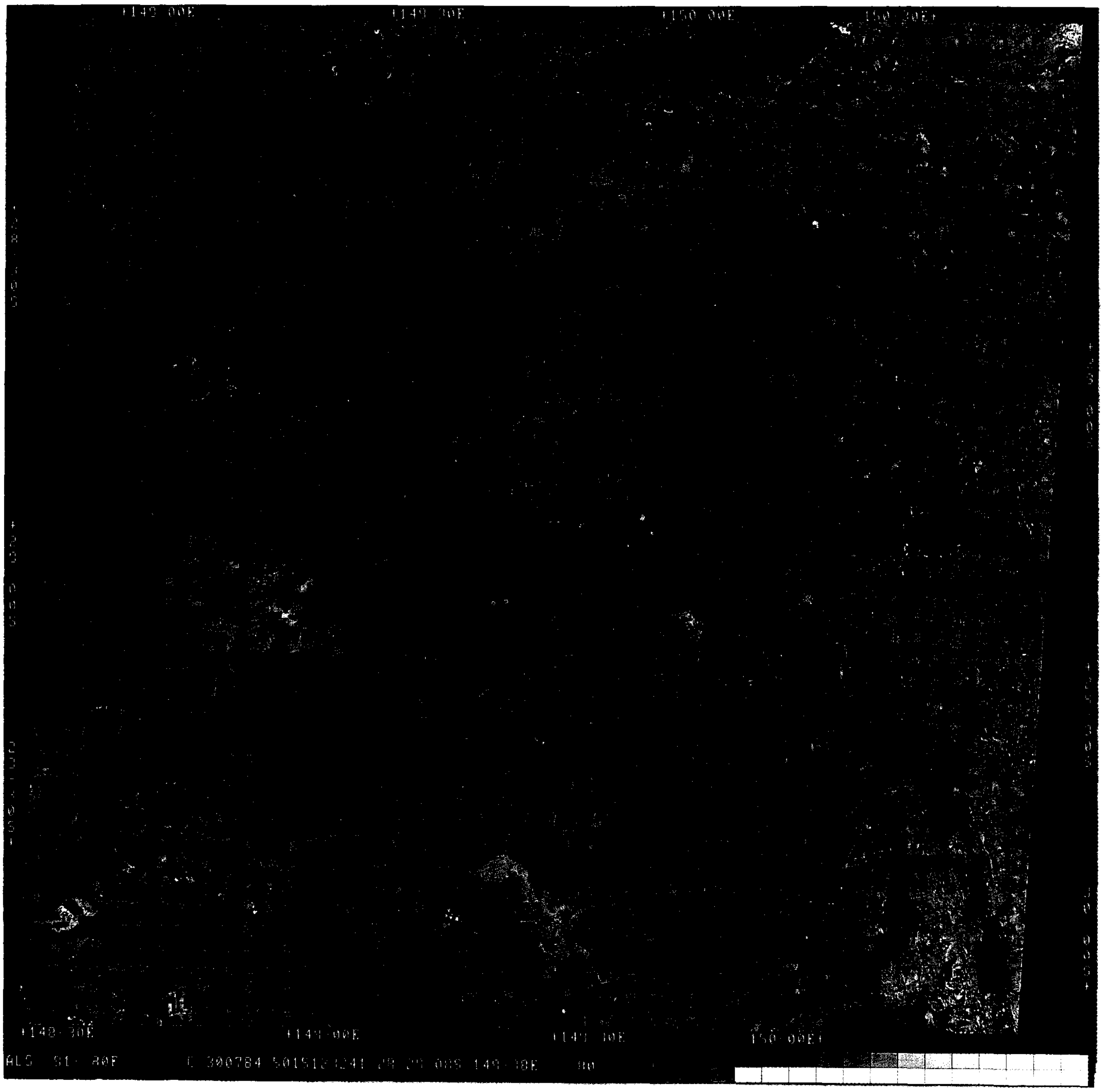


Figure 1.

An early stage of the July/August 1984 flood on the Macintyre/Gwydir/Barwon River system. This July 31st Landsat image shows that the flood peak is located in a zone vertically down the centre of the image from top to bottom. The bright blue areas are sediment-laden floodwater. The black areas are ponded local runoff and saturated bare black soil.

of Australia's first flood images which were obtained of the Darling River at Bourke in 1974. However, in those early days a number of features were poorly understood, difficult to explain and, in some cases, have been incorrectly interpreted. A prime example has been the variety of water colours observed.

The Bourke flood scene displayed streamlines of light and dark toned waters persisting side-by-side in relatively shallow water of constant depth. A number of other images of flood conditions on the western flowing rivers of New South Wales also showed this phenomenon.

A co-operative study between the Water Resources Commission and the Commonwealth Scientific and Industrial Research Organisation was undertaken during 1979/1980 (Green, et al 1983) to determine the origin and nature of these streamlines. The results of this study have shed light on the nature of flooding in those rivers, the mechanics of their sediment transport behaviour and allowed this information to be used as an inexpensive technique to assist in the planning of flood mitigation measures.

Application of Landsat images in other areas of water engineering include floodplain mapping, flood

Figure 2.

The same area as Figure 1, but 16 days later on August 16th. The flood peak is now on the left side of the image near the Barwon River. The saturated soils in the former flooded areas in the centre show as various shades of dark blue or black. The sediment has settled out of the ponded floodwater, making it appear black also.

forecasting, monitoring the operation of flood protection schemes and the selection of weir sites.

Investigations

It is most unusual for adequate hydrological data to be available in sufficient quantity and quality to provide the basis for comprehensive analyses of proposed water projects. In the past, some multi-million dollar water development projects have been designed and constructed against a background of meagre information.

The collection of conventional hydrologic data is expensive and is usually confined within economic bounds by limiting the size of the recording network for individual catchments. The results observed in one catchment are not directly transferable to another. To overcome this problem of deficiencies in hydrologic networks, engineers have developed mathematical modelling techniques to synthesise data sets. Although these models can generate data which resembles that produced by the natural processes (in a statistical or physical sense), such data cannot replace actual observations with full confidence.

In this regard, Landsat imagery has proved to be a useful tool in helping to overcome some of the deficiencies in hydrologic networks. Its greatest advantage is the repetitive coverage it provides of environmental events or change. If the imagery created coincides with a flood, the data is invaluable. Its value is further increased if these observations include a repetitive cover of the same flood or floods of different magnitude within a river valley. The cost of obtaining the same information by conventional means would be increased by a factor of 10.

Image Analysis

Most of the information the Commission requires on flooding can be obtained from Landsat's Multi-Spectral Scanner (MSS) images in bands 4 or 5 which show the streamlines mentioned before and bands 6 and 7 which show the flood limits. Bands 4 and 5 sense the reflectance of light from sediment particles in the water. Radiation in bands 6 and 7 is almost completely absorbed by water and hence, their images show sharp contrast between the high reflectance from soil and vegetation on dry areas and the very low reflectance of water.

In some cases, a black and white linear contrast stretched print of band 7 is adequate. More information can be obtained from the scene if it is presented in the form of a contrast stretched colour composite print of bands 4, 5 and 7 (ALS standard) or 5, 6 and 7, at a scale of 1:250,000 or larger. Maximum information is only available when a digital image analyses computer system is used to enhance the appearance of flooding on small floodplains. The Landsat MSS resolution must be pushed to its limit to determine inundation limits for an area imaged after the flood peak and requires scene classification to aid interpretation. The best classification technique to use for this particular situation is presently one of the main topics of remote sensing research by the Commission.

Due to the limitations of the Landsat MSS, remote sensing studies of small floodplains with short-term floods must await access to more advanced high resolution imagery. The Commission is looking forward to obtaining Thematic Mapper imagery with its increased spectral and spatial resolution, to SPOT imagery with its even higher spatial resolution and its more frequent coverage from off-nadir viewing, and to ERS-1 or RADARSAT satellite radar imagery with its ability to provide data during times of cloud cover or at night.

Applications

As mentioned previously Landsat imagery can be valuable at the formulation stage for a range of water-related projects. In recent years, the Water Resources Commission of New South Wales has been employing Landsat imagery as an analysis technique covering a range of projects. These applications are briefly summarised in the following sections.

Floodplain Management

The first stage of any comprehensive floodplain management study must be the delineation of zones liable to flooding. Once the areal of extent of flooding has been established (preferably for a range of flood conditions) information is required on the distribution of flow velocity across the entire floodplain.

Determination of these aspects across the floodplain from streamflow measurements at established stream gauging stations is both time-consuming and expensive. It is also limited in accuracy because of the problems associated with contour maps.

Remote sensing techniques, and especially Landsat imagery, has proved to be a practical alternative for the gathering of this type of information. By using appropriate enhancement techniques, Landsat imagery readily discriminates the boundary between flooded and dry areas. Using this approach, flood inundation maps which define the flooded area for a flood of given magnitude can be rapidly prepared. The principal advantage of this approach is its inherent accuracy compared to other methods. The limit of flooding is automatically related to physical features and can be defined in relation to the land surface. It is not essential that the imagery created coincides with the peak flow. The extent of flooding can be fairly easily detected on the basis of saturated ground if the imagery is taken when the flood is receding or shortly after (Figures 1 and 2).

The different spectral responses of water displayed on colour enhanced images allows identification of the origin of flooding and a relative measure of the velocity distribution across the floodplain.

Because the different water colours usually indicate various sediment concentrations, colour enhanced imagery can be used to determine the origin of floodwater. For example, the darker coloured water usually represents areas of backwater, containing clearer water. This water can originate as local runoff or it can indicate water which may be slow moving and which has a lower sediment load. On the other hand, the light blue water has a much higher sediment load. Figure 3 shows these features which are captured in the colour enhanced Landsat image of the February 1974 flood in the Darling River at Bourke.

The pattern traced out by the streamlines is indicative of the relative velocity distribution across the floodplain. Zones of acceleration and retardation are depicted by the convergence and divergence of the differently coloured streamlines.

This type of analysis, when correlated with actual streamflow measurements, has proved to be a useful tool in the development of floodplain management strategies.

Project Monitoring

As part of its flood damage reduction programme, the Commission has formulated a number of co-ordinated levee-floodway schemes to protect highly-

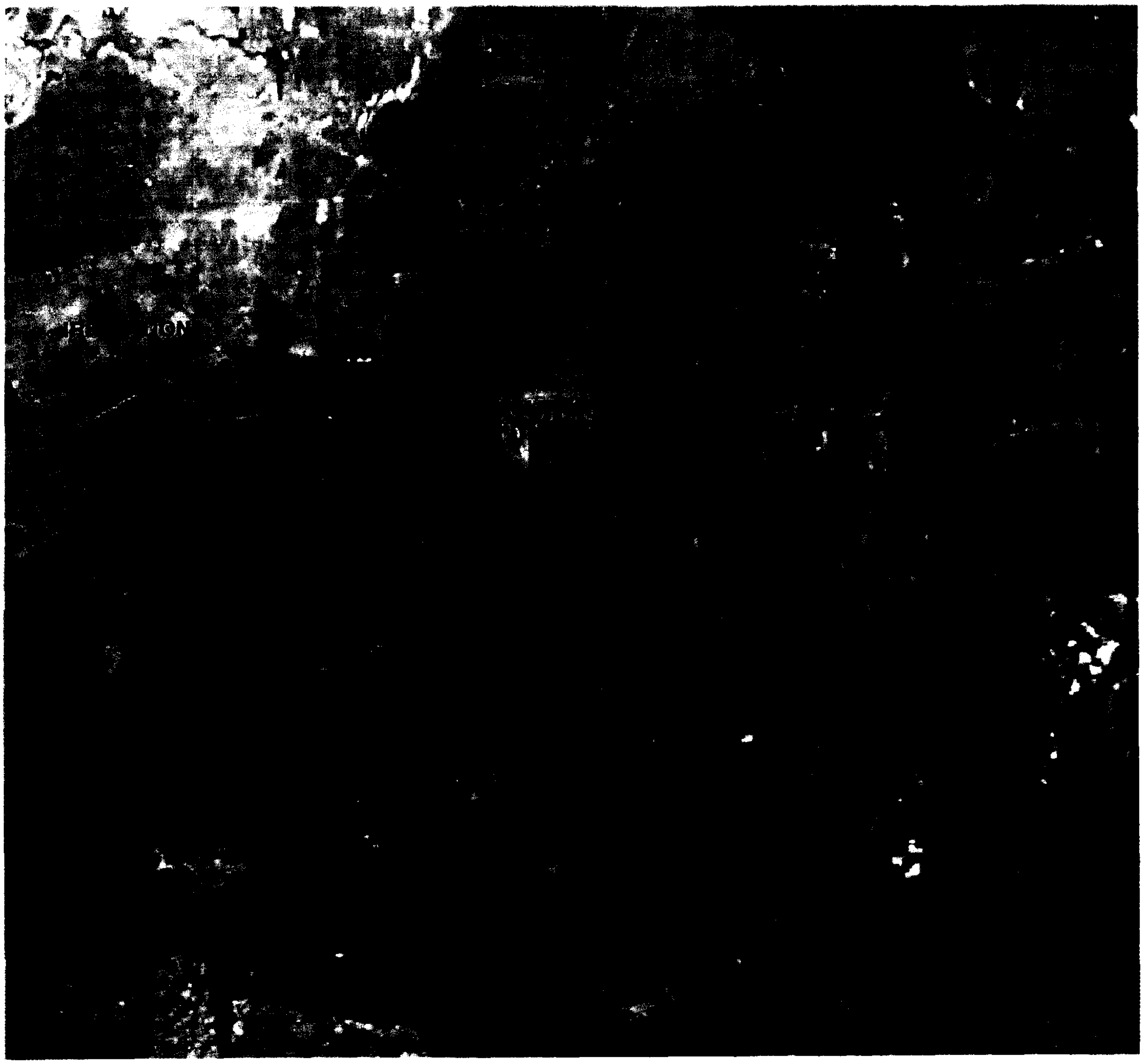


Figure 3.

A Landsat image of the February 1974 flood on the Darling River floodplain near Bourke. The different water colours (bright blue, dark blue and black) are caused by different sediment concentrations and indicate the flow direction and velocity.

developed agricultural lands along the floodplains of the western flowing rivers in New South Wales.

Widespread and comparatively shallow flooding is experienced on the broad floodplains of the inland rivers which have been largely developed for intensive irrigation of agricultural crops.

Detailed investigations of a range of flood mitigation strategies demonstrated that levee-floodway schemes were clearly the most cost-effective flood protection measure for these areas. This approach involves the provision of floodways of adequate hydraulic capacity and continuity by preserving the natural flood channels for the effective conveyance of flood flows. The spread of floodwaters onto developed land is restrained by the construction of levees bordering the floodways. Other measures, such as the construction of flood mitigation storages, channel improvements, and catchment treatment would be less effective and would be much more expensive. It might be noted, that although schemes are investigated and designed by the Commission they are constructed by the landholders at their own expense.

The Commission is in the process of preparing some 43 individual schemes which will provide flood protection of some 40,000 square kilometres of highly developed agricultural lands. This area represents 5 percent of the total land surface of New South Wales or about 20 percent of its flood-affected land.

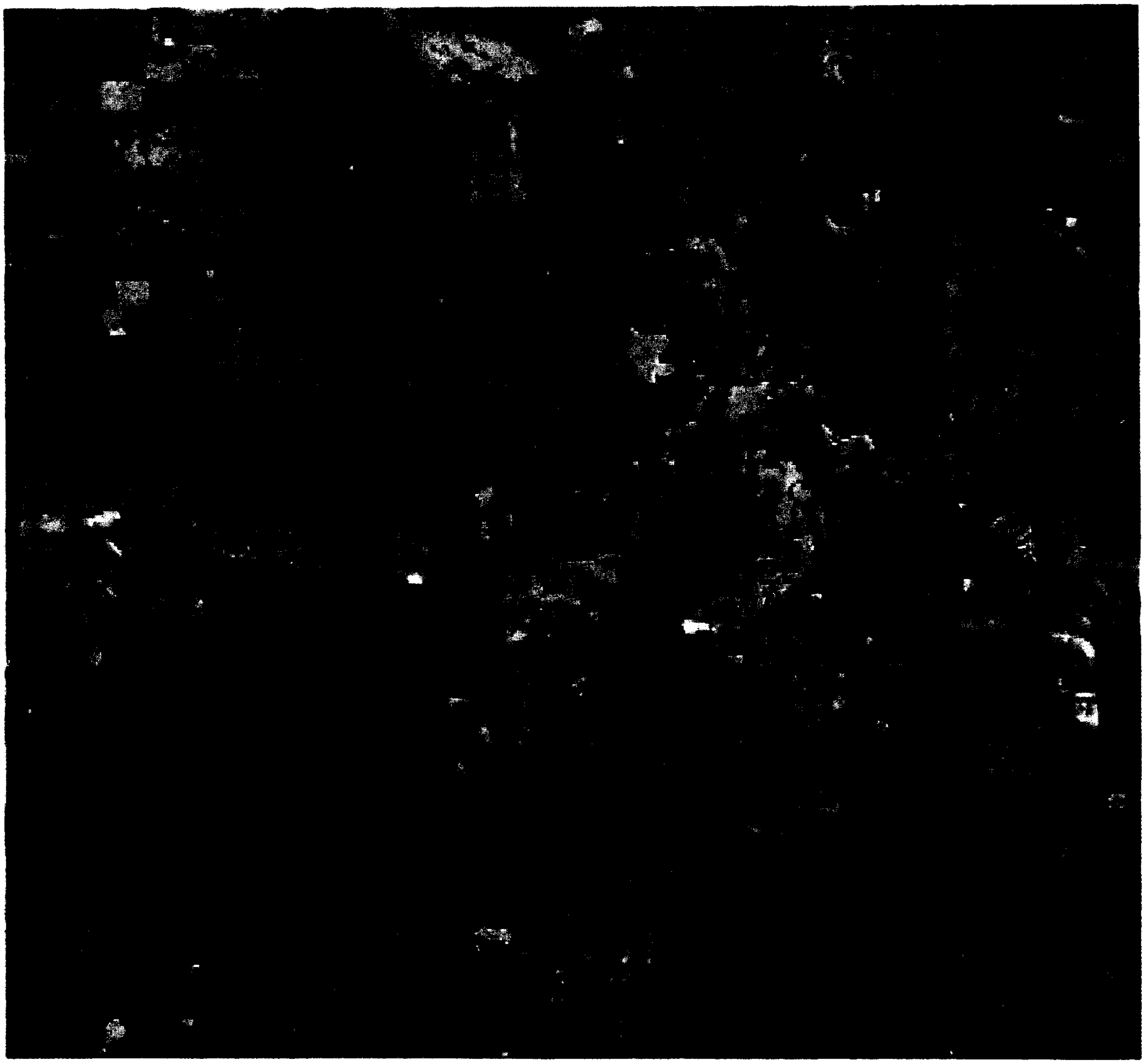


Figure 4.

A July 31st, 1984 non-standard Landsat bands 5, 6 and 7 image of flooding in the Narrabri-Wee Waa area. The floodwater is being conveyed safely through irrigation areas by levees built on each side of the floodways. These are the narrow linear bright blue features running through the dark blue-grey rectangular areas. Off-river storages can be identified by their geometric shape and light to dark blue colours.

Aerial photographs and Landsat images have been used extensively to determine the extent of floodplains, water levels, relative water velocities, flow direction and floodway locations. Because the basic hydraulic information is not always available at all locations, some approximations in sizing the scheme floodways is necessary. The need to verify the design criteria also makes it necessary to monitor the scheme's hydraulic performance. Stream gauging and aerial photography are used during the passage of a flood and post-flood surveys are undertaken. Landsat images are a valuable adjunct if the absence of cloud cover permits creation of the imagery. Figure 4 is a Landsat image showing the operation of floodways in the Narrabri-Wee Waa Scheme during moderate flood conditions.

River Operation

Landsat imagery has been used for assessing the distribution and magnitude of water losses when a flood wave moves through a river system. This technique can improve the accuracy of flood forecasting and enable more efficient operation of water storages. Its greatest potential application relates to the inland rivers of New South Wales, such as the Darling River which experiences large overbank losses in the natural riverside lakes.

Flows in the lower reaches of the Darling River are regulated by a group of inter-connected natural lakes on its floodplain which have been equipped with weirs and regulators. These lakes are collectively known as the Menindee Lakes Scheme (Figure 5) and have a

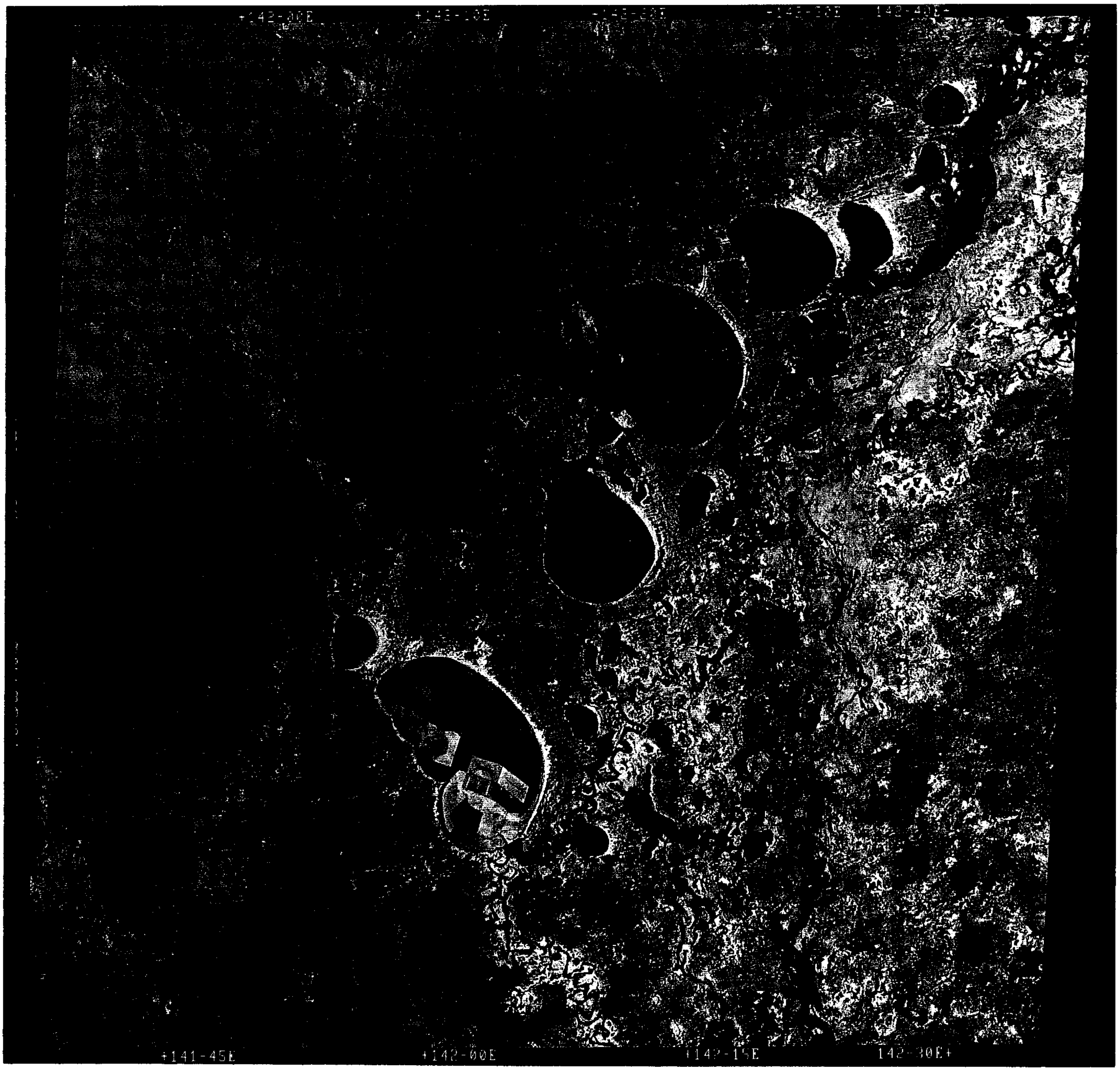


Figure 5.

The Minindee Lakes in the lower reaches of the Darling River provide natural storage for 1.8 million Megalitres of water. Image: Landsat 4 WRS 95/83 of 9 February 1984 (Quarter scene).

storage capacity of 1 800 000 megalitres. Groups of natural lakes are characteristic of the lower Darling River.

Accurate flood forecasting on the Darling River can produce improved water management of the whole of the Murray-Darling River System. These benefits result from the early release of stored water from the Menindee Lakes Scheme to satisfy the water requirements of South Australia. Such releases permit the use of water stored in the headwater reservoirs of the upper Murray River to augment supplies to New South Wales and Victoria thereby increasing the overall system yield.

By the periodic monitoring of losses into the natural lakes as the flood wave moves down the Darling River dramatic improvement in the accuracy of forecast inflows into the Menindee Lakes Scheme has been achieved. Successive Landsat images have been used to record the change in volume of the natural lakes which is a direct measure of the distribution and magnitude of losses, as most of the inflow into the lakes does not return to the river.

Selection of Weir Sites

Landsat imagery can materially assist in the identification and initial planning of water conservation projects, especially weir sites. The synoptic view of floodplain topography provided by the imagery can be employed to great advantage at the conceptual stage of project planning.

Landsat imagery has been used to good effect for water conservation purposes by George Whitehouse when he was a member of an Australian Development Assistance Bureau study team investigating a proposed agricultural development scheme in North-east Thailand during 1977.

Specifically, Landsat proved to be a valuable tool for water conservation development on the Mun River in Thailand where conventional storage sites are scarce and costly to develop. Many sites that are geologically suitable involve flooding of good agricultural land and the consequent displacement of large populations. Visual comparison of Landsat scenes of the area depicting dry and flood conditions suggested an attractive water storage scheme for dry season irrigation. The significant constrictions along the Mun River floodplain which were identified by the imagery appear as suitable sites for the construction of an integrated system of large gated weirs. This form of development is considerably cheaper than conventional storages, does not involve the flooding of good agricultural land or exacerbate the existing flood problem.

This technique also led to the identification of a number of other potential weir sites on that river.

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DETECTION OF ECONOMICALLY SIGNIFICANT VOLCANIC STRUCTURES IN NORTHEASTERN QUEENSLAND FROM LANDSAT MSS IMAGERY

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Abstract

Analysis of circular structures visible on Landsat imagery over the fold belts of the Circum-Pacific region suggest that many are related to high-level magmatic activity. Depending on local levels of erosion, the structures may be associated with surface volcanic phenomena o, .vith subvolcanic plutonic bodies which typify pre-Tertiary terranes. Styles of associated mineralisation vary accordingly. An application of these concepts to the Permo-Carboniferous volcanic province of northeastern Queensland has resulted in the delineation of previously unmapped volcanic centres and assisted in a significant new gold discovery.

Satellite imagery acquired over the past decade has revealed the widespread occurrence of circular structures, particularly in Circum-Pacific orogenic belts. The relationship of these often enigmatic structures to epigenetic mineralisation has formed an important aspect of regional tectonic and metallogenic studies carried out by Hunting Geology and Geophysics in North America, Australasia and the southwestern Pacific region. These studies have clearly demonstrated that an understanding of the significance of circular structures is dependent upon an integrated assessment of both tectonic evolution and geomorphology within a given region.

In the extensive Tertiary volcanic sequences which characterise the Cordillera of North and South America, circular structures frequently correspond to volcanic domes, calderas and silicic eruptive centres, all of which are readily identifiable on Landsat imagery (Baker, 1982). Although a strong spatial correlation exists between ignimbritic calderas of the Western United States and epigenetic mineral deposits (Rytuba, 1981), the mineralising events are frequently much younger than caldera formation, perhaps suggesting that the structures themselves are important in the localisation of epithermal and hydrothermal deposits rather than specific magmatic events. Similar relationships pertain in the Central Andes where Francis et al., (1983) have pointed out that tin/silver mineralization of the Bolivian type and certain porphyry-type deposits display a correlation with Late Tertiary silicic volcanic centres visible on Landsat Imagery.

In older and more deeply-eroded fold belts where the volcanic superstructure has been stripped away, circular structures are often associated with granitoid plutons. Mineralization accompanying the latter may occur in thermal aureoles in the surrounding strata or in younger intrusive systems emplaced along the structurally weakened margins of magmatic bodies, as noted in the Palaeozoic terranes of New Zealand by Eggers (1979).

General Model

The relative depths of erosion in a particular region are consequently of critical importance in the interpretation of circular structures. A generalised model illustrating the types of mineral deposit which may be associated with high-level magmatic activity is depicted in Figure 1, after Baker and Nash (1984). From the model it would be anticipated that epithermal bulk-tonnage precious metal deposits are unlikely to be found in association with circular structures except in terrains where erosion has been minimal. In eroded Mesozoic and Palaeozoic fold belts, various types of hydrothermal porphyry and skarn type mineralization are to be anticipated.

Application to Northeastern Queensland

The foregoing concepts have been embodied in a study of the Tasman Orogenic Zone in Queensland, carried out in 1983. In this investigation, linear and circular structures were interpreted from Landsat imagery acquired by the Australian Landsat Station in 1981; data were compiled as 1:250,000 scale overlays to published geological map sheets at the same scale. Circular structures were interpreted with regard to the morphology of known Permo-Carboniferous caldera structures which occur throughout the Georgetown-Bowen region. Attention was also paid to the small, topographically prominent silicic volcanic bodies which are known to host copper/gold mineralization at several localities, examples being the rhyolite agglomerate and breccia pipes at Mount Leyshon and Mount Wright.

A portion of the resulting interpretation, covering an area south of Charters Towers, is depicted in Figure 2B, which corresponds to the Landsat image depicted in Figure 2A. The prominent circular features in the eastern part of the scene are related to the Rangeview collapse structure. The remaining interpreted volcanic structures appear to form two distinct east-northeast trending alignments, denoted by arrows in Figure 2B.

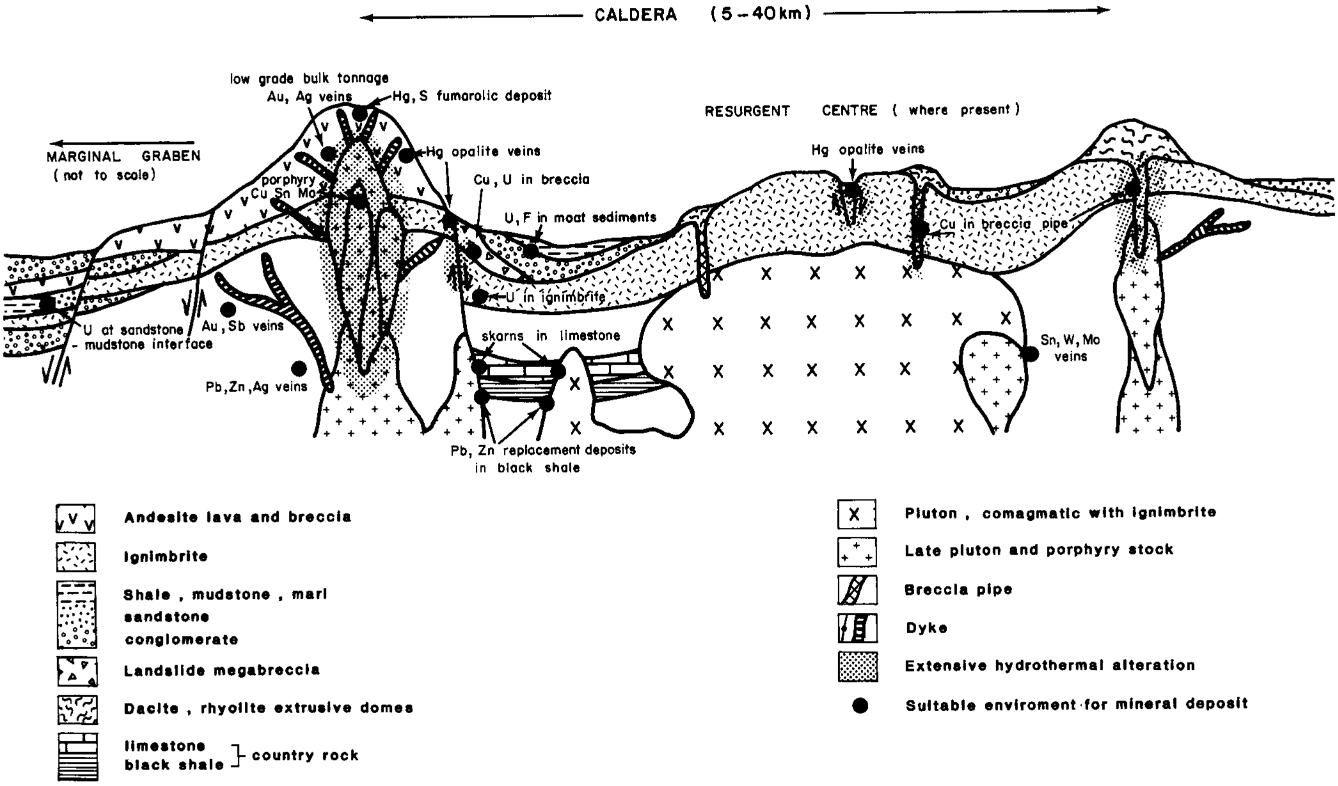

Figure 1.
Section through model of composite caldera showing suitable environments for mineralisation.
(After Baker and Nash, 1984)

The northern alignment passes through the Mount Leyshon and Highway areas, which are both locations of current gold exploration activity, while the southern alignment includes disseminated porphyry-style copper/molybdenum mineralization at Town Creek which is associated with Late Carboniferous breccia and rhyolite plugs, expressed as recognisable features on Landsat imagery. Further west along this trend, a significant new gold discovery has recently been made at Pajingo (Gold Gazette; March, 1985) in which the Landsat interpretation described above played a significant role. The Pajingo area had previously been regarded as part of the Early Carboniferous Drummond Basin sequence, however its Landsat expression clearly suggests a correlation with other small Permo-Carboniferous volcanic bodies to the west which form topographic highs through the Tertiary Campaspe Beds.

Acknowledgments

The Landsat interpretation depicted in Figure 2B is published with the kind consent of Hunting Geology and Geophysics (Australia) Pty. Ltd., Canberra. The writers also acknowledge the expert guidance of Dr Mike Baker in interpretation of volcanic structures.

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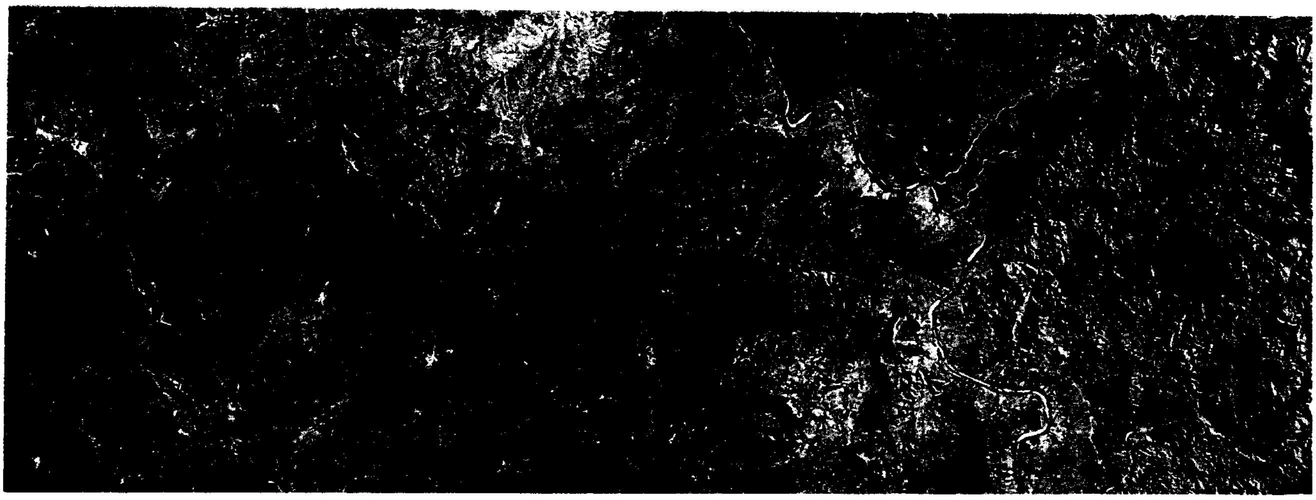

Figure 2A. Portion of Landsat MSS image 22357-23290, acquired by Australian Landsat Station on 06-07-1981.

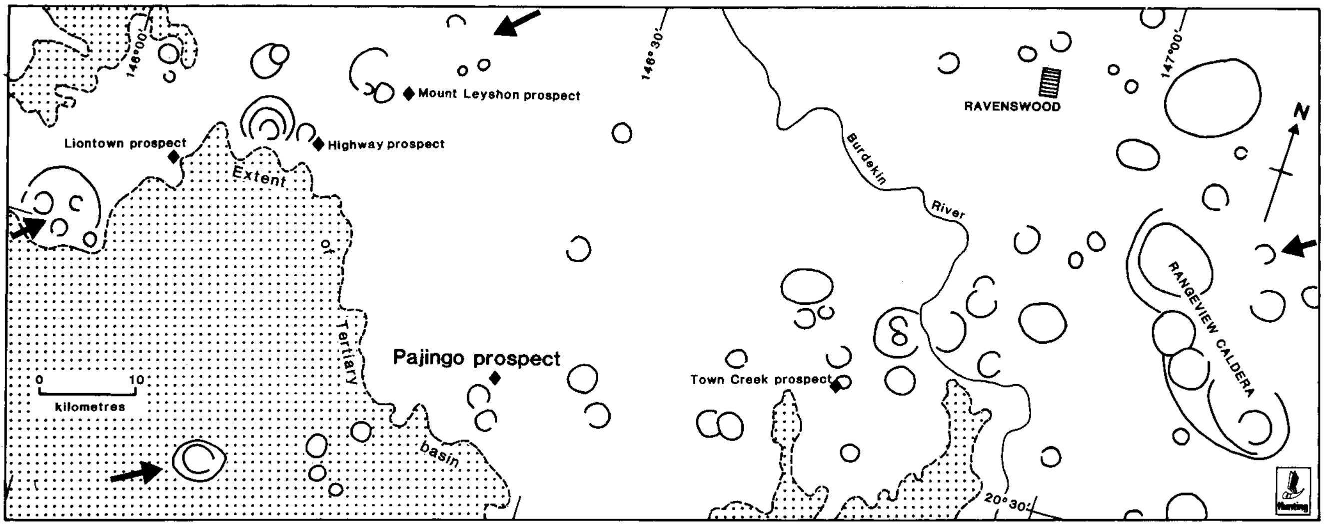

Figure 2B. Interpreted volcanic structures of Permo-Carboniferous age in the area south of Charters Towers.

AGRICULTURAL LAND CLASSIFICATION MAPPING FROM LANDSAT FALSE COLOUR IMAGES

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Nowra. NSW 2541

Abstract

The identification and classification of land in terms of its suitability for agricultural production will assist in preserving the best agricultural land for agricultural purposes, by diverting alternative forms of rural land use onto lands of lesser agricultural quality. Traditionally, land classifications have been prepared by combining land resource information with detailed field surveys. This method has a high degree of accuracy, but is costly in terms of manpower and travelling expenses. In this paper the use of Landsat False Colour Imagery and its integration with other data sources is evaluated for the mapping of agricultural land classification of rural lands in New South Wales. The results of this pilot study indicate that False Colour Composite Images provide land resource planners with an indispensable operational tool. This includes the provision of spatial, spectral and temporal information on earth's surface features, over large areas at a relatively low cost.

Introduction

The availability of information for the identification and classification of all land in terms of suitability for agricultural production will assist in keeping the best agricultural land for agricultural purposes, by diverting other rural land use onto land of a lesser agricultural quality.

Traditionally, this information has been prepared by combining a wide range of land resource data with detailed field surveys. Data sources include the New South Wales Central Mapping Authority Topographic Maps, New South Wales Department of Mineral Resources Geological Maps, Aerial Photography and New South Wales Soil Conservation Service Land Capability Maps.

Although being highly accurate, this method has the major disadvantage of being costly in terms of manpower and travelling expenses.

To overcome these limitations a methodology has been developed to utilize Landsat False Colour Imagery for mapping the agricultural land classification of large tracts of rural land in New South Wales.

Landsat Multi Spectral Scanner data have the advantage of providing spatial and spectral information on earth's surface features over large areas at relatively low cost and may be supplied as a series of temporal scenes of the same areas or features. The reflectance characteristics may be visually interpreted from False Colour Composite Images or digitally enhanced from Computer Compatible Tapes (CCT's).

Aim

The aim of this pilot study was to evaluate the use of Landsat imagery for agricultural land classification mapping in New South Wales, with particular emphasis on the classification of land for agricultural purposes. Significant factors are the cost effectiveness using Landsat data and the accuracies that can be achieved.

Definitions

The term land capability as used in this essay can be defined as mapping of landscape characteristics, such as physiological features which influence the biological environment. This is the first stage in assessing the agricultural potential of rural lands.

The second stage involves the addition of 'cultural' and 'socio-economic' parameters for agricultural land mapping. Agricultural land class assessments are made when key bio-physical, cultural and socio-economic requirements are evaluated in terms of specific agricultural enterprises or collectively as agriculture.

Classes

Assignment of agricultural land use classes to an area of land is based on the highest, and most suitable use without long term environmental degradation. This highest use is based on the lowest limitations for each biophysical, cultural or socio-economic attribute required by the nominated agricultural enterprise.

These class ratings for agricultural assessment are defined in full in the New South Wales 'Rural Land Evaluation Manual' by Woodward and Nelson (1981). The following are abridged descriptions.

- CLASS 1 — Land capable of regular cultivation for cropping (cereals, oilseeds, fodder etc) or intensive horticulture (vegetables, or orchards). Has a very good capability for agriculture, where there are only minor or no constraints to sustained high levels of production. Will include irrigated areas with high production.

- CLASS 2 — Land suitable for cultivation for cropping, but not suited to continuous cropping or intensive horticulture. Has good capability for agriculture, but where constraints limit the cropping phase to a rotation with improved pastures and thus reduce the overall level of production.

- CLASS 3 — Land suitable for grazing. Well suited to pasture improvement and can be cultivated for an occasional cash crop or forage crop in conjunction with pasture management. Overall level of production is moderate as a result of high environmental costs which limit the frequency of ground disturbance. Has a moderate capability for agriculture. Pasture lands are capable of sustained high levels of production; although conservation measures may be required.

- CLASS 4 — Land suitable for grazing and not suitable for cultivation. Agriculture is based on native pastures or improved pastures relying on minimum tillage techniques. Overall level of production is low. Environmental constraints made arable agriculture uneconomic.

- CLASS 5 — Land suited for only rough grazing or land not suited to agriculture. Agricultural production is very low or zero. Severe or absolute constraints to production imposed by environmental factors.

Interpretation of Aerial Photographs and Landsat Images

As aerial photographs and Landsat images contain a detailed record of ground cover features at the time of exposure, they should be systematically examined by an interpreter. This process identifies the nature of these physical objects or landform features. Skill in this process depends on the interpreter's training and experience, the nature of the objects being interpreted and the quality of the aerial photographs of Landsat images. The most capable interpreters have keen powers of observation, intuition and a great deal of patience. For most agricultural applications the six characteristics of features recorded in an image (size, shape, shadow, tone or colour, pattern and texture) are used, as are interpretation strategies such as location and association, temporal change and convergence of evidence. (McCloy, 1983)

Criteria for Image Selection

In selecting Landsat False Colour Composite Imagery for interpretation of agricultural classes it is essential to select an image highlighting the differences between the classes under typical or average conditions.

The factors that need to be considered are:

i. the year of the image (to avoid abnormal conditions)
ii. the season (to get the best expression of image features)
iii. anticipated enhancements.

Sometimes, image selection may be based on abnormal conditions. This assists in identifying extreme differences in surface cover features, not normally apparent during average seasons. On other occasions, more than one image will be necessary to highlight seasonal changes during the onset of spring or early summer, or following the receipt of rain.

Interpretation Process

The interpretation process is based on established principles used in resource surveys. Various data bases provide information on landform, geology, and types of soil. When integrated with Landsat imagery taken at a suitable time or times it is possible to identify agricultural classes. Interpretation involves three successive stages:

Classification of Land Resources

This basically involves segmentation of a region into areas with distinctive characteristics and definition of important resource bases, and is achieved by combining all base data sources to delineate areas with uniform landform, geology, soils and vegetation features. Here a vital role is played by aerial photography and Landsat False Colour Composite Images, which can provide important terrain information by systematic observation of key elements. Distributive features are landform (topography, drainage patterns and erosion) obtained from pattern and texture; outcropping bedrock and soil types from pattern and tone or colour, vegetation and land use from pattern, shape and colour (see Table 1).

Assessment of Agricultural Land Use Ratings

This stage consists of assessing the resource data in terms of possibilities, problems and limitations for each agricultural enterprise, particularly the implications for developing and maintenance of each enterprise without environmental degradation. In this process the characteristics of bio-physical resource bases and the requirements of individual pastures, crops and animals within various enterprises are considered. For example, the agronomy and husbandry requirements of cereal production and livestock enterprises should match the bio-physical and socio-economic limitations of each land unit.

This land use assessment concept is based on a strong correlation between land cover and land use features. These features can be visually interpreted from Landsat imagery, particularly when the geomorphic and biophysical interactions are understood in relation to each land use activity.

These inter-relationships are used to provide valuable clues for predicting the performance of each land use activity within the environment-site potentials or limitations.

Assessment of Agricultural Land Classification Ratings

In assessing the agricultural classification of uniform areas of land it is necessary to combine climatic, cultural and socio-economic influences with Agricultural Land Use Ratings. This process requires a thorough understanding and knowledge of the following components:

- inherent potentials and limitations of bio-physical and economic attributes
- degree to which these potentials and limitations may be feasibly modified by new technology
- technical problems which first must be solved for each enterprise
- difficulties which may be involved in achieving optimum development
- risk of deteriorating natural resources through processes such as soil erosion and salination if a given land use policy is practised.

Application of the Interpretation Process

The interpretation process is conducted in an established sequence. This involves:

1. the rapid identification of more obvious visible features
2. a detailed examination of the more subtle physical features
3. the progressive development of new sets of inter-relationships.

This process progressively builds up a considerable amount of detailed descriptive data until a complete description is postulated, essentially as an inductive process. Further analysis and interpretation are then combined with appropriate field data, and used to evaluate all aspects of the hypothesis, basically as a deductive evaluation. Flaws revealed in this hypothesis will require an explanation, together with amending or redrafting the hypothesis. This sequence is thus an interactive process.

Relationship Between Landsat False Colour Composite Images, Terrain Features and the Rural Land Use Evaluation Manual (RLEM)

Landsat False Colour Composite Images were used to identify the (RLEM) Land Classes of Table 1 which indicates the relationship between Terrain Features and the RLEM Land Classes in the Orange area of New South Wales; Figure 1 shows these classes superimposed on a rectified Landsat MSS image, acquired on 2 June, 1983.

Table 1

CLASS 1: continuous cultivation; wide range of crops, horticulture etc. *Characteristics:* deep well drained soil; highly fertile with excellent growing conditions. *Landform:* uniform to gently rolling; little indication of landform patterns of textures on the imagery; pattern of drainage will often be meandering in flatter country and may have coherent tree structure in the gentler rolling country. *Soils:* darker soils will be dark blue/green on colour composites. *Vegetation:* clear pattern of paddocks with uniform texture within paddocks due to monoculture or ground preparation; colours are often saturated (intense).

CLASS 2: not continuous cultivation. *Characteristics:* sandy loam soils to heavy clays; excellent to moderate fertility; very good growing conditions. *Landform:* well developed drainage patterns; often coherent in structure; can be meandering on floodplains; may see subtle suggestion of landform. *Soils:* colours can vary from light to dark with patterns crossing cultural boundaries. *Vegetation:* selection of suitable imagery will contain pattern of cropped paddocks of uniform distribution across the area; pasture areas will have more texture in paddocks.

CLASS 3: occasional cultivation in conjunction with sown pastures. *Characteristics:* moderately flat to undulating shallow soils, some cultivation good growing conditions. *Landform:* can vary from flat to hilly, usually with deep soils so that the terrain is rounded; drainage patterns will usually be obvious, and there can be subtle to distinct indications of landform in patterns and texture. *Soils:* all colours occur with patterns crossing cultural boundaries. *Vegetation:* most of the area contains texture, with fence lines being subtle or indistinct other than for the occasionally cropped paddock; colours are not as intense as cropped areas.

CLASS 4: pasture improvement without cultivation. *Characteristics:* flat to hilly low fertility soil; fair growing conditions. *Landform:* terrain can be flat to hilly, with thin soils and rocky outcrops; scattered tree cover; terrain features will usually give textural information in the imagery and sharp patterns due to rock outcrops can be obvious. *Soils:* wide range of soil colours. *Vegetation:* wide range of colours, usually with considerable variability across the area; soil colours often dominate; suitable imagery can show differential browning off of the pastures on poorer or thinner soils.

CLASS 5: rough timbered areas. *Characteristics:* hilly to mountainous heavy timber salt or scalded areas; poor growing conditions. *Landform:* well developed irregular patterns with dark colours representing very steep areas. *Soils:* usually lighter colours. *Vegetation:* well developed patterns often textured various colours.

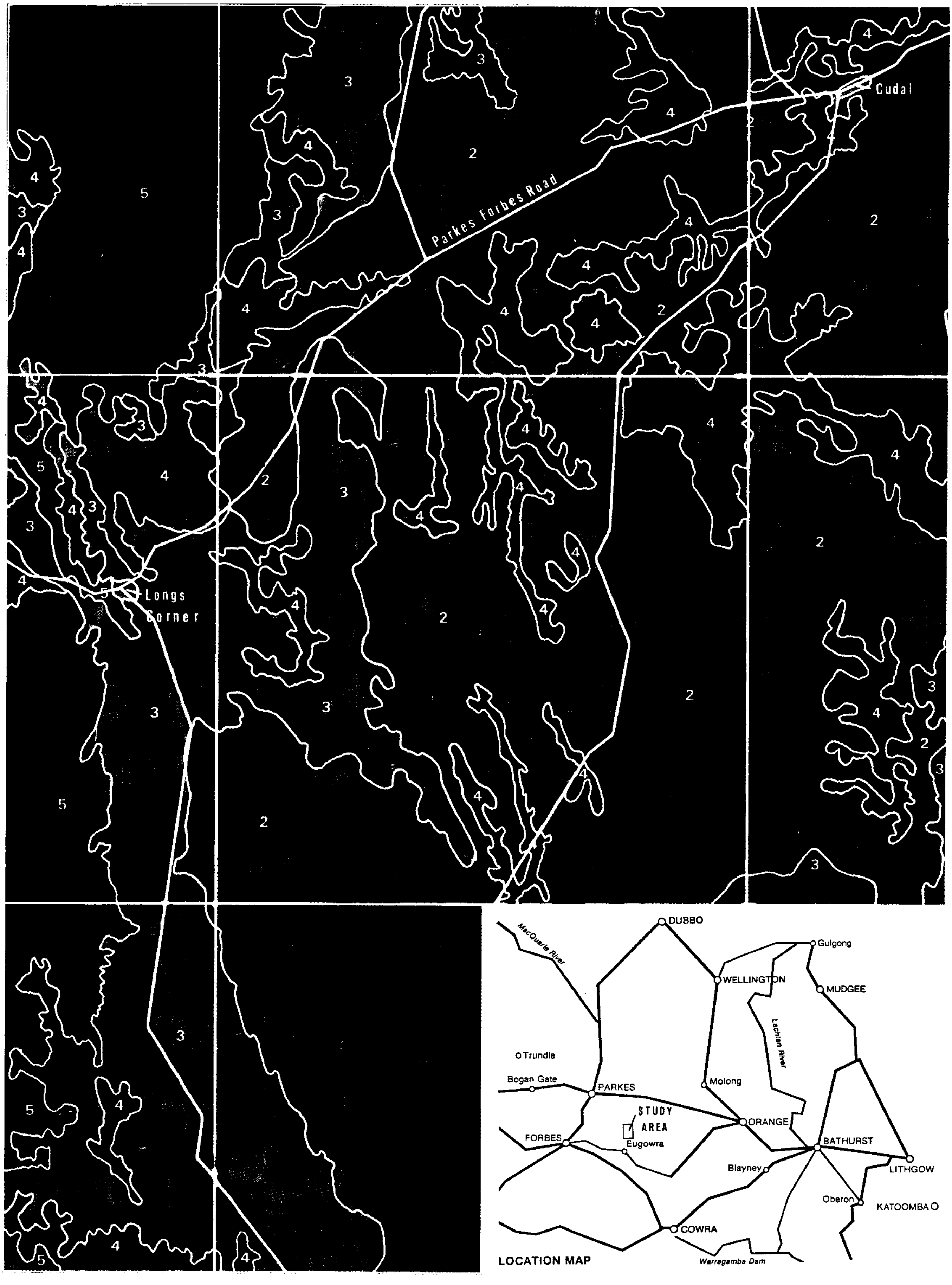
Cudal
Parkes Forbes Road
Longs Corner
DUBBO
MacQuarie River
Gulgong
WELLINGTON
MUDGEE
Lachlan River
O Trundle
Bogan Gate
PARKES
Molong
STUDY AREA
ORANGE
FORBES
Eugowra
BATHURST
LITHGOW
Blayney
Oberon
KATOOMBA O
COWRA
LOCATION MAP
Warragamba Dam

Figure 1.

The following procedure was used for mapping and field identification of agricultural classes.

- Discussions were held with Regional Liaison Officers (RLOs) to review information and data from existing agricultural land classification studies, determine standards for new projects, and if necessary arrange inspections of problem areas within the study area.
- All base data sources were examined to determine location, extent and value of resource data.
- Discussions were held with District Officers, existing and potential agricultural and livestock practices, their role and limitations in view of the present state of technology for each enterprise.
- Inter-relationships, possibilities, problems and limitations were assessed for all relevant biophysical, cultural and socio-economic attributes used by the particular pasture, crop and livestock enterprises.
- Determine the agricultural classes for each uniform area of land using the attribute limitations outlined in the above step. Particular attention should be paid to soil erosion hazards, climatic and current land use practices.
- Boundaries were identified and drawn between adjacent (agricultural) classes on clear plastic film placed over the data base sources, such as Landsat False Colour Composite Images. This is achieved by combining information from all the base data sources, and then considering their characteristics and limitations in relation to the appropriate land use practises in the district.
- Inspections were arranged with District Extension Officers to resolve any ambiguities in problem areas. This part of the procedure also helped establish the relationships between land resource features and the same features shown on Landsat False Colour Composite Images. The images need to depict only a minimum amount of additional base data such as roads, railways etc to be useful in the field.
- Maps were completed in the office with emphasis placed on boundary reconciliation between maps and location of State Forests, National Parks and Urban areas are excluded from the survey area.

Accuracy Assessment

Accuracy measurements are shown on agricultural land classification maps, together with a description of the methodology in the accompanying report. This assists users in interpreting the information.

Two basic methods have been used to determine accuracy:

a. Linear measure of deviation. This system measures the distance or deviation from the mapped position of the class boundaries compared with the correct position as determined during field inspections. The results are presented either as an average deviation for the map, or between individual pairs of classes.
b. Spatial measure of all classes. This system measures the percentage area of the test sites correctly classified.

A suggested methodology for spatial measurement would be to select a minimum of thirty sample sites per strata, to meet the criteria of 90% accuracy requirements for a stratified random sample technique. (Van Genderen, Lock and Vass, 1977) Each sample site would be one square kilometre, and selected using random numbers to identify the spatial co-ordinates for easting and northing bearings on the Australian Map Grid.

These sample cells or sample sites are marked on clear plastic film placed over a base data source such as a Topographic Map. In the field, Agricultural Classes are identified and boundaries are drawn between adjacent classes. Similar attribute and limitation criteria are used for mapping the whole study area from Landsat.

The map showing the sample sites is reproduced at the standard map scale of 1:100,000., although in many cases, the field work would have been carried out at a larger scale. Direct measurements can then be made to determine the percentage area of agricultural classes correctly classified within the sample sites, by comparing the transparency overlay of the agricultural classes with the overlay of the corresponding sample sites. The percentage area of agricultural classes correctly and incorrectly assigned are recorded in a 'confusion' matrix.

Two maps have been produced for the project in this way, one indicating agricultural classes for the whole study area and the other, agricultural classes within each of the one kilometre 'ground truth' sample cells or sample sites.

Discussion

This paper has outlined the use of False Colour Composite Images produced from Landsat Multi-spectral Scanner Data for mapping the agricultural classes of large tracts of rural land at the reconnaissance level throughout New South Wales. The advantages of using these data may be divided into two broad categories.

a) **Advantage of Reflectance Data**
Landsat's Multi-Spectral Scanner data has the advantage that it provides spectral information on the distribution and temporal changes of earth surface features in digital form. Images may be analysed and enhanced using numerical techniques.

b) **Advantage of the Mapping Technique**
The main advantage of the mapping technique may be expressed as the capacity of Landsat False Colour Imagery to provide cost effective land resource

data of a specified resolution and accuracy at the regional level. (Diez and others, 1979)

In practical terms, this includes both the effectiveness and cost-savings, as well as the timeliness and compatibility between information sources and data characteristics. (Reeves, 1975)

Final acceptance of Multi-Spectral Scanner data for this type of mapping will depend on whether the technique can provide agricultural land classification maps at an appropriate scale, resolution and accuracy, and at competitive prices. Other important considerations are the staff and societal perceptions, concerning the needs and importance of this work. Future research work should be directed towards evaluating the role of higher resolution data in assessing agricultural classes, particularly in intensively farmed areas.

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1-6 December 1986
WESTAC Symposium 1986
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3-4 December 1986
Remote Sensing with Synthetic Aperture
Radar
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2-4 February 1987
Introduction to Remote Sensing (Course)
University of Queensland
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9-12 February 1987
Basic Digital Image Processing (Course)
University of Queensland
Brisbane

April 1987
29th Australian Survey Congress
Perth

27-30 April 1987
New Generation Sensors (Course)
University of Queensland
Brisbane

11-12 May 1987
Synthetic Aperture Radar
(Introductory Course)
University of New South Wales
Sydney

11-13 May 1987
Image Processing in Exploration Geology
(Course)
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11-17 May 1987
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14-18 September 1987
4th Australasian Remote Sensing Conference
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26-28 September 1987
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of the Southern Hemisphere
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30 November - 4 December 1987
Vegetation Mapping and Ground Truth
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10-13 November 1986
99th Annual Meeting and Exosition
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SYDNEY
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LANDSAT PRODUCTS

Processed satellite images and related products are available from the Australian Landsat Station, where these are made as colour and monochrome photographic prints at a range of scales and sizes, as well as photo transparencies of full scenes and sub-scenes. Pre-processed image data is also available on Computer Compatible Tape (CCT) in 800 and 1600 BPI format for user analysis and application. Precision rectified images are available as photographic products with some user selected image enhancements and radiometric/ geometric corrections.

For selection of images and cloud assessment, data and colour image catalogues are available in microfiche form. These may be subscribed to annually for any number of fiche or the complete set, for each Landsat cycle. Australian Landsat Station products may be ordered from either of the ALS facilities in Canberra and Alice Springs, or through a number of Distribution Centres located throughout Australia.

ADELAIDE
Mapland
Department of Lands
12 Pirie Street
Adelaide SA 5000
Ph (08) 2274904

ADELAIDE
The South Australian Centre for
Remote Sensing
Innovation House
First Avenue
Technology Park
The Levels SA 5095
Ph (08) 2600134

ALICE SPRINGS
Australian Landsat Station
Heath Road
Alice Springs NT 5750
Ph (089) 523353

BRISBANE
Sunmap
Aerial Photography Section
Dept of Mapping and Surveying
11th Floor, Watkins Place
288 Edwards Street
Brisbane QLD 4000
Ph (07) 2277938

CANBERRA
Australian Landsat Station
22-26 Oatley Court
Belconnen ACT 2616
Ph (062) 524411

DARWIN
Survey Mapping Division
Dept Lands and Housing
Moonta House, Mitchell Street
Darwin NT 5790
Ph (089) 897214

HOBART
Tasmanian Government Publication
Centre
134 Macquarie Street
Hobart TAS 7000

MELBOURNE
Air Photographs Pty Ltd
624 Burwood Road
Hawthorn VIC 3123
Ph (03) 8828031

MELBOURNE
Dept of Property & Services
Div. of Surveying and Mapping
Map Sales
35 Spring Street
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