Emerging role for the resources satellite

Although few Australians take much notice, a parade of data-chattering witnesses watches over us. These are the satellites. Some were launched for military use, but others relay information for peaceful purposes, giving us a new insight on the earth. A major contributor to this knowledge is the Landsat series of satellites. Landsat-1 went into orbit in mid 1972; its companion, Landsat-2, followed early in 1975. Landsat-3 will be launched in September.

The Landsats impartially observe the spread of our cities, the extent of our floods, and the features of our remote regions. They can report the areas we plant to crops, and observe when storms strike down our wheat. They cover the entire area of the earth, apart from a minor fringe at the poles, in big 'pictures', each one of which is 185 km square.

There was some initial scepticism about the capability of the Landsat sensors—orbiting 920 km above it—to provide a useful record of the earth's surface. The first pictures Australia received, when enthusiasm was running high, came as a severe disappointment. They were small and of poor quality.

Since then, we have learned a lot more about transforming the information from Landsat into spectacular, fine-detailed pictures (imagery is the term generally used). And, with this new quality, a host of uses is becoming apparent.

In fact, Landsat's imagery has passed one major test of acceptability in our society. It has been introduced as evidence in a legal claim. The claim—concerning flood damage—came to court last year. A Victorian landholder alleged that water the State Rivers and Water Supply Commission had released from a storage had flooded his land and caused damage. The Commission countered by saying the water was 'natural' run-off following a very large storm that had occurred.

At the time of the alleged flooding a satellite had flashed across the sky. Its four sensors had recorded the scene below (quite routinely), had stored the information on tape, and had relayed it to an American reception station in Alaska. The sensors were operating in various segments of the electromagnetic band—some visual and some just beyond the fringes of the human eye's receptivity. But the tiny cells of information they had collected had been recorded on tape. This in turn had been processed to correct for minor variations of the satellite's position and the time of day and had been printed out as a colour photograph, available in Australia.

When a photo interpreter examined the photograph, he was able to estimate the 'age' of the floodwater—and this indicated its source.

At the start of a flood, little or no erosion has occurred and the water absorbs infrared radiation. When the flood reaches its peak, however, the water carries much more sediment—which reflects infrared radiation. These two situations look different on a satellite picture and an interpreter can tell which is which.

Although Landsat's evidence had been accepted, it was not put to a complete legal test. The case was withdrawn and a settlement reached. But new ground had been broken. A monitor in space could not only record large-scale features of the earth's surface below, but could provide evidence detailed enough to be used in a local dispute. Space sensing came legally of age in Australia.

Getting the picture

Landsat-1 and its follower Landsat-2 are now facts of life. Their orbit takes them from north to south over the polar zones. Their speed is synchronized with that of the sun. The earth rotates below them, and in a cycle every 18 days a satellite photographs (or senses) conditions over the whole earth.

The sensors on the existing Landsats cover four bands of the spectrum (see the box on page 6). When Landsat-3 begins work later this year, it will have an additional sensor to assess temperature differences, allowing it to make readings even when the earth below is in darkness.

It is the global scale that distinguishes satellite information from that of other forms of remote sensing, for instance aerial photography. Just over 500 Landsat pictures—compared with hundreds of thousands of aerial photographs—cover the whole of Australia.

The effect of the 1 : 1 000 000 Landsat images differed completely from those of previous attempts to secure small-scale, broad-brush views of the Australian land surface—through, for instance, amalgamating mosaics of 1 : 80 000 aerial photographs and re-photographing them. The perspective of the satellites gave us exciting information. The pictures 'showed', for example, the huge scope of flooding in western Queensland and the spread of streams like the Diamantina River and Coopers Creek.

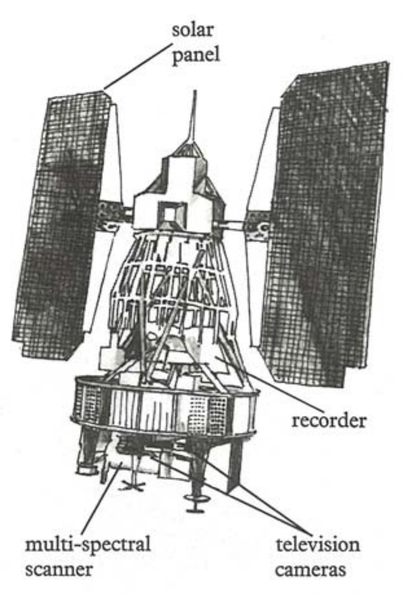
Improving the image

The early disillusion with the Landsat imagery came from the way it was presented to Australia. Tracking stations on earth can only pick up the Landsat data transmissions while the satellite is within their line of sight. As there are, as yet, no stations for Landsat in Australia, the data translations of our landscape had to be recorded on tapes. These were later replayed on command and picked up by American stations like the one in Alaska. When processed into imagery and made available to us, their quality was disappointing. They were small (in a 70-mm format), lacked contrast, and had poor definition.

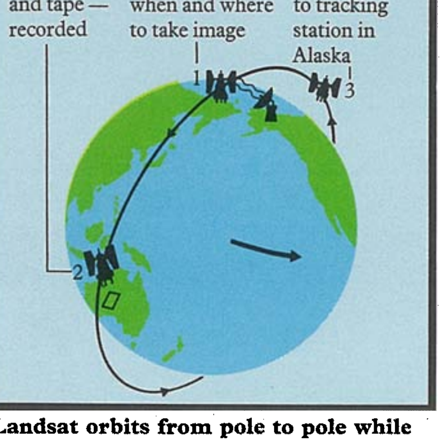
The initial reaction here in Australia was that these poor-quality pictures resulted from limitations in Landsat's equipment. This assumption turned out to be wrong, as high-quality American imagery soon showed.

Each of these problems—size, contrast, and definition—could be overcome. The CSIRO Division of Mineral Physics, working in Sydney, decided to try for greatly improved pictures.

What Landsat looks like in orbit



How Australia has obtained its Landsat imagery so far



Landsat orbits from pole to pole while the earth rotates beneath it. An Australian tracking station could short-circuit the steps shown here by receiving signals directly as the satellite passes overhead.

First, the processing team established the contrast range of each frame. They found that the American processing stations had used a median value for levels of contrast over the world, and had assumed that each place on earth spanned a full range of contrast, from bright to dark. But our landscape is generally much brighter than this arbitrarily chosen median, and an image balanced to Australian standards of brightness immediately showed more detail.

The definition problem was similar. Each of the initial small pictures of Australia—with poor contrast—was copied into a master for retention in the United States. This master was copied again to get an Australian master, and further reproduction then occurred here to get our imagery. And so Australian workers were trying to use fourth-copy imagery that had started out as an inadequate picture in the first place.

The Sydney workers decided that the answer lay in obtaining Landsat's original taped data and processing it to get bigger pictures of Australia, balancing the contrast to suit our conditions.

Using the taped data, they were able to analyse each Landsat image and examine its contrast range. Images can be presented visually using 64 gradations of contrast, ranging from dark to bright. In most Australian scenes, darker areas such as water do not require much detail while brighter areas of land do. By establishing the spread of useful contrast, they were able to 'stretch' the range in each frame so that a balanced picture resulted.

Tender loving care

The same process of individual attention could also be applied to minor corrections on each image. For instance, at the time of storing the data contained in each frame, the satellite's light-detecting mechanism could vary slightly. But this can be compensated for by adjusting each tiny picture-element, or pixel.

The 80-metre-square pixels are the smallest units of definition available in the Landsat imagery. They can be compared with the 'grain' in an orthodox photographic image. No matter how much the negative is enlarged, the picture cannot be resolved any finer than the grain—or in the case of Landsat, the pixel—permits. The CSIRO team found that adjusting the pixels resulted in a much sharper picture, within the limits of their 80-metre size.

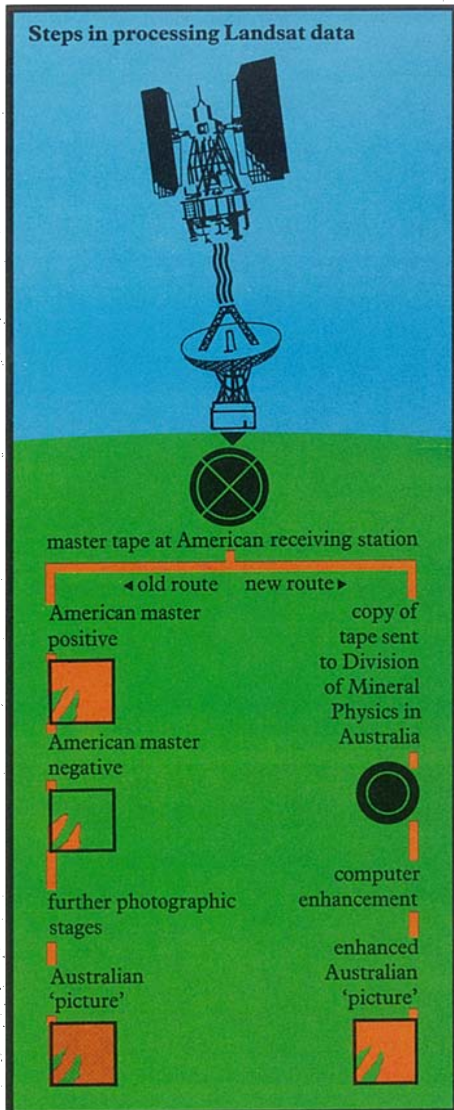
These new pictures gave high definition on a 1 : 1 000 000 scale, capable of being enlarged to the standard 1 : 250 000 used in topographic mapping or even to 1 : 100 000. In these enhanced Australian pictures, much useful detail is evident. And so we have had an upsurge of interest in the computer processing of Landsat imagery. Projects using it include the mapping of parts of Antarctica and reefs off the Western Australian coast, a full-scale ecological survey in South Australia, and the development of techniques that will eventually be used in crop measurement and forecasting.

Given the ability to produce balanced sharp pictures, the next priority was to get a full coverage of Australia with the imagery relatively free from cloud. A coverage of about 90% is available so far. Many of these images are still on tape. But, when processed, they will provide an historical record of Australia in the 1972–74 period, giving workers so much information it may take them many years to interpret it fully.

Mapping on land and sea

One of the first proposed applications of Landsat imagery was to the mapping of Australia. However, despite the country's extensive area, the national mapping program was highly advanced, largely through the use of aerial photography during the past 20 years. This provided opportunities to relate the Landsat imagery to known points on the earth's surface. It also made the use of the imagery as a basic mapping tool unnecessary here. However, the method can still apply to countries that have not yet been thoroughly mapped.

One of these is Antarctica, where the Department of National Resources, Division of National Mapping—the custodian of Australia's Landsat pictures—has prepared a number of 1 : 500 000 and 1 : 250 000 pictorial mosaics. These are regarded as an interim map series that will greatly assist exploration and serve as the basis for complete contoured maps, which will eventually be produced from conventional aerial photography.



The Division of Mineral Physics now receives each satellite picture as numbers on magnetic tape. Using computer enhancement techniques, the Division produces pictures superior to those obtained previously by a series of photographic steps.

Another application is the mapping of Western Australian coastal waters. Experimental work by the CSIRO Division of Land Resources Management in Perth has shown that one of the four Landsat sensors, monitoring the green band, can penetrate water to a depth of about 20 metres. Using computer analysis of the imagery, work now under way suggests that depths down to 10 m can be indicated accurately to within 1 m. Depths down to 16 m can be estimated to within 2–3 m.

In fact, one trial map—showing broad details of features such as reefs and shoals and costing $500—was almost as useful as a $50 000 chart prepared by orthodox means. A mixture of the two technologies, old and new, may be desirable in future.

Ecological surveys

On the shore, Landsat imagery has also assisted various land use surveys in Australia. The Division of National Mapping has begun a program of land-use mapping at a scale of 1 : 1 000 000 covering initially the south-east of Australia. The Division aims at building up a broad picture of present land use, as a basis for ecological and other studies and to assist land-use planners.

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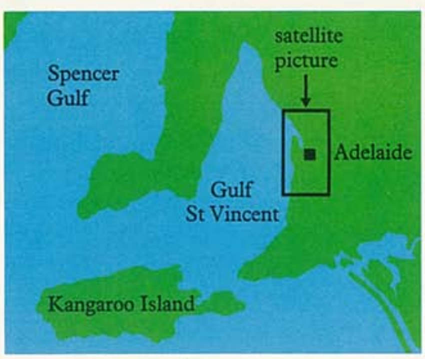
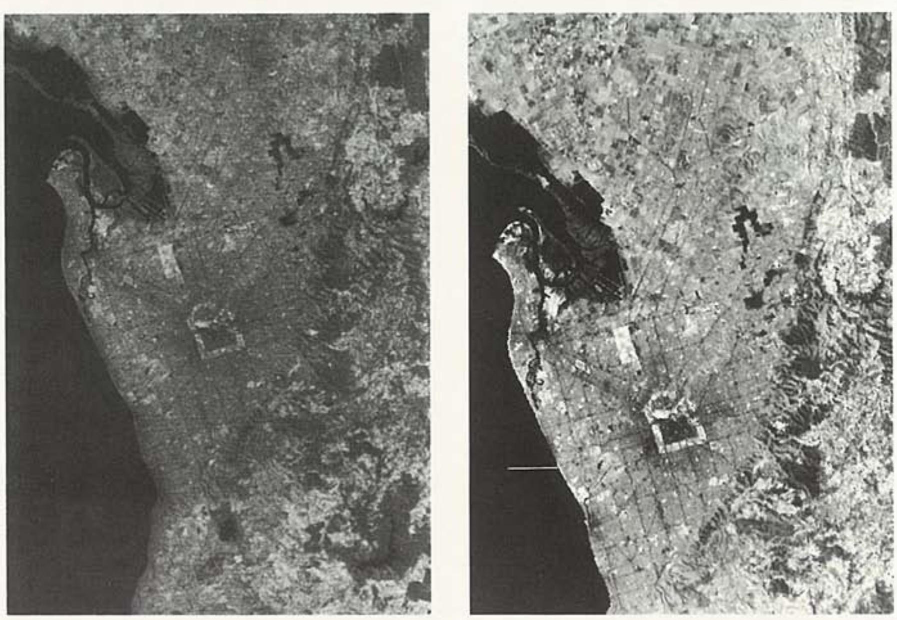
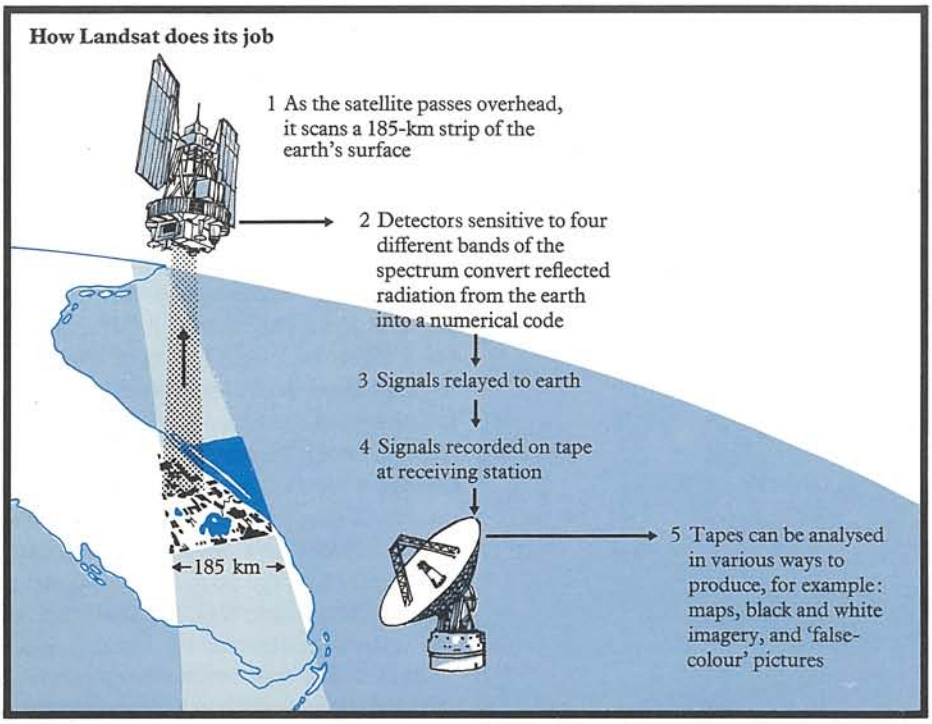




Two satellite views of the Adelaide area. The picture on the left came via several photographic steps from a master positive in America. Much more detail is evident in the one on the right, obtained by the computer enhancement method.



It is the global scale that distinguishes satellite information from that of other forms of remote sensing.

How Landsat works

Landsat-1 began its career as ERTS-1, which is an acronym for Earth Resources Technology Satellite. This orbiting laboratory, as the Americans refer to it, and the very similar Landsat-2, are projects of the United States government, through the National Aeronautics and Space Agency (NASA). Powered by solar cells, they each weigh just under a tonne, and are based on the earlier Nimbus satellites, which were designed for weather-watching.

In orbit, the satellites use two sensing systems: one has television cameras to take snapshots; while the other, the multi-spectral scanner, sweeps the earth below in four wavelength bands. The scanner has proved the more valuable and has contributed virtually the entire stock of imagery used in Australia.

The satellites were designed with two tape recorders each. The purpose of these was to record the scanner's signals when the satellite was on the opposite side of the earth from its tracking stations in the United States. As the satellite rounded the earth's curvature and came into the line of sight of a tracking station, the recorded information could be relayed to the ground.

Landsat-1 has been in orbit for 5 years, against a projected life of only 1 year, and both of its recorders have broken down. Only one recorder is fully operational on Landsat-2. And so NASA has stated that it is unwilling to tax the existing recorder with routine work.

Since 1972, a number of countries other than the United States have built their own tracking stations so that they do not have to rely on recorded information. They can receive direct transmissions from the satellite as it passes over them.

As Australia has no receiving station yet, it is unable to take advantage of the direct transmissions. We have had to depend on recorded information from America. In fact, we received most of our imagery during 1972–74, with comparatively little being available since then.

The two Landsats orbit at a height of 920 km, girdling the earth on a sun-synchronous polar course every 100 minutes. They are arranged so that between them, complete earth coverage can be obtained every 9 days (depending on cloud cover, of course). If Australia had its own tracking station, it could take advantage of this 9-day cycle.

The multi-spectral scanner uses an oscillating mirror that sweeps from west to east across the satellite's track covering a 185-km strip. The radiation it collects passes through an optical system into four radiation detectors sensitive to different wavelengths of visible and near-infrared light.

The detectors measure the light intensities from individual units of the earth's surface just under 80 metres square, or roughly 0·6 ha each. These units are the fundamental picture elements, or 'pixels'—a standard 185-km-square picture contains 7·5 million of them.

The light value for each pixel is converted to a digital signal for transmission back to earth. The raw signals can be measured and classified by computer means or converted into visual imagery for recording on photographic film.

The four spectral bands are in green (0·5–0·6 micrometres), red (0·6–0·7), infrared 1 (0·7–0·8), and infrared 2 (0·8–1·1). When the images are presented visually, they first appear in monochrome with 64 contrast gradations between white and black. However, for interpretation, colours can be assigned for each spectral image to give the familiar 'false-colour' imagery, reproduced in this issue.

Landsat-3, when it goes into orbit later this year, will have an additional sensor in the thermal part of the spectrum (10·4–12·6 micrometres). This will enable it to 'see' temperature differences and to map them. It will have improved ability to measure ocean features such as currents and shorelines, to map certain rock types, to distinguish between types of vegetation and the limits of Man's habitation, and, of course, to operate at night.

Imagery obtained in summer is proving the most valuable, although winter scans show a clearer contrast between vegetation types, such as between grasslands and forests.

Landsat imagery is providing one of the mapping tools for the National Wetlands Survey, a project to which several CSIRO Divisions are contributing. The images provide a clear definition between land and water areas. During periods of flooding, for instance, the satellite can disclose the extent of the flood plains. It can also measure the expansion and contraction of fixed bodies of water such as lakes or even billabongs.

The CSIRO Division of Land Use Research in Canberra is participating in a pilot ecological survey of South Australia on a 1 : 250 000 scale. It has already published two volumes, in association with the South Australian government's own agencies. The aim is to establish classifications and techniques, including the use of satellite data, that will have a place in a comparable national survey.

Landsat information has shown itself a useful tool in measuring the condition of grazing lands. In one experiment involving the CSIRO Division of Land Resources Management and the Western Australian Department of Agriculture, areas around Broken Hill, N.S.W., around Alice Springs, and around Kalgoorlie, W.A., were compared. Distinct differences in grazing patterns could be determined, even to the extent where the border between South Australia and New South Wales could be distinguished by the different grazing standards on each side of it. There were also indications of the effects of rainfall and seasonal changes.

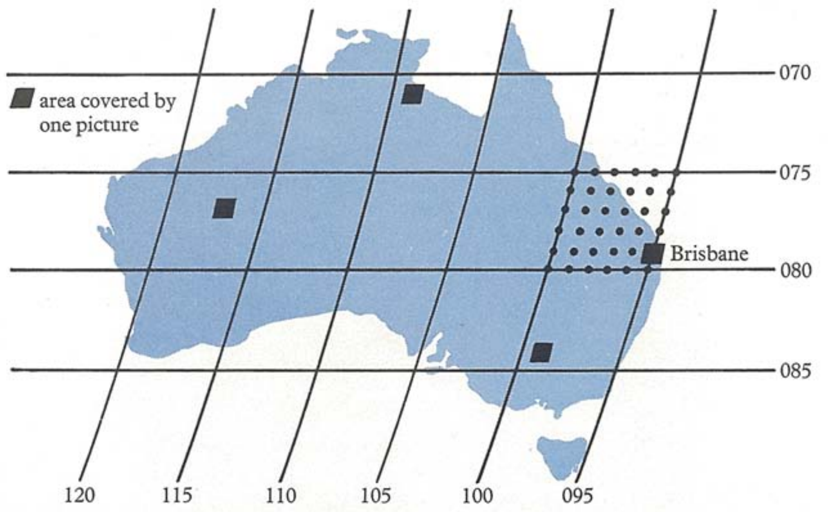
However, the research indicated that the imagery was best regarded as another tool rather than a sole source of range management data.

Crop forecasts

Direct economic advantages may arise from a cooperative project involving the Division of Mineral Physics and the New South Wales Department of Primary Industry. It is an attempt to use Landsat data to provide crop forecasts.

A great deal of work has already been done overseas on the use of satellite data for predicting crop yields. One such attempt was the American–Canadian Spring Wheat Project, carried out during 1970–74. Another, known as LACIE—for Large Area Crop Inventory Experiment—will determine the feasibility of monitoring crop areas on a global scale.

Landsat coverage of Australia

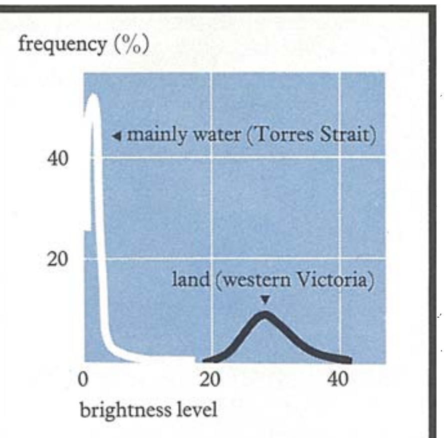


The 500 or so Landsat pictures of Australia are identified by three-digit path and row numbers. Thus the picture including Brisbane is 095–079. The satellite takes four photographs of each area—in the green, red, near-infrared, and infrared bands of the spectrum.

Australian researchers have surveyed a small lake-bed south of the Menindee Lakes near Broken Hill, both on the ground and from the air at the time of a Landsat pass. The dried lake-bed, used for cropping, had the advantage of being an easily distinguished and defined area.

The researchers measured the radiation reflected from the various crops and the angle of the sun at the time. With this knowledge of 'ground truth', they could clearly recognize the areas of different crops on the Landsat imagery. In addition, an agronomist could estimate the quality of the crop and even distinguish in it an area that had been blown down in a recent storm.

The 80-metre-square pixels are the smallest units of definition available in the Landsat imagery.



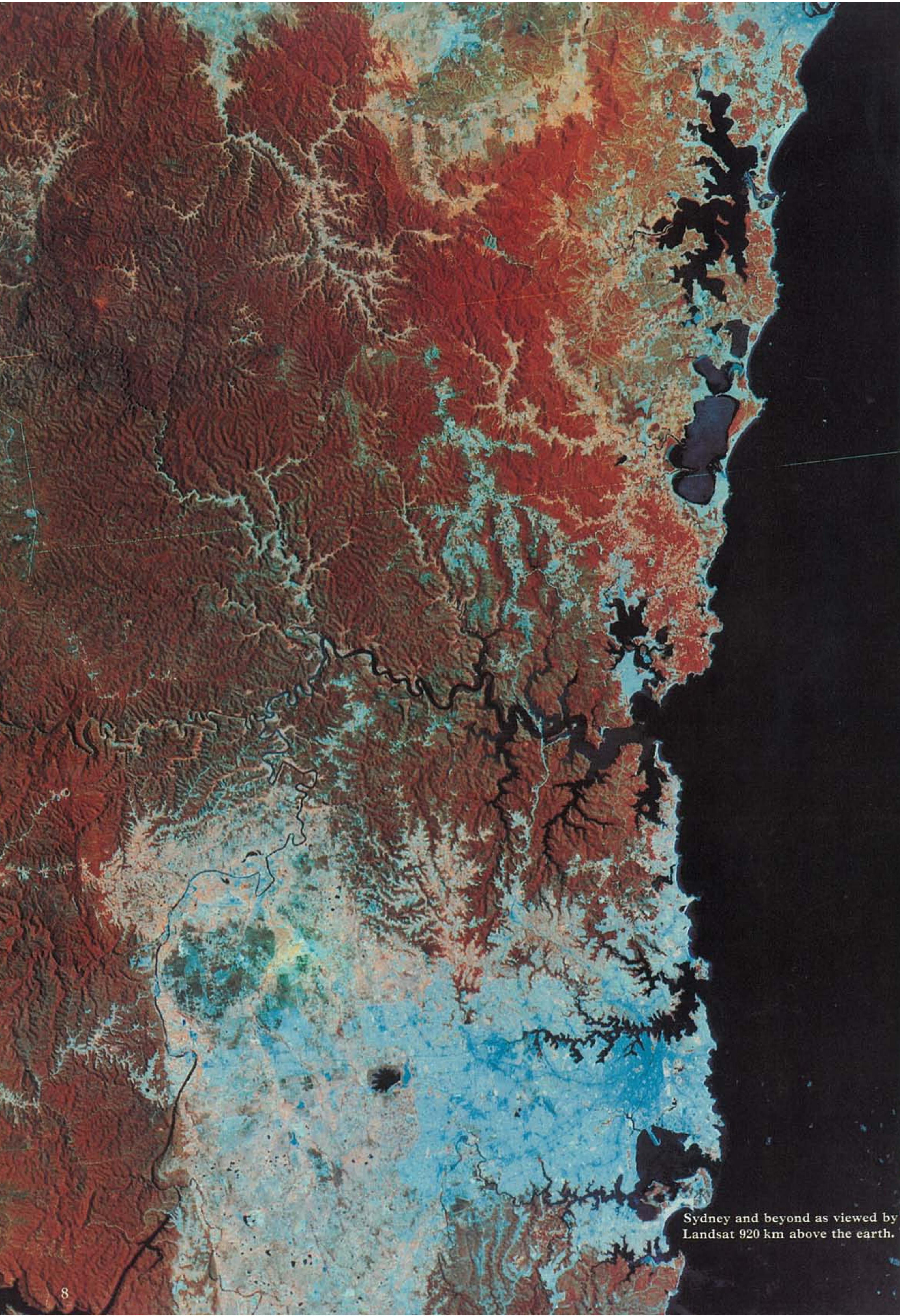
The difference in brightness between land and water as discerned by the satellite's 'infrared 2' sensor.

The radiation readings from this experiment were taken to the American study centre in Sioux Falls, where computer time was made available. The computer generated false-colour images—in which a special colour clearly defined the area under barley, for example, from those planted to most other crops.

This technique could enable the production from Australia's major grain crops to be determined by satellite measurement during the growing season. We would then get earlier and more accurate crop forecasts. The present forecasting technique uses area estimates prepared by people on the spot. As the yields from given soils under given weather conditions are fairly well known, the major variable is the area planted. Preliminary work suggests that the areas under wheat, for instance, can be readily determined from the satellite imagery, and furthermore that skilled interpreters may possibly be able to estimate crop quality as well.

The difficulty is that it is not known whether wheat has a common 'signature' in Australian Landsat imagery. The reflected radiation may vary from wheat type to wheat type and also from area to area.

The solution lies in training the computer to imitate human interpretation techniques. In each Landsat frame—



Sydney and beyond as viewed by Landsat 920 km above the earth.

Measuring radiation reflected from cropland in western New South Wales. Researchers armed with such 'ground truth' are better able to interpret Landsat imagery.

covering around 35 000 sq km—several known areas of wheat would be identified. The computer would be taught to recognize these areas and search the frame, pixel by pixel, for other areas with the same signature. The frame-by-frame maps would then be combined to produce estimates of total crop area.

Upon reflection

Reflection from the earth's surface varies from time to time, both during the day and seasonally, depending on the angle of the sun and also on the atmospheric conditions. Such variations can make interpretation difficult. In an attempt to measure them, CSIRO researchers from the Divisions of Mineral Physics and Entomology have positioned sensors with the same characteristics as those of Landsat above pastures and croplands in a number of areas. In one experiment, they found that the reflectance properties Landsat measured could yield information about grazing pressures and various types of pastoral practices.

Similar techniques are being used, in association with a research project of the University of Sydney, to determine the extent of the soybean rust disease, with promising results so far.

These particular projects suggest that, before the immense amount of data in each Landsat frame can be used, the physical conditions that determine reflectance must be thoroughly understood. However, it does seem possible that eventually tapes of satellite data transmissions may be used at fairly frequent intervals to yield accurate agricultural information that large-scale surveys now provide.

By disclosing the structure of the continent, Landsat imagery is also assisting in the location of possible areas of mineralization. Geologists have already located previously unknown fault structures. A study of faulting in the Sydney Basin is concentrating on features of possible significance in coal-mine development, among other things. One program of the CSIRO Division of Mineralogy in Perth is the search for distinctive areas of rock type in the Fortescue region of Western Australia that are associated with copper deposits.

Seasat coming up

While not being able to forecast the global fish crop, satellites have their uses at sea. The CSIRO Division of Fisheries and Oceanography has, for instance, successfully used facilities in the United States Nimbus-6 weather satellite to track buoys, about 5 m long, drifting in the currents and eddies off Western Australia. These buoys, powered by solar cells, transmit information about sea and water conditions. Although most buoys have been trapped in swirls close to the coast, one has crossed the Indian Ocean and is near Malagasy.

Preliminary work suggests that the areas under wheat, for instance, can be determined from the satellite imagery.

As Australia has no receiving station yet, it has had to depend on recorded information from America.

The Division is also using weekly temperature charts of oceans around Australia supplied from the United States through a satellite belonging to NOAA (National Oceanic and Atmospheric Agency). The eventual aim here is to locate cold upwellings of water that could indicate large amounts of plankton and consequent rich fisheries.

The Division, like other marine science organizations, hopes to make use of another satellite family, Seasat. In 1978, NASA plans to launch the first of a series of Seasats—intended, as the name suggests, primarily for ocean monitoring. These will orbit at a reduced height of about 700 km, and will have a sideways-looking radar that may have a resolution as small as 25 metres. Seasat will also have wave-height sensors, accurate to within centimetres, and improved temperature sensors as well. The Seasat is planned to give daily coverage of the earth's surface by about 1982.

When and where

One of the important considerations emerging from these widespread applications of satellite data—and more uses are likely to arise in future—is the frequency of sensing required.

Land-use applications, such as the ecological survey, probably need full satellite coverage only about every 10 years to measure, for instance, the spread of cities or the areas being converted to agricultural uses. Other but related uses may require much more frequent monitoring. For instance, wetlands would probably require comparisons between seasons as well as several measurements in a single year.

Crop forecasting too would require much more frequent imagery, varying with the progress of the crop itself. The two Landsats now in orbit produce information once every 9 days. This will become more frequent when Landsat-3 arrives.

There may also be occasions when

continued on page 11

Many countries, including Brazil and Italy, have set up their own receiving stations to collect and process data from Landsat-1 and Landsat-2. Iran and Zaire have proposals for stations intended to cover a large part of Africa and the whole of the Middle East. In fact, some 15 centres throughout the world are operational, or have been approved for construction, or are under consideration (see the map). Australia may well be the last continent to have a ground station.

Canada has recently installed a second station and is now considered comprehensively covered. The organization of the Canadian reception centre is often cited as a model for Australia: the federal government operates the station and its processing facility, and passes data to users in the provinces.

So far, Australia has relied for its Landsat imagery on recorded data—stored on tape by the satellite as it passes over the continent—and later relayed back to earth in the United States. If Australia wants access to up-to-date satellite imagery, it will need to operate its own ground station and collect and process its own data. The need is highlighted by the breakdown of tape-recording equipment on the Landsats, which means that priorities will have to be assigned as to who will get stored data.

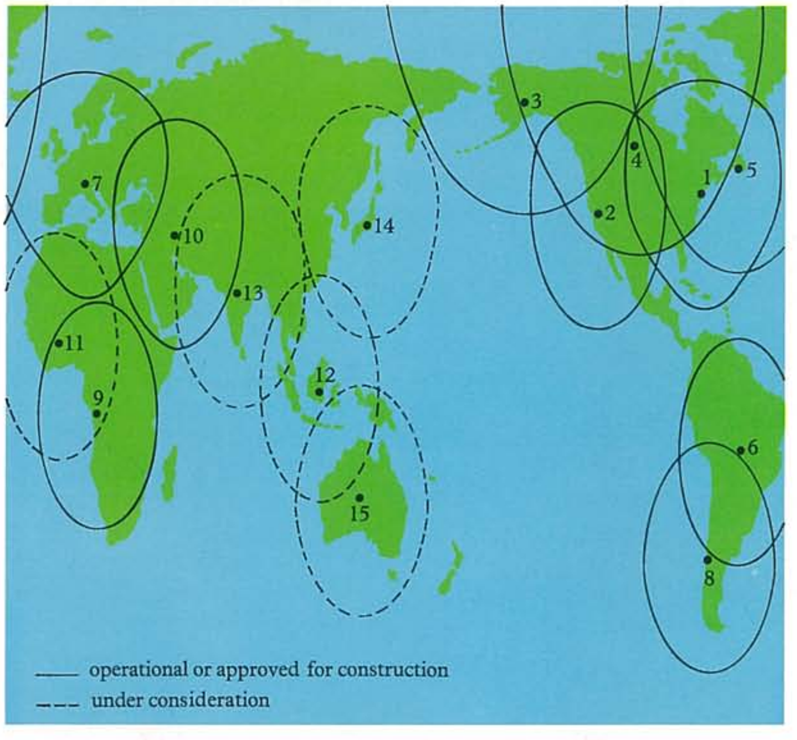
Given our own station, we would have access to much more information than we have obtained up to now. We would have the option of selecting the specific signals that interest us from the many that both satellites are sending out. And we would be able to organize and process the data in ways that suit our particular problems. For instance, if Australia uses Landsat imagery for crop monitoring and forecasting, it will need frequent coverage, at least during critical growing seasons. Similarly, this country is prone to disasters such as floods and bushfires. Measuring the impact of both of these is possible from the interpretation of satellite data.

Early in 1976, the Department of Science carried out a survey of potential users of Landsat imagery, as part of its job of identifying the need for Landsat ground facilities here. It found that the satellite's ability to view the earth's surface has a role in a multitude of practical tasks. Last year, the Minister for Science proposed that the Commonwealth government should establish facilities for receiving, processing, and analysing Landsat data. The proposal has been referred to the interim Australian Science and Technology Council to advise on its national significance and priority.

A ground receiving station should be able to cater for a circular area with a diameter of 5800 km—assuming no hills or other features hindered reception. A station located at Alice Springs would embrace Australia's entire land surface and also give coverage of the oceans surrounding it. The maps show the projected coverage of stations located at different sites.

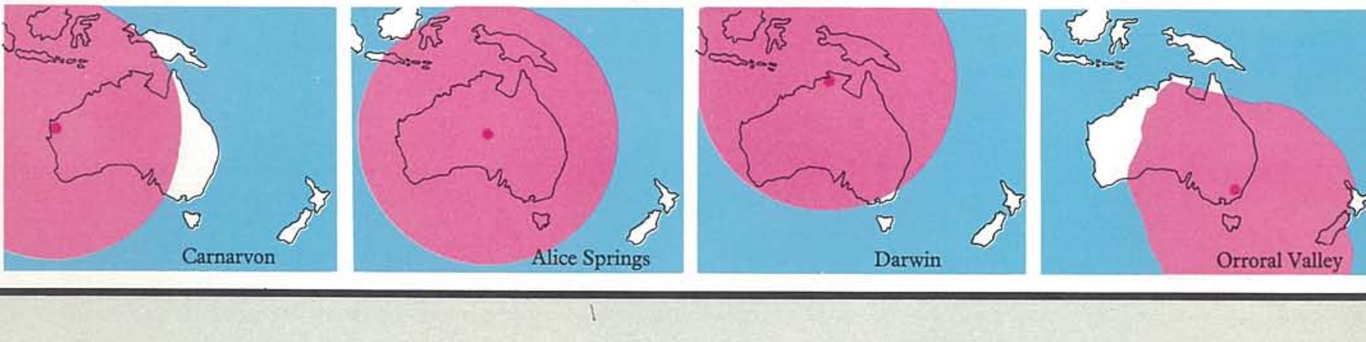
The acquisition, processing and distribution of data from the Landsat satellite and other remote sensing devices. K. Fuller. *New South Wales Science and Technology Seminar on Remote Sensing*, 1976.

World coverage by Landsat receiving stations



1. Goddard, U.S.A.
2. Goldstone, U.S.A.
3. Fairbanks, U.S.A.
4. Prince Albert, Canada
5. Shoe Cove, Canada
6. Cuiaba, Brazil
7. Fucino, Italy
8. Santiago, Chile
9. Kinshasa, Zaire
10. Tehran, Iran
11. Ouagadougou, Upper Volta
12. Balikpapan, Indonesia
13. India
14. Japan
15. Australia

Possible coverage of Australia from different Landsat receiving stations



'spot' imagery may be required, for instance in periods of national disaster. Fires and flooding may require pictures from every available pass, produced as quickly as possible. The ability of Nimbus satellites to spot developing cyclones is an instance of this need for rapid information. And the inclusion of heat sensors in Landsat-3 will allow some measurements, such as areas of flooding or fire burn, to be made at night.

If these satellite applications are to be a regular part of Australian economic and administrative planning, the requirement for methods of handling the data and for interpreting it, by either human or automated means, will expand enormously. This is the reasoning behind the suggestions (outlined in the box on page 10) to establish a satellite receiving station (or stations) in Australia and to set up a national body that will receive and distribute the satellite data.

The experience now gained in enhancing and interpreting Landsat information suggests that much wider use could be made of information from other satellites, such as the Nimbus weather-watchers and the forthcoming Seasats. The latter, with their finer resolution, could even permit the monitoring of shipping within Australian coastal waters.

Thus Landsat, having initially failed to live up to its early promise, has progressed beyond the stage of being only a research tool. Now, it seems, Australia and other developed countries will turn more and more to information being beamed down from sensors high above the earth's surface to manage and understand resources on the ground.

A Landsat picture of the Fortescue River region, W.A., enhanced to highlight certain brown geological patterns (lower centre). On pictures of the United States, similar markings were associated with useful copper deposits. ▶

More about the topic

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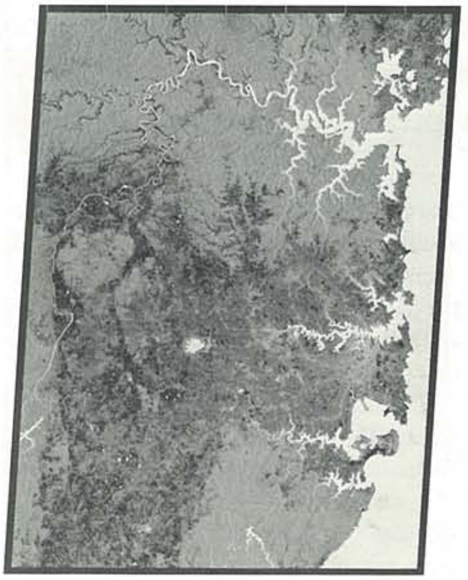

The Sydney region viewed through two different spectral bands. Left: as seen through Landsat's green band. Right: as shown by the 'infrared 2' band.