TITLE OF PAPER: The marine remote sensing experience of the Australian Surveying and Land Information Group.

AUTHORS: D.J. Gray, P.R. Holland and J. Manning
Australian Surveying and Land Information Group.

ADDRESS: Australian Surveying and Land Information Group, PO Box 2, Belconnen, ACT, 2616.
Telephone: (062) 527099
Facsimile: (062) 516735
Telex: AA 62230

BIOGRAPHICAL DETAILS:

Don Gray holds a Fellowship Diploma in Communications Engineering and served 15 years in the Technical Branch of the Royal Australian Air Force. From 1963 to 1978 he worked at various Australian tracking stations in support of the NASA space programs. Don has headed the Australian Centre for Remote Sensing (formerly the Australian Landsat Station) since its inception.

Peter Holland, B. Surv, Grad. Dip. Computing Studies, heads the remote sensing applications area of AUSLIG. He has been the project manager for a number of remote sensing projects, including satellite shallow water mapping in the Great Barrier Reef, Coral Sea, Timor Sea and Papua New Guinea. His work experience also includes system design and surveying in private industry.

John Manning, LS, M. Env. Sc, MBA, has been employed as a surveyor with the Commonwealth since 1966. In that time he has worked on a number of topographic mapping projects in Australia and Antarctica using aerial photography and space imagery. He is currently in charge of the Dandenong office of AUSLIG.

SYMPOSIUM ON REMOTE SENSING OF THE COASTAL ZONE, QUEENSLAND 1988

THE MARINE REMOTE SENSING EXPERIENCE OF THE AUSTRALIAN SURVEYING AND LAND INFORMATION GROUP

D.J. Gray, P.R. Holland and J. Manning

Australian Surveying and Land Information Group
P.O. Box 2, Belconnen, A.C.T., Australia. 2616
Telephone: (062) 527099
Facsimile: (062) 516735
Telex: AA62230

ABSTRACT

The Australian Surveying and Land Information Group (AUSLIG) is the organisation within the Commonwealth Department of Administrative Services responsible for the provision of surveying, mapping, geodetic, remote sensing and associated services. AUSLIG was formed by combining the former Australian Survey Office and Division of National Mapping. It continues to be involved in a number of satellite based marine remote sensing activities:

- reception, processing, archiving and distribution of Landsat MSS satellite data of the Australian continent and territorial waters by the Australian Centre for Remote Sensing (ACRES). ACRES is presently being upgraded to receive high resolution Landsat TM and SPOT data as well as data from experimental satellites such as European ERS-1 and Japanese MOS-1;

- enhanced and rectified satellite image mapping and geocoding of extensive areas of coast and offshore reefs for applications such as hydrographic charting, marine geoscience, marine park management and environmental monitoring. Depth of water penetration methodologies originally developed using Landsat MSS data have been applied to SPOT and Landsat TM data;

- 1:100 000 scale digital planimetric mapping of the Great Barrier Reef using space shuttle Large Format Camera and SPOT data.

This paper describes the current status of these activities within AUSLIG and plans for the future.

INTRODUCTION

The Australian Surveying and Land Information Group (AUSLIG) was formed in July 1987 by the merger of the former Australian Survey Office and Division of National Mapping, and includes the Australian Centre for Remote Sensing (ACRES). AUSLIG is a part of the Commonwealth Department of Administrative Services and is responsible for providing surveying, geodesy, remote sensing, mapping and land-related information services throughout Australia and its Territories to government agencies, policy makers and the private sector where appropriate.

AUSLIG, through ACRES, receives satellite imagery of Australia and nearby offshore areas at the Alice Springs antenna facility. The data are processed in Canberra into a range of products for distribution to customers.

Products and services provided by ACRES include:

- LANDSAT and SPOT satellite imagery -
  - Catalogues, microfiche and floppy disk
  - Computer compatible tapes (CCT)
  - Photographic products, colour and black and white

- Airborne scanned digital data from the United States/ Australian joint scanner project

- Photographic products from customer-supplied digital data.

AUSLIG also provides a remote sensing applications bureau service to clients who have responsibility for:

hydrographic charting;
environmental studies;
engineering site analyses;
military exercises;
national park management;
natural disasters management;
land degradation;
marine geoscience.

Bureau services include:

acquisition, enhancement and interpretation of satellite, aircraft and other data;

consultancy and advice on remote sensing matters;

project management;

specialised training;

client use of image processing facilities.

The following sections of this paper focus on the marine related remote sensing activities taking place in AUSLIG. These activities include:

- the current status and future plans of ACRES. ACRES is presently being upgraded to receive high resolution Landsat TM and SPOT data as well as data from experimental satellites such as European ERS-1 and Japanese MOS-1;

- enhanced and rectified satellite image mapping and geocoding of extensive areas of coast and offshore reefs for applications such as hydrographic charting, marine geoscience, marine park management and environmental monitoring. Depth of water penetration methodologies originally developed using Landsat MSS data have been applied to SPOT and Landsat TM data;

- 1:100 000 scale digital planimetric mapping of the Great Barrier Reef using space shuttle Large Format Camera and SPOT data.

AUSTRALIAN CENTRE FOR REMOTE SENSING

Australian users purchased LANDSAT imagery directly from the United States prior to the establishment of the Australian Landsat Station (ALS), now ACRES, facility. The ACRES ground station at Alice Springs allows data reception over the Australian continent, parts of Indonesia and Papua New Guinea, as well as marine areas 1000 km and more from the Australian coast.

Routine recording and archiving of the low resolution Landsat Multi-Spectral Scanner (MSS) data began in Australia in December 1979. This program is ongoing with a network of Australian Browse and Reference Centres assisting in the distribution of data. By arrangement with SPOT Image, SPOT data has also been distributed from late 1986.

In 1986 the Australian Government recognized the potential benefits to the Australian community of the Landsat Thematic Mapper and SPOT data by approving funding for an upgrade to the ACRES facilities to enable the direct reception and processing of this data. As part of the upgrade, the existing NOAA AVHRR reception capability will be enhanced to provide near real time support to the Bureau of Meteorology. A contract has been awarded to MacDonald Dettwiler Technologies Ltd of Canada for the major upgrade with the associated receiver and antenna work to be carried out under separate contracts with other suppliers. The upgrade will be completed in mid 1989.

The ACRES upgrade will provide a system which is, as near as possible, independent of particular satellites so that only relatively small expenditures are needed to receive and process data from new satellite sensors.

The higher resolution data will lead to an expansion of the ACRES product range. There will be 10 levels of processing divided into 3 main product groups:

- bulk-corrected products with optional radiometric corrections and across-track (i.e. along scan) geometric corrections of 'a priori' errors in instrument geometry, instrument performance and earth dependent distortions (e.g. earth rotation and panoramic distortion)

- geo-referenced products, radiometrically corrected, geometrically corrected along-track and across-track and re-sampled to standard map projections with precision Ground Control Point (GCP) correction optional

- geo-coded products which in addition to the geo-referenced corrections, have been rotated and aligned to standard map sheets and resampled to a standard rectangular pixel size and placed on a pre-determined map grid at multiples of 6.25 metre intervals to permit overlaying of various data sets at different resolutions.

In addition an interactive image analysis package will be used to generate customized products. This package processes imagery and generates products which may contain specific enhancements and/or specific feature(s) identification. Examples of these products are:

- image products at a user selected map scale;
- image products where specific feature(s) are highlighted or enhanced;
- products with overlaid graphics containing user selected annotation.

In the period before completion of the upgrade the joint ACRES/CSIRO Signal Processing Experiment is continuing, enabling the reception of Thematic Mapper data at the Alice Springs Data Acquisition Facility using hardware developed by the CSIRO Division of Radiophysics and the Division of Minerals and Mineralogy.

While only nominal processing of the experimental TM data can be undertaken it is providing a valuable archive and the Australian Mineral Industries Research Association (AMIRA) is distributing the data on computer compatible tape (CCT) at standard EOSAT prices under an agreement with ACRES.

The European ERS-1 satellite is planned for launch in May 1990. The objectives of the ERS-1 program concentrate on ocean related phenomena, aimed at increasing scientific knowledge of ocean parameters and bathymetric features, with the goal of improving forecasts of weather, sea-state and ice conditions. This will influence activities in fields such as offshore exploration, ship routing and fish resource management. A contract has been let by the Department of Industry, Technology & Commerce, to enable the ACRES receiving facility at Alice Springs to receive data from ERS-1, including the high-bit-rate data from the Synthetic Aperture Radar (SAR) instrument. A Memorandum of Understanding will be concluded between AUSLIG and ESA for access to the ERS-1 data.

From Australia's response to the ESA Announcement of Opportunity some 24 projects evaluating ERS-1 data have been provisionally accepted. This represents in excess of 10% of all provisionally accepted proposals indicating the importance Australia places on investigating the uses of ERS-1 data.

The Japanese MOS-1 satellite was successfully launched in February 1988. MOS-1 is intended to establish Japanese capability in earth observation satellites, primarily by observing oceanic phenomena such as ocean colour and temperature. The CSIRO Office of Space, Science and Applications (COSSA) has an arrangement with the Japanese Space Development Agency (NASDA) for the assessment of MOS-1 data by 15 accredited Australian researchers. Australian designed and produced reception and processing equipment was installed at the ACRES Alice Springs facility and the first images were received in April 1988 to test the equipment. Experimental quantities of MOS-1 data will be received during July-September 1988 and December-February 1988/89.

ACRES User Services

In the case of MSS data scene selection has been a relatively easy task and the Data and Image Catalogues produced by ACRES have been well received. With the addition of TM and especially SPOT, there is a big increase in the number of scenes available and the added complexity of varying viewing angles and instrument selection. In anticipation of this increase in size and complexity coupled with an expected widening user base an on-line catalogue system is to be implemented. Although still in the early design phase this system will allow remote access by users connected via AUSTPAC to the Catalogue Data Base. The existing data and image catalogues will continue for those not connected to AUSTPAC.

Over the past seven years of operation there have been occasions when high speed turnaround of cloud cover assessment and in some cases products has been required. These requests are generally associated with natural disasters. The capability of ACRES to meet these requests has been hampered by the physical separation of the acquisition facility at Alice Springs and the processing facility at Canberra with data being air freighted between the two sites. As a start to overcoming this problem a computer will be installed in the acquisition facility for the subscene sampling of data in real time and the transmission of this data to the processing facility via land line.

ENHANCED AND RECTIFIED SHALLOW WATER IMAGERY

The Barrier Reef image analysis (BRIAN) methodology and its application.

The BRIAN methodology is an approach to image interpretation which has been realised as a mini and micro computer based set of interactive programs developed at the CSIRO Division of Water Resources. The methodology was developed in response to the needs for very large area remote sensing by Landsat. These needs arose specifically during a project entitled 'Remote Sensing by Landsat as an Aid to Management of the Great Barrier

Reef'. This was a collaborative project between CSIRO, AUSLIG, James Cook University and The Great Barrier Reef Marine Park Authority. The BRIAN methodology and its operational use have been reported by CSIRO in Jupp and others, 1985a and 1985b.

AUSLIG has undertaken, on behalf of Commonwealth agencies, an extensive program of mapping around Australia with the BRIAN methodology for the most part using Landsat MSS source data (see figure 1). The standard mapping products from this program consist of rectified satellite images at various map scales and highlighting different themes such as approximate bathymetry, reef environmental parameters such as exposure to weather, and reef geomorphology and cover zones. Images have been rectified and registered to a standard map projection wherever possible. These products are known as raw data, depth of penetration, exposure and classified images (Jupp and others, 1985c, Wedderburn-Bisshop and others, 1985).

The raw data image is an enhanced false colour composite of three bands of satellite data and highlights reef shape and position.

The depth of penetration image is an approximate bathymetric image describing 5 zones of water depth down to a maximum depth of approximately 15 metres for Landsat MSS data.

The exposure image is an approximate sea floor elevation model and provides a dramatic enhancement of reef morphology in the same way that relief shading helps in geomorphological mapping on land.

The classified image indicates a combination of depth and the composition of the reef cover. At the most general level composition may be reduced to cover by coral, coralline algae and sand. These have been produced as preliminary products for further detailed study by reef scientists.

These products are used in a broad range of application areas. The Great Barrier Reef Marine Park Authority applies the products for park planning and management. The Royal Australian Navy Hydrographic Service is using rectified Landsat imagery in the planning and preparation of new hydrographic charts of Australasian waters. The Australian National Parks and Wildlife Service has derived reef habitat classifications from Landsat data and underwater surveys over the remote National Nature Reserves in the Timor and Coral Sea (Guerin, 1985). The satellite imagery provides assistance in the identification of major habitat zones, for planning surveys and for drafting and implementation of management plans (Ivanovici, 1984). The Bureau of Mineral Resources (BMR) Division of Marine Geosciences and Petroleum Geology has employed enhanced Landsat imagery in major research projects over the continental margins of north eastern and western Australia. The imagery was used during planning to identify passages in the Great Barrier Reef and in the reefs of the Queensland plateau through which seismic vessels would need to pass while towing underwater equipment. The imagery was also used to identify suitable sites for geological sampling. AUSLIG has used rectified satellite imagery of the Great Barrier Reef to assist in the planning and

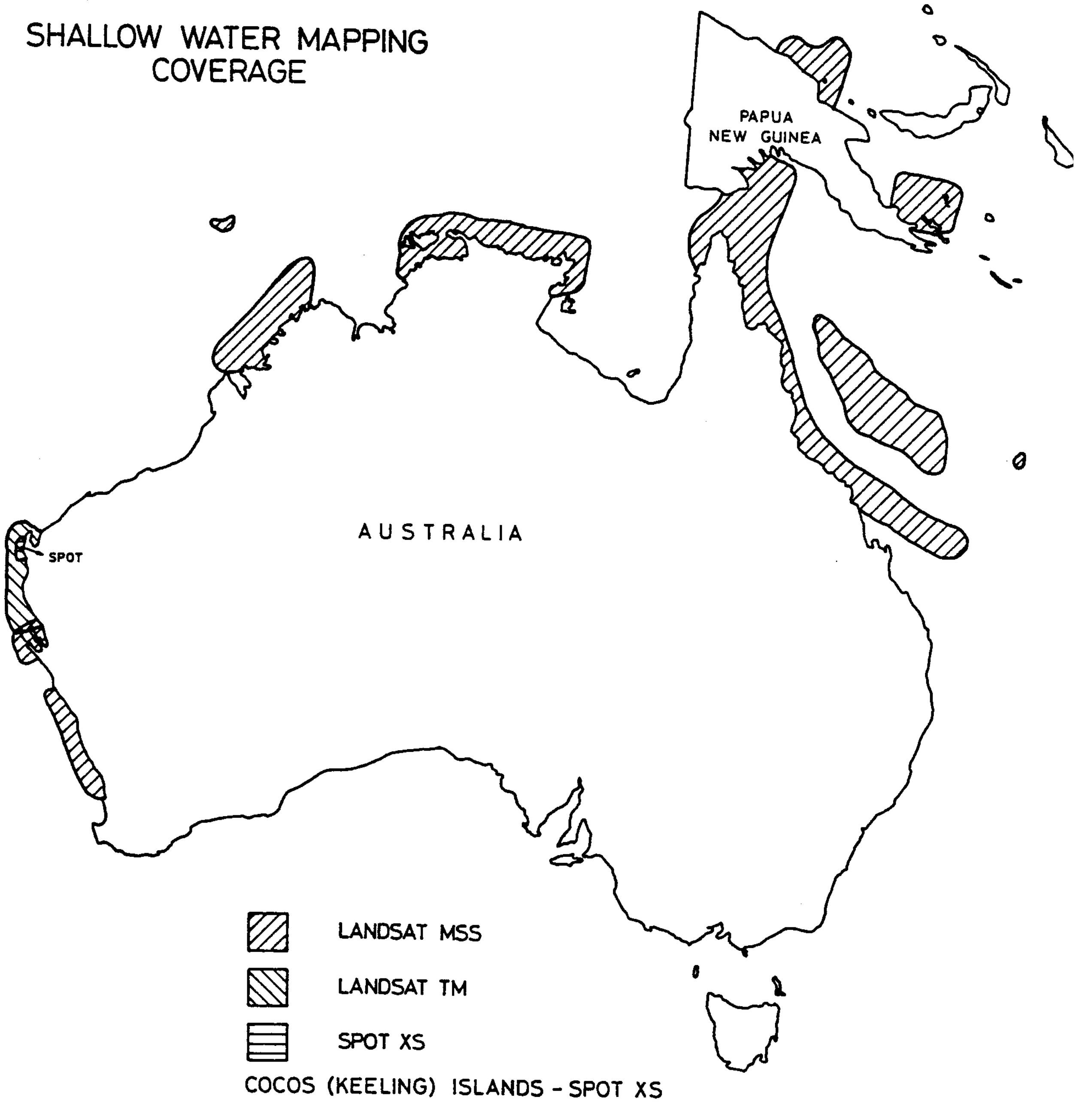
SHALLOW WATER MAPPING
COVERAGE
PAPUA
NEW GUINEA
AUSTRALIA
SPOT
LANDSAT MSS
LANDSAT TM
SPOT XS
COCOS (KEELING) ISLANDS - SPOT XS

FIGURE 1

execution of the bathymetric survey of Australia. Shallow water satellite imagery has also been produced by AUSLIG in co-operative projects in Papua New Guinea, Indonesia and Fiji.

Depth of penetration mapping using Landsat TM and SPOT data

AUSLIG has undertaken BRIAN depth of penetration image mapping with Landsat TM and SPOT XS data. This approach has been tested at Ningaloo Reef and Shark Bay in Western Australia, and Cocos (Keeling) Islands in the Indian Ocean. A summary of the test results appears in table 1.

Table 1

BRIAN depth of penetration mapping using Landsat TM and SPOT XS data

% of test points no greater than 1 metre outside correct depth zone

Depth Zone (m)	SPOT XS (bands 1,2,3) Ningaloo	SPOT XS (bands 1,2,3) Cocos	Landsat TM (bands 1,2,3,5) Ningaloo/Shark Bay	Landsat TM (bands 2,3,4,5) Ningaloo/Shark Bay
0- 0.5	0%	N/A	N/A	0%
0.5- 2.5	72%	59%	N/A	88%
2.5- 5	91%	72%	N/A	92%
0 - 5	N/A	N/A	100%	N/A
5 -10	78%	85%	72%	83%
10 -15	34%	85%	73%	78%
15 -20	N/A	N/A	80%	N/A
20 -25	N/A	N/A	49%	N/A

In summary, these results indicate that the BRIAN depth of penetration approach to approximate water depth mapping can be successfully applied using Landsat TM and SPOT XS data. Loss of accuracy may be encountered in shallow and deep water. Landsat TM band 1 allowed acceptable mapping to 20 metres depth and was able to detect the seabed between 20 and 25 metres depth. As has been previously reported the accuracy of this type of mapping is dependent upon the nature of the seabed (topography/cover), water quality (surface conditions, turbidity, suspended sediment) and atmospheric conditions at the time of the satellite overpass.

Calibrated water depth mapping using known depth data

AUSLIG is investigating several techniques of absolute water depth mapping from satellite data. One of these techniques is provided by the microBRIAN system (Mayo and others, 1987). MicroBRIAN is a commercial implementation of the BRIAN methodology on an IBM AT compatible microcomputer using high resolution graphics hardware. MicroBRIAN provides the capability for shallow water image mapping as well as other land resource management applications. MicroBRIAN improves on the approximate depth of penetration mapping approach by allowing the fitting of exponential models to known depth and channel data. This approach is described in the user manual, MPA (1988).

An alternative technique is provided by the DIPIX Aries III image processing system. The technique is based on the approach of the Defence Mapping Agency and described in Doak and others, (1980). A water depth model is generated by a multiple regression solution of the formula:

$$Z = \frac{-1}{2(k_i - k_j)} \ln \left(\frac{(\text{Band}_j - V_{sj}) \times V_{oi}}{(\text{Band}_i - V_{si}) \times V_{oj}} \right)$$

Where Z = known depth
k_i = water attenuation co-efficient for band i
V_{si} = deep water signal for band i
V_{oi} = limiting signal as depth approaches zero

Seabed cover mapping from digitised aerial photography

A pilot study was undertaken by AUSLIG to evaluate the utility of remote sensing technology in mapping seagrass beds in shallow coastal waters at Dongara in Western Australia. Colour aerial photography at 1:5 000 scale had been acquired bi-annually for 7 years over 2 study sites to monitor change in areal extent of seagrass beds. Initially the extent of seagrass was determined manually by tracing the area from enlarged photographs onto squared paper and counting squares.

As an alternative procedure the photography was converted to a 3 band digital image using a digital scanning camera and colour filters. A multispectral classification was used to group cover types and produce a thematic image showing seagrass, sand and detritus. The statistics on areas, which are automatically available from the image classification process, showed very good agreement with those obtained by visual interpretation and manual counting of squares.

Further evaluation of this technique is being undertaken with a project to map seagrass at Albany W.A.

Marine remote sensing and geographical information systems

Several Commonwealth agencies, such as the Great Barrier Reef Marine Park Authority, Royal Australian Navy Hydrographic Service and the Australian National Parks and Wildlife Service, are developing computer based spatial information systems to improve data management and decision making within their marine areas of responsibility.

By holding the source data in a computer database such as a GIS a number of problems can be overcome - the data are held in a centralised form and can be readily updated and modified; they may be interrogated graphically without the need for hard copy; the data may be manipulated (overlays, thematic matching/comparison) and linked to non-spatial attribute data; and, the data may be readily output at the desired scale.

Satellite remote sensing data are an important layer of information within such information systems. The shallow water mapping output which has traditionally been produced by AUSLIG in hard copy form for these agencies is now also being requested in digital form suitable for direct input to a GIS. As an example, work is presently underway to georeference all AUSLIG depth of penetration data sets over the Great Barrier Reef.

As a further development of this activity AUSLIG is investigating problems associated with georeferencing, scene mosaicing, integration of multisource and multitemporal data, database update, data formatting, data exchange and data standards.

GREAT BARRIER REEF MAPPING FROM SPACE PHOTOGRAPHY

Background

The detailed and accurate mapping of the vast stretches of the Great Barrier Reef have traditionally presented a technological problem to the map maker since the times of James Cook and Mathew Flinders. This problem persisted into the late 1960s when aerodist control networks were cantilevered out from the Queensland coast to establish the first set of homogeneous ground control of the outlying islands and reefs. A miscellany of isolated aerial photography has since been flown but any homogeneous aerotriangulation of the area presented significant photogrammetric problems with the need to bridge between widely spaced ground control and the impossibility of selecting pass points on photography over featureless ocean expanses.

Large Format Camera photography

The technical problem of controlling photogrammetric images over the GBR was included in the European Space Agency metric camera space project but no imagery of Australia was obtained when the metric camera was flown on Shuttle Flight STS-9 in 1983. Success with photography from an aerial camera on a manned space flight was, however, achieved when high resolution large format camera (LFC) photography was taken on board shuttle flight STS-41G, over the Queensland coastal strip in October 1984. The orbits flown covered about 80% of the inner and outer reefs but unfortunately the northern areas contained an increasing amount of cloud. The photography of Torres Strait, between Thursday Island and New Guinea contained almost full cloud cover and of consequence were of little use to the map maker.

The areas of cloud free LFC imagery however provided an excellent medium for economically extending the 1:100 000 National Series topographic mapping of the continent over much of the Great Barrier Reef. The large areas covered by each stereo model provide a stable geometric medium for detailed plotting at 1:100 000 map scale.

The LFC coverage in this area was on colour 2445 film and forward motion compensation was employed to overcome image motion. The operational photographic resolution obtained by the LFC depends on the film used and the contrast of the ground target but a minimum resolvable target of 10 metres reported by LFC users was confirmed empirically on photographs taken along the Queensland coast. A worst resolution of 50 LP/mm in the corners of the format was used as a design criteria (Doyle 1979). Calibration for the LFC system was carried out by NOAA using the Stellar method as in Fritz and Schmid (1974).

Aerotriangulation of LFC data

To provide a homogeneous base for detail stereoplotting of the GBR the relevant LFC frames were linked together in an aerotriangulation controlled by the very sparse Aerodist control points and more recent Doppler satellite position fixes where they could be readily identified and transferred. Very little redundant control was available but, as others such as Newton (1986), Jacobsen (1986) and Geirloff-Emden (1986) have found, the accuracy of the aerotriangulation result using LFC depends largely on the selection and quality of transfer of control points, rather than a large number of control points.

For adjustment of LFC imagery the geocentric co-ordinate system was adapted into a local vertical system. The computation was carried out in an orthogonal co-ordinate system (Jacobsen 1986) of a plane, tangential to the ellipsoid. It was found that this secant plane co-ordinate system provided a more accurate approach for earth curvature over large areas than applying the usual formulae.

Due to pressing user requirement from GBRMPA it was decided to carry out aerotriangulation in three sub sections each with a north/south latitudinal band of five degrees and a longitudinal band of six degrees east/west. Each sub section spanned one or more AMG zones and a secant plane co-ordinate system was adopted for each section.

Control extension was carried out using the Modblock independent models adjustment program. Sub-block 1 was adjusted in June 1987 and trial results were checked by the Bundle adjustment program RAY, and by PATM43 in conjunction with the University of New South Wales. These check methods generally confirmed the Modblock results and showed that an improved result was obtainable using the secant plane control approach.

To date adjustments of two of the three planned sub blocks have been undertaken.

The residuals on control points on Orbit 93 (colour photography frames) were larger than those on Orbit 77 (black and white frames). Possible reasons were:

- Poorer resolution (20 metres c.f. 10 metres)
- Poorer control identification
- Residual effects of increased film distortion.

The results of both sub blocks indicate that a general planimetric accuracy of 20-25 metres (rmse) could be attained. This is larger than the 15-20 metres accuracy reported by Derenyi and Newton (1987) and is likely to be due to the uncertainty of control identification and transfer to LFC imagery, especially for coastal control points on terrain with significant relief. These control points showed much poorer residuals than those on reefs or on flat ground.

Detail stereoplotting

A 7.5 times LFC enlargement.(1:100 000 scale) of each model area was annotated to serve as a plotting interpretation guide. The following zonal reef classifications were marked up on the enlargements to assist direct plotting from LFC models.

- Islands, dry land above HWM, coastline, rocks
- Sand cays
- Reef platform edges
- Submerged reef platforms
- Approximate shoal edges

The sources used for the photo interpretation guide for sub block 1 included:

- Gulf Oil aerial photography (B&W 1:60 000 1964)
- Isolated project colour photography flown at various scales
- Available hydrographic charts
- Australian Pilot.

Stereodigitising of reef detail followed using secant plane model control for photogrammetric set up to minimise transformation errors. Feature coded digital data were then produced in this system. An average of one model was digitised per day using a BC1 analytical plotter. Verification plots at 1:250 000 were plotted and all digital data files were then transformed from the secant plane system to the appropriate AMG zone co-ordinates.

The results from the large LFC model provide more accurate and uniform data than the isolated and piecemeal methods previously used to compile the offshore island maps off the Queensland coast. The LFC digital data produced has also identified some accuracy shortcomings with existing topographic maps.

The positioning of the inner reef features Carlisle Island and Brampton Island were found to have gross errors of some 300-400 metres, having been incorrectly positioned by less rigourous photogrammetric techniques from jet aircraft photography.

The areas not covered by imagery on flight STS41-G were programmed for more LFC photography in May 1986 on a second space flight shuttle mission with this camera. But due to technical and logistic problems encountered with the shuttle program in 1986 it is now problematical whether the LFC will be used in space again.

In February 1986 the first of the SPOT series of satellites was successfully launched and imagery from this satellite is being used to supplement cloud covered areas of LFC imagery. It is also planned to extend SPOT imagery cover over the GBR and then to the isolated reefs and islands of the Coral Sea. Both panchromatic (10 metre pixels) and multi spectral (20 metre pixel) imagery is being used. Pending the build up of an archive of stereoscopic imagery and the development of software to provide an aerotriangulation like network of this imagery, level 1B imagery is being used to position detail from photographic products. This SPOT imagery is being integrated to LFC aerotriangulation control and fitted to any existing ground control. Digitizing is being undertaken on Altek digitizing tables and the first composite 1:100 000 map sheet (9056) has been digitally compiled using both LFC and SPOT (1B) imagery. Agreement between LFC and SPOT derived mapping is generally good positionally, however interpretation has been found to be better using LFC. Direct digital image analysis would however improve the result.

Future space photography

Further Large Format Camera space photography by NASA is unlikely due to the high cost of maintaining the system and recent program setbacks with the space shuttle program.

Russian space photography now has a composite coverage of about 90% of the Australian continent. This has been built up over a number of years from photography taken on the manned SOYUZ series of satellites since 1975. Coverage of the Great Barrier Reef is not yet available but future coverage with the KFA-1000 high resolution camera (format 30 x 30cm, scale 1:200 000) with colour film is possible as special client programs are being considered.

The acquisition of any optical imagery over the Barrier Reef however is inhibited by persistent cloud cover over reef areas and at present only a small coverage of SPOT 10 metre panchromatic and 20 metre resolution multispectral imagery is available.

The current upgrade of the ACRES space data receiving station will make it much easier to acquire SPOT, TM, MOS 1 data and other marine orientated space imagery. Information from microwave sensors on satellite platforms such as ERS 1 will enable cloud penetration resulting in improved data acquisition over cloudy areas of reefs or offshore islands.

To maximise the use of digital data from different sensors, integration by geocoding techniques of SPOT, TM and radar imagery will be necessary. Additionally the geometric fit to aerotriangulated LFC, stereoscopic SPOT or Russian KFA 1000 imagery will be desirable to link all data to ground control in a homogeneous network.

CONCLUSION

Remote sensing will play a key role in the future mapping and management of Australian continental and marine resources. The ACRES upgrade is designed to support the needs of the Australian remote sensing user community toward the turn of the century. It will provide a comprehensive, flexible and versatile system allowing reception of future satellite data with minimal modification. The new ACRES product range is clearly focussed on user needs, particularly the need to readily merge remote sensing and other data sets. AUSLIG's remote sensing bureau services will continue to provide cost effective solutions to Commonwealth programs. There will be a strong emphasis on the integration of remote sensing, GIS and digital mapping technologies for problem solution, and a continuing involvement in marine applications using new generation aircraft and satellite data sources. Remote sensing techniques will become an integral part of the efficient and effective revision of the National Topographic Map Series at 1:100 000 and 1:250 000 scale.

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