100 Years of National Topographical Mapping

Imagery for Mapping Australia

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Abstract

This paper reviews the transition from aerial photography to remotely sensed satellite imagery for topographic and other mapping in Australia from the post-war years until the early 2000's. This period saw the completion of the 1:100,000 and 1:250,000 scale topographic mapping series and the on-going revision program. This was facilitated by the development of digital image processing and the requirements of emerging Geographic Information Systems.

Introduction

Aerial photography was flown during World War 1 mainly for reconnaissance and between the World Wars for the Australian Army's topographic mapping program with systematic coverage for mapping evolving during World War 2. From the late 1940's the RAAF, private contractors and a number of Commonwealth and State agencies flew photography at various scales for their larger scale mapping programs and for specific projects.

With the advent of manned spacecraft in the 1960's small scale film photography of the earth captured the imagination of the public. The agencies concerned with monitoring weather systems, the oceans, land use and the environment also saw its potential. From the 1970's the USSR and the USA and from the 1980's other nations developed unmanned polar orbiting satellites with sensors designed to acquire multispectral digital imagery for various purposes including mapping.

Driven by defence and civilian imperatives and enabled by technology advances, today's powerful instruments and data processing capabilities, satellite sensed data are mainstream for many applications including topographic mapping.

Royal Australian Air Force (RAAF)

Following the Australian forces use of photography in WW1 and for various programs between the wars the No 1 Photographic Reconnaissance RAAF unit, later the 87 (Survey) Squadron operated in Australia from June 1942. The Squadron ceased operations in 1953 as the Government had determined that the Commonwealth's aerial photography needs would be met by the private sector. From 1973 to 1983 the RAAF acquired photography for Army's mapping needs using Canberra bombers and other aircraft.

Government mapping agencies

The National Mapping Section (later Office) was established in 1947 within the Department of Interior which also housed the Property and Survey Branch, which was later renamed as the Australian Survey Office (ASO). The National Mapping Office was transferred to the Department of National Development in 1956 with responsibility for the Commonwealth's topographic mapping programs. The 1956/57 budget for the National Mapping Office totalled 279,000 pounds of which 120,000 pounds (43%), was for aerial photography. Payments to the States for mapping were 15,000 pounds (Lines 1992).

The 1:250,000 and 1:100,000 scale mapping was shared between the Royal Australian Survey Corps (RASC) and National Mapping. The State Lands' Departments in some instances contributed to the program but were mainly concerned with larger scale mapping. Some of the States eventually acquired their own aerial photography capability.

From the 1950's the Commonwealth funded private sector contractors to fly photography and loaned them aerial cameras in some instances. The Wild RC9 and RC10 cameras, usually with a Super Wide Angle Lens, enabled 1:80,000 scale photography from a flying height of 25,000 feet. Prominent amongst the early aerial photography contractors was ADASTRA. Others included Australian Aerial Mapping, QASCO, Associated Surveys and Photomappers. From the late 1970's National Mapping chartered a Learjet and other aircraft until purchasing and crewing a Cessna 421 in 1982, with the last systematic mapping photography flown in 1990.

National Mapping increasingly utilised private sector contractors for aerotriangulation and map compilation until the 1980's. National Mapping quality checked the contractors' work and maintained an in-house capability.

Satellite based imagery

The USSR and the USA used non-metric cameras for photography from their various spacecraft during the 1970's including over large areas of Australia. The USA's SKYLAB station in 1973 carried a range of sensors including a film camera as part of the Earth Resources Experimental Package (EREP). A United Nations workshop in 1971 predicted that "the direct copies of SKYLAB photography will permit production of small scale (probably 1:250,000 scale) planimetric maps from familiar materials and by methods that are already established" (UN 1971).

The National Aeronautics and Space Administration (NASA) launched the Earth Resources Technology Satellite (ERTS 1 later renamed as LANDSAT 1), near- polar orbiting satellite in 1972 with 251 orbits achieving complete coverage of the Earth in 18 days. The on-board MultiSpectral Scanner (MSS) and Return Beam Video (RBV) instruments acquired colour infrared imagery. The RBV consisted of three television-type cameras aligned to view the same 185 x 185km scene through different colour filters, with images taken every 25 seconds resulting in a 10% north/south overlap and an 80 metre resolution. The MSS had two spectral bands in the red and green visible spectrum and two in the infra-red spectrum and continually scanned the earth in a 185km swath at right-angles to the satellite track with a nominal resolution of 80 metres.

In 1973 Dr Lambert the Director of National Mapping commented that while "in areas of sharp contrast the imagery is surprisingly good ……. in view of the advanced status of the present program it was unlikely that ERTS will be used to any great extent in the topographic mapping of Australia" (Lambert 1973). Dr Lambert went on to say "both the ERTS and SKYLAB / EREP are tremendous concepts ..... for the efficient assessment and management of the earth's resources".

By 1985 satellite imagery's potential as a primary data for Australian mapping was recognised with a National Mapping paper reporting in 1985 on resolutions (pixel sizes) to achieve various mapping scales (Veenstra et al 1985).

Initially LANDSAT tape recorded data was down-linked as it orbited within range of the three United States ground stations in Alaska, Maryland and California and later via the USA's Tracking and Data Relay Satellites (TDRSS). The satellite was controlled from Goldstone, California via NASA's Space Tracking Network which included the Tidbinbilla station outside Canberra. Over subsequent years imagery was received by a network of global ground stations that had negotiated a Memorandum of Understanding, initially with NASA and later with the National Oceanic and Atmospheric Administration (NOAA), paying significant access fees and royalties on distributed image products.

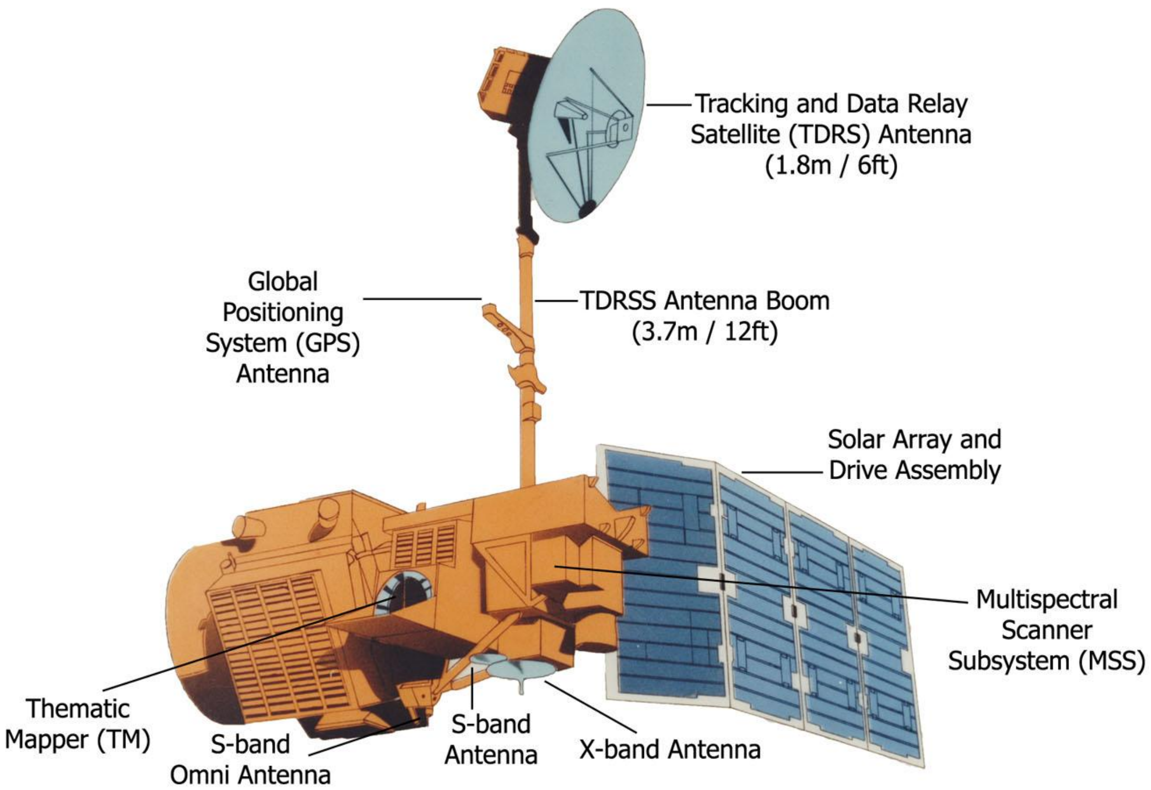


Figure 1: LANDSAT 4 schematic.

LANDSAT 1 (1972-1978) followed by LANDSAT 2 (1975-1982) and LANDSAT 3 (1978-1983) all carried similar instruments. LANDSAT 4 (refer Figure 1) was launched in 1982 but due to system failures was replaced by LANDSAT 5 in 1984. Both satellites were equipped with the MSS sensor for data continuity but also carried the Thematic Mapper (TM) sensor with a 30 metre panchromatic band. LANDSAT 6 failed during launch in 1993, and LANDSAT 7 with spectral bands and an enhanced 15 metre panchromatic band was launched in 1999.

Australian involvement

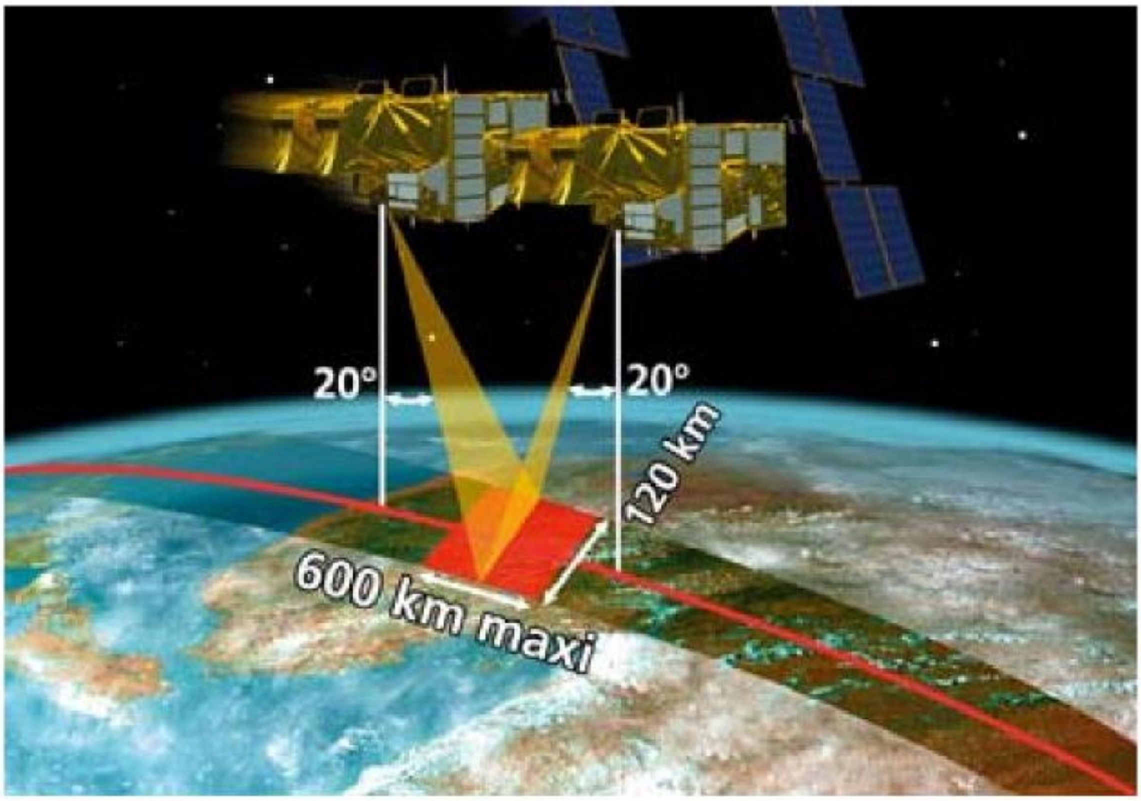
Under NASA's Investigator Program's initiative the Commonwealth set-up in 1971 the Australian Committee for the Earth Resources Technology Satellite (ACERTS), comprising over fifty researchers from the public and private sectors, to receive LANDSAT 1 film products. The enthusiasm from researchers especially from the agricultural and geological communities was pivotal in the subsequent funding of the ALS. For example the Bureau of Mineral Resources (BMR) had previously viewed hand held photography, taken by astronauts on the Gemini mission in 1965, which had included the Gosses Bluff feature west of Alice Springs and was aware of LANDSAT's potential (Rayner 2002).

After Cabinet Submissions in 1976 and 1977 the Commonwealth approved in 1977/78 funding for the Australian Landsat Station (ALS) within the Department of Science and Technology which was responsible to NASA for the Tidbinbilla station. Tidbinbilla operated under a private sector contract and the Commonwealth specified that the ALS be similarly operated.

Figure 2: Australian Landsat Station (ALS) just after construction.

The ALS at Alice Springs became operational in 1979. Refer figure 2. The Alice Springs antenna's field of view included the Australian continent, Papua New Guinea and part of the eastern Indonesian archipelago. Product catalogues were to be maintained in each State and Territory and the Lands Departments were subsequently selected as the appropriate agencies.

The Australian Liaison Committee on Remote Sensing by Satellite (ALCORSS) and the Commonwealth Users Committee on Remote Sensing (CUCRS) were formed in 1979 with Commonwealth Secretariats, to provide advice and feedback to Government on the ALS operations.



Oblique viewing: stereoscopy and accessibility

Figure 3: SPOT schematic.

The ALS was transferred in 1984 to National Mapping within the Department of Resources and Energy. The ALS was by then receiving data from the newer LANDSAT 2 and 3 satellites but was not equipped for the X-Band transmissions from the higher resolution Thematic Mapper (TM) sensors on LANDSAT 4 and 5. Pending government approval of funding for an ALS upgrade, the Commonwealth Scientific and Industrial Research Organization (CSIRO) with financial support from the Australian Minerals Research Association (AMIRA) devised the Signal Processing Experiment (SPE). This system provided interim products to the participating mining companies generated from TM data received at the Alice Springs ground station. The ALS distributed products to other users.

The ALS was renamed in 1986/87, the Australian Centre for Remote Sensing (ACRES) as part of the budget decision to upgrade the ALS for the reception and processing of LANDSAT TM data and from the newly launched French Systeme Pour l'Observation de la Terre (SPOT) satellite. Refer Figure 3. This upgrade was completed in 1989 (Friedel & McMaster 1989). Subsequent upgrades enabled reception and processing of data from the later LANDSAT and SPOT satellites to maintain continuity for mapping and other client applications. Other satellites accessed included the Japanese Marine Observation Satellite (MOS 1), the European Space Agency's, European Remote-sensing Satellite (ERS 1&2 using radar), the Japanese Earth Remote-sensing Satellite (JERS 1 using radar), the USA's Moderate Resolution Imaging Spectroradiometer (MODIS), the Japanese Advanced Land Observing Satellite (ALOS), the Canadian's RADARSAT 1&2, and in 2008 from the Indian Resource Satellite (IRS 1).

In 1996 the Tasmanian Earth Resources Satellite Station (TERSS) established through a joint project between the Australian Surveying and Land Information Group (AUSLIG), CSIRO, the Australian Bureau of Meteorology, University of Tasmania and the Antarctic Division, enabled reception of LANDSAT and SPOT data at a new antenna outside Hobart. This extended Australian coverage south and east including most of New Zealand and provided a partial overlap with the Alice Springs ground station's coverage. New Zealand was an early beneficiary acquiring SPOT imagery via an innovative delivery system through an agreement between Spot Imaging Services in Sydney and Terralink NZ.

AUSLIG was formed in 1987 with the merger of National Mapping and the Australian Survey Office and in 2001 became part of Geoscience Australia (GA). ACRES was in GA's Remote Sensing Group (renamed in 2009 as the National Earth Observation Group), with a continuing role of supplying data to GA's mapping programme and to other government agencies and the private sector.

Satellite imagery in mapping Australia

1:1 million scale mapping

National Mapping was responsible for the production and revision of the World Aeronautical Charts (WACS) for aviation and the International Maps of the World (IMWS) both at 1:1 million scale. The topographic base map for the 43 charts covering Australia were normally revised every 1, 2 or 3 years depending on the amount of change and as a derivative product, relied on the progress of the 1:100,000 and 1:250,000 scale mapping programs.

To meet the 1:1 million scale revision cycles National Mapping investigated in 1982 the use of LANDSAT MSS imagery especially in remote areas. While few point changes were detectable in the study area over the central Queensland area, the infrastructure associated with coal mining activity was readily identifiable on the LANDSAT film products and able to be plotted with sufficient accuracy. Map detail was augmented using other published information and by verification in the field by observation from light aircraft. By 1984, 16 of the 43 1:1 million scale maps covering Australia had been revised (Payne and Lawler 1984).

Great Barrier Reef Mapping

Large Format Camera

The Large Format Camera (LFC) was flown on NASA’s Challenger Shuttle in 1984 with two orbits acquiring overlapping images across central Australia and the Queensland coast including over parts of the Great Barrier Reef (GBR). Following a joint study by the University of NSW and National Mapping over a test area in Western Australia it was resolved that planimetric accuracies suitable for 1:100,000 scale mapping could be achieved. The shuttle’s altitude of 235 to 300km with the LFC’s focal length of 306mm and film format of 23cm by 46cm with resultant scales of around 1:750,000 made it difficult to identify control points and point features in areas of poor contrast.

National Mapping used the LFC imagery to update and extend the 1:100,000 scale mapping of parts of the GBR for the Great Barrier Reef Marine Park Authority (GBRMPA). Due to the large areal coverage of an LFC stereo-model and better feature contrast, bridging enabled the relatively sparse ground control points to be used. Positional inaccuracies of 300 to 400 metres were found on the existing 1:100,000 scale maps including on the relatively close in-shore Brampton and Carlisle Islands (Manning 1987).

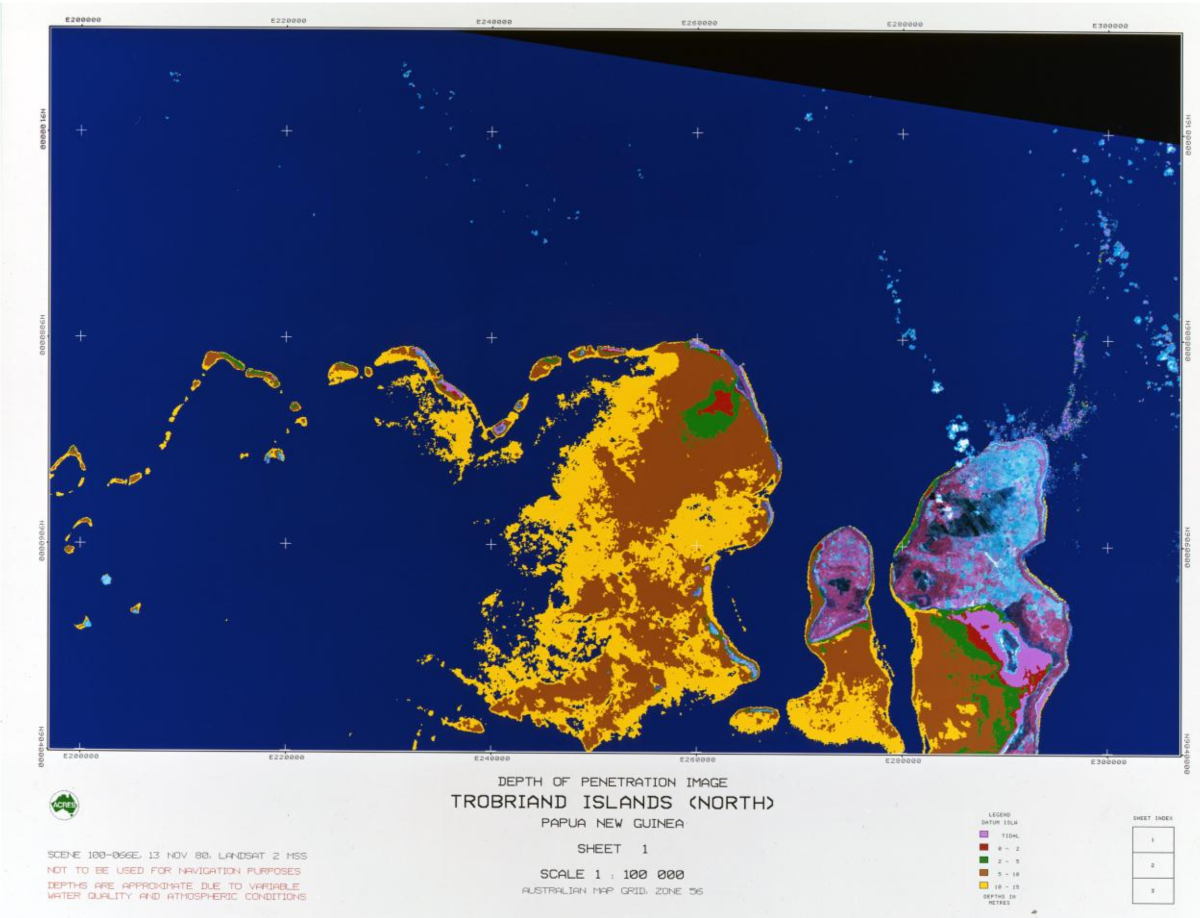


Figure 4: Depth of water image as a result of BRIAN processing.

Barrier Reef Image ANalysis (BRIAN) system

In 1982 an Australian Marine Sciences and Technologies Advisory Council (AMSTAC) funded research project interpreted LANDSAT imagery for reef cover and structure and water depths over several areas of the Great Barrier Reef. The CSIRO Division of Water and Land Resources in cooperation with the Great Barrier Reef Marine Park Authority (GBRMPA), used the Barrier Reef Image ANalysis (BRIAN) system developed by the CSIRO. The project's report noted that while LANDSAT interpretations are less precise than aerial photography, LANDSAT has advantages in terms of objectivity, speed and cost. The report recommended that the planned work by the Australian Survey Office be integrated with the reef mapping as a basis for reconnaissance mapping and the LANDSAT based mapping be extended to the whole of the Great Barrier Reef (Jupp et al 1985).

By 1991 after the amalgamation of the ASO and National Mapping, AUSLIG had undertaken marine mapping of 350,000 sq. km of the GBR at an estimated saving of $20 million and in less time than conventional mapping techniques. The PC based MicroBRIAN system was used to generate shallow water mapping products including depth of penetration, reef exposure, and land cover from georeferenced LANDSAT and SPOT multispectral imagery including over other offshore areas. Refer to Figure 4. These maps were used by a number of Commonwealth Departments including the Royal Australian Navy Hydrographic Service, the Bureau of Mineral Resources, AUSLIG's bathymetric mapping program and the various agencies concerned with management of the GBR (Wise & Manning 1991).

Figure 5: Part of Beaver Lake satellite image map.

Australian Antarctic Territory mapping

Mapping Australian territory was important to establish proof of occupation, and to aid exploration and geoscientific studies. National Mapping personnel flew aerial photography in the 1970's from a non-pressurised Pilatus Porter in Enderby Land. These flights were logistically difficult and relatively expensive. Ground control by traversing and electronic distance measuring (EDM) surveys was supplemented by JMR equipment accessing the Transit satellite constellation, a forerunner of today's Global Positioning System (GPS). LANDSAT MSS image mosaics were used for reconnaissance.

However it was evident that for mapping, satellite imagery offered a less costly alternative to aerial photography in terms of acquisition and ground control. AUSLIG used imagery from the SPOT satellite in 1988 to produce a 1:25,000 scale, four colour image map of the Larsemann Hills delineating ice and rock features for ANARE scientists. Over succeeding years further image maps using SPOT and LANDSAT data were produced for the Australian Antarctic Division. Refer to Figure 5.

The National Topographic Map Series (NTMS)

In 1988 at a ceremony to mark the completion of mapping Australia at 1:100,000 scale, the Minister for Administrative Services said that the programme was never envisaged as a bicentennial event when it began in 1965. However while National Mapping had for many areas used aging 1:80,000 scale photography for this program, the reality was that many maps were out-of-date especially in areas of rapid change. Map compilations were updated in 1:250,000 scale map blocks by ground inspection and from light aircraft and new or corrected features annotated on the compilations. The aircrew took spot photography or recommended systematic new block coverage where warranted (Crane 1986).

While research had demonstrated that satellite imagery had the potential to offer a faster and less costly way to keep map detail current, LANDSAT's 1 to 3, 80 metre resolution did not meet the detail or accuracy specifications of the NTMS programme. SPOT 1 launched in 1986 with resolutions of 10m Panchromatic (PA) and 20m Multispectral (XS) and a stereoscopic capability, offered a solution. National Mapping participated in the French Programme d'Evaluation Preliminaire Spot (PEPS) international exercise to determine if SPOT imagery would meet the NTMS specifications. The selected study area equivalent to a 1:100,000 scale map sheet in central Queensland embraced a diversity of land use including grazing, cropping, coal mining and its associated infrastructure. The evaluation compared compilations derived from a SPOT panchromatic stereo-model with 50 stereo-models from similar date 1:80,000 scale black and white aerial photography over the same area. Ground control was intensified to enable accuracy checks and field surveys verified map detail. The SPOT compilation met positional accuracies to 1:50,000 scale map specifications and while linear features were identifiable, the smaller point features were not. The clearly defined vegetation boundaries were correctly delineated to 1:100,000 scale map standards (Veenstra & McMaster 1987).

The study concluded that SPOT imagery could replace aerial photography for mapping the more sparsely settled areas of Australia if reliable reference material was used to ensure completeness of map detail. Further analysis showed that SPOT was less expensive than aerial photography and that the SPOT multispectral imagery improved feature identification (Manning & Evans 1988).

Through the early 1990's AUSLIG developed the methodology to produce topographic maps using satellite imagery. The development of SIMAP (Satellite Image MAPping) within AUSLIG led to the production of a Canberra 1:100,000 scale, LANDSAT TM image base map overprinted with vector data such as roads, railways, water features (Wise 1992). Refer Figure 6.

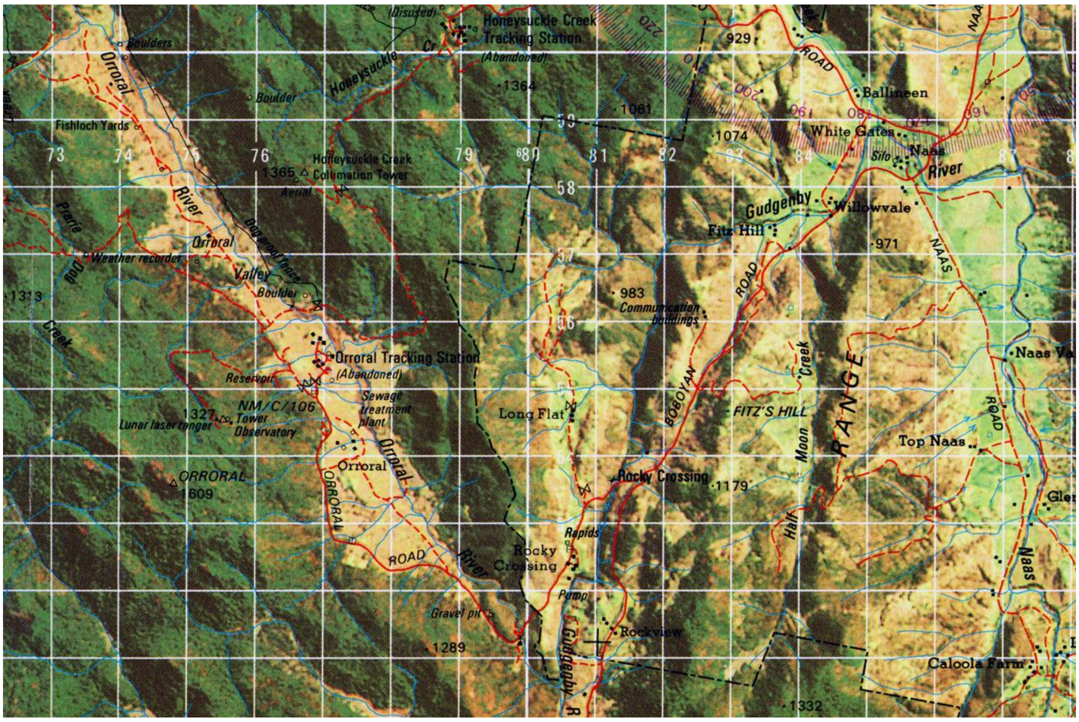


Figure 6: Part of the Canberra 1:100,000 scale satellite image map (SIMAP).

Digital product development

In 1991 AUSLIG began the digital conversion of its topographic maps and by 1994 the 544 NTMS 1:250,000 scale series was completed generating the GIS compatible Geodata 250K product. A pilot study using the Warragul map sheet in 1994 had concluded that a combination of LANDSAT Thematic Mapper (TM) and SPOT Panchromatic (PA) data together with intelligence from users including Automobile Associations was able to meet the criteria for the revision of the TOPO-250K Geodata product. The imagery was also useful in resolving positional and other inaccuracies in the original product (Smith 1994).

AUSLIG's revision of the Geodata product used geocoded imagery from ACRES corrected for relief using the nine arc second digital elevation model (DEM) with around two LANDSAT TM and six SPOT PA images required for a TOPO-250K "tile". Holland forecast that higher resolution data from a range of newer satellites would enhance AUSLIG's map revision programme (Lawford & Smith 1996).

By 2003 a range of high resolution satellite imagery was available and affordable. GA had evaluated various higher resolution imagery in a number of studies for the revision of mapping. For example SPOT 5's, 2.5m resolution imagery could be considered for mapping at scales of 1:50,000 and 1:25,000 and semi-automated feature extraction was now a future possibility (Forgani et al 2003).

Concluding remarks

By the early 2000's aerial photography had been largely replaced by satellite imagery in Australia's continental topographic medium scale mapping programs. The decision in 1984 to locate the Australian Centre for Remote Sensing within the Division of National Mapping was critical to this process. Meanwhile the Google Earth website has popularised satellite imagery and brings the geographic world to everyone's desktop.

However for the specialist, data from higher resolution satellites and digital aerial cameras allows seamless, ortho-corrected datasets to match the scale and accuracy needs of any particular application including mapping.

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