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100 Years of National Topographic Mapping

Australian Topographic Mapping in Antarctica

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Abstract

Australia first became involved in Topographic mapping in Antarctica in 1899 this continued with involvement in the British expeditions of Scott and Shackleton before Mawson broke away from the race for the pole and led the Australian Antarctic Expedition in 1912. These expeditions produced very little topographic mapping and it was not until ANARE was formed in 1947 that serious approach national approach commenced .

This heralded a significant Australian involvement in Antarctica in the second half of the 20th century and in international leadership within the SCAR. This strong leadership role in geodesy for mapping continued commenced in 1958 and continued unbroken for 34 years until 2002. Since that time this contribution to both sciences has continued but under a different structure. Using space geodesy techniques Australia created the Geodetic Infrastructure of Antarctica (GIANT) project and pioneered direct digital mapping from satellite imagery

Today Australia has mapped the coastal and mountains regions of the Australian Antarctic Territory. Responsibility for Antarctic geodesy is held by Geoscience Australia, while the responsibility and international interface for spatial data within Scientific Committee for Antarctic Research (SCAR) is maintained by Antarctic Division.

Australian Topographic Mapping in Antarctica

1. Background

Australian involvement in topographic mapping in Antarctic commenced more than 100 years ago when Louis Bernacchi from an Italian emigrant family joined the Borchgrevink British Antarctic Expedition in 1899. This expedition was the first to winter on the Antarctic continent. Cartographically it produced only a small local map of the vicinity of Cape Adare but set a new furthest south record by sledging on the Ross Ice Shelf before returning to Australia in 1900. (Bernacchi 1901)

At the turn of the century Australian adventurers became involved in topographic and geological mapping with the British expeditions of Scott and Shackleton. But it was the Mawson AAE 1911-13 expedition to Antarctica which then captured the Australian's public imagination and whetted the appetite for Australian further involvement in the frozen continent. Mawson broke away from the area of British activity in the Trans Antarctic Mountains to ambitiously explore and chart the East Antarctic coastline between Cape Adare and the area of the Gaussberg discovery of the 1904 German Drygalski expedition near Gaussberg. Relying on information from the 1839 Wilkes expedition he planned three wintering bases. The Wilkes information was misleading and anomalous and Mawson succeeded in establishing a base on rock at Cape Denison Commonwealth Bay and a second temporary base on the floating Shackelton ice shelf. John King Davis as master of the expedition ship Aurora contributed to the charting of the coastline between the bases in what eventually became the Australian Antarctic Territorial Claim. (Davis 1962)

The AAE was an acclaimed scientific success and the cartographic results were presented in the scientific reports in the Geographical Journal and Cartography report (Mawson 1942). The cartographic presentation from the period relied on information from these ground expeditions usually as inset maps of the individual expedition reports rather than as a coordinated advance in unveiling the continent. The Mawson report includes the map of Macquarie Island made personally by surveyor Blake in 1912 using plane table techniques. Overall the heroic era period 1899 –1918 saw little progress in the overall cartographic unveiling of the vast continent, beyond the limited results from the individual expeditions.. While the cartographic output was less artistic in its interpretation with an emphasis on fact not conjecture, results were minor in extent when viewed against the size of the whole of the Antarctic continent.

Through the exploration period ship borne exploration was limited by sea ice and encounters with uncharted rocks whilst the land exploration of this heroic era concentrated mainly on attaining single line objectives such as the geographic or geomagnetic poles. Scott and Shackleton briefly ascended in a tethered balloon from the edge of the Ross Ice Shelf in February 1902 and one month later, on the other side of the continent, the German Drygalski 1902-03 expedition undertook two similar ascents from the sea ice. These tethered balloon ascents produced little beyond providing an insight into how to better view the immediate area of the frozen continent.

The introduction of the aircraft to Antarctica dramatically changed the approach to exploration and consequently the cartographic depiction of the surface topography of the frozen continent. The great difficulty previously encountered by ships in forcing passage through a frozen sea to map the coastline was overcome, as was the need to explore a massive interior ice cap by foot, sledging ponies or dog teams.

In the 1920s the success of long distance aircraft exploratory flights across the Arctic heralded in a new era of polar exploration. The Australian George Hubert Wilkins made the first Antarctic aircraft flight on 16 November 1928 from a makeshift airstrip at Deception Island. This flight of flew 1500 km along the Antarctic Peninsula was to be a reconnaissance for further flights across the Antarctic continent to the Ross Sea. The information from this single adventurous flight opened a new dimension to the exploration of the continent, but it also demonstrated that new mapping skills were required to interpret and document this information. These early Wilkins flights misinterpreted the topography and reported straits cutting right through the spine of the Antarctic Peninsula. The subsequent exploration flights made by Wilkins in Antarctica in the next ten years were always inhibited by the inability to locate suitable aircraft take off sites , whether sea ice, or calm sea areas for major long distance discovery flights. However these flights produced much general information and indicated that the future way to explore and reveal the nature of the frozen continent was by using aircraft.

Following the French territorial claim to Terre Adelie being announced in 1924 the question of Antarctic territories was placed on the agenda of the Imperial Conference in London in 1926. Australia then took the lead in arranging for a fresh coastal charting of east Antarctica as basis for a British claim to be made, consolidating the previous work by British ship sighting and the land exploration of Australasian Antarctic Expedition (AAE). This was the British New Zealand and Australian Research Expedition (BANZARE) over two summers, 1929-30 and 1930-31, led by Douglas Mawson. This expedition made only four landings on the continent and charting was often made from positions outside the pack ice and well out to sea but it became the basis for the British claim from 45° east to 136° east and from 142° to 160° east. This claim was transferred to Australia in 1933 and proclaimed as the Australian Antarctic Territory in 1936. The cartographic outcome from this expedition was consolidation of previous sightings and coastal charting without land exploration. The expedition reports were not finalized at the time of Mawson's death in 1958 and eventually published by Grenfell Price (1962).

A map of the known British discoveries in East Antarctica had been attempted by the Department of Interior in 1929 to assist Mawson's expedition. However this was not published as the information was sketchy and unreliable. However following the AAT claim the Dept was again asked to prepare a map. After ten years a comprehensive map of Antarctic was published at both 1:5million and 1:10 million scales. This was very significant Australian publication on a world stage.(Manning 2010)

The closer integration of aircraft and ground activities was taken a step further with the detailed mapping of the Antarctic Peninsula in the British Graham Land expedition 1934-37. Led by another Australian, John Rymill, it combined use of light aircraft, tractor, oblique aerial photography, and dog sledge parties to prove that the Antarctic Peninsula was a continuous spine of mountains not a dissected group of large islands as reported by the reports from the early flights of Wilkins.(Rymill 1938) Wilkins' earlier plan to fly to the Bay of Whales from the Antarctic Peninsula was followed up in 1935 when he

supported the swashbuckling American Lincoln Ellsworth's flight across the Antarctic icecap from Dundee Island near the northern part of the Antarctica to Little America in the Bay of Whales in the Ross Sea. Wilkins was again manager of the Wilkins/Ellsworth expedition in 1938 to the region of the Vestfold Hills. Searching for a suitable sea ice for an aircraft landing strip he made several landing in the Rauer group of islands and two more landings in the Vestfold Hills. At one of these he left a note claiming Australian territory, this was wrapped in a Walkabout Magazine (located in 1957 by Stinear and Lied.) Little mapping resulted from this expedition as Wilkins map appears to have been lost in Canberra. Norwegian whalers from the Christensen group had earlier undertaken the initial charting of the area for whaling activity in the 1930s. This included a landing on Tyrne Island in 1935 by Mikkelsen and his wife Caroline, where he built a wooden beacon.

The Second World War diverted attention away from Antarctic land exploration although wartime activities were carried out in sub Antarctic waters. Kerguelen Island was used by Germany as a part time operational base for its armed raiders in the Southern Ocean. This led to the stalking and capture of the Norwegian Whaling fleet near South Sandwich Islands in 1941 by the German raider *Pingvin*. In the closing years of World War 2, the British navy secretly established permanent bases along the Antarctic Peninsula, in Operation Tabarin to watch for hostile shipping, waters and to strengthen their territorial claims. This triggered a response from both Chile and Argentina in a base building race to also strengthen their individual territorial claims. The activities of the German Raiders also caused security concern for Australia and in 1942 the heavy cruiser Australia was sent to Kerguelen Island to look for sign of these raiders.

Interest in Antarctica quickly stepped up after the war. A number of countries, including the United States, established Antarctic agencies within government. The United States, with Admiral Byrd as commander in chief, organized a massive services cold weather training exercise as Operation Highjump which flew much of the East Antarctic coastline in 1946-47, with tri met photography from seaplanes operating from ships. This aerial reconnaissance had a massive impact with the acquisition of massive amounts of information and aerial photographs. However it also provided an ongoing technology challenge in how to get sufficient ground control through field geodetic operations to be able to take advantage of the masses of individual aerial photographs. Although continuous runs of photographs could be linked by photogrammetric techniques, it still required extensive ground control and it was often impossible to clearly identify linking features on photographs in continuous photo runs in a featureless ice cap between the rock features being mapped.

2. Renewed Australian exploration

In 1947 Australia made a decision to g ahead with further expeditions and the Antarctic Division within the Department of external affairs was created for that purpose. Lacking developed expertise, and the failure of the 1947/48 *Wyatt Earp* expedition to find a suitable site for a base on the continent, a stepping stone strategy was commenced with placement of parties on Heard Island and Macquarie island.

This then launched Australia into its first offshore survey and mapping activities since 1912. The wintering party at Heard Island was given the almost impossible task of

mapping the island during the winter of 1948. During the base establishment a RAAF Walrus aircraft had flown a circuit around the island taking mapping oblique photographs. This two hour sortie was its final flight before being destroyed by fierce winds back at the base that evening. With the loss of further aerial photography support, mapping of the island relied on the establishment of ground control and the positioning of major features from ground survey to complement the oblique photographs. This was undertaken by the surveyor R.G. Dovers and survey assistant G.S. Compton (Scholes 1949). The resultant map was published the next year as Aus606. It is a great tribute to immense personal effort, coping with danger and perseverance with inadequate equipment. On relief Dovers went immediately to Macquarie Island to observe positional origin astronomic observations and local survey. He then joined the French Expedition to Terre Adelie as surveyor and dog handler in 1952 to gaining experience on the Antarctic continent and to map the Terre Adelie region for France. It is interesting to note that his father had wintered with Mawson's western party in 1912 as surveyor and cartographer and had sledged to Drygalski's Gaussberg.

The next major step in Australia's involvement in Antarctic survey and mapping occurred in 1954 with establishment of Mawson Base. Dovers as leader of the wintering expedition set the benchmark tradition for future ANARE surveyors. Law as director of the Antarctic Division was always supportive of Antarctic survey and mapping and took every opportunity to fly quality aerial photography from ship borne aircraft. In 1954 Dovers undertook a dramatic autumn expedition east to Scullin Monolith losing a living caravan and a weasel vehicle when fierce winds caused the sea ice to break up around them. This was followed by a long distance exploration to the west by Dovers and the French observer Schwartz using two dog teams on the sea ice. The major summer exploration was to the south to locate a line of features just visible on the American Highjump photography. On reaching the edge of this line of features they were named the Prince Charles Mountains. The following year surveyor Bob Lacey using weasel vehicles ventured into the start of this massive mountain range and established initial Astro fix positions

ANARE's capability in mapping exploration was enhanced when Law arranged for RAAF fixed wing aircraft to winter at Mawson to fly extensive trimetrogon photography and to support ground parties. This combination of aircraft reconnaissance, aerial photography logistic support for ground vehicles and dog teams was particularly productive. In the northern prince Charles mountains surveyor Kirkby observed 18 Astro fixes as control for aerial photography to produce the first reconnaissance mapping of the area. This was subsequently published in a series at a scale of 1:2 million.

Until 1958 ANARE field surveyors were employed by Antarctic Division in Melbourne and extended control for mapping with aerial photography sorties from Mawson and Davis. In 1958 Graham Knuckey together with geologist Ian McLeod made a notable land dog sledge journey with aircraft support from Amundsen Bay in Enderby back to Mawson Base.

The wintering surveyors employed as specialist to the ANARE expeditions from 1947 to 1968 is listed in Table 1 below. After 1968 it was considered that the distance from the Base to the survey and mapping areas was to great to be effectively accomplished using ground transport alone. Beyond that time The Division of National Mapping provided surveyors and survey technical officers to the intense summer mapping operations which

operated from temporary bases and fuel depots in the mountain areas established by tractor trains during the winter. Their great work is not covered here.

Wintering surveyors	Station	year
Bob Dovers	Heard Island	1948
Bob Dovers	Terre Adelie	1952
Bob Dovers	Mawson	1954
Bob Lacey	Mawson	1955
Syd Kirkby	Mawson	1956
Morrie Fisher	Mawson	1957
Graham Knuckey	Mawson	1958
Chris Armstrong	Mawson	1959
Syd Kirkby	Mawson	1960
Dave Carstens	Mawson	1962
John Farley	Mawson	1964
Keith Budnick	Wilkes	1964
Max Corry	Mawson	1965
John Quinert	Mawson	1966
John Manning	Mawson	1967
Max Rubeli	Mawson	1968

Table 1: ANARE Mapping and Geodesy wintering surveyors (Manning 2002)

In addition to those employed as survey and mapping specialists other surveyors at times were selected not for survey duties, but as station leaders. These included George Hamm in 1968, Bruce Smith in 1975, and Syd Kirkby in 1980 at Mawson, with Ian Sutherland at Casey in 1994.

With an explosion of interest in science in Antarctica during the International Geophysical Year in 1957/58, Director Law looked to consolidate the Antarctic science programs with the support of universities and Federal agencies. In 1958 Bruce Lambert as Director Division of national Mapping joined the Antarctic Planning Committee. Within Australia Lambert took over the role of responsibility for Antarctic mapping and the employment of Antarctic surveyors for ANARE as well as the storage of Antarctic aerial photography. Each year a series of base compilation transparencies were up dated from the activities of the wintering surveyors, these covered the whole of the territory at the scale of 1:1 million and at 1:250 000 and 1:100 000 for areas of greater activity. These were reproduced for expedition field work as dyelines and some were converted to full colour cartographic products. Within the Division of National Mapping ,Department Of National Development, an Antarctic Mapping Branch was created , headed by Commander D'A Gale an ex naval Hydrographer. As well as topographic recording soundings from track charts were fair drawn and sent to the hydrographer for inclusion in offshore charts.

In 1960 Syd Kirkby returned to Mawson for another very important year as RAAF had upgraded their fleet to a DC3 aircraft equipped with a radio altimeter. Extensive photography and heighting of the Antarctic ice cap were undertaken. In the autumn of that year Kirkby started the year with a dog sledge journey from Cape Batterbee through

Enderby Land to King Edward Gulf before being met by aircraft and flown back to Mawson. Seven astro fixes were observed during the year and a major aircraft supported ground circuit of the Southern Prince Charles Mountains was made to isolated mountain feature for mapping control. With the continued loss of aircraft, RAAF withdrew all wintering aircraft operations. But almost all the rock and major ice features of the region within range of Mawson station had been sighted in some way. The initial exploration phase had almost been completed in this region. But there was much accurate mapping left to do and ground control was difficult and relied heavily on solar position line techniques.

2. Australia's role in Antarctic Geodesy

Antarctic was heavily involved in the IGY activities in the years 1957 to 1958. Following the success of this the international project a permanent body was established to coordinate ongoing science program activities in Antarctica. This body was Scientific Committee for Antarctic Research (SCAR) which then in turn established a series of working groups to coordinate separate discipline activities

At the first SCAR meeting in 1958 Cartography, as it was known then, was part of Working Group 2 (along with Geology, Glaciology and Morphology). At III SCAR meeting in September 1959 Cartography met as a Working Group in it's own right. The following year at IV SCAR a Permanent Working Group on Cartography was established (in September 1960). The Chief Officer was General C R Laclavére from France. The name was changed at V SCAR in October 1961 to the Working Group on Geodesy and Cartography. The WG's Chief Officer was B P (Bruce) Lambert from Australia. Since then the Chief Officers position has been held by an Australian representative from the National Mapping organisation. In 1988, at XX SCAR in Hobart, the name of the group was changed to the Working Group on Geodesy and Geographic Information (WG -GGI) to better reflect its total scope of activity

The end of the IGY also saw introduction of a new ground position technique to replace the astronomical control of much higher relative accuracy. The advent and development of portable electronic distant measuring equipment by Wadley in South Africa in the mid 1955 had revolutionized field geodetic surveying across the world. In Antarctica, MRA1Tellurometers were first used by FIDS during the 1958-59 Antarctic summer in the sub Antarctic islands. Bill Chapman and the USGS survey team began using electronic distance measuring techniques in 1960/61 to establish a geodetic network through the Trans Antarctic Mountains. Australian surveyor David Carstens successfully trialed the use of the Tellurometer distance measuring equipment near Mawson base in East Antarctica the following summer in 1961/62 and Kirby measured a trilateration figure near Casey the same year. The advent of this accurate technique began to be used by Australia when the new approach of mobile teams supported by helicopters and fixed wing was introduced by Kirkby and Law in beginning to extend the work of Carstens from the Framnes Mountains to Enderby Land in a summer blitzkrieg style program.

This new technique enabled geodetic triangulation traverses to be extended through continuous mountains ranges in Antarctica usually with helicopter support. This greatly improved accuracy of ground control for topographic maps, greatly improving the positional accuracy of the new maps. With ingenuity the problem of connecting between isolated mountain networks was addressed when Max Corry succeeded in a Tellurometer across the moving ice cap to carry the survey connection from the coastal Frames

Mountains to the edge of the Prince Charles Mountains in 1965. (Corry was later to brilliantly extend this technique for glaciology on the Amery Ice Shelf) John Quinert carried this connecting traverse into the Northern Prince Charles the next year and in 1967 the Framnes survey network was extended to the Gustav Bull Mountains to the east and the Corry inland traverse repeated. From the summer of 1968/69 intense summer surveys were undertaken each year through both the Northern and Southern Prince Charles Mountains extending through the Amery Ice Shelf to Davis station in the east and through Enderby Land to the Russian base of Molodezhnaya in the west.

While this continuous geodetic network was being established by ground methods, intercontinental connections to determine tectonic motion of the Antarctic continent required a better technique for accurate positioning than astronomical observations with their inherent dependency on the local variation of the vertical and geoidal anomalies. Geodesists began to consider accurate intercontinental connection using space geodesy. The first application of space geodesy to address the problem of intra continental connection and to accurately determine the coordinates of some Antarctic stations in a global reference frame was commenced in 1969 when the global astro-triangulation PAGEOS program occupied Antarctic sites at McMurdo, Mawson, Palmer and Casey, photographing passive satellites against a star background. In the 1970s satellite based active microwave positioning proved more useable than the optical photographic approach and firstly Transit Doppler and later GPS became available on global scale. The development of positional accuracies achievable from the different geodetic techniques is summarised in Table 2 below.

Period	Technique	Baseline accuracy
1950s	Positional Astronomy	+- 200metres
1969-70s	Satellite/Stellar photography (PAGEOS)	10 metres
mid 1970s	TRANSIT Doppler	3-5 metres
late 1980s	GPS	1-2 metre
1990	VLBI	1 decimetre
1995	GPS	1 decimetre
2000	GPS	Several centimetres
2003	GPS, enhanced VLBI	Sub centimetre

Table 2: Positional accuracy progression in Antarctica sites

By the mid 1970s portable Doppler observing units Geo and JMR being were employed for geodetic positioning and ice motion for glaciology (Clarke 1978). This now provided a technique for positioning anywhere in Antarctica at the few metre level if observed carefully for several days and suitably processed. The early Antarctic space geodesy programs were the initiatives of individual countries as part of more extensive global programs, and no coordinated international geodetic program existed on the Antarctic

continent. In 1976 the SCAR WG-GGI began to look at the possibility of linking the individual national geodetic networks by Doppler techniques and work commenced on gathering the extent of each nation's geodetic networks with view to a joint approach, but due to logistic limitations no overall plan was implemented to link the individual networks. Ten years later the US Military Global Positioning Service series of satellites became available to the community and despite initial doubts in early trials In 1988 the XXth meeting of the SCAR working Group endorsed a proposal by Australia to test the developing GPS technique for mapping control and potential applications in monitoring crustal motion. This pilot study was undertaken in two phases:

- Feasibility observations January 1990
- Test observations in January 1991

At the XXII meeting of SCAR at Bariloche in 1992, the results of the SCAR GPS Antarctic Project 1990-92 were assessed (Govind at al 1990) (Morgan and Tiesler 1991). and it was decided to extend the GPS projects to develop collocation network of other techniques such as VLBI, Absolute Gravity, DORIS and tide gauges. This was collectively identified as the Geodetic Infrastructure for Antarctica (GIANT) the coordinating program for Geodesy. (Manning 1999). A parallel structure of spatial information activities were identified as the Geographic Information (GI) program.

The ongoing GIANT program objectives are to:

- Provide a common geographic reference system for all Antarctic scientists and operators.
- Contribute to global geodesy for the study of the physical processes of the earth and the maintenance of the precise terrestrial reference frame
- Provide information for monitoring the horizontal and vertical motion of the Antarctic.

Since the SCAR 1992 meeting the GIANT program has evolved as the coordinating program for all Antarctic geodesy with an interface to other geophysical based programs such as ANTEC and PoleNet. The application of space geodesy technology now enables a more comprehensive study of crustal movements within Antarctica and its relationship to other fragments of the ancient Gondwanaland

A number of permanent GPS receivers have been installed in Antarctica and data is increasingly being retrieved by satellite transmission from these sites and forwarded in real time to global earth science sites Data from these sites in Antarctica are of ongoing importance to global geodesy, especially in the determinations of precise orbits and the integration of different observational techniques. This fiducial network of GPS points, forms the basis for an integrated geodetic infrastructure for Antarctica as the basis for all scientific spatial data.

From its inception the working group encouraged compatible mapping of the Antarctic continent and established a set of recommendations and standing resolutions as mapping standards. Initially it recommended the use of the Hayford 1924 International spheroid as the basis for mapping and positional computations. The essential role of Geodesy within the working group at that time was the provision of control for exploration and mapping. This has evolved to the measurement of the current tectonic motion of the continent and its linkage to other continents. Responsibility for the geodetic framework and the contribution

of Antarctic information into global geodesy monitoring bodies was retained by National Mapping when the mapping aspects was transferred to Antarctic Division and geodetic records are maintained by Geoscience Australia. Since 1992 the GIANT program has been chaired and promoted by Australia .It has been revised and endorsed at each major SCAR conference on a two yearly basis. Current Chairman is Gary Johnston from Geoscience Australia

3. Australia's role in mapping

Despite the technological efficiency achieved in ground control positioning, mapping in Antarctica was still costly and time consuming. Since 1958 the SCAR Geodesy and Cartography Working Group promoted the cooperative and uniform mapping of the whole Antarctic continent as its objective. International meetings, workshops, and seminars supported the cooperative interaction of the SCAR working groups usually very two years. Australia was the driving force for this working group for the next 34 years. Guidelines, specification and standard symbols for Antarctic cartographic application were promulgated internationally .A network of Antarctic Mapping Centres was created followed by an agreed free circulation of all new maps between these centers. A reference catalogue of the maps and charts was produced to show mapping available from SCAR nations. After five hard copy editions, this is now available as online from the Australian Antarctic Division web site, on the behalf of SCAR.

A comprehensive SCAR names gazetteer of names, approved by all nations, was developed as an aid to mapping and as a step towards resolving the historical problem of features having multiple names. The concept of the composite gazetteer is to reduce the duplication of new names being created on features already named. This is a very useful on line facility but question of rationalizing features with historical multiple names and the wider acceptance of the "one feature one name" philosophy remains unresolved.

In 1968 man made earth sensing satellites began to send information from space. The first views were from weather satellites, such as the NIMBUS series of satellites which transmitted low-resolution distorted images of Antarctica, showing cloud patterns for weather monitoring and forecasting and some information on sea ice cover for navigation. The first metric quality satellites, the Earth Resources Technology Satellites, were then developed and launched by NASA in July 1972 and the data quickly became available for Antarctic Science. The satellite series was renamed LANDSAT and the early images had a resolution of 80 metres in four optical spectral bands, which required daylight and frequently cloud obscured features on the Antarctic continent. Despite the relatively low resolution and lack of stereoscopic facility, each image covered 180km x 180km instead of a nominal 10km x10 km from an aerial photograph, that is one image covered the area of 1,000 aerial photographs. The ground control required being significantly less and the larger format having the ability to bridge between features over wide areas of featureless Antarctic ice cap.

The relatively broad coverage Landsat images were soon applied to Australian Antarctic mapping to correct horizontal positioning on existing maps lacking ground control. Australia for example corrected features on all their of 1:1 Million series maps across East Antarctica and the USA produced excellent satellite image maps of the Trans Antarctic mountains. In the 1970s the Soyuz series of manned satellites took film stereo photography from spacecraft. This was retrieved by parachute landing and used for photo

triangulation for wide area Antarctic mapping by USSR. Eventually this material was made available to Australian 20 years later.

The use of images from space enabled the entire remote coastline to be viewed and the delineation, and even the motion, of ice shelves accurately assessed where ground control could be established. The Landsat satellites required daylight for its optical sensing bands and was placed in a sun synchronous orbits which ensured imagery being repeated the same time each day. Despite the need for cloud free daylight the wealth of information available enabled all medium or larger sized features to be identified on the imagery. In the 1980s imagery from the French SPOT satellite with a higher resolution of 15 metres became available enabling smaller nunataks to be also viewed. Importantly the data from the Spot satellites could be viewed stereoscopically enabling elevation to be determined if sufficient ground control cloud be identified. In the mid 1990s thermal imaging band began to be used and the use of short wavelength band sensing radar in satellites was developed commercially with Canadian Radarsat system launched in 1995. This used using high frequency band to sense through clouds and during the hours of darkness. Coupled with the accurate positioning technology from satellites such as the Global positioning system, this imagery was used to develop a Digital Elevation Model over the ice cap and enabled differential ice flow to be detected, being particularly useful for ice shelf monitoring

In 1988 following a federal reorientation and the take over of the Division of national Mapping by the Australian Survey office, responsibility for Antarctic mapping was transferred to the Australian Antarctic Division. Mapping continued on a user paid basis with an additional funding allocation of one million dollars to the Antarctic division. This was tied to work undertaken by National Mapping for two years. Mapping in that period using space imagery techniques saw the rapid development of direct digital printing.

The operational aspects of the WG-GGI was reviewed during XX SCAR in 1992 changing from a focus on mapping standards and individual national activities, to a theme based structure with identified project responsibilities. The Geodetic Infrastructure of Antarctic program was identified as GIANT at the meeting. Since that time the overall program has further evolved into two major umbrella streams each with an overall coordinator:

- Geodesy (GIANT)
- Geographic Information

This structural grouping proved successful and both streams initiated projects and produced products which were increasingly available through the web site as Internet technology developed.

The demand for information quickened considerably with need for instant access to spatial information and the need to be able to use the digital information coupled with other attributes. To integrate individual published maps from different sources, British Antarctic Survey (BAS) undertook the production of a SCAR composite digital topographic map of the whole of Antarctica; the Antarctic Digital Database (ADD) , to be available on CD Rom. Australia contributed all its 1:1 million mapping information to the project. The SCAR digital topographic database was successfully produced in 1998 and became the default resource basis for many cartographic representations. With the release of the second edition of the ADD in 2003 as a free downloadable online resource, the basic topographic representation of Antarctica can be considered to be reasonably complete and the data readily available for digital use beyond the topographic map.

At the XXVI SCAR meeting in Shanghai in 2002 the long standing and successful WG-GGI (including GIANT) was merged with other SCAR working groups to form the Geoscience Scientific Standing Science Group (GSSG) and as such lost its direct reporting stream to the SCAR Executive Committee. The WG-GGI was renamed the Geospatial Information Group of Experts (GIG) with the intention to broaden its scope to also include Geophysical network information. This did not work and as a further development the geographic information sub group was promoted within SCAR structure to become a Permanent Committee On Spatial Information. This is now actively chaired by Henk Brolsma from the Australian Antarctic Division.

Australia's mapping of the Australian Antarctic Territory is well presented with extensive traditional and space imagery hard copy maps . There is basic cover of all rock features in the 1:1Million base compilation two colour series and six editions of the overall continent at 1:10 million. At larger scales much of the rock areas have been covered at 1:100 000 and in the vicinity of bases larger scale coverage in digital format is available on line from the Antarctic Division web site. Aerial photography and feature names are positioned and correlated for use.

4. Conclusion

Australia role in geodesy and mapping in Antarctica has been outstanding through the second half of the 20th century as technology has progressed in both fields. Australia has also played a very important role as a leader in international programs to take advantage of global advances in positioning and in space imagery through the Scientific Committee for Antarctic Research.

Responsibility for Antarctic Geodesy remains with Geosciences Australia, while responsibility for mapping and spatial information is held by the Australian Antarctic Division. International activity within the SCAR Spatial Information group is chaired by Henk Brolsma whilst the SCAR Geodetic infrastructure program (GIANT) is chaired by Gary Johnston.

International scientific interest in the Antarctic Geodesy and Spatial information remains high as climate change becomes a major concern for humanity.

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