THE JOSEPH BONAPARTE GULF, W.A./N.T., MEDUSA BANKS AND PORT KEATS, AIRBORNE GEOPHYSICAL SURVEY, 1994, OPERATIONS REPORT

by

R. C. Brodie

Australian Geological Survey Organisation
Record 1999/09

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SUMMARY

The Australian Geological Survey Organisation flew an airborne geophysical survey of 67,570 line kilometres over the entire Medusa Banks 1:250 000 map sheet area and the western two–thirds of the Port Keats 1:250 000 map sheet areas from July to September 1994.

The survey was flown along east-west flight lines spaced 500 metres apart at a nominal terrain clearance of 100 metres.

The total magnetic intensity, gamma-ray spectrometric and digital elevation model data which were collected during the survey, have been processed and are available for purchase, in both digital (point located data and gridded) and map form, from the Australian Geological Survey Organisation. Colour and greyscale pixel image maps are also available.

1. SURVEY AREA AND PARAMETERS

(i) Area Description

The Joseph Bonaparte Gulf Airborne Geophysical Survey covers the Medusa Banks 1:250 000 map Sheet and the western two–thirds of the Port Keats 1:250 000 map Sheet in the coastal zone of the East Kimberley area of Western Australia. The exact survey area is shown in Appendix A.

(ii) Survey Parameters

Terrain clearance:	100 metres
Flight line direction:	East – West
Tie line direction:	North – South
Survey line spacing	
Flight line spacing:	500 metres
Tie line spacing:	5000 metres
Survey distance flown	
Lines:	61,530 kilometres
Ties:	6,040 kilometres
Total distance:	67,570 kilometres
Sampling interval	
Magnetics:	0.1 seconds (approx 7 m)
Gamma–ray spectrometrics:	1.0 seconds (approx 70 m)
GPS:	1.0 seconds (approx 70 m)
Doppler:	1.0 seconds (approx 70 m)
Altimeter:	1.0 seconds (approx 70 m)
Barometric pressure:	10.0 seconds (approx 700 m)
Temperature:	10.0 seconds (approx 700 m)

2. LOGISTICS

(i) Operating Base and Dates of Flying

(a) Operating Base

The survey continued on from the East Kimberley Airborne Geophysical Survey of the Lissadell 1:250 000 map Sheet area (Bacchin, 1997), with the same crew and equipment. Aircraft and crew were based at Kununurra in Western Australia for the duration of the survey.

(b) Flying Dates

The first calibration flight to compensate for the magnetic field of the aircraft using an automatic aeromagnetic digital compensator was flown on 5 July during the course of the above mentioned survey of the Lissadell 1:250 000 map sheet area. Further calibration flights were undertaken on 29 July, 21 August and 11 September 1994. Production flying commenced on 16 July and continued through to 21 September. Appendix B summarises flying days and production kilometres flown. The aircraft was required to perform high altitude gamma–ray spectrometric calibrations off the north Queensland coast near Cairns from 20 to 22 July.

(ii) Survey Aircraft and Field Crew

(a) Aircraft

Aero Commander 500 S "Shrike", VH-BGE

(b) Field Crew

Party Leaders:	Ross Brodie	
	Mario Bacchin	
Technician:	Phillip Doolan	
Operators:	Selwyn Wilcox	
	Lars Rickardsson	
Pilots:	Capt. John Biffin	(Skywest Aviation)
	Capt. Murray Terwey	(Skywest Aviation)

3. SURVEY EQUIPMENT

(i) Major Equipment

Magnetometer:	Geometrics G833 helium magnetometer
Compensator:	RMS Instruments Automatic Aeromagnetic Digital Compensator
Gamma–ray spectrometer:	Geometrics gamma-ray spectrometer consisting of a GR820 spectrum processor, and two DET1024 spectrometer crystal detectors (33.56 litres total volume)
Altimeter:	Collins ALT–50 radar altimeter
Barometer:	AGSO digital – Setra sensor
Thermometer:	AGSO digital – RS sensor
Navigation:	Ashtech XII "Ranger" GPS receivers and Ashtech "Ranger" differential processing software
Doppler:	Racal (Decca) doppler antenna (80561 CAD) Sperry C 14 D compass
Video:	National colour video camera (WV CL 302E) National VCR (NV 180) National LCD TV (TCL 3A) National Time Date Generator (WJ 810)
Acquisition hardware:	HP-A400 computer, HP9122 720 Kb 3.5 inch dual floppy disc drive, HP Thinkjet printer, Contura Notebook and 120 Mb portable hard disc drive
Acquisition software:	AGSO-developed HP assembler language program

(ii) Navigation

(a) GPS Navigation System

Aircraft navigation was carried out using an Ashtech XII global positioning system (GPS). A receiver in the aircraft received range data from satellites every second and calculated the aircraft's current latitude and longitude coordinates in the World

Geodetic System 1984 (WGS84). The range data were recorded internally in the GPS receiver every five seconds.

The calculated position of the aircraft was recorded on the aircraft acquisition system every second and used to provide the pilot with aircraft guidance information on an LCD display.

To enable differential GPS post flight processing, a second GPS receiver was set up in AGSO's field office caravan as a GPS base station and internally recorded range data every five seconds. The data were post processed using Ashtech "Ranger" software at the end of each flying day. The error in position of the post processed flight path data is 5 – 10 metres.

The position of the base station GPS receiver was accurately determined by differential GPS surveying using two permanent survey markers as fixed reference points; AR35, located approximately 1 kilometre from the Kununurra airport near the Duncan Highway and WYN1 on top of Kelly’s Knob, a small hill in Kununurra.

The coordinates (WGS 84) for AR35 trig site reference point are :
Longitude :128° 43' 5.40902" E
Latitude : 15° 47' 7.22714" S
Ellipsoidal height :95.568 metres

and the coordinates (WGS 84) for WYN1 Kelly’s Knob are:
Longitude :128° 44' 33.1660" E
Latitude : 15° 45' 54.0595" S
Ellipsoidal height :238.095 metres

The determined base station GPS coordinates (WGS 84) were:
Longitude :128° 42' 59.53041" E
Latitude : 15° 46' 59.53041" S
Ellipsoidal height :106.699 metres

(b) Doppler Navigation System

Doppler navigation data were used as a secondary navigation system on the aircraft and as a back-up for the main navigation system (GPS), infilling gaps less than 10 kilometre in the GPS data.

(c) Video Flight Path Recording

The aircraft's flight path was recorded on a VHS video system consisting of a National colour video camera with a wide angle lens, a National VCR and a National LCD TV. This system was also used for locating start and end positions for the gamma-ray spectrometer test line.

(iii) Magnetometer

A Geometrics G833 helium magnetometer, with the sensor mounted in a boom attached to the rear of the aircraft, was used for the survey. The specifications of the magnetometer are summarised in Appendix C.

The recorded total magnetic field data were compensated in real time using an RMS Instruments automatic aeromagnetic digital compensator (AADC). The AADC compensates for the effects of aircraft motion and heading. The specifications of the

AADC are summarised in Appendix D. Compensation procedures are described in Chapter 4.

The AADC applies a low pass filter to the total magnetic field intensity data using a second order 0.9 Hz recursive Butterworth filter. The filtered compensated total magnetic field intensity data were recorded on the aircraft acquisition system.

(iv) Gamma-ray Spectrometer

An Exploranium gamma-ray spectrometer, incorporating two DET1024 crystal detectors with a total volume of 33.56 litres, was used. The crystal gains were controlled by an Exploranium GR820 spectrum processor. Appendix E summarises the specifications of the gamma-ray spectrometer components.

Two hundred and fifty six channels of data, between 0.0 MeV and 2.81 MeV, were recorded every second. These data were recorded on a portable hard disc via a communications link between the HP-A400 computer acquisition system and a Contura Notebook computer.

Additionally, five windows of data were recorded once a second using the following window limits:

total count	0.410 – 2.810 MeV
potassium	1.370 – 1.570 MeV
uranium	1.660 – 1.860 MeV
thorium	2.410 – 2.810 MeV
cosmic	3.00 MeV and above

Total count, potassium, uranium and thorium window counts were used for data checking during acquisition and the cosmic counts were used for cosmic background estimation and later data processing. A cumulative 256 channel spectrum between 0.0 MeV and 2.81 MeV was also recorded every 100 seconds. System live time (sample time - total dead time) was output with the data for later data processing.

(v) Altimeter

A Collins ALT-50 radar altimeter was used to measure ground clearance. The radar altimeter display indicates ground clearance from 0-2000 feet. The manufacturer's specifications claim a +/-2% accuracy for the ALT-50 system.

The radar altimeter system was checked by flying the aircraft at 50 metre height intervals, up to a height of 300 metres over the ocean using the aircraft's barometric altimeter as the height reference. Radar altimeter and GPS height data were recorded for each height interval flown. A comparison of these data with the aircraft's barometric altimeter verified that the system was operating satisfactorily.

(vi) Barometer and Thermometer

Atmospheric temperature and pressure were measured using a digital barometer (Setra sensor) and digital thermometer (RS sensor). The analogue output sensors were integrated into the data acquisition system via an analogue to digital converter. The sensors were factory calibrated and no AGSO calibrations were performed.

(vii) Base Station Magnetometer

Daily variations of the Earth's magnetic field were monitored using a Geometrics G833 helium magnetometer, the specifications of which are given in Appendix F. The base station was set up in an area of shallow magnetic gradient, away from cultural influences and within telemetry range of AGSO's office caravan.

The magnetometer was connected to a Chicony 486 SLC laptop computer incorporating a GT100 universal counter card to calculate the magnetic field values, and a Magellan OEM GPS module to enable synchronisation of the diurnal data with aircraft data. The magnetic values were sampled and recorded every one tenth of a second. These 0.1 second data were later used for diurnal corrections during data processing.

Data from the base station were also telemetered back to the AGSO's field office caravan every 20 seconds for real time display and recording on a Toshiba T1600 lap-top computer. The telemetry system used AGSO-built modems incorporating Phillips 828 UHF mobile radiotelephone transmit boards at a frequency of 471.8 MHz.

The base station system and acquisition software were developed in-house at AGSO.

(viii) Aircraft Data Acquisition

The aircraft acquisition program and system were run using a HP-A400 computer with data recorded on 3.5 inch floppy discs using a HP9122 720 Kb disc drive. The one second multichannel spectra were recorded on a portable hard disk linked to the acquisition system through a Contura notebook computer.

This acquisition program was developed in-house at AGSO. The data were displayed in real time in the aircraft in analogue form on a HP Thinkjet printer. A schematic diagram of the aircraft's acquisition system is shown in Appendix G.

4. CALIBRATION

(i) Compensation for the Magnetic Field of the Aircraft

Compensation flights were flown in an area of low magnetic gradient prior to the start of the survey and after each aircraft service or change of aircraft alternators. The flights were flown at an altitude of 2600 metres above sea level, 100 kilometres north-northeast of Kununurra over an area between 129° 5' to 129° 10'E and 14°55' to 15°00'S.

The compensation comprises a series of rolls(+/-10°), pitches(+/-5°) and yaws(+/-5°) in the four cardinal headings to enable the AADC to calculate correction coefficients needed to remove aircraft manoeuvre noise. Each manoeuvre component was of 30 seconds duration.

The compensation manoeuvres were repeated after calculation of the coefficients to check the compensation quality. Peak-to-peak noise during repeat manoeuvres and after the final compensation was 0.20 nT or less. On normal survey flights, noise levels from all sources were generally less than 0.13 nT peak-to-peak.

The AADC calculates basic statistics which reflect the degree of merit of the compensation. These include the standard deviation of the recorded data without corrections applied, the standard deviation with the corrections applied, the improvement ratio (the ratio of the standard deviation of the recorded data without and with the corrections applied) and the vector norm (the degree of difficulty in calculating the corrections). These statistics are given for all compensations in Appendix H.

(ii) Gamma-ray Spectrometer Calibration

The GR820 spectrum processor uses a sophisticated automatic control method to maintain crystal alignment while stabilising on naturally occurring isotopes (typically potassium or thorium). During operation, the system continuously monitors and accumulates a separate spectra for each crystal detector. When the confidence level for the selected stabilisation peak (potassium or thorium) is exceeded, the peak channel of this isotope is computed, compared to the correct peak location, and the gain is then corrected.

Crystal alignment checks were performed (using a small thorium source) on at the start of each day prior to production flying. The resolution of the gamma-ray spectrometer system was measured using the full width at half maximum method (IAEA, 1991). Adjustments were made to ensure the spectrometer stabilised on the thorium 2.62 MeV photopeak at channel 206.

Gamma-ray spectrometric test lines were flown at the beginning and end of each production flight. These lines were flown at survey altitude along a dirt road and lasted 100 seconds or approximately 7 kilometres. The location of the test line used for the survey is shown in Appendix I. Background estimates for the low level test lines were obtained from the production lines flown just after or immediately prior to the test lines.

After each flight, statistics were calculated from data recorded between fixed reference points, observed on video, along the test line and from background estimates on production lines flown just after or immediately prior to the test lines. These statistics were calculated for the total count channel, recorded in spreadsheet form and compared to the preceding flights in order to detect any irregularities. In particular, the difference between the average in the total count channel on the first test line and the last test line of each flight was analysed. This value only rarely exceeded 10% for the test line, well inside a 15% variation which was considered acceptable.

5. DATA PROCESSING

Flight path recovery, data checking and editing, and preliminary gridding and imaging were performed at the survey base mainly using the AGSO developed ARGUS processing system. Final magnetic, gamma-ray spectrometric and digital elevation model data processing were carried out in Canberra using the INTREPID data processing system.

(i) Data Checking and Editing

Data recorded on the aircraft acquisition system were transferred on a flight by flight basis to the hard disk of a Compaq SLT386s/20 laptop computer. This computer was networked to a Sun Sparcstation IPX and all aircraft data were transferred to the Sun hard disk to be edited for missing values, noise, spikes or steps using AGSO-developed software from the ARGUS processing system. All the recorded data were displayed for each survey line and any errors were interactively corrected. Anomalies arising from cultural influences, such as drilling rigs, sheds, houses and fences, were usually not edited out.

(ii) Flight Path Recovery

Range data, which were recorded internally every five seconds on both GPS receivers, were post-processed daily in the field using "Ranger" – an Ashtech proprietary program. "Ranger" calculates the corrected flight path (longitude, latitude and height) relative to the WGS84 reference ellipsoid.

At the end of each flying day the corrected longitude and latitude data calculated at five second intervals by "Ranger" were used to correct the GPS data which were recorded every one second on the aircraft acquisition system. As well as the standard "Ranger" corrections, other acquisition system specific corrections were applied. Position data were converted from the WGS84 coordinate system to the Australian Geodetic Datum 1984 (AGD84) coordinate system which is defined in Appendix J. The full correction procedure is described in Appendix K and is outlined below.

(a) Position calculation delay correction.
(b) Fiducial synchronisation correction.
(c) "Ranger" corrections.
(d) Low pass filter.
(e) Coordinate system conversion.
(f) Reference navigation data to position of magnetometer sensor.
(g) Doppler infill of short gaps.

The fully corrected flight path was plotted each day to check the position of survey lines and their spacing. Navigation reflies were determined by the following criteria:

Line Spacing	Across Track Deviation	Distance along line
500 metres	80 metres	greater than 5 km

Where both the across track deviation and along line distance are exceeded that portion of the survey line is reflown. This only occurred on two of the survey lines.

(iii) Magnetic Data Processing

Raw magnetic data were read into an INTREPID database which included the navigation data. Diurnal variation corrections were applied. The 0.1 second data recorded from the G833 helium base station magnetometer were used for the diurnal variation correction. These 0.1 second data were low pass filtered prior to the correction being applied. The filter used removed high frequency variations with periods less than 1 minute.

The IGRF 1990 geomagnetic reference field, updated to 15 August 1994 and for an altitude of 120 metres above sea level, which was estimated to be the mean survey altitude, was then subtracted from the data. IGRF values were calculated every 100 metres along the lines. The IGRF was calculated from the coefficients defined by the IAGA (1991). All magnetic values were adjusted by a constant so that the average residual magnetic field value was approximately 5000 nT.

The data were levelled using standard tie line levelling procedures. The steps involved in the tie line levelling were as follows.

(a) Tie line 430 was chosen as a reference tie.

(b) All other ties were levelled to tie line 430 using degree two piecewise polynomial adjustments.

(c) Lines were adjusted on a flight by flight basis to minimise the differences at line/tie crossover points. Degree two piecewise polynomial adjustments were used for most of flights with degree three being used for some.

(d) Finally the lines were individually adjusted to minimise crossover differences, using degree three piecewise polynomial adjustments for most of the lines and degree two for the remainder.

The data were micro-levelled using the technique described by Minty (1991). Filter characteristics used are described below:

(a) Low pass filter in the flight line direction with a cut-off wavelength of 10000 metres.

(b) High pass filter in the tie line direction with a cut-off wavelength of 1000 metres.

(c) Correction strings were low pass filtered with a cut-off wavelength of 1000 metres before being applied to the line data.

(d) Correction values to the line data were constrained to lie within the range +/- 5 nT.

The micro-levelled data were gridded using the minimum curvature technique described by Briggs (1974), employing a 110 metre (3.6 second) grid cell size.

(iv) Gamma-ray Spectrometer Data Processing.

The one second multichannel spectrometer data were imported into an INTREPID database before being corrected for system deadtime and then energy calibrated. The energy calibration technique used involves nominating a standard spectrum to which all other spectra are matched by iteratively adjusting the zero level and gain using a double quadratic minimisation technique (Minty and others, 1990).

Four-channel data were created by summing adjacent channels from the deadtime corrected and energy calibrated multichannel data over the conventional 4 windows (as given in Chapter 3 - Section (iv)). Background estimates for each of the four recording windows were removed. These estimates were determined as follows:

(a) Aircraft and Cosmic Background

Minty and Richardson (1989) derived aircraft and cosmic spectra for the AGSO aircraft from high altitude calibration flights.

(b) Atmospheric Radon Background

Full spectrum analysis (Minty, 1992) was used to calculate the radon contribution to the background in the uranium window.

(c) Total Background

The total background in the uranium window is the sum of the aircraft, cosmic and radon background. The total count and potassium window backgrounds were estimated directly from the uranium background since they are linearly dependent (Grasty, 1975). The thorium window was considered to be unaffected by atmospheric radon, so total thorium background was estimated from the aircraft and cosmic backgrounds.

Channel interaction corrections (stripping) to correct for Compton scattering were applied to the data. Stripping ratios for the AGSO system were determined by Minty and others (1990) using portable calibration sources. The corrections were applied as follows:

$N_{TH(corrected)} = N_{TH}$

$N_{U(corrected)} = N_U - A \times N_{TH(corrected)}$

$N_{K(corrected)} = N_K - B \times N_{TH} - C \times N_{U(corrected)}$

where

N_{TH} = counts in the thorium channel

N_U = counts in the uranium

N_K = counts in the potassium channel

A = 0.3047 + 0.000388*height

B = 0.3923 + 0.000911*height

C = 0.8295 + 0.001365*height

The data were then corrected for height attenuation and reduced to a nominal flying height of 100 metres. Where the aircraft attained a height of 250 metres or higher above the ground gamma-ray spectrometric data have been set to undefined. Height attenuation corrections were made using the following formula:

$$N_{corrected} = N_{uncorrected}\, e^{-u(H-h)}$$

where

$N_{corrected}$ = corrected counts

$N_{uncorrected}$ = uncorrected counts

H = nominal flying height

h = measured flying height

u = attenuation coefficient

Attenuation coefficients for each channel are given below:

$u_{total\ count} = 0.006323$

$u_{potassium} = 0.009365$

$u_{uranium} = 0.006248$

$u_{thorium} = 0.006156$

Before any further processing of the gamma–ray spectrometric data the associated position data were corrected for a parallax error of -9.03 metres (ie. shifted toward the front of the aircraft by 9.03 metres) to account for the difference between the position of the spectrometer crystals and the position data reference point (at the magnetometer sensor).

The potassium and thorium data did not require tie line levelling. Total count and uranium data were tie line levelled in much the same way as the magnetic data. However prior to sampling the crossover points, a 5 point convolution filter with a cut-off wavelength of 350 metres was passed over the data. Note that these filtered data were only used for the crossover analysis and the final point located data have not been filtered.

The steps involved in tie line levelling were as follows:

(a) Tie line 430 was chosen as a reference tie.

(b) All other ties were levelled to the reference tie line using degree two piecewise polynomial adjustments.

(c) Lines were adjusted on a flight by flight basis using degree two piecewise polynomial adjustments to minimise the differences at line/tie crossover points.

(d) The lines were then individually adjusted to minimise crossover differences using degree two degree piecewise polynomial adjustments.

All gamma-ray spectrometric data were micro-levelled using the technique described by Minty (1991). Filter characteristics are described below:

(a) Low pass filter in the flight line direction with a cut-off wavelength of 15000 metres for all channels.

(b) High pass filter in the tie line direction with a cut-off wavelength of 3000 metres for all channels.

(c) Correction values to the line data were limited to the following ranges:

  - -75 to + 75 cps for total count
  - -20 to +20 cps for potassium
  - -20 to + 20 cps for uranium
  - -10 to +10 cps for thorium.

(d) Correction strings were low pass filtered with a cut-off wavelength of 1000 metres before being applied to the line data.

All channels were gridded to a 110 metre (3.6 second) cell size using Brigg's minimum curvature technique. Prior to sampling data for gridding, the data were filtered with a five point low pass convolution filter with a cut-off wavelength of 350 metres. As in the case of filtering prior to crossover sampling, the data were only filtered for the purpose of gridding and the final data were not filtered.

(v) Digital Elevation Model Data Processing.

As described in Chapter 5 – Section ((ii)), range data recorded internally every five seconds on both GPS receivers were post-processed on a daily basis using "Ranger" - an Ashtech proprietary program. "Ranger" calculates the position of aircraft GPS receiver's antenna, including longitude, latitude and height relative to the WGS84 reference ellipsoid for each set of range data (every five seconds).

As in the case of the longitude and latitude data, the following acquisition system specific corrections, which are described in Appendix K, are applied to the height data:

(a) Position calculation delay correction.

(b) Fiducial synchronisation correction.

(c) Coordinate system conversion.

The corrected height data, which are relative to the Australian Geodetic Datum 1984 (AGD84) reference ellipsoid, are then linearly interpolated to one second samples (70 metres) and are merged with the longitude and latitude data.

A radar altimeter provided the aircraft's ground clearance, the altimeter data being sampled every one second.

The raw ground elevation data were then calculated as the difference between the height of the aircraft above the ellipsoid and the height of the aircraft above the ground. These raw elevation data calculated every one second (70 metres) are relative to the AGD84 reference ellipsoid - the ellipsoid being a horizontal datum.

The next step is to convert the heights relative to the AGD84 ellipsoid to heights relative to the geoid. The geoid, which is defined as "the equipotential surface of the gravity field which best approximates mean sea level", is usually chosen as the datum to which heights plotted on maps are referred. The height of the geoid above the AGD84 ellipsoid is called the geoid - ellipsoid separation or N value.

Geoid - ellipsoid separation information for the survey area were supplied by the Australian Surveying and Land Information Group (AUSLIG) in April 1995. The set of N values were supplied as a 10 minute of arc (approximately 18 km) grid. AUSLIG also provides a program "DINTER" which uses bilinear interpolation to calculate N values on a fifteen second of arc (approximately 450 metre) grid.

These values were then read into an INTREPID database and gridded using the INTREPID software package to a cell size of 72.0 seconds of arc (approximately 2200 metre). This grid of N values was used to calculate correction strings to be subtracted from the elevation data. The correction strings were low pass filtered with a cut-off wavelength of 2000 metres before being applied to the point-located elevation data.

The elevation data were then corrected to account for the vertical separation between the antenna of the aircraft's GPS receiver, on the roof of the aircraft, and radar altimeter on the belly of the aircraft. This antenna separation distance of 1.675 metres was subtracted from the elevation data.

Before any further processing of the digital elevation model data the associated position data were corrected for a parallax error of -11.4 metres (ie. shifted toward the front of the aircraft by 11.4 metres) to account for the difference between the position of the GPS and radar altimeter antennae and the position data reference point (at the magnetometer sensor).

In place of tie line levelling the first pass of levelling the elevation data was carried out by using the off–shore data as a zero level reference. The steps involved were as follows:

(a) The average elevation value for the off–shore portion of each flight line and tie line was calculated.

(b) The average off-shore elevation value for each flight line and tie line was subtracted from every sample on that flight line or tie line.

These data were then micro-levelled using the technique described by Minty (1991). The filter characteristics are described below:

(a) Low pass filter in the flight line direction with a cut-off wavelength of 15000 metres.

(b) High pass filter in the tie line direction with a cut-off wavelength of 3000 metres.

(c) Correction strings were low pass filtered with a cut-off wavelength of 1000 metres before being applied to the line data.

(d) Correction values to line data were constrained to be within the range +/- 35 metres, although generally the correction values were in the range +/- 10 metres.

The micro-levelled data were gridded using Brigg's minimum curvature technique, employing a 110 metre (3.6 second) grid cell size.

(vi) Final Products

(a) Standard AGSO geophysical maps

An AGSO standard set of geophysical maps have been produced at scales of 1:250 000 and 1:100 000 for the entire survey area. Profile, flight path and contour maps were produced using the INTREPID programs. The standard set of maps produced are shown in Appendix L.

(b) Digital Data

Final processed point-located data and grids were archived in the standard AGSO ARGUS format, on exabyte magnetic tape cartridges and magneto-optical discs, in ASCII format (Appendix M).

(c) Pixel Image Maps

Additional to the standard AGSO geophysical maps listed in Appendix L, pixel image maps have been compiled using the method described by Milligan and others (1992). The following pixel image maps have been released at 1:250 000 scale for both the Medusa Banks and Port Keats 1:250 000 map sheets as well as for the combined area.

(i) Colour gradient enhanced total magnetic intensity.

(ii) Greyscale gradient enhancement of total magnetic intensity.

(iii) Colour gradient enhanced total magnetic intensity reduced to the pole.

(iv) Greyscale gradient enhancement of total magnetic intensity reduced to the pole.

(v) Colour gradient enhanced first vertical derivative of total magnetic intensity reduced to the pole.

(vi) Greyscale gradient enhancement of the first vertical derivative of total magnetic intensity reduced to the pole.

(d) Interpretation Package

AGSO produced an interpretation package. The package includes;

(i) The image products detailed above.

(ii) Contours of total magnetic intensity at 1:250 000 scale.

(iii) Contours of total magnetic intensity reduced to the pole at 1:250 000 scale.

(iv) Contours of the first vertical derivative of total magnetic intensity reduced to the pole at 1:250 000 scale.

(v) Greyscale gradient enhancement of the band pass filtered total magnetic intensity reduced to the pole image at 1:250 000 scale.

(vi) Colour low pass filtered first vertical derivative of total magnetic intensity reduced to the pole image at 1:250 000 scale.

(vii) Colour analytic signal image at 1:250 000 scale.

(viii) Euler depth determination plot at 1:250 000 scale.

(ix) Gravity maps at 1:250 000 scale.

(x) Structural interpretation maps at 1:250 000 scale.

(xi) Detailed computer modelling of key anomalies.

(xii) Report synthesising the above in terms of the geology of the Bonaparte Gulf Basin (Gunn et al 1995).

6. REFERENCES

Briggs, I.C., 1974 - Machine contouring using minimum-curvature. *Geophysics*, **39**, 39-48.

Bacchin, M., 1997 - Lissadell, East Kimberley W.A. Airborne Geophysical Survey, 1994 - Operations Report. *Australian Geological Survey Organisation, Australia, Record 1997/9.*

Grasty, R. L., 1975 - Uranium measurements by airborne gamma-ray spectrometry. *Geophysics*, **40**, 503-519.

Gunn, P. J., Brodie, R. C., and Mackey, T., 1995 - Interpretation of aeromagnetic data over the Southern Joseph Bonaparte Gulf in the context of petroleum prospectivity. *Australian Geological Survey Organisation, Australia, Record 1995/40.*

International Association of Geomagnetism and Aeronomy, 1991 - Division V Working Group 8. International Geomagnetic Reference Field, 1991 Revision. *Journal of Geomagnetism and Geoelectricity*, **43**, 1007-1012.

International Atomic Energy Agency, 1991 - Airborne Gamma Ray Spectrometer Surveying. *International Atomic Energy Agency Technical Reports Series Number 323*, IAEA Vienna.

Milligan, P. R., Morse, M. P., and Rajagopalan, S., 1992 - Pixel map preparation using the HSV colour model. *Exploration Geophysics*, **23**, 219-224.

Minty, B. R. S., Morse, M. P., and Richardson, L. M., 1990 - Portable calibration sources for airborne gamma-ray spectrometers. *Exploration Geophysics*, **21**, 187-195.

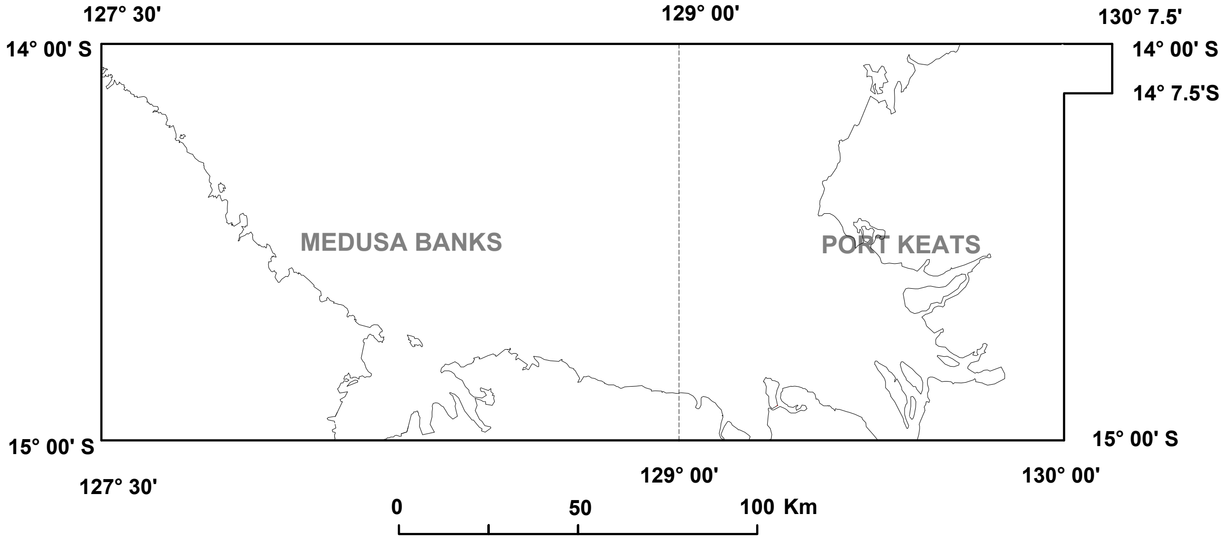
Minty, B. R. S., 1991 - Simple micro-levelling for aeromagnetic data. *Exploration Geophysics*, **22**, 591-592.

Minty, B. R. S., 1992 - Airborne gamma-ray spectrometric background estimation using full spectrum analysis. *Geophysics*, **57**, 279-287.

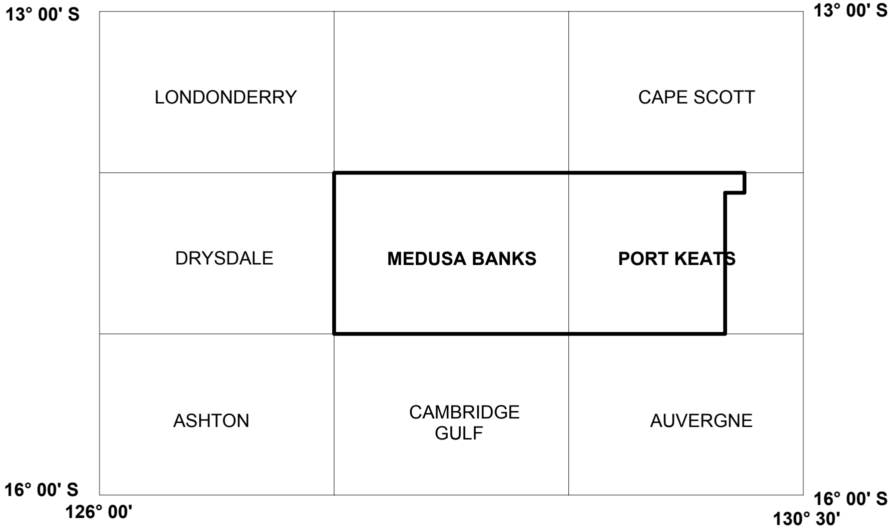
Minty, B. R. S., and Richardson, L. M., 1989 - Calibration of the BMR airborne gamma-ray spectrometer upward-looking detector, February 1989. *Bureau of Mineral Resources, Australia, Record 1989/8*.

Appendix A-1

Survey Area



REFERENCE TO AUSTRALIA 1 : 250 000 STANDARD MAP SERIES



Appendix B-1

Flying Dates and Production Kilometres Flown

Date	Flight Number	Comments	Line / Tie Kilometres
5/07/94	265	Compensation & test flight (Lissadell survey)	0
16/07/94	283	Active diurnal flight abandoned	0
17/07/94	284	Spectrometer test flights	0
18/07/94	285	Operations normal	842
19/07/94	286	Operations normal	842
19/07/94	287	Operations normal	842
20/07/94		Ferry to Cairns for spectrometer calibration	0
21/07/94	288	Spectrometer calibration flight	0
22/07/94		Return ferry from Cairns	0
23/07/94	289	Cylinder in left hand engine cracked	792
29/07/94	290	Compensation and refly portion of 2 lines	50
29/07/94	291	Compensation	0
30/07/94	292	Operations normal	842
30/07/94	293	Operations normal	842
31/07/94	294	Operations normal	856
31/07/94	295	Operations normal	856
1/08/94	296	Multi Channel spectra data not recovered	970
1/08/94	297	Operations normal	970
2/08/94	298	Operations normal	970
2/08/94	299	Operations normal	642
3/08/94	300	Operations normal	642
3/08/94	301	Operations normal	970
4/08/94	302	Operations normal	642
4/08/94	303	Operations normal	970
5/08/94	304	Operations normal	742
5/08/94	305	Operations normal	956
6/08/94	306	Operations normal	970
6/08/94	307	Operations normal	856
8/08/94	308	Using potassium as stabilisation peak	856
9/08/94	309	Back to thorium peak as stabilising peak	856
9/08/94	310	Operations normal	898
10/08/94	311	Operations normal	670
10/08/94	312	Operations normal	898
11/08/94	313	Operations normal	856
11/08/94	314	Operations normal	628
12/08/94	315	Operations normal	856
12/08/94	316	Operations normal	856
13/08/94	317	Operations normal	856
13/08/94	318	Operations normal	856
15/08/94	319	Operations normal	842
15/08/94	320	Operations normal	856

Appendix B-2

16/08/94	321	Operations normal	756
16/08/94	322	Operations normal	870
20/08/94	323	Compensation flight abandoned, alternator U/S	0
20/08/94	324	Compensation flight - results not acceptable	0
21/08/94	325	Successful compensation flight	0
21/08/94	326	Operations normal	861
22/08/94	327	Operations normal	628
22/08/94	328	Operations normal	934
23/08/94	329	Operations normal	856
23/08/94	330	Operations normal	929
24/08/94	331	Operations normal	856
24/08/94	332	Operations normal	655
25/08/94	333	Operations normal	870
25/08/94	334	Operations normal	742
26/08/94	335	Operations normal	870
26/08/94	336/7	System restarted in-flight - 2 flight numbers	921
27/08/94	338	Operations normal	870
27/08/94	339	Operations normal	902
29/08/94	340	Operations normal	856
29/08/94	341	Flight aborted - problem with spectrometer	460
30/08/94	342	Operations normal	876
30/08/94	343	Operations normal	856
31/08/94	344	Operations normal	824
31/08/94	345	Operations normal	668
1/09/94	346	Operations normal	561
1/09/94	347	Operations normal	815
2/09/94	348	Operations normal	856
2/09/94	349	Operations normal	906
3/09/94	350	Operations normal	856
3/09/94	351	Operations normal	856
5/09/94	352	Operations normal	856
5/09/94	353	Operations normal	856
6/09/94	354	Operations normal	856
7/09/94	355	Operations normal	628
7/09/94	356	Operations normal	856
11/09/94	357	Compensation	0
11/09/94	358	Operations normal	328
11/09/94	359	Operations normal	856
12/09/94	360	Operations normal	856
12/09/94	361	Operations normal	856
13/09/94	362	Operations normal	842
13/09/94	363	Operations normal	856
14/09/94	364	Operations normal	856
14/09/94	365	Operations normal	856

15/09/94	366	Operations normal	856
15/09/94	367	Landed Port Keats due to rain	484
15/09/94	368	Depart Port Keats	143
16/09/94	369	Operations normal	856
16/09/94	370	Operations normal	856
17/09/94	371	Operations normal	856
17/09/94	372	Operations normal	842
19/09/94	373	No second test line due to lack of time	856
19/09/94	374	Operations normal	856
20/09/94	375	Refly of part of flight 296	640
21/09/94	376	Operations normal	849
21/09/94	377	Refly of part of flight 296	330
24/09/94		Ferry - Kununurra to Tindal	0
			67570

SUMMARY

Total line kilometres flown	67570
Productive survey flights	83
Unproductive survey flights	15
Total flights in survey	98

Unproductive survey flight consisted of:

Aircraft ferries	3
Compensation flights	7
Test flights	2
Abandoned flights	3

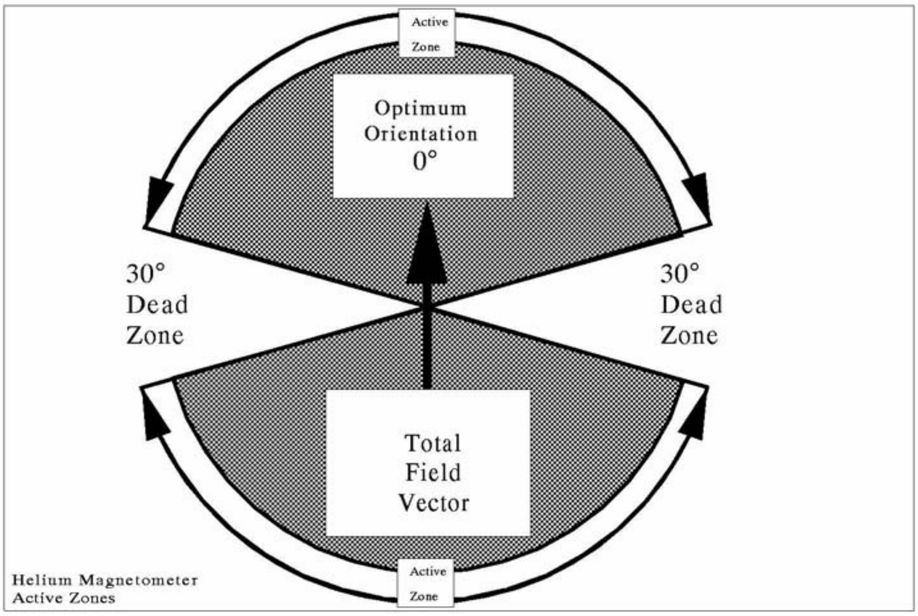
Abandoned flights:

Active diurnal	1
Equipment failure	2

Appendix C-1

Specifications – G833 Helium Magnetometer

Operating range:	20,000 to 95,000 nT
Temperature:	-20 to +50 °C
Sensitivity:	0.0032 nT/root Hz RMS
Bandwidth:	350 Hz (-3dB point)
Loop scan rate:	1000 cycles/second
Input power:	28 V DC, 6 A max
Output signal:	At Helium gyromagnetic frequency, approximately 28.02468 Hz/nT. 3 volts peak to peak
Dimensions:	Sensor cell - 80 mm diameter x 145 mm length Scan processor - 270 x 120 x 85 mm Control panel - 48.26 cm rack mount
Weight:	approximately 6 kg



Appendix D-1

Specifications – RMS Instruments
Automatic Aeromagnetic Digital Compensator

Inputs:	one or two high sensitivity magnetometers of optical absorption type
Input frequency range:	70 kHz – 350 kHz – Cs sensor 140 kHz – 700 kHz – K sensor 560 kHz – 2800 kHz – He sensor 850 Hz – 4260 Hz – Overhauser
Magnetic field range:	20,000 nT – 100,000 nT
Resolution:	1 pT (picoTesla)
Compensation procedure:	improvement ratio 10 – 20 (typical for total field) improvement ratio 20 – 100 (typical for gradient)
Accuracy of compensation:	0.35 nT standard deviation for the entire aircraft flight envelope in the bandwidth 0 – 1 Hz typical
Data output rate:	10 Hz
System frequency response:	0 – 0.9 Hz
Internal system noise:	less than 2 pT (standard deviation in the bandwidth 0– 1 Hz)
Duration of calibration flight:	5 – 8 minutes typical
Vector magnetometer:	Develco Model 9202–02 (3-axis fluxgate)
Microcomputer:	SBC-11/21 Plus (DEC) Front End LSI–11/73(DEC) Main CPU
Keyboard:	limited alphanumeric
Display:	green fluorescent, 80 character self scan panel
Outputs	serial data communication port RS232C – max. rate 19.2 K Baud parallel output port:– 16 bit with full handshaking (DRV11–J) (optional)
Power:	28 ± 4 VDC 5A, 150 W (for single magnetometer) 7A, 196 W (for gradiometer system)
Environmental:	Operating temperature: 0°C to 50°C Storage temperature -20°C to 55°C Relative humidity 0–99%, non-condensing Altitude 0–6000 metres
Physical data:	console dimensions: 483 x 178 x 440 mm console weight: 12.5 kg power supply dimensions: 225 x 180 x 220 mm power supply weight: 5.5 kg

Appendix E-1

Specifications – GR820 Spectrometer System

A. Detector Controller

- Maximum number of crystals – 16. Each crystal has individual pole–zero cancellation, semi–gaussian shaping and advanced base line restoration circuitry.
- Continuous, individual–crystal spectrum analysis ensures that optimum system stabilisation is achieved. Resolution is calculated by a sophisticated gaussian curve fitting algorithm to perform an accurate centroid analysis of the selected stabilisation peak.
- High energy cosmic pulses are accumulated in a separate channel.
- Accurate pile-up rejection for simultaneous pulses allows qualitative gamma–ray spectrum analysis almost independent of the system count rate. Special circuitry analyses for pulse pile–up and permits only detector signals from single events to be analysed. Simultaneous events in adjacent crystals are added to reduce the Compton effect.
- Residual pulse pile–up at 100,000 counts/sec are less than 2%.

B. Analogue to digital converter (ADC)

- 50 MHz Wilkinson ramp ADC.
- Linearity – integral – less than 0.2% ; – differential – less than 1%.
- Average system dead-time is less than 5 microsec/pulse.
- Live–time channel records the actual system live–time. This data is output with the digital data which allows post correction for system dead–time to an accuracy of 0.1%.
- Number of channels – selection of 256 channels or 512 channel operation.
- Maximum number of counts/channel – 65,535 (16 bits).
- The lower threshold – manually selectable from channel 2 to channel 50 (20–500 keV).
- The upper threshold is set to 3 MeV. All pulses above 3 MeV are accumulated in the cosmic channel as a direct measure of cosmic ray activity.
- ADC offset set from the keyboard.
- The maximum input count rate is 100,000 counts/second.

C. System outputs

- Visual display – the front panel display is a 640x200 electroluminescent (EL) high contrast graphics display which allows full spectrum display, system set–up and various parameter monitoring functions. In the spectrum display mode, the region of interest and cursor may be viewed by channel number or directly in keV.
- The internal channel number to energy level (keV) conversion table compensates for non–linearity of the detector's light output.
- The front panel has a 21 button keyboard for easy operator control.
- The system's operation is fully menu driven.
- Digital outputs:

  - RS−232 port (1200 to 19200 baud).
  - IEEE-488 bus output – talk listen/talk only.
- Geometrics GR−800 output format.
- Some system functions can be controlled remotely by an external computer via the RS−232 and the IEEE−488 digital ports.
- Analogue output:
  - 4 channels of roi data can be selected for output on the analogue port. The outputs have 10 bit resolution (0−10V). Scaling can be set from the keyboard (100−50K counts/sec FSD) and output data may be raw or stripped using internally stored calibration constants. Analogue output wraps at FSD limits and is dead-time corrected.

D. Miscellaneous

- Regions of interest (ROI): 8ROIs can be selected. The upper and lower thresholds can be individually set over the entire spectrum range.
- The first 4 ROIs are available for digital and analogue output. The second 4 ROIs are available only for digital output on the RS−232 or the IEEE−488 ports.
- System resolution. Detector resolution is automatically computed for each (and summed crystals) during peak analysis and is displayed for operator monitoring when required. The summed down resolution is also output on the data stream.
- System test. At power on, a full system test of all internal pcb handshaking is performed. Included in the testing is the lithium back-up battery, the system ram memory, display handshaking, the systems configuration (options installed), the selected detectors (checked via ADC analysis) and peripheral handshaking response.
- Configuration menus. The configuration menus allow the selection of the number of detectors in use, confidence levels for gain analysis, maximum crystal resolution levels for each detector (with operator warning if levels exceeded), output configurations for analogue and digital data and various special display/monitoring functions.
- Maintenance. A set of special menus allows the user to test and calibrate many system functions including system test, ADC offset, low level discriminator etc.
- Power: 28V – 1.25 amps

E. Detectors

The crystals are housed in a specially designed hi−impact polystyrene cases using low background materials for minimum signal attenuation. Full thermal and internal shock protection allows the units to be directly mounted to the floor. A very low noise, high voltage power supply is housed in each pack so high voltage is not present in the connecting cables. A unique preamplifier with special processing for signal optimisation is used. The GPX−1024 has 4 crystals with a total volume of 16.78 litres

- Outputs: Individual BNC connectors output each crystal's signal separately
- Size: GPX−1024 : (73x51x30 cm)
- Weight: GPX−1024 : 84kg
- Power: 28V @ 0.5A/crystal pack

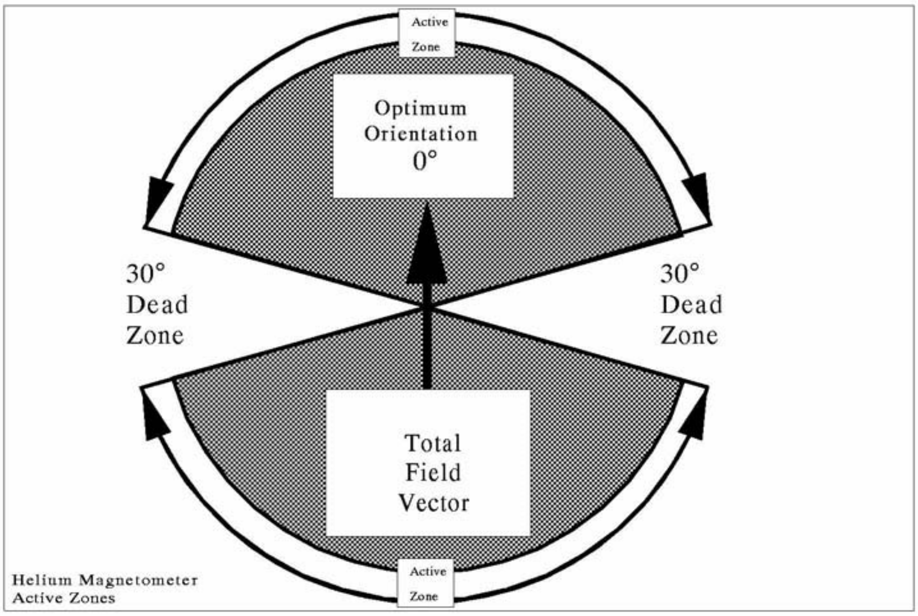
Appendix E-3

- Temperature limitations
    - Closed pack: storage -40°C to +60°C, operation -40°C to +60°C
    - Open pack: not recommended
- Temperature gradient
    - Closed pack: -40°C to +50°C (instantaneous)
    - Open pack: a change of 1°C/hr

Appendix F-1

Specifications - G833 Helium Base Station Magnetometer

Operating range:	20,000 to 95,000 nT
Temperature:	-20 to +50 °C
Sensitivity:	0.0032 nT/root Hz RMS
Bandwidth:	350 Hz (-3dB point)
Loop scan rate:	1000 cycles/second
Input power:	28 V DC, 6 A max
Output signal:	At Helium gyromagnetic frequency, approximately 28.02468 Hz/nT. 3 volts peak to peak
Dimensions:	Sensor cell - 80 mm diameter x 145 mm length Scan processor - 270 x 120 x 85 mm Control panel - 48.26 cm rack mount
Weight:	approximately 6 kg



Appendix F-2

Specifications - Magellan OEM GPS Module

Operational characteristics	
Position update rate:	1 second continuous (approximate)
Time to first fix:	
Warm start:	30 seconds (approximate) with almanac / date / time / initial position and ephemeris < 2 hours old
Cold start:	75 seconds 2D/3D (9 seconds approximate) with almanac / date / time / initial position
Autonomous start:	5 - 12 minutes typical (no almanac / ephemeris / date / time / initial position
Position accuracy:	HDOP < 2, Cno > 47 db-Hz, 2D and with selective availability disabled
Horizontal position:	25 metres RMS in 2D 30 metres RMS in 3D
Vertical position:	50 metres RMS
Electrical Characteristics:	
Power:	
OEM/PS:	9 - 16 VDC 235 mA at 12 VDC typical, 250 mA max
OEM/5V:	5 VDC +/- 0.2 VDC 170 mA
Interfaces:	RS232
Baud rates:	Jumper - selectable 1200,2400,4800, or 9600
Receiver type:	4 channels dedicated to tracking satellites 1 channel dedicated to tracking all other satellites
Firmware functions:	
Timing:	Timing pulse ON/OFF UTC or GMT reference Time only mode Single satellite timing default all modes Hour, minute, second, day, month, year Status indicator Satellites in solution Signal quality
OEM antenna:	Active Quadrifilar Helix

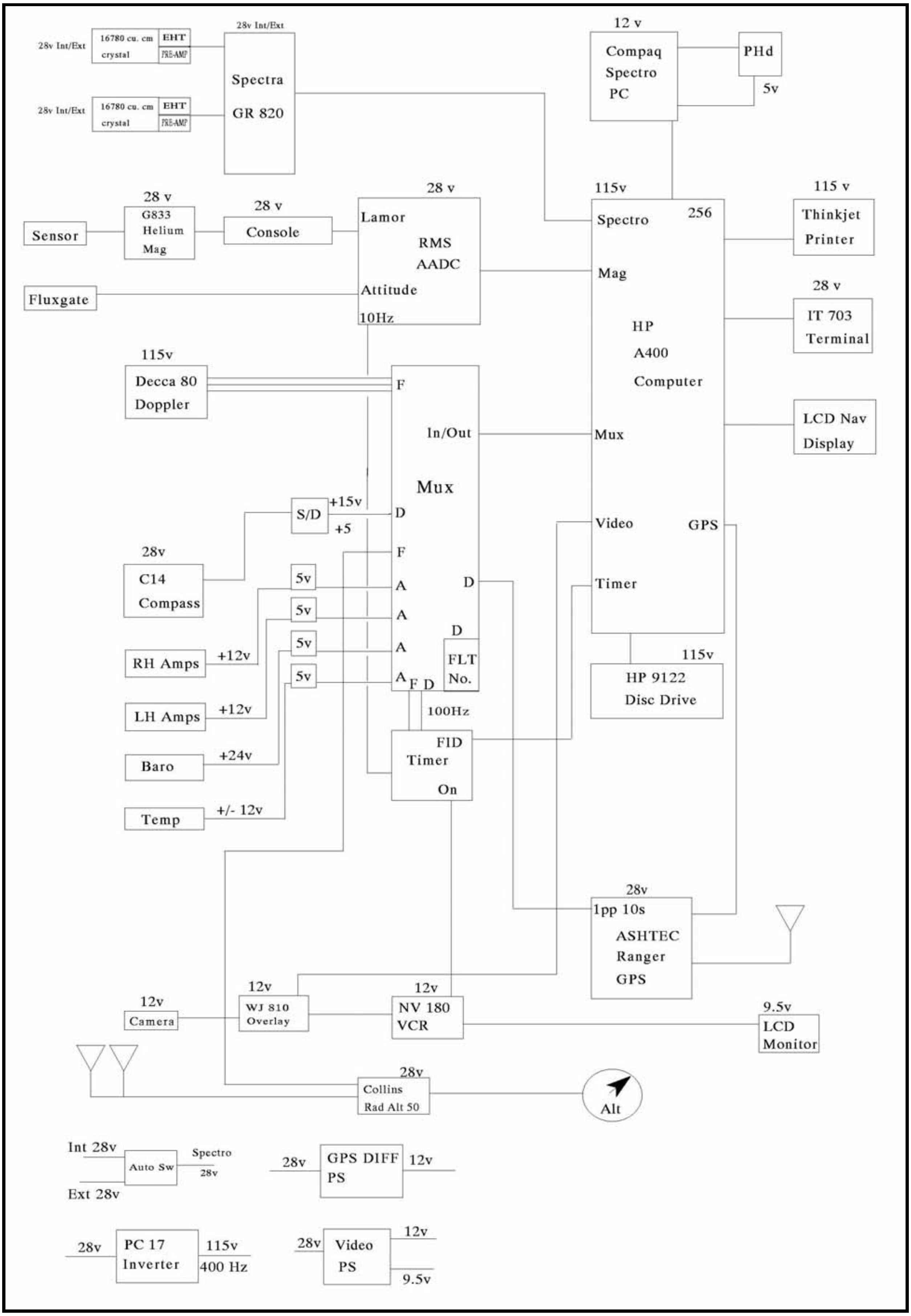
Appendix F-3

Specifications - GT100 Universal Counter

Input Characteristics	
Channels A and B	
Frequency Range:	DC to 100 MHz
Signal Operating Range:	+5 V to -5 V
Sensitivity:	
Sinewave:	25 mV RMS DC to 20 MHz 50 mV RMS 20 MHz to 50 MHz 160 mV RMS 50 MHz to 100 MHz
Pulse:	450 mV peak–peak at 5 ns pulse width
Measurement Functions:	
Resolution:	+/- LSD +/- Freq *1.4 *Trigger Error/Gate time Hz
Accuracy:	+/-Resolution +/- Time Base Error Hz
General:	1 full size slot in any PC/XT, PC/AT or
Compatibility:	compatible, using DOS 3.0 or higher. Compatible with any programming language.
Time pulse:	Standard 10 MHz Crystal Oscillator Accuracy +/- 100 ppm (0.01 %)

Appendix G-1

Aircraft Acquisition System



Appendix H-1

Compensation Results

Compensation 1

Date flown	5 July 1994
Dates used	16 July to 23 July

Air conditioner off

$\sigma_u = 0.5680$
$\sigma_c = 0.07074$
$\lambda = 8.0$
$\nu = 19.0$

Air conditioner on

$\sigma_u = 0.5963$
$\sigma_c = 0.06839$
$\lambda = 8.7$
$\nu = 19.6$

Compensation 2

Date flown	29 July 1994
Dates used	not accepted

Air conditioner off

$\sigma_u = 0.4793$
$\sigma_c = 0.06216$
$\lambda = 7.7$
$\nu = 19.0$

Air conditioner on

$\sigma_u = 0.5021$
$\sigma_c = 0.06282$
$\lambda = 8.1$
$\nu = 19.6$

Compensation 3

Date flown	29 July 1994
Dates used	29 July to 16 August

Air conditioner off

$\sigma_u = 0.4079$
$\sigma_c = 0.03206$
$\lambda = 12.7$
$\nu = 17.9$

Air conditioner on

$\sigma_u = 0.4914$
$\sigma_c = 0.03200$
$\lambda = 15.4$
$\nu = 18.8$

Appendix H-2

Compensation 4

Date flown 20 August 1994
Dates used not used

Air conditioner off

σ_u = 0.4697
σ_c = 0.06267
λ = 7.5
ν = 20.2

Air conditioner on

σ_u = 0.6258
σ_c = 0.09513
λ = 6.4
ν = 21.7

Compensation 5

Date flown 21 August 1994
Dates used 21 August to 7 September

Air conditioner off

σ_u = 0.4942
σ_c = 0.03371
λ = 14.7
ν = 19.2

Air conditioner on

σ_u = 0.4615
σ_c = 0.08140
λ = 5.7
ν = 21.3

Compensation 6

Date flown 11 September 1994
Dates used 11 to 21 September

Air conditioner off

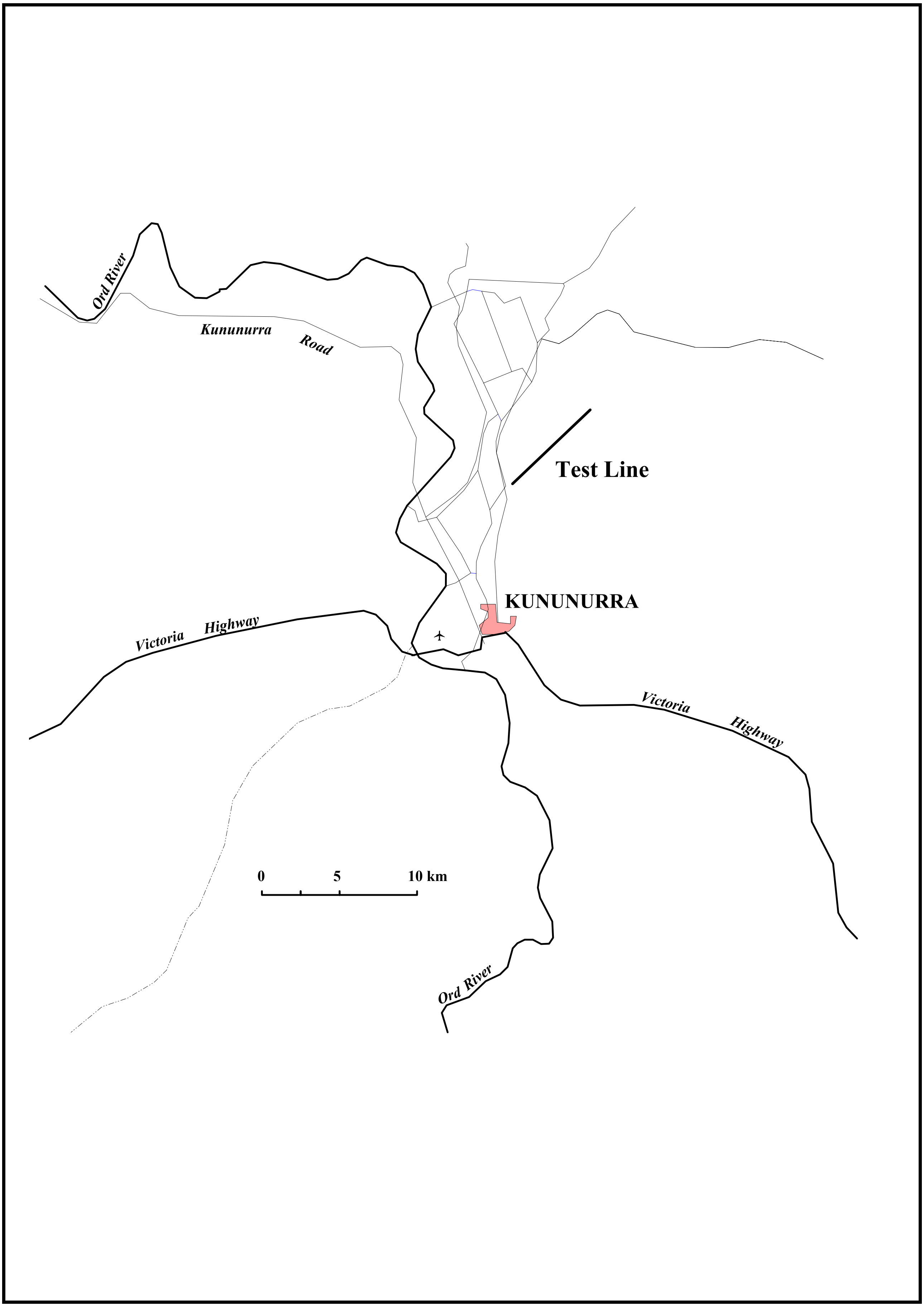
σ_u = 0.3915
σ_c = 0.04861
λ = 8.1
ν = 18.9

Air conditioner on not done

σ_u = standard deviation of data recorded during manoeuvres
σ_c = standard deviation of data recorded during manoeuvres after compensation corrections have been applied
λ = improvement ratio = σ_u / σ_c
ν = vector norm, a measure of the degree of difficulty in calculating the coefficients

Appendix I-1

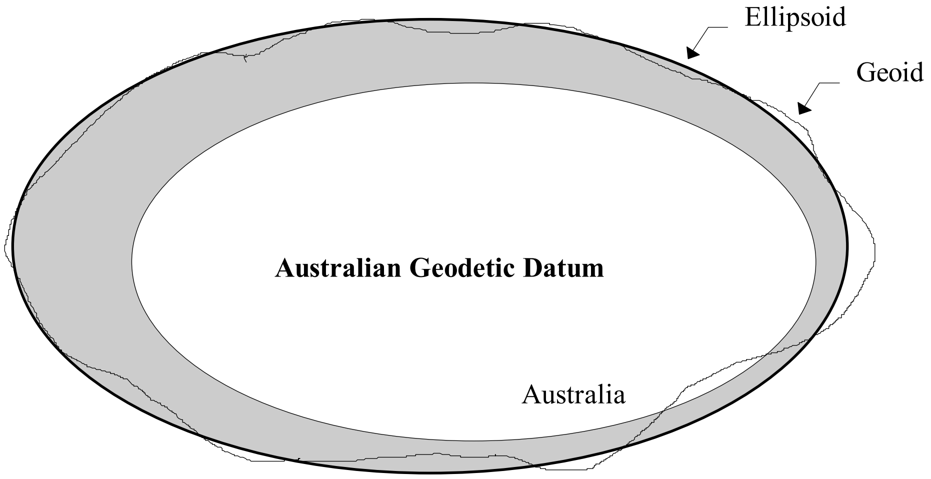
Gamma-ray Spectrometer Test Line Location



Appendix J-1

The Australian Geodetic Datum

For geophysical surveys the real shape of the earth has to be considered. An ellipsoid of revolution around the earth's north-south axis approximates the earth's shape. This figure is called the spheroid. The mean sea level equipotential surface describing the shape of the earth is known as the geoid.



Calculated positions from the GPS are in the World Geodetic System 1984 (WGS84). During processing these positions are converted to the local reference datum, AGD84 or Australian Geodetic Datum 1984.

This non-geocentric datum comprises the Australian National Spheroid (ANS) oriented and located in such a manner as to "best-fit" the geoid over the Australian continent.

The Australian geodetic datum is defined by a semi-major axis (a) and flattening (f) of the selected ellipsoid and the geodetic coordinates of the origin or fundamental station. The origin is referred to as the Johnston Origin. For AGD84:

a	=	6378160 m
f	=	1/298.25
latitude	=	25° 56' 54.5515" S
longitude	=	133° 12' 30.0771" E
height	=	571.2 metres above ellipsoid

For an ideal local datum the geoid-spheroid separation over a region should be small and uniform. At the time of the AGD84 adjustment it was assumed that the geoid and the spheroid coincided at Johnston.

Appendix K-1

Corrections to Differential GPS Navigation Data

(a) Position calculation delay correction

A correction due to the finite time taken for the GPS system to calculate a position and transfer the information to the acquisition system. A delay of 0.6 seconds has been determined for calculations using up to eight satellites by flying clover leaf patterns over a reference point. This value is considered to be representative and was used for all delay corrections.

(b) Fiducial synchronisation correction

A correction due to the time lag between when a GPS position is available to the acquisition system and when the next fiducial is available to pair the position with.

(c) "Ranger" corrections

Using the range data which are recorded internally on the aircraft and base GPS receivers five seconds, "Ranger" calculates the correct positions at one second intervals along the flight path. These corrected positions are utilised to correct the raw aircraft position data recorded every second.

Discontinuities (steps) and spikes sometimes occur in the raw aircraft GPS data. These may also be manifested as steps in the correction set. When such steps in the raw aircraft GPS data occur between successive correction values, the corrections are linearly interpolated to the step boundary using corrections from the appropriate side of the step.

If multiple steps in the raw GPS data occur between successive correction values it is impossible to interpolate corrections over this interval, in which case the intervening GPS data are set to undefined.

(d) Low Pass filter

The problem described in (a) can lead to small steps in the data where the original steps were too small to detect so were not corrected. A low pass 5 point Fuller filter with a cut-off wavelength of 175 metres was passed over the navigation data. The terrain data are not filtered.

(e) Infilling "Ranger" data

Data gaps can appear in the "Ranger" data and not in the raw aircraft data. To infill these gaps the difference between the raw aircraft data and the "Ranger" data are calculated at each point for which both exist. It is these differences that are actually infilled, therefore preserving the shape of the aircraft's flight path over the gap in the "Ranger" data whilst still moving the navigation data to the absolute locations defined by the "Ranger" data. The maximum gap that will be infilled by this method is 10 seconds (700 metres).

(f) Reference navigation data to position of magnetometer sensor

The calculated GPS positions refer to the position of the GPS receiver's antenna. Since the magnetometer is the most position–sensitive instrument, all position data are shifted 11.4 metres towards the rear of the aircraft to correspond with the position of the magnetometer sensor. In the processing of the gamma-ray and digital elevation model data parallax corrections are made to account for this shift.

(g) Coordinate system conversion

GPS data were converted from the WGS 84 geodetic coordinate system to the AGD 84 geodetic coordinate system. See Appendix J for details of the Australian Geodetic Datum.

(h) Generation of terrain data

The terrain data is generated by subtracting radar altimeter clearance data from the "Ranger" ellipsoidal height data. The terrain data are linearly interpolated to match the five second sampling interval of the "Ranger" corrected navigation data.

(i) Doppler infill of gaps

Whenever gaps (<10 km) in the GPS data occurred they were infilled with data generated from the doppler navigation system. Gaps in the GPS data greater than ten kilometres were reflown.

(j) Barometric infill of height data gaps

Whenever gaps less than 5 km in the GPS height data occur, these gaps are infilled with height data calculated using the recorded barometric and temperature data. Gaps greater than 5 km require the line to be reflown or an infill line flown.

Appendix L-1

Geophysical Maps

Name	Type	Interval or Scale	Reference Number
1:250 000 scale			
Medusa Banks	TMI Contours	5 nT	22-1/D52-10/1
	Total Count Contours	75cps	22-1/D52-10/2
	Flight line System		22-1/D52-10/3
	DEM Contours	10 m	22-1/D52-10/19
Port Keats	TMI Contours	2 nT	22-1/D52-11/1
	Total Count Contours	100 cps	22-1/D52-11/2
	Flight line System		22-1/D52-11/3
	DEM Contours	5 m	22-1/D52-11/19
1:100 000 scale			
Casuarina	TMI Contours	5 nT	22-2/D52-10/1-1
	Total Count Contours	30 cps	22-2/D52-10/2-1
	Flight line System		22-2/D52-10/3-1
	TMI Profiles	200 nT/cm	22-2/D52-10/4-1
SD52-10/2	TMI Contours	0.5 nT	22-2/D52-10/1-2
	Total Count Contours	water only	22-2/D52-10/2-2
	Flight line System		22-2/D52-10/3-2
	TMI Profiles	20 nT/cm	22-2/D52-10/4-2
SD52-10/3	TMI Contours	1 nT	22-2/D52-10/1-3
	Total Count Contours	water only	22-2/D52-10/2-3
	Flight line System		22-2/D52-10/3-3
	TMI Profiles	10 nT/cm	22-2/D52-10/4-3
Berkley	TMI Contours	5 nT	22-2/D52-10/1-4
	Total Count Contours	30 cps	22-2/D52-10/2-4
	Flight line System		22-2/D52-10/3-4
	TMI Profiles	100 nT/cm	22-2/D52-10/4-4
Medusa	TMI Contours	2 nT	22-2/D52-10/1-5
	Total Count Contours	30 cps	22-2/D52-10/2-5
	Flight line System		22-2/D52-10/3-5
	TMI Profiles	40 nT/cm	22-2/D52-10/4-5
Knob Peak	TMI Contours	0.5 nT	22-2/D52-10/1-6
	Total Count Contours	30 cps	22-2/D52-10/2-6
	Flight line System		22-2/D52-10/3-6
	TMI Profiles	10 nT/cm	22-2/D52-10/4-6

Appendix L-2

Pearce	TMI Contours	0.5 nT	22-2/D52-11/1-1
	Total Count Contours	30 cps	22-2/D52-11/2-1
	Flight line System		22-2/D52-11/3-1
	TMI Profiles	5 nT/cm	22-2/D52-11/4-1
Keats	TMI Contours	1 nT	22-2/D52-11/1-2
	Total Count Contours	50 cps	22-2/D52-11/2-2
	Flight line System		22-2/D52-11/3-2
	TMI Profiles	40 nT/cm	22-2/D52-11/4-2
Turtle Point	TMI Contours	0.5 nT	22-2/D52-11/1-4
	Total Count Contours	30 cps	22-2/D52-11/2-4
	Flight line System		22-2/D52-11/3-4
	TMI Profiles	10 nT/cm	22-2/D52-11/4-4
Keyling	TMI Contours	0.5 nT	22-2/D52-11/1-5
	Total Count Contours	30 cps	22-2/D52-11/2-5
	Flight line System		22-2/D52-11/3-5
	TMI Profiles	15 nT/cm	22-2/D52-11/4-5

Appendix M-1

AGSO Archive Data, Grid and Magnetic Tape Format for Airborne Geophysical Data

CONTENTS

TABLES

Appendix M-2

1. THE AGSO SEQUENTIAL FILE STRUCTURE

(i) Introduction

This appendix describes the general sequential file structure used by AGSO to store airborne geophysical data. For the purpose of this survey eleven data chains are involved for each line and tie. They are:

channel 4 edition 1 (corrected GPS navigation data)
channel 4 edition 2 (corrected magnetic data)
channel 4 edition 3 (corrected spectrometric data)
channel 4 edition 4 (corrected digital elevation model data)
channel 5 edition 1 (doppler navigation data)
channel 6 edition 1 (raw spectrometric window data)
channel 8 edition 1 (raw magnetic data)
channel 10 edition 1 (raw multi-channel spectrometric data - 100 second)
channel 14 edition 1 (pressure, temperature, cosmic data)
channel 16 edition 1 (raw GPS navigation data)
channel 17 edition 1 (raw multi-channel spectrometric data - 1 second)

(ii) General File Structure

The information pertaining to each traverse (line or tie) is held on the file as a separate entity called a segment. Segments are separated from each other by industry standard EOF records. The end of the file is indicated by two or more consecutive EOF records. Each segment consists of two types of records. Both types are 5120 characters long.

Segment Directory Record (SDR):	the first record on each segment; defines the data content of the segment.
Data Records (DAR's):	hold the measured data values.

(iii) Channels and Samples

Data are recorded at regular intervals in time along a traverse. The data recorded at one instant of time are held as any ordered set or sub-set. Each set is held logically distinct and referred to as a channel. The data records in a segment hold all the information for one channel in the form of a data chain, then all the data for the next channel and so on for as many channels as the segment holds.

Each channel is uniquely defined by a channel number and an edition number. The measurement(s) taken for a channel at a given time is called a sample. Samples are held within each channel in increasing order of fiducial (time).

In defining channels the channel number can be used to define the sample format and the edition type of the data. For example, within AGSO, samples with format (longitude, latitude, value, value....) have a channel number of 4 with edition 2 for magnetic data and edition 3 for gamma–ray spectrometric data.

(iv) Segment Directory Record (Sdr)

Lines and ties are uniquely identified as follows:

Project number:	a unique number to identify the survey

Group number:	a unique number within a survey for each flight made. That is, several lines may be recorded on one flight (group). AGSO convention is for group numbers to lie between 001 and 999 inclusive.
Segment numbers:	a unique number within a survey for a line or tie. AGSO convention is for ordinary line numbers to lie between 1000 and 9999 inclusive and tie line numbers between 100 and 999 inclusive.

The segment directory record identifies the data segment at Project, Group and Segment level and defines the data channels, their structure and the location of their data chains in the segment. Each SDR consists of one or more 10 word blocks. The first, the Segment Identification Block (SIB), identifies the segment and gives the number of data channels held in the segment.

For this survey the number of data channels is nine as mentioned in the introduction. Subsequent blocks, one for each data channel, define the data channels and their location within the segment. These are called Channel Identification Blocks (CIB's). A typical SDR is shown in Figure 1 and its exact format given in Table 1. All unused words in the SDR are set to zero.

The last word in the record in the past has been used as check sum and represents the sum of all the other words in the record. The check sum word is no longer used and is set to zero.

The overall record format is 2I9, 509I10, I12.

(v) Data Record (Dar)

These each contain 512 values. The first two are fiducials giving the fiducial range of the samples contained in the record. The next 508 represent data values, the second last is always zero (to maintain compatibility with our random access file format) and the last is a record check sum representing the sum of all other values in the record.

If a record is the last one in a data chain for a given channel all unused values are set to zero, with the next channel commencing at the start of the next data record. The N data records in a segment are numbered from 2 to N+1, the SDR being regarded as record one in a segment, with records for a given channel following each other sequentially. The data record addresses in the channel identification block of the SDR refer to this sequential numbering of the data records. A typical segment is shown in Figure 1 and the exact format of a data record given in Table 2.

The overall format of each data record is: 2I9, 509I10, I12.

(vi) No Data Value

For a variety of reasons it is sometimes necessary to flag a data value to indicate it is to be ignored. This is achieved by replacing the data word in question by the value 536870912. If a gap exists in a data chain each word of every sample involved must be replaced by 536870912, the so-called missing value. Thus a 1:1 correspondence is maintained between the fiducials encompassed by a data chain and its samples.

(vii) Standard Data Channels

The standard AGSO data channels are:

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channel 4 edition 1 (corrected GPS navigation data)
channel 4 edition 2 (corrected magnetic data)
channel 4 edition 3 (corrected spectrometric data)
channel 4 edition 4 (corrected digital elevation model data)
channel 5 edition 1 (doppler navigation data)
channel 6 edition 1 (raw spectrometric window data)
channel 8 edition 1 (raw magnetic data)
channel 10 edition 1 (raw multi-channel spectrometric data - 100 second)
channel 14 edition 1 (pressure, temperature, cosmic data)
channel 16 edition 1 (raw GPS navigation data)
channel 17 edition 1 (raw multi-channel spectrometric data - 1 second)

C4 E1 - Corrected GPS Navigation Data

channel number = 4
edition number = 1
sample size = 2 words
word 1 = longitude (degrees) * 1 000 000
word 2 = latitude (degrees) * 1 000 000

C4 E2 - Corrected Total Magnetic Intensity Data

channel number = 4
edition number = 2
sample size = 4 words
word 1 and word 2 as for C4 E1
word 3 = final non micro-levelled TMI (nT) * 1000
word 4 = final micro-levelled TMI (nT) *1000

C4 E3 - Corrected Gamma-ray Spectrometer Data

channel number = 4
edition number = 3
sample size = 7 words
word 1 = parallax corrected longitude (degrees) * 1 000 000
word 2 = parallax corrected latitude (degrees) * 1 000 000
word 3 = final total count (counts/sec) * 1000
word 4 = final potassium (counts/sec) * 1000
word 5 = final uranium (counts/sec) * 1000
word 6 = final thorium (counts/sec) * 1000
word 7 = radar altimeter (metres above ground level)

C4 E4 - Corrected Digital Elevation Model Data

channel number = 4
edition number = 4
sample size = 4 words
word 1 = parallax corrected longitude (degrees) * 1 000 000
word 2 = parallax corrected latitude (degrees) * 1 000 000
word 3 = final aircraft elevation (metres above WGS84 ellipsoid) * 100
word 4 = final terrain elevation (metres above sea level) * 100

C5 E1 - Doppler Navigation Data

channel number = 5
edition number = 1
sample size = 2 words
word 1 = doppler along track (km)
word 2 = doppler across track (m)

C6 E1 - Raw Gamma-ray Spectrometer Window Data

Channel number = 6
Edition number = 1
Sample size = 5 words
word 1 = total count (counts/sec) * 1000
word 2 = potassium (counts/sec) * 1000
word 3 = uranium (counts/sec) * 1000
word 4 = thorium (counts/sec) * 1000
word 5 = radar altimeter (metres above ground level)

C8 E1 - Raw Magnetic Data

channel number = 8
edition number = 1
sample size = 1 word
word 1 = compensated TMI (nT)* 1000

C10 E1 - Raw Multi-channel Gamma–ray Spectrometer Data 100 second intervals

Channel number = 10
Edition number = 1
Sample size = 290 words
word 1 = start fiducial for spectra
word 2 = integration time for spectra (seconds)
word 3 - 34 = define energy range of spectra, fiducials etc.
some control words yet to be defined.
word 35 = channel 0 (counts) * 1000
word 36 = channel 1 (counts) * 1000
word 290 = channel 255 (counts) * 1000

C14 E1 - Pressure, Temperature and Cosmic Data

Channel number = 14
Edition number = 1
Sample size = 7 words
word 1 = pressure in (millibars) * 10
word 2 = temperature in (degrees Celsius) * 10
word 3 - 6 = not used
word 7 = cosmic channel (counts) * 1000

C16 E1 - Raw GPS Navigation Data

Channel number = 16
Edition number = 1
Sample size = 4 words
word 1 = longitude (degrees) * 1 000 000
word 2 = latitude (degrees) * 1 000 000
word 3 = GPS time (seconds) * 1000.
GPS time is recorded in seconds from midnight the previous Sunday
word 4 = Lag time. Time difference between time when a position is calculated and time until the next fiducial is generated by the data acquisition system. (hundredths of a second)

C17 E1 - Raw Multi-channel Gamma–Ray Spectrometer Data
1 second intervals

channel number = 17
edition number = 1
sample size = 290 words
word 1 - 34 = various control information words
word 35 = channel 0 (counts) * 1000
word 36 = channel 1 (counts) * 1000
word 290 = channel 255 (counts) * 1000

2. PHYSICAL FORMAT OF STORAGE MEDIA

(i) General

Each exabyte magnetic tape or CD−ROM consists of a sequence of segments, each segment consisting of one or more physical records. Segments are to be separated by one EOF marker. The end of all information on the media must be flagged by two or more consecutive EOF markers. Industry standard EOF records apply. Records are to be fixed length and each block is to contain one record.

(ii) Physical Parameters of Media

(a) Exabyte Tapes are 8 mm wide, computer grade standard data cartridge.

(b) CD−ROM are 74 minute (640 Mbyte) standard media.

(c) Each media have an external label identifying the airborne survey, character code, recording density, date data written.

(iii) Tape Structure

(a) Written in ASCII.

(b) No multi-tape files.

(iv) Physical Records and Blocks

(a) Fixed length records of 5120 characters.

(b) One record per block.

3. GRID FILE FORMAT

(i) Header Record

The first record on the file defines the content of the grid, including:

(a) Origin in latitude and longitude.

(b) Grid cell size.

(c) Number of rows and columns in the grid.

(d) Storage mode, ie whether the data is stored row by row or column by column. In general the data is stored by row.

(e) The exact header record format is in Table 3.

(ii) Data Records

Each data record contains 320 values in E16.10 format. No location data is held in the data records – the location of a grid point is determined by its sequence within the file. The data for the grid may be sequenced in row or column order (ie row by row or column by column respectively). Each row or column is written on consecutive records and begins at the start of a new record. If the rows/columns do not contain a multiple of 320 values the last record for each row/column is padded with zeros. Any point in the grid which is undefined is set to -9999.0.

In ROW mode, rows are sequenced from north to south and within each row values are ordered from west to east.

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In COLUMN mode, columns are sequenced from west to east and within each column values are ordered from north to south.

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Table 1

Segment Directory Record Format

1. Segment Identification Block

Word	Content And Use	Format
1	Project identification	I9
2	Group identification	I9
3	Segment identification	I10
4	Number of channels on segment	I10
5	Date code – yymmdd	I10
6	Fiducial factor – (fiducial size in seconds)	I10
7	Time of day at fiducial zero in seconds	I10
8	Bearing in degrees (0 – 359) measured east of north	I10
9	Altitude in metres above sea level	I10
10	Ground clearance in metres	I10

2. Channel Identification Block (for the Nth channel)

Word	Content And Use	Format
1	Channel code	I10
2	Edition numbers	I10
3	Fiducial interval between samples	I10
4	Number of data values (words) per sample	I10
5	Address of first data record for channel	I10
6	Address of last sample in data chain	I10
7	Fiducial of first sample in data chain	I10
8	Fiducial of last sample in data chain	I10
9	Unused – set to zero	I10
10	Unused – set to zero	I10

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Table 2

Data Record Format

Word	Content And Use	Format
1	Fiducial at first data sample in record	I9
2	Fiducial at last data sample in record	I9
3	First word of first sample	I10
4	Second word of first sample	I10
.		
.		
.		
.		
.		
.		
.	First word of second sample	I10
.	Second word of second sample	I10
.		
.		
.	Etc	
511	Always unused – set to zero	I10
512	Always unused – set to zero	I12

NOTE:
1. A data sample can be of any length greater than zero.
2. Each record contains an integral number of samples. This may lead to several unused words at the end of the record which are set to zero.
   ie If a sample is 7 words long 72 samples will fit in a data record and words 507–510 will be set to zero.

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Table 3

Grid Header Record Format

Character Position	Field Length	Fortran Format	Content
1-60	60	6A10	Grid Identification
61-170	10	11A10	Facts defining data acquisition/processing
171-180	10	A10	x,y units defining grid, Usually degrees.
181-192	12	E12.6	x origin of surface. Bottom left hand corner.
193-204	12	E12.6	y origin of surface. Bottom left hand corner.
205-214	10	A10	Type of z data in grid (eg TMI).
215-216	2	A2	Blanks.
217-228	12	I12	Number of data records per column or row.
229-240	12	E12.6	Grid increment in the x direction
241-252	12	E12.6	Grid increment in the y direction
253-262	10	A10	Time when original surface created (hh.mm.ss).
263-286	24	2A10,A4	Filter used on original z data.
287-310	12	2E12.6	x,y co-ordinate of the bottom left hand corner of the grid. Same as x,y origin.
311-320	10	A10	Date of creation of surface (dd/mm/yy).
321-344	24	2A10,A4	Blanks.
345-368	12	2E12.6	x,y co-ordinate of top right hand corner of grid. NOTE: these values are too large by one grid increment for tapes created prior to 01/06/85.
369-373	5	I5	Number of rows in the grid.
374-378	5	I5	Number of columns in the grid.
379-382	4	A4	Blanks.
383-388	6	A6	Defines if the grid is stored in column mode (COLUMN) or row mode (ROW).
389-5120			Blank filled.