KINGSTON, WA AIRBORNE GEOPHYSICAL SURVEY, 1998 OPERATIONS REPORT

by

R. Franklin

RECORD 1999/03

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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Australian Geological Survey Organisation

DEPARTMENT OF INDUSTRY, SCIENCE & RESOURCES

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Parliamentary Secretary: The Hon. Warren Entsch, MP
Secretary: Russell Higgins

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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SUMMARY

The Australian Geological Survey Organisation (AGSO) flew an airborne geophysical survey of 47 325 line km covering the Kingston 1:250 000 map Sheet area in the northern gold fields of Western Australia. The survey formed part of the National Geoscience Mapping Accord and was flown along north – south flight lines, 400 metres apart at an altitude of 80 metres above ground level. AGSO flew the survey from 15 July to 29 August 1998.

The total magnetic intensity, gamma-ray spectrometric and digital elevation model data collected during the survey, have been processed and are available for purchase. These data are sold as digital point located data, grids and hardcopy maps by the Australian Geological Survey Organisation. Colour and greyscale pixel image maps are also available.

1. SURVEY AREA AND PARAMETERS

(i) Area Description

The Kingston airborne survey covered the entire 1:250 000 topographic map Sheet of Kingston in Western Australia. See Appendix A for a diagram of the exact survey area.

(ii) Survey Parameters

Altitude:	80 m nominal terrain clearance
Flight line direction:	North – South
Tie line direction:	East – West
Survey line spacing	
Flight line spacing:	400 metres
Tie line spacing:	4000 metres
Survey distance flown	
Lines:	42 887 km
Ties:	4 438 km
Total distance:	47 325 km
Sampling intervals	
Magnetic (compensated, uncompensated and vector):	0.1 seconds (approx 7 metres)
Gamma–ray spectrometric 4 – channel data:	1.0 seconds (approx 70 metres)
Accumulated 256 channel spectra:	1.0 seconds (approx 70 metres)
GPS:	0.5 seconds (approx 35 metres)
Altimeter:	1.0 seconds (approx 70 metres)
Barometric pressure:	1.0 seconds (approx 70 metres)
Temperature:	1.0 seconds (approx 70 metres)
Humidity:	1.0 seconds (approx 70 metres)

2. LOGISTICS

(i) Operating Base and Dates of Flying

(a) Operating Base

Aircraft and crew were based at the Jundee Gold Mine, 54 km northeast of Wiluna, for the duration of the survey from 15 July to 29 August 1998.

(b) Flying Dates

Calibration flights for the Automatic Aeromagnetic Digital Compensator (used to compensate for the magnetic field of the aircraft) were flown at the start of the survey and after aircraft services. Production flying commenced on 17 July and continued through to 28 August 1998.

Appendix B summarises flying days and distances flown.

(ii) Survey Aircraft and Field Crew

(a) Aircraft

Aero Commander 500 S "Shrike", VH-BGE

(b) Field Crew

Party Leader:	Ross Franklin	15 July to 29 August 1998
Technicians:	Trevor Dalziell	15 July to 16 August 1998
	Jim Whatman	15 July to 20 July 1998
		19 August to 29 August 1998
Operator:	Craig Smith	15 July to 29 August 1998
Pilots (Pearl Aviation):	Capt. Lee Geraghty	15 July to 29 August 1998
	Capt. Shane Lawry	15 July to 29 August 1998

3. SURVEY EQUIPMENT

(i) Major Equipment

Magnetometer:	Geometrics G822A caesium magnetometer
Compensator:	RMS Instruments Automatic Aeromagnetic Digital Compensator
Gamma–ray spectrometer:	Exploranium gamma–ray spectrometer consisting of a GR820 spectrum processor and two DET1024 spectrometer crystal detectors (33.56 litres total)
Altimeter:	Collins ALT–50 radar altimeter
Barometer:	AGSO digital – Setra sensor
Thermometer/Humidity:	AGSO digital – RS combined temperature and humidity sensor
Navigation:	Ashtech XII "Ranger" GPS receivers and Ashtech "Ranger" differential processing software Fugro OmniSTAR Plus real time differential GPS base station system
Video:	National colour video camera (WV CL 302E) National VCR (NV 180) National LCD TV (TCL 3A)
Acquisition hardware:	Axiom–Ax6150A industrial computer, 3.5 inch floppy disc drive, 504 Mb removable SCSI hard disc, IOMEGA SCSI zip drive and Planar VGA monitor
Acquisition software:	AGSO-developed QNX C language program

(ii) Navigation

(a) GPS Navigation System

Navigation in the survey aircraft made use of the real–time differential GPS method. The aircraft navigation system used an Ashtech XII global positioning system (GPS) receiver which manipulated range data received from satellites every half second and calculated the current latitude and longitude coordinates of the aircraft in the World Geodetic System 1984 (WGS84). The range data were recorded internally in the GPS receiver every second. Differential GPS corrections to the range data, supplied by Fugro Starfix Pty Ltd, were transmitted in real time via an Optus satellite link to a Fugro OmniSTAR Plus base station system. The real time method employed is described more fully in Appendix C.

The real–time differentially corrected position of the aircraft was recorded on the aircraft acquisition system every half second and was 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 near AGSO's field office caravan as a GPS base station and internally recorded range data every second. The data were post processed using Ashtech "Ranger" software at the end of each flying day. Relative precision from point to point along a post processed flight line is expected to be better than ±5 metres.

The position of the base station GPS receiver was accurately determined by differential GPS surveying using as a fixed reference point, the survey mark, Wiluna 15, located approximately 300 metres west of the survey base. This was carried out at the start of the of the survey.

The WGS 84 coordinates for the reference point Wiluna 15 are:

Longitude:	120° 33' 03.82444" E
Latitude:	26° 20' 59.24317" S
Ellipsoidal height:	567.260 metres

The determined base station GPS coordinates (WGS 84) were:

Longitude:	120° 33' 16.6440" E
Latitude:	26° 21' 01.2552" S
Ellipsoidal height:	564.869 metres

The horizontal positions of the geophysical data from the survey are reported with respect to the WGS84 datum which is almost identical to the Geocentric Datum of Australia (GDA). It is intended that the GDA will be fully adopted in Australia by the year 2000. In the survey area there is an apparent northeasterly translation in geographical position of approximately 200 metres from AGD66 to WGS84.

(b) 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.

(iii) Magnetometer

A Geometrics G822A caesium 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 D.

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 E. 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 uncompensated, the filtered compensated total magnetic field intensity data and the XYZT components of the fluxgate sensor were all 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 F summarises the specifications of the gamma-ray spectrometer components.

Two hundred and fifty six channels of data between 0.0 MeV and 3.00 MeV were recorded every second.

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

Total Count:	0.41-2.81 MeV
Potassium:	1.37-1.57 MeV
Uranium:	1.66-1.86 MeV
Thorium:	2.41-2.81 MeV
Cosmic:	3.00 MeV and above

The total count, potassium, uranium and thorium data were used for data quality control and the cosmic counts were used for background estimation and later data processing.

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.

(vi) Barometer, Thermometer and Humidity

Atmospheric temperature, pressure and humidity were measured using a digital barometer (Setra sensor) and combined digital thermometer/humidity (RS sensor). Although both of these units were built by the AGSO, 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 G–823B base station caesium magnetometer, the specifications of which are given in Appendix G. 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. Data from the base station were telemetered back to the AGSO's field office caravan for display and recording on a Toshiba Pentium 110 CS lap–top computer. The telemetry system used Proxim Proxlink MSP–500 modems. The software program, "DIURNAL", developed in–house by AGSO, was used to display and log diurnal data.

Base station diurnal data were recorded at an interval of 0.1 seconds for every production and compensation flight.

(viii) Aircraft Data Acquisition

The aircraft acquisition program and system were run using an Axiom–Ax6150A industrial 486 computer with data recorded via an IOMEGA SCSI zip drive onto 100 Megabyte zip discs.

The acquisition program written in the QNX C language was developed in-house at AGSO. See Appendix H for a schematic diagram of the aircraft's acquisition system.

4. CALIBRATION

(i) Compensation for the Magnetic Field of the Aircraft

Compensation flights were flown prior to the start of the survey flying and after aircraft services. These flights were conducted over a magnetically quiet zone above Jundee airfield, approximately 15 km to the west of the survey area at an altitude of 2800 metres above sea level, between longitudes 120° 23' E and 120° 43' E and latitudes 26° 22' S to 26° 38' 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 20 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 0.20 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). Appendix I lists these statistics, the dates the compensations were performed and the period for which each compensation was used.

(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 Thorium). During operation the system continuously monitors each of the eight crystals signals and accumulates a separate spectra for each configured signal. When the confidence level for the selected stabilisation peak (Thorium) is reached, the peak channel of this isotope is computed, compared to the correct peak location, and the gain is then corrected.

As a verification that the system sensitivity has remained constant, thorium source tests were carried out at the start and end of each day's survey flying. The background corrected thorium window count rate fell within the accepted ±5% difference between the current value and that from the most recent pad calibration value. Spectrometer system resolution was also checked as part of the thorium source check. This value averaged out at 5.7%.

Gamma-ray spectrometric test lines were flown at the beginning and end of each day's production flying as well as at the start of the second flight for the day. These lines were flown at survey altitude along a line located 5 kilometres east of Jundee airfield. Acquisition along the line lasted for 100 seconds (approximately 7 kilometres). Appendix J shows the location of the test line used for the duration of the survey.

After each flight, statistics were calculated from data recorded between fixed reference points along the test line. These statistics were recorded in spreadsheet form and compared with the preceding flights in order to detect any irregularities. In particular, the difference between the average in the total count channel for the most recently flown test line and the running average of all the previously flown test lines was analysed. This value only rarely varied by greater than 5% for the test line, well inside a 10% variation which would be considered acceptable.

5. DATA PROCESSING

Flight path recovery, data checking, editing, diurnal variation and preliminary IGRF corrections applied to the magnetic data, gridding and imaging were performed at the survey base using the INTREPID airborne geophysical data processing and visualisation system. Final magnetic, gamma-ray spectrometric and digital elevation model data processing were carried out in Canberra, again using the INTREPID data processing system.

(i) Data Checking and Editing

Data recorded on the aircraft acquisition zip drive were transferred on a flight by flight basis from the zip disc to a Graphics Computer Systems Scorpion 10 Workstation (SUN Clone). All data transferred to this workstation was edited for missing values, noise, spikes or steps using INTREPID software. All the recorded data were displayed for each survey line and any errors were interactively corrected. Anomalies arising from cultural influences, such as sheds, houses and fences, were usually not edited out.

(ii) Flight Path Recovery

Range data recorded internally every second on the aircraft GPS receiver were post-processed daily in the field using the base station GPS data and "Ranger" - an Ashtech proprietary program. "Ranger" calculates the corrected flight path (longitude, latitude and height) relative to the WGS84 reference ellipsoid.

The corrected longitude and latitude data calculated at one second intervals by "Ranger" were used each day to correct the GPS data recorded every half second on the aircraft acquisition system. As well as the standard "Ranger" corrections, other acquisition system specific corrections were applied. Position data were retained in the WGS84 coordinate system. The World Geodetic System 1984 (WGS84) coordinate system is defined in Appendix K. Taking the accuracy of the navigation data into account, the WGS84 system can be considered the same as the Geodetic Datum of Australia (GDA) for the survey data.

The full post–processing correction procedure applied to the position data is described in Appendix L and is outlined below:

(a) "Ranger" corrections.

(b) Infilling of "Ranger" data.

(c) Infilling of final navigation data.

(d) Low pass filter.

(e) Reference navigation data to position of magnetometer sensor.

The fully corrected flight path was plotted each day to check the position of survey lines and their spacing. For the survey line spacing of 400 metres, navigation reflies were determined by the following criteria:

Across Track Deviation	Distance along line	GPS Data Gap
≥ 30 metres	≥ 3 km	≥ 4 km

Whenever the across track deviation and along line distance or the GPS data gap are exceeded, the survey line is re–flown or an infill line flown to rectify the problem. These criteria were never exceeded during survey.

(iii) Magnetic Data Processing

At the survey base raw magnetic data were merged with the navigation data, and diurnal variation corrections were removed. IGRF corrections using the IGRF 1990 geomagnetic reference field, updated to 1 August 1998 at an altitude of 600 metres above sea level, (estimated to be the mean survey altitude), were subtracted from the data during final processing in Canberra.

The IGRF was calculated at a spacing of 7 metres 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 5000 nT.

The data were levelled using standard tie line levelling procedures. Luyendyk (1997) describes the procedure involved in the tie line levelling method in more detail. The steps involved in the tie line levelling were as follows:

(a) Tie line 290 was chosen as a reference tie.

(b) All other ties were levelled to tie line 290 using degree two polynomial adjustments.

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

(d) Finally the lines were adjusted individually using degree two polynomial adjustments to minimise crossover differences.

The data were micro-levelled using the technique described by Minty (1991). Filter characteristics for the micro–levelling were as follows:

(a) Low pass filter in the flight line direction with a cut-off wavelength of 5000 metres.

(b) High pass filter in the tie line direction with a cut-off wavelength of 800 metres.

(c) Correction strings were low pass filtered with a cut-off wavelength of 1000 metres before being applied to the line data and were constrained to fall within the range ±10.0 nT, (90% of these corrections fell in the range -1.8 nT to 1.3 nT).

The final micro-levelled data were gridded using the minimum curvature technique described by Briggs (1974), with a 80 metre (1.5 second) grid cell size.

(iv) Gamma-ray Spectrometer Data Processing.

A combination of full–spectrum and 3–channel processing methods were used to correct the gamma–ray spectrometric data. The raw spectra were first smoothed using the Noise Adjusted Singular Value Decomposition (NASVD) spectral smoothing technique described by Hovgaard and Grasty (1997) applied to spectral clusters according to the methodology described by Minty and McFadden (1998). This method transforms observed spectra into orthogonal spectral components. The higher–order components represent the signal in the observed spectra and the lower–order components represent uncorrelated noise.

Noise is removed from the observed spectra by rejecting noise components and reconstructing smooth spectra from the higher–order components. For this survey, 8 higher–order components were used to reconstruct the smooth spectra. The smoothed spectra were livetime corrected, energy calibrated and background corrected. The spectra were then summed over the conventional 4–channel windows (IAEA, 1991), for subsequent stripping and height correction as described below.

The energy calibration was effected by using the positions of prominent photopeaks in the sum spectrum for each line to obtain an estimate of the energy at channel one and the gain (keV per channel). These parameters were then used to correct each spectrum in the line by resampling each channel to its correct energy range.

The three components of background were removed as follows.

(a) Aircraft and Cosmic Background

Aircraft and cosmic spectra for the AGSO aircraft were determined from high altitude calibration flights using the procedure described by Minty and Richardson (1989).

(b) Atmospheric Radon Background

A full spectrum method (Minty, 1998) was used to remove radon background. The method is based on the assumption that the observed spectrum (after correcting for aircraft and cosmic background) is the linear sum of the spectra due to K, U, and Th in the ground and atmospheric radon. Since the shapes of these spectra can be determined through suitable calibrations, the atmospheric radon contribution to the observed spectrum can be estimated.

The energy–calibrated and background–corrected spectra were then summed over the conventional 4–channel windows recommended by the IAEA (IAEA, 1991). Stripping (channel interaction correction) to correct for Compton scattering were then applied to the K, U, and Th window count rates. Stripping ratios for the AGSO system were using the procedure recommended by the International Atomic Energy Agency (IAEA, 1991). 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 channel

N_K	=	counts in the potassium channel
A	=	0.2588 + 0.00049 * height
B	=	0.4300 + 0.00065 * height
C	=	0.7518 + 0.00069 * height

The total count, potassium, uranium and thorium window count rates were height corrected to a nominal survey flying height of 80 metres. Where the aircraft attained a height of 250 metres or higher above the ground, 250 metres was used to height correct the total count, potassium and thorium data. For uranium, the maximum aircraft height used in the height correction was 160 metres. Height attenuation corrections were made using the following formula:

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

where

$N_{corrected}$	=	corrected counts (cps)
$N_{uncorrected}$	=	uncorrected counts (cps)
H	=	nominal flying height (m)
h	=	measured flying height (m)
u	=	attenuation coefficient (m^{-1})

Attenuation coefficients for each channel are given below

$u_{total\ count}$	=	0.00785 (m^{-1})
$u_{potassium}$	=	0.00943 (m^{-1})
$u_{uranium}$	=	0.01150 (m^{-1})
$u_{thorium}$	=	0.00747 (m^{-1})

The corrected window count rates were converted to ground concentrations of K, U and Th using the expression:

$$C = \frac{N}{S}$$

where

C	=	concentration of the radioelement (K%, U ppm or Th ppm);
S	=	broad source sensitivity for the elemental count rate; and
N	=	the fully processed elemental count rate (cps).

The broad source sensitivities were obtained from flights over the Lake Hume calibration range. The following sensitivities were used:

potassium:	110.42 cps/%K
uranium:	8.33 cps/ppm eU
thorium:	5.79 cps/ppm eTh.

The total count was converted to the equivalent air–absorbed dose rate at ground level using the expression:

$$D = \frac{N}{F}$$

where

D = the air absorbed dose rate (nanoGrays per hour, (nGh^{-1}));
F = the conversion factor determined experimentally from flights over a calibration range (29.70 cps/nGh^{-1}); and
N = the total count rate (cps).

Before any further processing of the gamma–ray spectrometric data the associated geodetic data were corrected for a parallax error of -9.03 metres.

The gamma-ray spectrometric data did not require tie line levelling.

The four channels of gamma–ray spectrometric data were micro-levelled using the technique described by Minty (1991).

Filter characteristics for the dose rate micro–levelling were as follows:

(a) Low pass filter in the flight line direction with a cut-off wavelength of 5000 metres.

(b) High pass filter in the tie line direction with a cut-off wavelength of 800 metres.

Filter characteristics for the percent potassium and ppm thorium micro–levelling were as follows:

(a) Low pass filter in the flight line direction with a cut-off wavelength of 3200 metres.

(b) High pass filter in the tie line direction with a cut-off wavelength of 800 metres.

The ppm uranium data were micro-levelled with the following filter characteristics:

(a) Low pass filter in the flight line direction with a cut-off wavelength of 6400 metres.

(b) High pass filter in the tie line direction with a cut-off wavelength of 3200 metres.

Correction strings for all four data channels were low pass filtered with a cut-off wavelength of 1000 metres before being applied to the line data.

Adjustments were restricted to fall in the ranges given in the table below. In the third column is a listing of the range that 90% of these adjustments fall into.

Data channel	Restriction on adjustments	Range of 90 % of adjustments
dose rate	-20.0 to +20.0 nGh^{-1}	-3.4 to +3.7 nGh^{-1}
% potassium	-0.3 to +0.3 %K	-0.06 to +0.06 %K
ppm uranium	-0.5 to +0.5 ppm	-0.16 to +0.16 ppm
ppm thorium	-4.0 to +4.0 ppm	-0.98 to +1.01 ppm

The four channels of micro–levelled data were gridded as individual grids with a 80 m (1.5 second) cell size using Briggs (1974) minimum curvature technique.

(v) Digital Elevation Model Data Processing

As described in Chapter 3, Section (ii), range data recorded internally every second on both GPS receivers were post–processed on a daily basis using "Ranger" — an Ashtech proprietary program. "Ranger" calculates the position of the aircraft GPS receiver's antenna, outputting the longitude, latitude and height relative to the WGS84 reference ellipsoid for each set of range data every second.

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

(a) "Ranger" corrections.

(b) Barometric infill of height data gaps.

The corrected height data, which are relative to the WGS84 reference ellipsoid, are then linearly interpolated to half second samples (35 metres) and merged with the longitude and latitude data.

A radar altimeter provided the aircraft's ground clearance, the altimeter data being sampled every 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 half second (35 metres along the ground) are relative to the WGS84 reference ellipsoid - the ellipsoid being a horizontal datum.

Elevation data were levelled in much the same way as the magnetic data and the steps involved are described below. Before levelling the data the associated longitude and latitude data were corrected for a parallax error of -11.4 metres.

(a) Tie line 290 was chosen as the reference tie.

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

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

(d) Finally the lines were adjusted individually to minimise crossover differences, using degree two polynomial adjustments.

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

(a) Low pass filter in the flight line direction with a cut-off wavelength of 5000 metres.

(b) High pass filter in the tie line direction with a cut-off wavelength of 1600 metres.

(c) Correction strings were low pass filtered with a cut-off wavelength of 1000 metres before being applied to the line data. Adjustments were constrained to lie within the range of ± 10.0 metres (90% of the corrections were in the range -2.47 to +2.85 metres).

The next step is to convert the heights from being relative to the WGS84 ellipsoid to being 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 WGS84 ellipsoid is called the geoid-ellipsoid separation or N value.

Geoid-ellipsoid separation information for the area covered by the Cootamundra survey area were supplied by the Australian Surveying and Land Information Group (AUSLIG). 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 one minute of arc (approximately 1 800 metre) grid. These values were then regridded to a cell size of 10 seconds of arc (approximately 270 metres). This grid of N values was then 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 1000 metres before being applied to the point-located elevation data.

The elevation data were next 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 located on the underside of the aircraft fuselage. This antenna separation correction was applied by subtracting 1.675 metres from the elevation data.

The accuracy of the position located height data is expected to be better than ± 10 metres. Relative precision from point to point along a flight line is expected to be better than ± 5 metres.

These micro–levelled data, corrected for the geoid–ellipsoid and antennae separations were gridded using the minimum curvature technique described by Briggs (1974), with a 50 metre (1.875 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. Flight path, TMI profiles and contour maps were produced using the INTREPID processing system. The standard set of maps produced are listed in Appendix M.

(b) Digital Data

Final processed point-located data and grids were archived in the standard AGSO ARGUS format, onto CD–ROM discs, in ASCII format (Appendix N).

(c) Pixel Image Maps

Additional to the standard AGSO geophysical maps, pixel image maps have been compiled using the method described by Milligan and others (1992). The following pixel image maps have been released:

(a) Greyscale 1:250 000 scale image of the fractional vertical derivative (1.5) of the total magnetic intensity reduced to the pole.

(b) Colour 1:250 000 scale image of total magnetic intensity reduced to the pole with northeast illumination of its first vertical derivative.

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APPENDIX B-1

Flying Dates and Line Kilometres Accepted

Date	Flight	Comments	Line Km
16/ 7/98	200	Compensation #1	0
16/ 7/98	201	Corrupt GPS base data- reflown	0
17/ 7/98	202	Operations Normal	909
18/ 7/98	203	Operations Normal	909
18/ 7/98	204	Operations Normal	909
19/ 7/98	205	Operations Normal	909
19/ 7/98	206	Operations Normal	909
20/ 7/98	207	Flight abandoned - noisy rad alt	0
20/ 7/98	208	Rad Alt test	0
20/ 7/98	209/210	Rad Alt test	0
21/ 7/98	211	Operations Normal	909
21/ 7/98	212	Operations Normal	909
22/ 7/98	213	Operations Normal	909
22/ 7/98	214	Operations Normal	909
23/ 7/98	215	Operations Normal	909
23/ 7/98	216	Operations Normal	909
24/ 7/98	217	Flight abandoned - fog	0
30/ 7/98	218	Compensation #2	0
31/ 7/98	219	Compensation #3	758
31/ 7/98	220	Operations Normal	909
7/ 8/98	221	Operations Normal	909
7/ 8/98	222	Operations Normal	909
8/ 8/98	223	Operations Normal	1212
8/ 8/98	224	Operations Normal	909
4/ 8/98	225	Operations Normal	303
5/ 8/98	226	Operations Normal	1515
6/ 8/98	227	Operations Normal	1212
6/ 8/98	228	Operations Normal	1212
7/ 8/98	229	Operations Normal	1212
7/ 8/98	230	Operations Normal	909
8/ 8/98	231	Operations Normal	1161
8/ 8/98	232	Operations Normal	909
9/ 8/98	233	Operations Normal	1112
9/ 8/98	234	Operations Normal	909
11/ 8/98	235	Operations Normal	1065
12/ 8/98	236	Operations Normal	303
12/ 8/98	237	Operations Normal	303
13/ 8/98	238	Operations Normal	303
13/ 8/98	239	Operations Normal	303
14/ 8/98	240	Operations Normal	303
14/ 8/98	241	Operations Normal	303
15/ 8/98	242	Operations Normal	303
15/ 8/98	243	Operations Normal	1112
16/ 8/98	244	Operations Normal	909
20/ 8/98	245	Operations Normal	986

APPENDIX B–2

Flying Dates and Line Kilometres Accepted

Date	Flight	Comments	Line Km
20/ 8/98	246	Operations Normal	986
21/ 8/98	247	Operations Normal	986
21/ 8/98	248	Operations Normal	948
22/ 8/98	249	Operations Normal	1038
22/ 8/98	250	Operations Normal	1061
23/ 8/98	251	Operations Normal	1112
23/ 8/98	252	Operations Normal	909
24/ 8/98	253	Operations Normal	1112
24/ 8/98	254	Operations Normal	909
25/ 8/98	255	Operations Normal	1061
25/ 8/98	256	Operations Normal	909
26/ 8/98	257	Operations Normal	1112
26/ 8/98	258	Operations Normal	909
27/ 8/98	259	Flight abandoned - diurnal too active	0
27/ 8/98	260	Flight abandoned - diurnal too active	0
28/ 8/98	261	Operations Normal	1112
28/ 8/98	262	Operations Normal	909

Total line/tie kilometres flown 47325

Summary

Productive survey flights	53
Compensation flights only	2
Equipment test flights	2
Flights with base data lost	1
Abandoned flights	4

Abandoned survey flights consisted of:

Weather	1
Diurnal too active	2
Aircraft equipment malfunction	1

APPENDIX C

Real time differential GPS

Real time differential GPS navigation is a method used to improve navigation accuracy. Line tracking using this method is more precise than by the single GPS receiver method thus allowing a pilot to fly an aircraft to within 5 metres planned lines.

The navigation equipment used for this survey consisted of two Ashtech XII GPS receivers; one at a known position on the Wagga Wagga airfield not far from the location of the office caravan, and the other in the aircraft. The ground based GPS receiver operated in non–differential mode while the aircraft GPS receiver was set up to run in differential mode.

Fugro Starfix Pty Ltd supplied satellite range corrections to the aircraft. The range corrections were calculated using Fugro's OmniSTAR Wide Area Differential GPS (WADGPS) service. OmniSTAR is a differential GPS service over Australia which is supported by a network of reference stations located throughout the continent to provide differential GPS corrections back to Fugro's Network Control Centre (NCC) in Perth. The WADGPS service allows monitoring of data from more than one reference station, quality control parameters, weighted least squares solution and improved accuracy over a single reference station.

The range corrections from all the available reference stations are transmitted to the NCC in Perth, then to an OmniSTAR Plus – Enhanced Differential System (EDS) receiver in the aircraft via the Optus satellite. The EDS receiver contains a demodulator board, an eight channel GPS engine, a computing engine and an interface and power supply board. The OmniSTAR Plus demodulator receives the Fugro compressed data from the satellite and using the aircraft's position and the "least squares method" computes an optimum set of RTCM (Radio Technical Commission for Maritime Services) corrections for output to the aircraft GPS receiver. The EDS receiver calculates the aircraft position from the internal GPS engine and then provides corrections for output to the aircraft GPS receiver in RTCM 104 format.

The EDS receiver obtains satellite range data through an Ashtech plate antenna and range correction data through an OPTUS plate antenna, both mounted on the upper fuselage of the aircraft. The Ashtech GPS receiver in the aircraft uses the Ashtech plate antenna for receiving satellite range data. The EDS receiver outputs corrections to the aircraft GPS receiver at 4800 baud.

APPENDIX D

Specifications – G822A Caesium Magnetometer

Operating principle:	Self-oscillating caesium vapour magnetometer
Operating range:	20,000 nT to 95,000 nT
Active zones:	Sensor equator ±10° H_o field sensor axis ±10°, switchable or auto switch
Noise level:	≤ 0.01 nT peak–to–peak
Heading error:	≤ ± 0.25 nT, ≤ 0.5 nT envelope
Power required:	26 to 32 VDC, 500 mA continuous, 750 mA while starting
Output:	2V p–p, f (Hz) = 3.498 H_o (nT)
Interface:	Larmor signal AC coupled to power input
Environmental:	-35°C to +50°C, humidity 95% non–condensing
Dimensions:	Sensor: 5 cm diameter, 18 cm long, 140 grams Electronics module: 5 cm wide, 5 cm high, 23 cm long, 170 grams Sensor electronics cable: 135 cm to 270 cm long
Qualification:	MIL–I–45208, MIL–M–19595

APPENDIX E-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 manoeuvres:	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)

APPENDIX E-2

Specifications – RMS Instruments
Automatic Aeromagnetic Digital Compensator

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 F-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.

APPENDIX F-2

Specifications – GR820 Spectrometer System

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

Specifications – GR820 Spectrometer System

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
- 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 G-1

Specifications – G823B Base Station Caesium Magnetometer

Operating principle:	Self-oscillating caesium vapour magnetometer
Operating range:	20,000 nT to 90,000 nT
Active zones:	Sensor equator ±10° H_o field sensor axis ±10°, switchable or auto switch
Noise level:	≤ 0.01 nT peak–to–peak
Heading error:	≤ ±0.25 nT, ≤ 0.5 nT envelope
Power required:	26 to 32 VDC, 500 mA continuous, 750 mA while starting
Output:	2V p–p, f (Hz) = 3.498 H_o (nT)
Interface:	Larmor signal AC coupled to power input
Environmental:	-35°C to +50°C, humidity to 99% non-condensing
Dimensions:	Sensor: 5 cm diameter, 18 cm long, 140 grams Electronics module: 5 cm wide, 5 cm high, 23 cm long, 170 grams Sensor electronics cable: 135 cm to 270 cm long
Qualification:	MIL–I–45208, MIL–M–19595

APPENDIX G-2

Specifications – CM–201 Larmor Counter

Operating frequency range: 70 kHz to 350 kHz

Operating field range: 20,000 nT to 100,000 nT

Cycle rate: variable from 20 sec to 0.01 sec in 0.005 second increments

Sensitivity (nT) (Counter LSB)	Noise (RMS) (nT)	Earth's Field (k nT)	Sample Rate (Hz)
0.001	0.003	30	1
0.002	0.004	50	
0.003	0.005	70	
0.013	0.015	30	10
0.023	0.020	50	
0.032	0.025	70	

Julian clock: Resolution: 0.01 seconds
Drift: < 1 second/day

A/D channels: Internal: one channel for Larmor signal amplitude
External: five, 12 bit channels

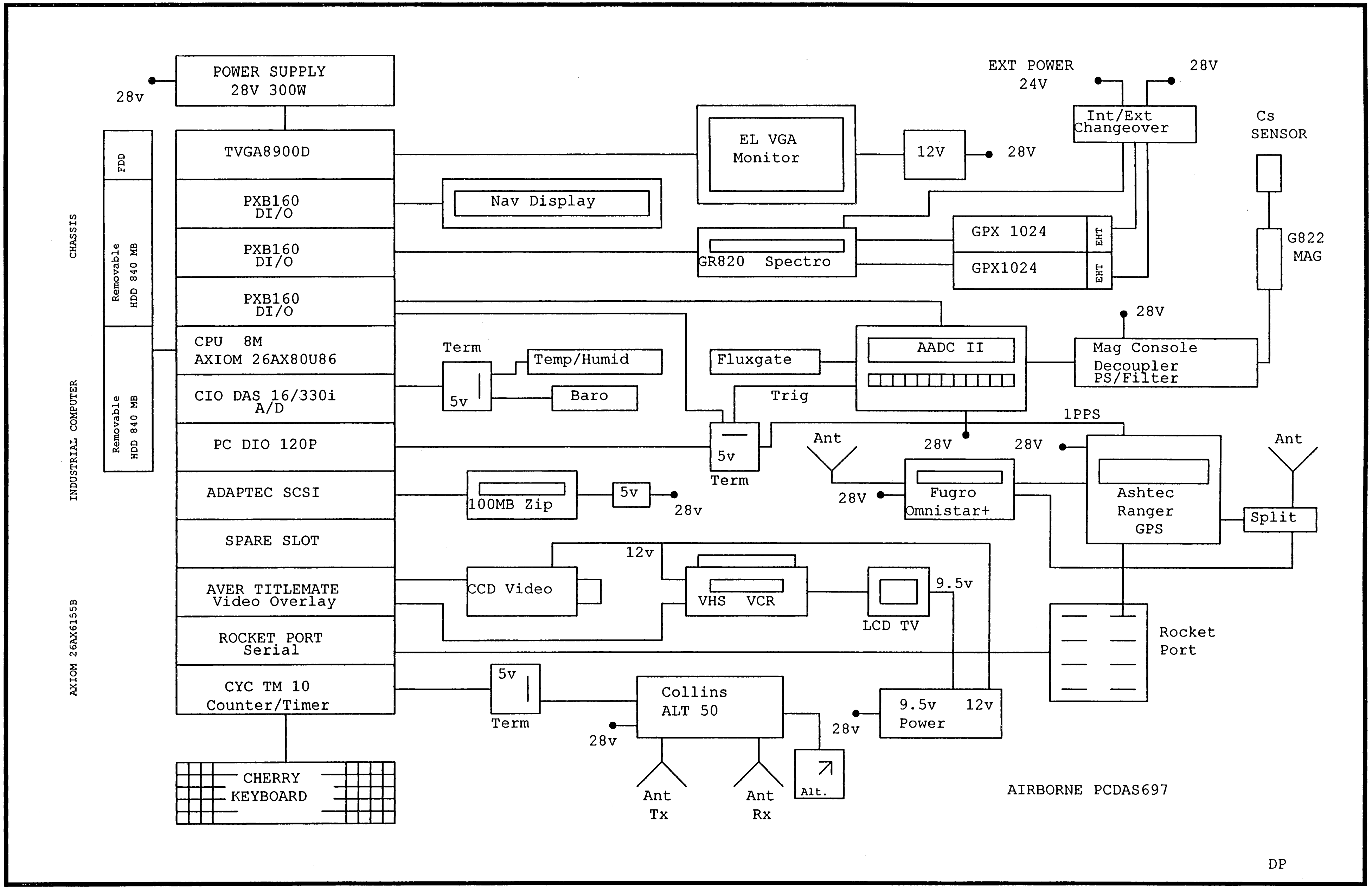
Data output: RS–232 standard serial port

Operating temperature: -25°C to +50°C

Power: CM–201 alone runs on 5 V @ 0.30 A

Compatibility: PC based systems

APPENDIX H
Aircraft Acquisition System



APPENDIX I-1

Compensation Results

COMPENSATION 1

Date flown:	16 July 1998
Air conditioner off:	SDU = 0.1450 SDC = 0.01592 IR = 9.1 VN = 24.4
Air conditioner on:	SDU = NA SDC = NA IR = NA VN = NA

COMPENSATION 2

Date flown:	30 July 1998
Air conditioner off:	SDU = 0.3028 SDC = 0.08341 IR = 3.6 VN = 25.6
Air conditioner on:	SDU = NA SDC = NA IR = NA VN = NA

APPENDIX I–2

Compensation Results

COMPENSATION 3

Date flown:	31 July 1998
Air conditioner off:	SDU = 0.2212 SDC = 0.01500 IR = 14.7 VN = 23.5
Air conditioner on:	SDU = NA SDC = NA IR = NA VN = NA

COMPENSATION 4

Date flown:	20 August 1998
Air conditioner off:	SDU = 0.2588 SDC = 0.02578 IR = 10.0 VN = 25.3
Air conditioner on:	SDU = 0.2765 SDC = 0.2583 IR = 10.7 VN = 30.6

SDU = Standard deviation of the data recorded during manoeuvres.

SDC = Standard deviation of the data recorded during manoeuvres after compensation corrections have been applied.

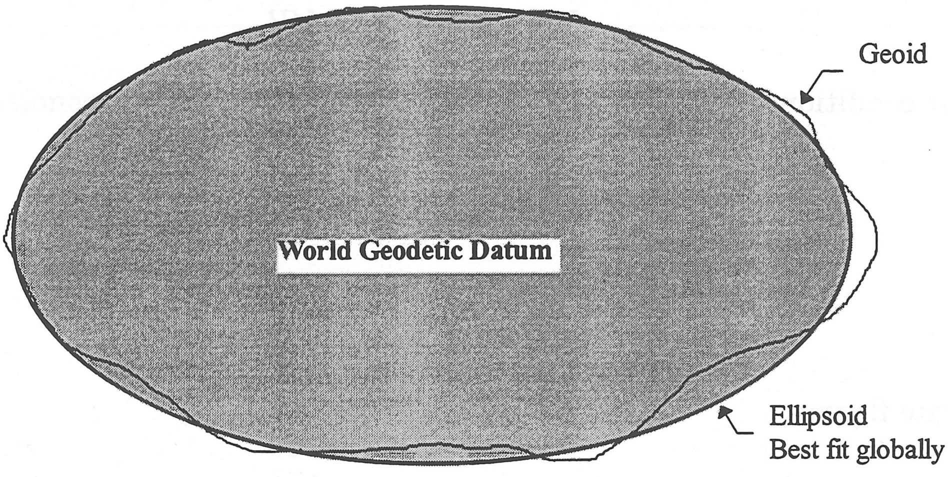
IR = Improvement ratio = SDU / SDC

VN = Vector Norm, a measure of the degree of difficulty in calculating the coefficients.

APPENDIX K

The World Geodetic System 1984 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). The WGS84 datum is a global geocentric reference datum that has as its origin the Earth's centre of mass.

This geocentric datum comprises a spheroid (also known as an ellipsoid) oriented and located in such a manner as to "best-fit" the geoid over the entire earth.

The WGS84 datum is defined by a semi-major axis (a) and flattening (f) of the selected ellipsoid.

$$a = 6378137 \text{ m}$$
$$f = 1/298.2572$$

APPENDIX L–1

Corrections to Differential GPS Navigation Data

(a) "Ranger" corrections

Using the range data which are recorded internally on the aircraft and base GPS receivers every second, "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 half 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.

(b) 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).

(c) Infilling final navigation data

For a variety of reasons, data gaps may appear in the final navigation data. Common causes are the multiple steps as in (a) above and gaps in the "Ranger" data. These gaps in the final navigation data are linearly infilled. The maximum gap size is 10 seconds.

(d) 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 half second sampling interval of the "Ranger" corrected navigation data.

(e) 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.

APPENDIX L–2

Corrections to Differential GPS Navigation Data

(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) 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 M

Geophysical Maps

Name	Type	Contour Interval	Reference Number

1:250 000 scale

Kingston	TMI Contours	15 nT	22-1/G51-11/1
	Dose Rate Contours	4 nG/h	22-1/G51-11/18
	DEM Contours	2 m	22-1/G51-11/19

1:100 000 scale

Wongawol	TMI Contours	10 nT	22-2/G51-11/1-1
	Dose Rate Contours	4 nG/h	22-2/G51-11/18-1
	Flight Line System		22-2/G51-11/3-1
Windidda	TMI Contours	2 nT	22-2/G51-11/1-2
	Dose Rate Contours	2 nG/h	22-2/G51-11/18-2
	Flight Line System		22-2/G51-11/3-2
Carnegie	TMI Contours	2 nT	22-2/G51-11/1-3
	Dose Rate Contours	2 nG/h	22-2/G51-11/18-3
	Flight Line System		22-2/G51-11/3-3
Yelma	TMI Contours	10 nT	22-2/G51-11/1-4
	Dose Rate Contours	2 nG/h	22-2/G51-11/18-4
	Flight Line System		22-2/G51-11/3-4
Collurabbie	TMI Contours	10 nT	22-2/G51-11/1-5
	Dose Rate Contours	2 nG/h	22-2/G51-11/18-5
	Flight Line System		22-2/G51-11/3-5
Von Treuer	TMI Contours	5 nT	22-2/G51-11/1-6
	Dose Rate Contours	2 nG/h	22-2/G51-11/18-6
	Flight Line System		22-2/G51-11/3-6

APPENDIX N-1

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

CONTENTS

APPENDIX N-2

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

1. THE AGSO SEQUENTIAL FILE STRUCTURE

1.1 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 (processed navigation data)
channel 4 edition 2 (processed magnetic data)
channel 4 edition 3 (processed spectrometric data)
channel 4 edition 4 (processed digital elevation model data)
channel 6 edition 2 (raw terrain above WGS84 ellipsoid)
channel 6 edition 3 (diurnal data)
channel 8 edition 1 (raw compensated magnetic data)
channel 8 edition 2 (vector data and uncompensated magnetic data)
channel 14 edition 2 (pressure, temperature, humidity, cosmic data)
channel 16 edition 2 (raw navigation data)
channel 17 edition 1 (raw 256 channel spectrometer data)

1.2 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.

1.3 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).

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

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.

1.4 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.

1.5 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.

1.6 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.

1.7 STANDARD DATA CHANNELS

The standard AGSO data channels are:

channel 4 edition 1 (processed navigation data)
channel 4 edition 2 (processed magnetic data)
channel 4 edition 3 (processed gamma–ray spectrometric data)
channel 4 edition 4 (processed digital elevation model data)
channel 6 edition 2 (terrain data above WGS84 ellipsoid)
channel 6 edition 3 (diurnal data)
channel 8 edition 1 (raw compensated magnetic data)
channel 8 edition 2 (vector and uncompensated magnetic data)
channel 14 edition 2 (pressure, temperature, humidity and cosmic data)
channel 16 edition 2 (raw navigation data)
channel 17 edition 1 (raw 256 channel gamma–ray spectrometric data)

C4 E1 - 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

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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 and word 2 as for C4 E1
word 3 = final total count (nanoGrays/hour) * 1000
word 4 = final potassium (%) * 1000
word 5 = final uranium (ppm) * 1000
word 6 = final thorium (ppm) * 1000
word 7 = radar altimeter (metres above ground level * 1000)

C4 E4 - Corrected Digital Elevation Model Data

channel number = 4
edition number = 4
sample size = 4 words
word 1 and word 2 as for C4 E1
word 3 = final aircraft elevation (metres above sea level) * 1000
word 4 = final terrain elevation (metres above sea level) * 1000

C6 E2 - Terrain Elevation Data above WGS84 Ellipsoid

channel number = 6
edition number = 2
sample size = 2 words
word 1 = radar altimeter (metres above ground level) * 1000
word 2 = terrain elevation above WGS84 ellipsoid (metres) * 1000

C6 E3 - Diurnal Data

channel number = 6
edition number = 3
sample size = 2 words
word 1 = diurnal (nT) * 1000
word 2 = filtered diurnal (nT) * 1000

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

C8 E1 - Raw Magnetic Data

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

C8 E2 - Vector and Uncompensated Magnetic Data

channel number = 8
edition number = 2
sample size = 5 words
word 1 = fluxgate X (nT) * 1000
word 2 = fluxgate Y (nT) * 1000
word 3 = fluxgate Z (nT) * 1000
word 4 = fluxgate T (nT) * 1000
word 5 = uncompensated magnetic data (nT) * 1000

C14 E2 - Pressure, Temperature, Humidity and Cosmic Data

channel number = 14
edition number = 2
sample size = 4 words
word 1 = pressure (millibars) * 1000
word 2 = temperature (degrees Celsius) * 1000
word 3 = humidity (%) * 1000
word 4 = cosmic channel (counts per second) * 1000

C16 E2 - Raw GPS data

channel number = 16
edition number = 2
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 = GPS Quality * 1000
(flag indicates whether data are real time corrected)

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C17 E1 - Raw 256 Channel Gamma–Ray Spectrometric Data

channel number = 17
edition number = 1
sample size = 290 words
word 1 - 34 = various control information words
word 35 - 290 = individual 256 channels from channel 1 to 256
(counts per second * 1000)

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

2. PHYSICAL FORMAT OF STORAGE MEDIA

2.1 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.

2.2 PHYSICAL PARAMETERS OF TAPES

(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.

2.3 TAPE STRUCTURE

(a) Written in ASCII.

(b) No multi-tape files.

2.4 PHYSICAL RECORDS AND BLOCKS

(a) Fixed length records of 5120 characters.

(b) One record per block.

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

3. GRID FILE FORMAT

3.1 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.

3.2 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.

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

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

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

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.