Airborne Geophysical Survey

WISO

Northern Territory, Australia

June 2000 - February 2001

Survey Operations and Logistics Report

For

Department of Mines & Energy Northern Territory

Survey flown and compiled by

FUGRO

Fugro Job Ref. No.: 1430

Report by: Ben Trevenen

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1 SURVEY OPERATIONS AND LOGISTICS

1.1 Introduction

Between June 2000 and February 2001 Fugro Airborne Surveys Pty. Ltd. (Fugro) undertook an airborne magnetic and radiometric survey for the Department of Mines and Energy Northern Territory (NTDME) over the WISO area in the central west of the Northern Territory, Australia. The survey was flown using a Cessna 404 Titan / Courier owned and operated by Fugro. This report summarises the procedures, details and equipment used by Fugro in the acquisition, verification and processing of the airborne geophysical data.

1.2 Survey Base

Due to the large size of the area the first half of the survey was based out of the township of Tennant Creek and the second half from the Tanami Mine. The last 2 flights of the job, nos. 76 and 77, were for reflights and were flown in January 2001 from Tennant Creek. For the first half of the job the survey aircraft was operated from the Tennant Creek airport with the aircraft fuel available on site. A temporary office was set up on site at Unit 2/29 Leichhardt St. in Tennant Creek where all survey operations were run from and the post-flight data verification and processing was performed. For the second half of the job the survey aircraft was operated from the Tanami Mine airstrip with the aircraft fuel transported in by road. A temporary office was set up on site at the Tanami Mine camp where all survey operations were run from and the post-flight data verification and processing was performed. The reflights flights were based from the Bluestone Motor Inn.

1.3 Flying Summary

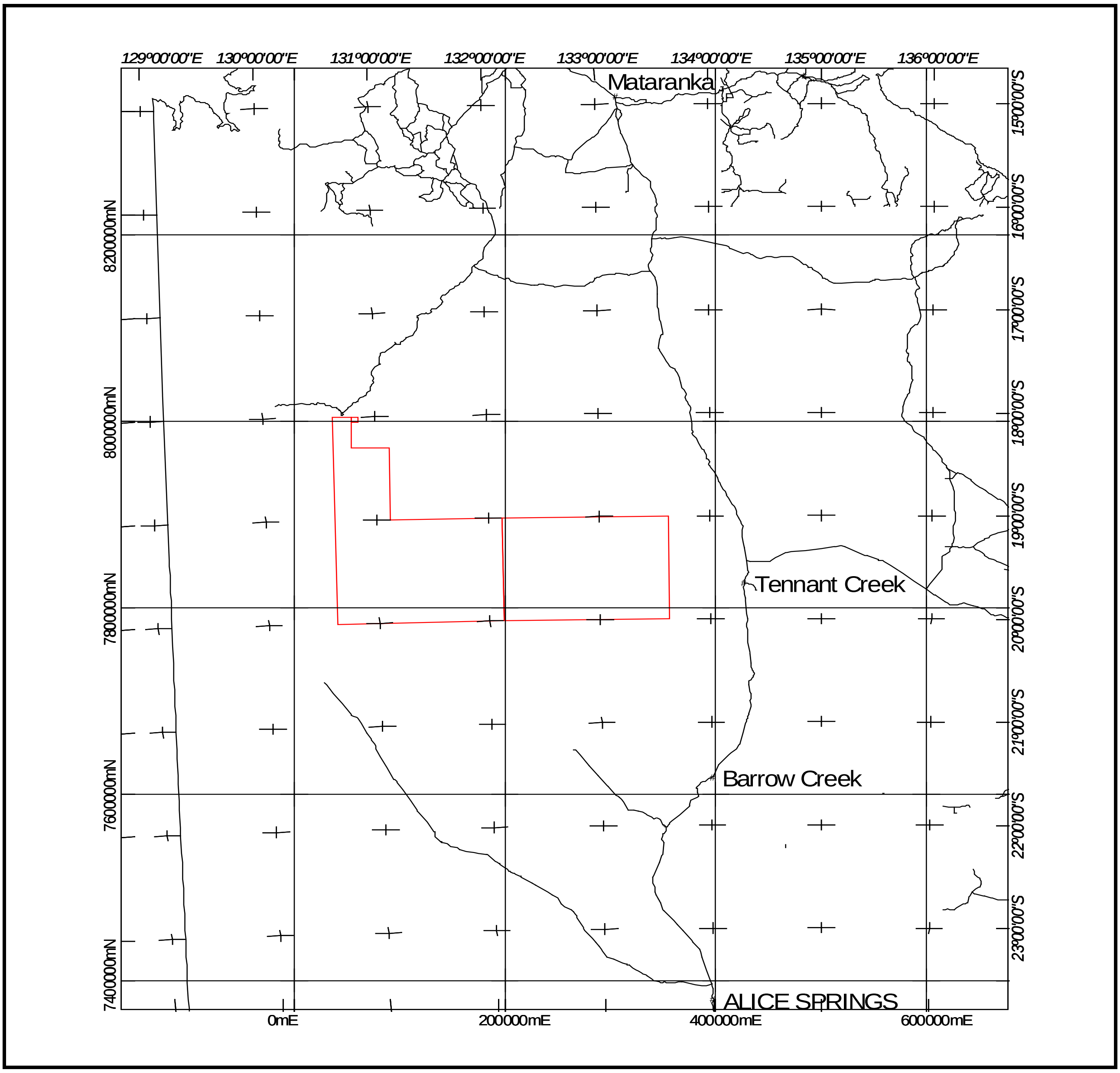
The terrain over the entire area was very flat with very little relief and sparse vegetation. The weather pattern was generally the same with clear weather every day. Cloud build-up was noted toward the end of the survey with the on-set of the wet season. Daily temperatures over the course of the survey increased which made conditions more turbulent. At the start of the survey temperatures were generally in the low to mid 20’s and by the completion of the survey had increased well into the 40’s. Most days were windy with calmer conditions in the early mornings and late evenings. In the last third of the survey bush fires in some parts of the survey area affected flying with increased turbulence and reduced visibility. These sections were usually left and surveyed at a later date.

1.4 Survey Personnel

The following personnel were involved on this project:

Project Manager/s (Perth)	Matt Trevenen
	Davin Allen
On-site Crew Leader/s	Ben Trevenen
	Tim Bailey
Pilots	Gabriel Kalotay
	Peter Hiskins
	Mitch Blakers
	Mark Tapp
	Noel Fuller
System Operators	Richard Barwise
	Norman House
	Pat Osmond
	Dave Woodbridge
On-site Data Processing	Ben Trevenen
	Tim Bailey
Electronics Technician	Dave Woodbridge
Aircraft Engineer	Reg Merryweather
	Michael Doyle
Data Processing (Perth)	Peter Chambers

1.5 Area Map



1.6 Survey Equipment

Survey Platform	-	Cessna 404 Titan / Courier
Data Acquisition System	-	Picodas Inc.PDAS-1000
Acquisition Software	-	Picodas / Fugro (in-house)
Magnetometer	-	Scintrex CS-2 Caesium vapour magnetometer
Fluxgate Magnetometer	-	Bartington model Mag-3 tri-axial fluxgate magnetometer
Spectrometer	-	Picodas PGAM 1000
Aircraft System GPS	-	Novatel GPS card
Aircraft Navigation System	-	Picodas PNAV
Real-time DGPS Receiver	-	Fugro Omnistar
Radar Altimeter/s	-	Collins ALT-50
	-	TRT ERT-11
Visual Tracking Camera	-	Panasonic WV-CD22
Visual Tracking Recorder	-	Panasonic AG-1070dc
Magnetic Base Stations	-	Primary: G823B Caesium Vapour Magnetometer
	-	Backup: Geometrics G-856 Proton Magnetometer
Base GPS	-	Ashtech
Base Logging Computer	-	IBM Compatible Pentium Notebook

Processing Computer	-	HP Pentium Notebook / IBM compatible Pentium PC
Processing Software	-	Fugro (in house) & Geosoft Oasis Montaj

2 SURVEY SPECIFICATIONS AND PARAMETERS

2.1 Area Co-ordinates

For the purposes of flight planning the survey area was divided into 3 areas. Areas 2 and 3 were planned flown and processed in Map Grid of Australia zone 52 and area 1 was planned, flown and processed in Map Grid of Australia zone 53. Areas 2 and 3 were processed as a single area.
(Note - Co-ordinates in Geodetic Datum of Australia 1994)

2.1.1 Area 1

Corner 1	-19º 00’ 00”	132º 00’ 00”
Corner 2	-19º 00’ 00”	133º 30’ 00”
Corner 3	-20º 00’ 00”	133º 30’ 00”
Corner 4	-20º 00’ 00”	132º 00’ 00”

2.1.2 Area 2

Corner 1	-18º 00’ 00”	130º 30’ 00”
Corner 2	-18º 00’ 00”	130º 39’ 60”
Corner 3	-18º 18’ 00”	130º 39’ 60”
Corner 4	-18º 18’ 00”	131º 00’ 00”
Corner 5	-19º 00’ 00”	131º 00’ 00”
Corner 6	-19º 00’ 00”	132º 00’ 00”
Corner 7	-20º 00’ 00”	132º 00’ 00”
Corner 8	-20º 00’ 00”	130º 30’ 00”

2.1.3 Area 3

Corner 1	-18º 00’ 00”	130º 39’ 60”
Corner 2	-18º 00’ 00”	130º 43’ 60”
Corner 3	-18º 03’ 00”	130º 43’ 60”
Corner 4	-18º 03’ 00”	130º 39’ 60”

2.2 Line Spacing

Traverse line spacing	-	400 m (all areas)
Tie line spacing	-	4000 m (all areas)

2.3 Line Heading

Traverse line heading	-	000º/180º (all areas)
Tie line heading	-	090º/270º (all areas)

2.4 Line Kilometres Planned

(Note – distances include overfly)

2.4.1 Area 1

Traverse line distance	44907 km
Tie line distance	4516 km
Total distance	49423 km

2.4.2 Area 2

Traverse line distance	57401 km
Tie line distance	5719 km
Total distance	63120 km

2.4.3 Area 3

Traverse line distance	136 km

Tie line distance	17 km
Total distance	153 km

2.4.4 Total Survey

Traverse line distance	102444 km
Tie line distance	10252 km
Total distance	112696 km

2.5 Line Kilometres Flown and Processed

2.5.1 Total Survey

Traverse line distance	103105 km
Tie line distance	10351 km
Total distance	113456 km

2.6 Survey Height

Mean survey height - Nominal 80m A.G.L. (all areas)

2.7 Data Sample Intervals

Data sample intervals calculated on a nominal aircraft speed of 288 km/h.

Magnetometer	-	8 m (@10 Hz)
Radar altimeter	-	8 m (@10 Hz)
Temperature	-	8 m (@10 Hz)
Pressure	-	8 m (@10 Hz)
GPS	-	80 m (@1 Hz)
Spectrometer	-	80 m (@1 Hz)
Magnetic base station (G-823B)	-	1 s
(G-856)	-	5 s

2.8 Survey Tolerances

As specified in the contract the following tolerances were used:

Traverse line separation	-	10 % of nominated line spacing over 2 km or more
Tie line separation	-	1 % of nominated tie line spacing over 2 km or more
Terrain clearance deviation	-	+/-10 m of nominal terrain clearance over 2 km or more
Total magnetometer system noise	-	More than 0.1 nT continuously over 1 km or more
Traverse line diurnal variation	-	More than 10 nT in 5 minutes
Tie line diurnal variation	-	More than 5 nT in 5 minutes
Diurnal noise	-	More than 0.5 nT for 5 minutes or more

3 SURVEY EQUIPMENT AND SPECIFICATIONS

3.1 Aircraft

Specifications

Manufacturer	-	Cessna
Model	-	404 Titan / Courier
Registration	-	VH-WGB (Australia)
Ownership	-	Fugro Airborne Surveys
Serial No.	-	404-0435
Year of Manufacture	-	1979
Engine/s	-	Twin, GTSIO-520m continental piston type
Propellers	-	Twin, 3 blade variable pitch McAuley 3FF 32C501
Dimensions	-	Wingspan 14.12 m
	-	Length 12.05 m
	-	Height 4.04 m
Fuel	-	Type - Avgas 100
	-	Capacity - Main tanks 346 US gallons (1317 litres)

	-	Endurance - @ 35 US gallons/hour = 10 hours (with aux. fuel)
Seating	-	Survey configuration - 4 seats.
Flight Instruments	-	Cessna 400 series auto pilot
	-	Bendix / King KY196ATSO Com VHF radios x 2
	-	Bendix / King KYKY53TSO Nav VHF radios x 2
	-	Bendix / King KR87TSO ADF VHF radios x 2
	-	Bendix / King multi-channel HF radio
	-	Bendix / King KT-71 transponder
	-	Bendix / King RPR2000 colour weather radar
	-	Bendix / King DME
	-	Collins Alt 50 radar altimeter
	-	TRT radar altimeter
	-	Garmen GPS 100
	-	1 x Thrane Inmarsat-C unit
	-	Sigtronics intercom
	-	Slaving compass coupled to autopilot

3.2 Aircraft Data Acquisition System

The main body of this system is the PICODAS (PDAS) computer which is coupled to a GPS receiver for timing. The GPS receiver is connected to a PICODAS navigation console (PNAV) which displays to the pilot a graphical representation of the line being flown. The PNAV has a flight plan with area boundaries including the start and end of the line co-ordinates loaded into memory via a pre recorded flight plan. The PNAV outputs to the acquisition computer the position co-ordinates and other relevant GPS information. A PICODAS 1000A-interface console powers the magnetometer, spectrometer, fluxgate magnetometer, barometric altimeter and other analogue channels. The acquisition computer also outputs line number, direction, current position and fiducial to a VHS video recorder which records the ground track of each line.

3.2.1 PDAS1000 Data Acquisition System

The Picodas PDAS1000 data acquisition system is the central airborne data logging system. The PDAS computer executes a proprietary survey program for data acquisition and recording, and it executes required calibration procedures on all acquisition equipment. The data is presented both graphically and numerically in real time on a LCD display for both verification and quality control. The windows contain information for the operator to ensure the airborne systems are calibrated and functioning correctly.
All data is stored to a hard disk drive on the PDAS1000 with the main data being in binary file format. Additional information is stored in log files, text files, raw GPS files and spectrometer files. Data is removed from the aircraft system via magneto-optical disk which enables the data to be transferred to a field processing computer.

Specifications

Model	-	Picodas PDAS1000
Motherboard	-	Teknor Viper 807
Processor	-	Intel i486DX100
Operating System	-	MS-DOS 6.22
Storage	-	Hard disk - 1.2 GB (min)
	-	Floppy disk - 1.44 MB
	-	Backup disk - 640 MB Magneto-optical disk

3.2.2 Processing Boards

Three input transputer magnetometer processor board
12 channel, 16-bit differential input, analogue processor board
Three input PGAM spectrometer master transputer board
12 channel Novatel GPS card
Video overlay card
Teknor VIPer807 i486DX100 motherboard
Picodas display interface board

3.2.3 PDAS1000A Power Console

A PDAS1000A power console is used in conjunction with the PDAS1000. This console contains the auxiliary power supplies to provide regulated power to the acquisition sensor instruments. This unit contains backup power supplies for the Caesium magnetometer. This unit interfaces all the analogue signals to the PDAS1000 analogue board.

3.3 Navigation System

3.3.1 PNAV2100 Navigation System

The Picodas PNAV2100 Navigation computer is used for real time navigation with RTDGPS corrected position data received from the GPS card. The PNAV computer loads a pre-programmed flight plan from a disk which contains boundary co-ordinates, line start and end co-ordinates and line spacing and cross track display scales. The client information, spheroid, boundary information, master point and line spacing are stored in a configuration file. This information is transformed to the local co-ordinate system for calculation of cross track, distance to go and in/out of area information. This information, along with ground heading and ground speed is displayed to the pilot numerically and graphically on a pilots crosstrack display. Differential update status is displayed to allow the pilot to assess the validity of the correction. In fixed wing aircraft the crosstrack information is also displayed on the aircraft horizontal situation indicator (HIS).
Information is also presented on an LCD display which gives a pictorial representation of the survey area, survey lines, and ongoing flight path.
The PDAS1000 and PNAV2100 are interlocked to enable autoselection and verification of the line to be flown.

Specifications

Model	-	Picodas PNAV2100
Motherboard	-	Axiom
Processor	-	Intel i486DX100
Operating system	-	MS DOS 6.22
Displays	-	LCD backlit display
	-	2 line LCD backlit display
	-	Horizontal situation indicator

3.3.2 Aircraft GPS Receiver

The Novatel GPS Receiver is used for airborne positioning and navigation and survey system timing. The GPS receiver is contained in the PDAS1000 computer and provides positional and satellite range data via the computer bus for display, recording and positional data via a serial port to the PNAV2100 for navigation. The GPS card accepts RTCM104 differential corrections via a serial port for real time differential solutions. Satellite range data is recorded for generating post-processed differential solutions. GPS information is displayed on the PDAS1000 in real time giving information on each satellite being tracked and all relevant receiver diagnostics. The PDAS1000 also shows the accuracy of the GPS position and the status of the differential update. The survey acquisition software will only record satellite data for fixes greater than 4 satellites

Specifications

Model	-	Novatel 3951R GPS Receiver
Channels	-	12
Position update rate	-	PDAS1000 @ 1 Hz
	-	PNAV2100 @ 1 Hz
Raw data update rate	-	1 Hz
Datum	-	User selectable
Time sync	-	1 PPS output
Position accuracy	-	50 cm (CEP)

3.3.3 Differential GPS Demodulator

The RACAL differential GPS service is utilised for providing real time differential corrections via the OPTUS satellite network. These corrections are received at the aircraft using a RACAL MK111 Demodulator and the data from the selected reference station is passed to the GPS card via a serial link. Status of the RTDGPS link can be monitored on the receiver and on the PDAS1000 display.

Specifications

Model	-	RACAL MK111
Received update rate	-	1-5 sec
Data format	-	RTCM 104 Ver .2

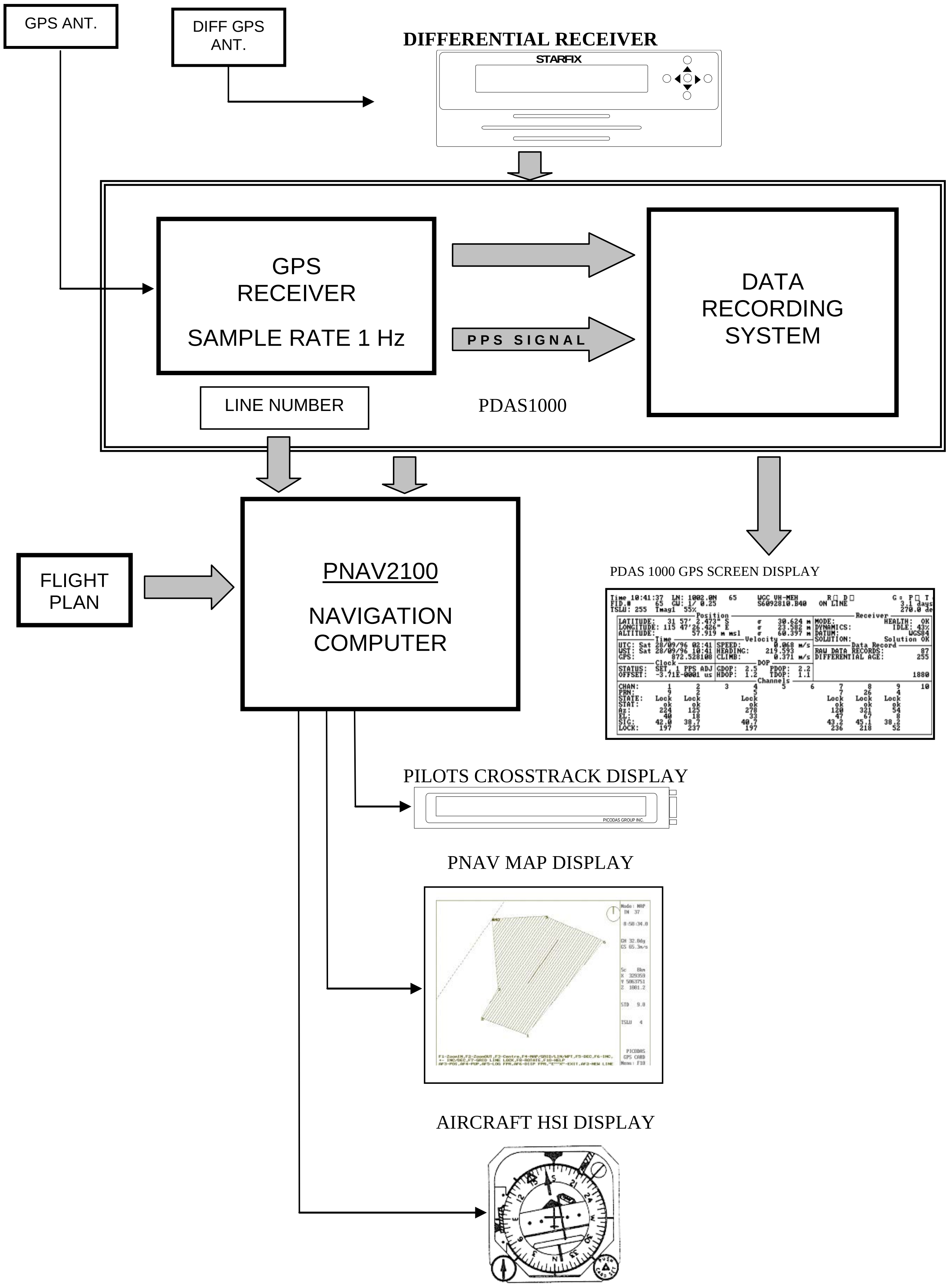
3.3.4 Data Checking

Data checking in the system is carried out automatically by the survey software and by real time display. The acquisition system will not allow GPS data to be collected for fixes of less than 4 satellites. The acquisition system will also display in real time the PDOP, HDOP, VDOP, TDOP, satellite azimuth, elevation and range. The survey system will allow any satellites, which may cause a distortion in the position to be locked out (i.e. low elevation). The survey system will also display the status of the differential update and the accuracy of the position fix in real time. The survey system will display to the operator any errors encountered in the navigation system.

3.3.5 Data Displayed and Recorded

Data Displayed	Unit	Label	Recorded
GPS week	-	WEEK	Y
GPS time	sec	TIME	Y
Latitude	deg	LAT	Y
Longitude	deg	LONG	Y
Altitude	m	H_MSL	Y
Latitude RMS position error	m	STDLAT	Y
Longitude RMS position error	m	STDLON	Y
Height RMS position error	m	STDHT	Y
Horizontal RMS position error	m	HRMS	N
Vertical RMS position error	m	VRMS	N
Position dilution of precision	-	PDOP	Y
Horizontal dilution of precision	-	HDOP	N
Time Shift dilution of precision	-	TDOP	N
Vertical dilution of precision	-	VDOP	N
Horizontal speed	m/s	VDOP	Y
Vertical speed	m/s	VDOP	Y
Horizontal heading	deg	VDOP	Y
GPS satellites	-	GPSS	Y
GLONASS satellites	-	GLOS	N
Navigation X	m	NAVX	N
Navigation Y	m	NAVY	N
Navigation Z	m	NAVZ	N
Satellite azimuth	-	raw	Y
Satellite range	-	raw	Y
Satellite status	-	raw	Y
Satellite signal	-	raw	Y

NAVIGATION SYSTEM AND POSITIONING



3.4 Aircraft Magnetometers and Current Sensors

3.4.1 Caesium Vapour Magnetometer Sensor

The caesium vapour magnetometer sensor is fitted in a tail mounted, kevlar/carbon fibre constructed airborne stinger. The sensor head is fixed in a Fugro universal sensor mount that allows for optimum alignment in any magnetic field. The sensor electronics are mounted in the base end of the stinger.

3.4.2 Power circuit

The magnetometer is powered by a dedicated isolated power supply in the PDAS1000A power console. Power is connected to the magnetometer using low loss coaxial cable. The Lamor frequency output of the magnetometer is modulated onto this power cable for input to the transputer magnetometer processor board in the PDAS1000. Remote hemisphere switching can be controlled electronically via switching to the magnetometer sensor.

Specifications

Model	-	Scintrex CS-2
Operating voltage	-	30 V DC
Operating range	-	15,000 - 100,000 nT
Sensitivity	-	0.001 nT
Heading error	-	+/- 0.25 nT
Noise envelope	-	0.002 nT pk-pk
Gradient tolerance	-	40,000 nT/m

3.4.3 Transputer Magnetometer Processor Board

The transputer magnetometer processor board provides frequency conversion for up to three input signals. The TMAG uses advanced transputer technologies allowing multi-tasking, multi-processing and floating-point calculations giving advanced resolutions. The TMAG board is timed with the GPS PPS signal to derive precise frequency counting on the three PLD counters. Onboard signal processing status is displayed by LED, whilst system diagnostics are displayed in the survey program. The TMAG processing board interfaces with the PDAS1000 computer and the survey program, which initiates data sampling and transfers.
Data is collected at 10 Hz for real time acquisition and sub sample data can be collected at 1 kHz. Barometric pressure and temperature are processed on the second and third inputs.

Specifications

Model	-	Fugro TMAG
Input range	-	15,000 - 100,000 nT
Resolution	-	0.5 pT
Sample rate	-	10 Hz Real-time acquisition
	-	1 kHz Sub-sample data
Transputer speed	-	30 MHz

3.4.4 Fluxgate Magnetometer

A Bartington three axis fluxgate magnetometer is used to determine the aircraft attitude. Each channel is recorded by the data acquisition system and can be displayed on the PDAS1000. This data is used to calculate compensation coefficients to remove all permanent magnetisation and induced magnetisation due to aircraft manoeuvres.
Combined with a compensation file the PDAS1000 can display and record real time TMI compensation data.

Specifications

Model	-	Bartington MAG-03M
Scaling Value	-	100 uT
Measuring Range	-	+/- 100 uT
Sample Rate	-	10 Hz

3.4.5 Current Sensors

Current sensors are used in the acquisition system to monitor any changes to the aircraft electrical system. These sensors will pick up changes in current that can cause spikes and level shifts in the magnetic data and unwanted electrical noise from aircraft radio and navigation systems. Current sensors are placed on each aircraft engine alternator and on the survey equipment rack.

3.4.6 Data Checking

Data checking is carried out in the survey system by displaying all available magnetic traces in real-time on the PDAS1000 display. Any errors detected by the survey system will be displayed to the operator.

3.4.7 Data Displayed and Recorded

Data Displayed	**Unit**	**Label**	**Recorded**
Raw Uncompensated TMI data	nT	TMAG1	Y
Compensated TMI data	nT	TCMA1	Y
Fourth Digital Difference of TMI data	pT	TFDD1	N
First Vertical Derivative of TMI data	pT/m	1VD	N
First Digital Difference of TMI data	nT	1DD	N
Ratio of TMAG1 and Fluxgate	nT/mV	RATIO	N
X axis Fluxgate	mV	XDEV	Y
Y axis Fluxgate	mV	YDEV	Y
Z axis Fluxgate	mV	ZDEV	Y
TMI Fluxgate	mV	FGATE	N

3.5 Gamma Ray Spectrometer System

The Picodas Gamma Ray Spectrometer system is utilised for airborne radiometric data acquisition. The system consists of two shock mounted fibreglass/Perspex casings, each containing four NaI (TI)
Crystals, giving a system volume of 33.56 litres. Each individual crystal has its own signal processing circuitry consisting of high and low voltage power supplies, analogue to digital conversion unit, EEPROM for storage of calibration coefficients and supporting circuitry for peak detection including adjustable threshold and coincidental peak recognition.
Each crystal pack has a slave transputer processing circuit for event processing and transferring each individual crystal spectra to the master transputer contained in the PDAS1000. The master transputer performs real time gain corrections on the individual spectra based on the tracking of the TI-208 (Th), K-40 or U photo peaks. Real time non-linearity corrections are applied according to individual coefficients determined during calibration under controlled conditions. For normal survey operation the summed 256-channel spectrum is transferred to the PDAS1000 for display and recording. Data can be displayed in real time showing individual crystal tracking statistics and crystal energy spectrums.
For pre and post-flight calibrations, the 256-channel spectrum for individual crystals are transferred for resolution determination and verification. In addition to the 256 channel summed spectra, individual energy windows may be defined for display and recording to the PDAS1000. These windows can be any of the IAEA defined energy windows or user selectable windows.
Raw 1024 channel individual crystal data is stored by the survey program as compressed spectra files. These files contain all the raw tracking information from each crystal. This data is used to post-energy calibrate any crystal peaks to obtain optimum performance.
All data recorded in the spectrometer system is dead time corrected and normalised to one second.

Specifications

Model	-	Picodas PGAM1000
Detector Volume	-	33.56 litres
Energy Channels Processed	-	1024
Energy Channels Recorded	-	256 summed data
	-	1024 compressed individual crystal data
Lower Energy Threshold	-	50 keV
Upper Energy Threshold	-	3000 keV
Cycle Rate	-	1 Hz

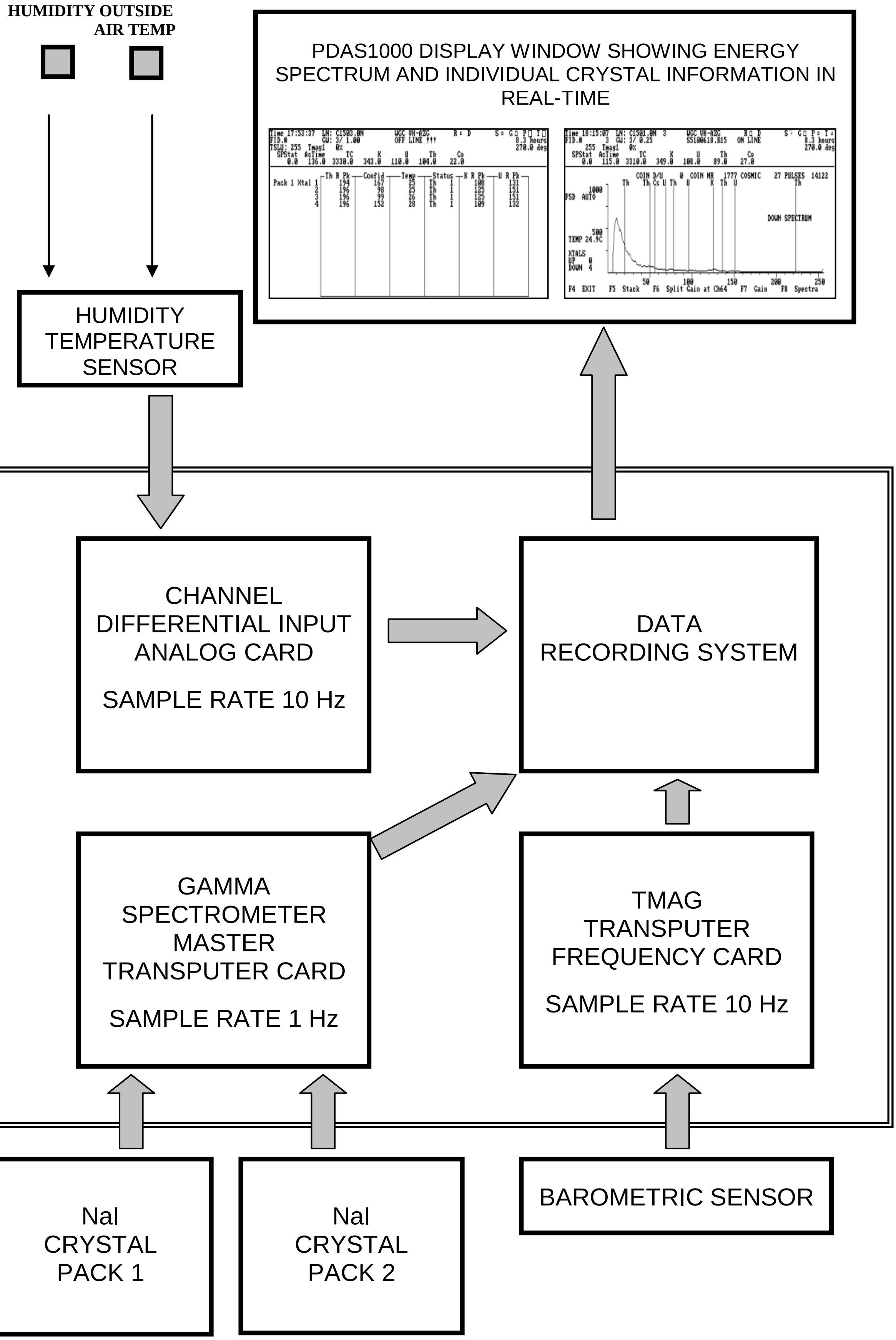
3.5.1 Data Checking

Data checking is in the survey system is carried out by the use of resolution procedures using known radiometric sources to verify system, real time display of individual crystal resolutions and system resolutions whilst surveying, real time display of raw and corrected peak channel tracking information, real time display of the energy spectrum showing counts, cosmic level and coincident pulse counts. The survey system will display to the operator any errors encountered in the spectrometer system

3.5.2 Data Displayed and Recorded

Data Displayed	**Unit**	**Label**	**Recorded**
Spectrometer Statistics	-	SpStat	Y
Acquisition Time	ms	AcTime	Y
Total Counts	cps	TC	Y
Potassium Counts	cps	K	Y
Uranium Counts	cps	U	Y
Thorium Counts	cps	Th	Y
Cosmic Counts	cps	C	Y
256 Channel Data	cps	TC	Y
Raw Peak Channels	-	XtalSt	Y
Corrected Peak Channels	-	XtalSt	Y
Individual Crystal Statistics	-	XtalSt	Y

GAMMA SPECTROMETER SYSTEM



CRYSTAL PACKS MOUNTED DIRECTLY TO THE AIRCRAFT FLOOR CLEAR OF FUEL TANKS.

3.6 Radar Altimeter

To maintain accurate minimum survey height clearance a COLLINS ALT-50 system is used. Data from this unit is recorded and displayed on the PDAS1000 for accurate terrain clearance. This information is displayed on a pilot instrumentation with low altitude warning annunciators set from a dialled up height. The height voltage is also displayed and recorded on the PDAS1000 in the form of raw mV height and a calculated altitude in either feet or meters. This height is calculated with a calibration procedure that accurately converts the voltage to an equivalent height. The data acquisition system also uses a TRT ERT-11 for back up. This altimeter has a range that will not allow for data height dropouts in severe terrain.

Specifications – Collins Alt 50

Model	-	Collins ALT50
Range	-	0-2000 ft
Accuracy	-	0 - 200’ +/- 6’
	-	200 - 500’ +/- 2 %
	-	500 - 2000’ +/- 3.5 %
Sample Rate	-	10 Hz

Specifications – TRT ERT-11

Model	-	TRT ERT011AHV-8
Range	-	0-10,000 ft
Accuracy	-	+/- (0.5’ + 2%) reading typical
	-	+/- (1’ +5%) reading maximum
Sample Rate	-	10 Hz

3.6.1 Data Checking

Data checking is carried out in the survey system by displaying the radar altimeter information in real-time on the PDAS1000 display. Any errors detected by the survey system will be displayed to the operator.

3.6.2 Data Displayed and Recorded

Data Displayed	Unit	Label	Recorded
Raw input voltage Rad 1	mV	RRAD	Y
Raw input voltage Rad 2	mV	RRAD2	Y
Radar height Rad 1	ft	RAD	Y

3.7 Barometric Altimeter

The output of the Digiquartz pressure transducer is used for calculating the barometric altitude of the aircraft. The atmospheric pressure is taken from a gimbal-mounted probe and fed to the transducer. The transducer uses a precise Quartz crystal resonator whose frequency of oscillation varies with pressure induced stress. The frequency is processed on the second channel of the transputer magnetometer board. The temperature of the pressure sensor is also recorded. In conjunction with the area QNH pressure and ambient temperature, the barometric altitude is calculated. This calculated altitude and the raw frequency are recorded and displayed on the PDAS1000.

Specifications

Model	-	Digiquartz 215A-101
Range	-	0 – 0.1 MPa
Accuracy	-	0.01 %
Resolution	-	$1x10^{-8}$ Pa
Sample Rate	-	10 Hz

3.7.1 Data Checking

Data checking is carried out in the survey system by displaying the Digiquartz information in real-time on the PDAS1000 display. Any errors detected by the survey system will be displayed to the operator.

3.7.2 Data Displayed and Recorded

Data Displayed	Unit	Label	Recorded
Pressure frequency	Hz	PFREQ	Y
Temperature frequency	Hz	TFREQ	Y
Converted height	ft	HEIGHT	Y

Converted temperature	deg	DTEMP	Y

3.8 Temperature and Relative Humidity System

A Vaisala humidity/temperature sensor is utilised for measuring the relative humidity and temperature of the atmosphere external to the aircraft. The sensor produces a linear voltage that is measured by the analogue processor board in the PDAS1000

Specifications

Model	-	Vaisala HMP133Y
Sample rate	-	10 Hz
Relative Humidity	-	Measuring range - 0-100 % RH
	-	Accuracy - +/- 1 %RH (0..90 %RH)
	-	Sensor - HUMICAP H-Sensor
Temperature	-	Measuring range - -20 to +60 ^{0}C
	-	Accuracy - +/- 0.2 ^{0}C
	-	Sensor - Pt 100 RTD

3.8.1 Data Checking

Data checking is carried out by displaying the atmospheric information in real time on the PDAS1000 displays. Errors in the system will be displayed to the operator.

3.8.2 Data Displayed and Recorded

Data Displayed	Unit	Label	Recorded
Relative Humidity	RH	HUMID	Y
Temperature 2	deg C	TEMP2	Y

3.9 Video Tracking System

WGC uses a colour video tracking system to allow recording of the flight path on a VHS-PAL videotape. The image data is recorded by a Colour CCD camera with an auto iris lens that is focused for optimum image. The video tape is synchronised with the recorded geophysical data by means of a video overlay card. The tape is overlaid with the PPS synchronised fiducial count, GPS position and line number. A video monitor is fitted onboard to allow the video data and timing information to be displayed. Time is displayed as a fiducial count that is synchronised with the GPS clock and time stamped on the data.

Specifications

Camera	Model	-	Panasonic WV-CL352
	Lens	-	HG4514FCS
	Footprint	-	60 m x 48 m
VCR	Model	-	Panasonic
	Format	-	VHS-PAL
Monitor	Model	-	Panasonic WV-5200

3.10 Flight Data Recording

All data recorded in the data acquisition system is stored in a digital format on the hard disk drive located in the PDAS1000. This data is then copied from the computer to a magneto-optical removable disk. The data is then transferred to the field processing computers for quality control examination.

Stored aircraft data consists of :

S.B files	-	Survey Binary files
S.T files	-	Survey Text files
R.R files	-	Raw Rover GPS files]
P.C files	-	PGAM Compressed spectrometer files

Survey binary files contain:

Header	-	Line
	-	Flight
	-	Direction
	-	Date
ID group	-	Fiducial
	-	Time

AD group	-	Fluxgate data
	-	Raw radar altimeter data
	-	Ambient temperature data
	-	Relative humidity data
HT group	-	Converted barometric height
	-	Converted radar altimeter height
TM group	-	Raw TMI data
		Compensated TMI data
NO group	-	GPS time
	-	GPS week
	-	GPS real-time position
	-	GPS speed and direction
	-	GPS position statistics
NS group	-	GPS status
	-	Satellite channels
	-	Datum data
DP group	-	Barometric pressure frequency data
	-	Sensor temperature frequency data
	-	Converted height data
	-	Converted temperature data
SP group	-	Spectrometer statistics
	-	Total count window data
	-	Potassium window data
	-	Uranium window data
	-	Thorium window data
	-	Cosmic window data
CH group	-	256 channel data
XS group	-	Crystal statistics

Survey text files contain:

Survey and flight information in ASCII format

Rover GPS files contain:

Raw GPS data for post-flight processing

PGAM compressed spectrometer files contain:

Raw individual crystal data stored in 1024 channels per crystal

3.11 Time Base

The time base for this survey was based on the atomic clock output of the GPS satellites in all aspects of data acquisition. The aircraft acquisition system software is set to GPS time then adjusted to the local area time, in this case Australian Central Standard Time, whenever the system is initialised. The entire acquisition process is continuously locked to the “PULSE PER SECOND” hardware signal from the Novatel GPS card receiver(s), which itself is intrinsically slaved to GPS satellite time.

3.12 Flight Following

During the course of the survey the aircraft’s position in real time was monitored using a Thrane & Thrane “CAPSAT” model INMARSAT-C/LM beacon installed on the survey aircraft. This equipment, with its independent GPS receiver, transmitted the position of the aircraft to a satellite over the Indian Ocean. This position was then relayed to Telstra via a ground station in The Netherlands. The aircraft’s position is then logged on a computer at the Fugro office in Perth, which is connected permanently to a Telstra line.

The antenna for this equipment was located on top of the aircraft fuselage so as to achieve the best-unobstructed view of the satellite as possible. This equipment emits a high power (approx. 80W), near microwave, omni-directional signal and consequently draws high current from the aircraft electrical bus for a short period of time (3-4 ms). This current spike is detected as a spike in the aircraft’s magnetic field by the magnetometer system and therefore is recorded in the magnetic data logged to disk. This interference is readily detectable in the 4^{th} difference trace and occurs as a single pulse or as a 2 or 3 pulse burst about every 5-10 minutes or so.

4 GROUND DATA ACQUISITION EQUIPMENT AND SPECIFICATIONS

4.1 Magnetic Base Station

Geometrics G-856 proton and G-823B Caesium vapour base station magnetometers were used to monitor the magnetic diurnal variation. All magnetometers were synchronised to the local time base of the aircraft survey system GPS prior to surveying each day. For the first half of the survey two G-856 and one G-823B magnetic base stations were set-up at the Tennant Creek airport with the G-823B being used as the primary base station from which all diurnal data used in processing for the survey was taken. During that period one G-856 was removed from the Tennant Creek airport and placed in the survey area to collect one days diurnal data to compare the variation in diurnal variation over the survey area. For the second half of the survey one G-823B and one G-856 magnetic base stations were set-up at the airstrip at the Tanami Mine. The base stations were set up in the same position at Tennant Creek airport for the reflights. Prior to positioning the base stations a mini-survey was conducted to establish a magnetically low gradient area. A base value for the primary base station was calculated and used in both locations in the diurnal correction of the magnetic data.

4.1.1 G-823B

Model		-	Geometrics G-823B Caesium vapour magnetometer
Operating range		-	20,000 – 90,000 nT
Sensitivity		-	0.002 nT @ 1 Hz
Noise (RMS)		-	0.004 nT @ 1 Hz
CM-201 Counter	Max. data rate	-	100 Hz
	Max. baud rate	-	19200
Sample rate		-	1 Hz

4.1.2 G-856

Model	-	Geometrics G-856 proton memory magnetometer
Displays	-	Six digit display of magnetic field to resolution of 0.1 nT or time to nearest second. Additional three digit display of station, day of year and record number.
Resolution	-	Typically 0.1 nT in average conditions.
Absolute accuracy	-	1 nT, limited by remnant magnetism in sensor and crystal oscillator accuracy.
Clock	-	Julian clock with stability of +/~2 seconds per day.
Memory	-	Approximately 12,500 readings.
Output	-	RS-232 output data in standard format.
Sample rate	-	Internal logging at 5sec (0.2 Hz) rate.

4.1.3 Magnetic Base Station Locations

Base station locations are given in the GDA94 datum.

Base	Longitude	Latitude	Base value
Tennant Creek	134° 11’ 08.109”	-19° 38’ 56.828”	50800 nT
Tanami Mine	129° 43’ 14.380”	-19° 57’ 49.663”	51396 nT
Remote	132° 41’ 09.468”	-19° 16’ 15.786”	

4.2 GPS Base Station System

4.2.1 GPS Base Station Locations

For the first half of the survey a GPS base logging station was set up at the survey base office in Tennant Creek and for the second half at the survey base at the Tanami Mine with the GPS antenna set in the following positions:
(Note - co-ordinates are in the WGS84 datum):

Base	Longitude	Latitude	Height
Tennant Creek	134° 11’ 08.109” E	19° 38’ 56.828” S	412.67 m
Tanami Mine	129° 43’ 14.380” E	19° 57’ 49.663” S	470.50 m
Tennant Creek (Reflights)	134° 11’ 02.222” E	19° 38’ 27.520” S	424.59 m

4.2.2 GPS Base Station Description

The GPS base system comprises a GPS receiver, a logging computer, an antenna and a UPS system to avoid down time if power fails or fluctuates. The GPS receiver is connected to the PC via a serial COM connector. Data is logged using proprietary software and displayed in real time on the screen.
Logged base data is processed in conjunction with the airborne GPS data to calculate the post-processed differential position of the aircraft.
Proprietary software is used to display and calculate flight path of the aircraft and altitude clearance.

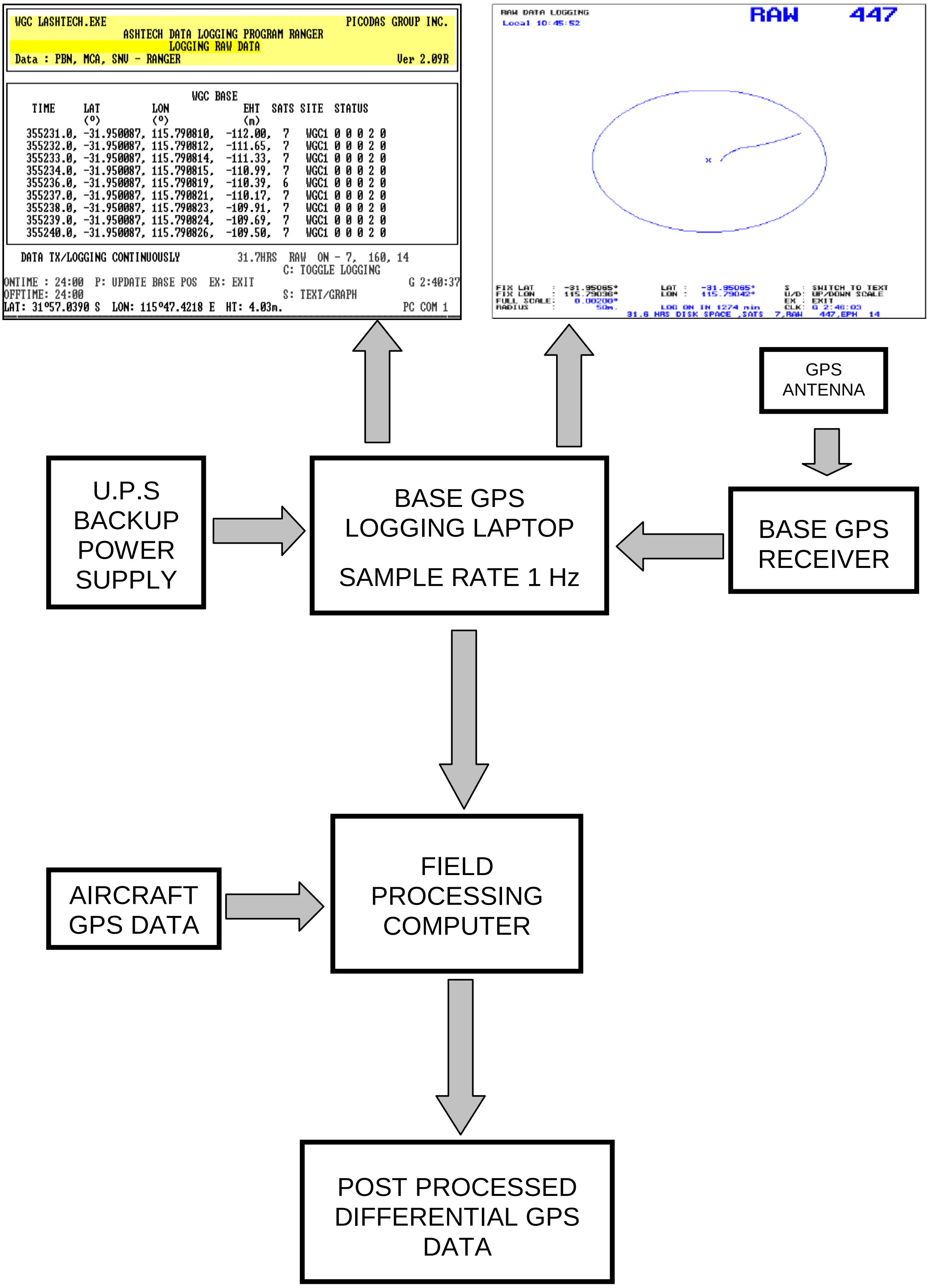
Specifications

Ashtech G12 Receiver

Model	-	Ashtech G12 Receiver
Receiver	-	12 Channel GPS code and carrier
Position Accuracy	-	Differential mode <40 cm

GPS BASE STATION AND PROCESSING SYSTEM

DATA DISPLAYS OF BASE GPS INFORMATION



5 EQUIPMENT CALIBRATIONS AND DATA ACQUISITION CHECKS

5.1 Survey Calibrations

A series of calibrations were performed as follows:

5.1.1 Dynamic Magnetometer Compensation

Carrying a magnetometer through a varying field in a non-uniform orientation produces manoeuvre noise. To compensate for this manoeuvre noise a standard compensation test flight called a "comp box" is flown. The compensation file produced also removes the majority of the heading error. Aircraft compensation tests were flown on the 4 survey line headings and also at +/- 7½ and 15^{o} to the line headings (to accommodate for cross wind flying conditions). The data for each heading consists of a series of aircraft manoeuvres with large angular excursions: specifically pitches, rolls and yaws. This is done to artificially create the worst possible attitudes and rates of attitudinal change likely to be encountered while on line and compensate for any magnetic noise created by the aircraft's motion within the earth's magnetic field. This data is processed to obtain the real time compensation terms. These coefficients are applied in real-time and later during post-processing. Note that this form of compensation will only remove those noise effects modelled in the manoeuvre test flight. Random motions of the stinger with respect to the aircraft airframe generally establish the noise floor for this type of installation. Comp boxes were flown at the start of the survey and whenever a change was made to the magnetic signature of the aircraft, e.g. 100 hourly service, equipment change or repair, etc.

Date flown	Flights covered
20/06/00	1 to 20
13/07/00	21 to 24
19/07/00	25 to 32
30/07/00	33 to 33
31/07/00	34 to 41
18/08/00	42 to 45
30/08/00	46 to 49
07/09/00	50 to 60
22/09/00	61 to 67
29/09/00	68 to 72
12/10/00	73 to 75
02/01/01	76 to 77

5.1.2 Parallax

Parallax error is caused by the physical difference in distance between the various sensors, the electronic delay and software timing in the acquisition system. Hence all variables are subjected to a displacement from the GPS co-ordinates. If these variables are processed without a position offset a parallax error will occur. The most suitable way to treat this problem is to use the 1 second radiometric data as a base with a zero correction. This will prevent interpolation of important variables (a filtering process). The co-ordinates were moved by linear interpolation and other data variables were displaced onto the radiometric data, without change, in multiples of 0.1 seconds.

5.1.2.1 Spectrometer

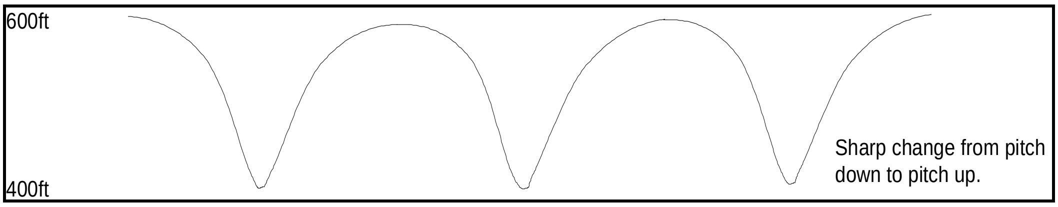
The spectrometer data were not parallaxed but a correction was made by applying a parallax to the co-ordinate data. This parallax was computed using a section of lines with a spacing of 100 metres and regridding the data until the appropriate amount of parallax was applied.

5.1.2.2 Magnetometer

The magnetometer parallax was computed using a section of lines with a spacing of 100 metres and regridding the data until the appropriate amount of parallax was applied.

5.1.2.3 Barometric and Radar Altimeter Parallax

In order for processing to accurately determine the parallax error associated with the barometric and radar altimeter data a parallax test line was flown. This line consisted of five sharp swoops between 600ft and 400ft. Starting at an altitude of 400ft the aircraft sharply descended to 400ft, then ascended upward to 600ft, levelling off for a few seconds before repeating this a further four times.



5.1.2.4 Data parallaxes

Data	Parallax
Radiometrics	0 seconds
GPS easting	-1.5 seconds
GPS northing	-1.5 seconds
GPS height	-1.5 seconds
Magnetics	-1.1 seconds
Radar altitude	-1.1 seconds
Pressure	-1.4 seconds
Temperature	0 seconds

5.1.3 Radar Altimeter Calibration Line

Height above the terrain is measured using a radar altimeter. The output voltage from the radar altimeter unit is recorded along with the survey data in the PDAS binary files. A look-up table is used to convert this output voltage into an altitude in metres. The lookup table is computed by recording the output voltage at various heights above the ground as indicated on the radar altimeter display.

5.1.4 Background and Cosmic Calibration Stacks

Radiometric data recorded by the PGAM 1000 is contaminated by various non-terrestrial sources. In order to provide an accurate representation of terrestrial (or natural) radiometric content these other sources must be identified and removed. This was done by flying a series of high level test lines over the ocean. Fixed barometric altitudes were flown for 5 minutes from 1000 ft above ground level (AGL) ascending at 2000 ft intervals up to and including 9000 ft A.G.L. then descending in the same manner.

5.1.5 Height Attenuation Calibrations

Gamma -rays are attenuated by air at approximately an exponential rate. It is therefore essential that corrections for aircraft altitude are incorporated into processing procedures. In order to correct for varying aircraft altitude and to accurately convert airborne counts into ground concentrations of potassium, uranium and thorium a series of height attenuation, or low level stacks, were flown. Over a calibration test line the stacks were flown starting at 150 ft and incrementing at 50 ft intervals to 450 ft, then 1000 ft, 1500 ft and 2000 ft with data recorded for 300 seconds at each level.

5.1.6 Daily Calibrations

A set of daily calibrations were performed each survey day as follows:

5.1.6.1 Magnetic Base Station Time Check

Prior to each days survey all magnetic base stations were time checked and synchronised with the time on the aircraft survey system GPS receiver. The temporal drift over a typical survey day of approximately 12 hours, was determined to be on the order of 1 second or less for all mag base stations.

5.1.6.2 Barometric Calibration

In order to correct the computed barometric height for pressure variations during the survey a correction is applied using a measured pressure at a known height. This pressure is known as QFE pressure and it was measured in the aircraft pre and post sortie at the airport. Barometric recorded for a period of 30 seconds.

5.1.6.3 Spectrometer Resolution Tests

Internal Quality Control of the Gamma-Ray Spectrometer (PGAM 1000) relies on continually monitoring the resolution and peak positions of individual crystals. Prior to and after each days survey a Thorium source was placed on the PGAM 1000 crystal pack in a designated location at least 50 cm from each detector pack with 120 seconds of resolution test data recorded. The calculated system resolution remained less than 7%. Refer to Appendix 7 for results

5.1.6.4 Spectrometer Button Tests

Hand sample checks were performed on the spectrometer before and after each days survey acquisition. Each sample was placed in a predetermined location and data recorded for 60 sec. Relative count rates above background were within +/- 5% of the average sample checks for the duration of the survey.

5.1.6.5 Low Level Test line

To monitor the effects of soil moisture and radon and to verify the system was functioning correctly a low level test line was flown in a constant direction at survey altitude for 5 km prior to and after each days production. The collected data was checked by the operator to ensure the Total Count and Th. for the low level test line was within +/- 10% of the initial average.
There were 2 designated low level test lines, one for the Tennant Creek base and the other for the Tanami base. The co-ordinates are in the GDA94 datum.

Base	Mean start		Mean end	
	Longitude	Latitude	Longitude	Latitude
Tennant Creek	133° 30’ 53”	-19° 47’ 04”	133° 56’ 19”	-19° 47’ 04”
Tanami Mine	130° 07’ 49”	-20° 00’ 03”	130° 13’ 11”	-20° 00’ 03”

6 SURVEY LINE NUMBERING SYSTEM

The following line numbering formula was employed for this survey, only the first 4 digits of the line number are shown, see sections 6.1 and 6.2 for additional explanation:

Line No./Range	Type	Duration	Frequency	Comments
1501	Caesium source	180 seconds	Daily	A.M. spec. cals
1502	Uranium source	180 seconds	Daily	A.M. spec. cals
1503	Thorium source	180 seconds	Daily	A.M. spec. cals
1504	Background	180 seconds	Daily	A.M. spec. cals
1508	Low level test line	~5 km	Daily	A.M. spec. cals
1601	Caesium source	180 seconds	Daily	P.M. spec. cals
1602	Uranium source	180 seconds	Daily	P.M. spec. cals
1603	Thorium source	180 seconds	Daily	P.M. spec. cals
1604	Background	180 seconds	Daily	P.M. spec. cals
1608	Low level test line	~5 km	Daily	P.M. spec. cals
1511	Baro. altimeter	30 seconds	Pre sortie	1st sortie
1611	Baro. altimeter	30 seconds	Post sortie	1st sortie
1512	Baro. altimeter	30 seconds	Pre sortie	2nd sortie
1612	Baro. altimeter	30 seconds	Post sortie	2nd sortie
1513	Baro. altimeter	30 seconds	Pre sortie	3rd sortie
1613	Baro. altimeter	30 seconds	Post sortie	3rd sortie
1800-1810	Heading checks	As required	Survey commencement	
1811-1820	Comp box	~260 seconds	As required	
1821-1825	Baro. altimeter stack	~ 30 seconds	Survey commencement	
1826-1830	Parallax checks	As required	Survey commencement	
1831-1845	High level spec	300 seconds	Annually	Over water
1850-1865	Low level spec	5 km	Annually	Carnamah test range
1870-1874	Pad cals pack #1	300 seconds	Annually	Bg, K, U, Th
1875-1879	Pad cals pack #2	300 seconds	Annually	Bg, K, U, Th
1881-1890	Altimeter checks	As required	Survey commencement	
1001-1403	Traverse line	As required		MGA zone 53
2001-2403	Traverse line	As required		MGA zone 52
3005-3019	Traverse line	As required		MGA zone 52
1702-1730	Tie line	As required		MGA zone 53
2702-2757	Tie line	As required		MGA zone 52

6.1 Survey line numbering

6.1.1 Digital data

All survey lines are stored as 5 digit integers in the digital data and take the form ANNNP where:

- A - Area number: for this survey a 1 indicates the line was flown as part of the MGA zone 53 block and a 2 or 3 indicates the line was flown as part of the MGA zone 52 block. e.g. **1**2340 is a line from the zone 53 block.
- NNN - Line number: if the 1st digit is a 7 then the line is a tie line. e.g. 2**014**0 is traverse line 14 from the zone 52 block, 1**713**0 is tie line 13 from the zone 52 block.
- P - Attempt number: if a line is scrubbed and reflown or flown in multiple parts the attempt number will be increment by 1. e.g. 2401**2** indicated the 3rd attempt for line 401 from the zone 52 block.

6.1.2 Flight logs

Survey lines written in the flight logs, and as displayed on video, are written in the form SANNN.PD where:

- S - Alphabetic descriptor: “ “ indicates a traverse line, “T” indicates a tie line, “S” indicates a scrubbed line.
- A - Area number
- NNN - Line number
- . - Decimal point
- P - Attempt number
- D - Direction: **N**orth, **S**outh, **E**ast or **W**est.

6.2 Calibration line numbering

6.2.1 Digital data

All calibration lines are stored as 8 digit integers in the digital data and take the form ANNNPFFF where:

- A - Area number: this is not important for a calibration line and is generally 1 for most calibration lines regardless of which block was being flown.
- NNN - Line number: as per the line number description table.
- P - Attempt number: unlike survey lines there are no part calibration lines
- FFF - Flight number: the flight number is appended to the line number as calibration lines are repeated during the survey.

6.2.2 Flight logs

Calibration lines written in the flight logs, and as displayed on video, are written in the form SANNN.PD where:

- S - Alphabetic descriptor: “C” indicates a calibration line, “S” indicates a scrubbed line.
- A - Area number
- NNN - Line number
- . - Decimal point
- P - Attempt number
- D - Direction: **N**orth, **S**outh, **E**ast or **W**est.

7 DATA VERIFICATION AND FIELD PROCESSING

All data verification and processing was conducted at the field offices, which were established on site at Tennant Creek and Tanami Mine for the duration of the survey. At the conclusion of each days survey all magnetic, spectrometer, altimeter, flight path and diurnal data was down loaded onto the field office computer for preliminary verification.

7.1 Field Processing Equipment

IBM compatible Pentium computer with optical disk drive.
HP Pentium notebook.
Canon bubble jet printer.

7.2 Magnetic Diurnal Data

Diurnal data recorded every second from the primary base station was down loaded from the magnetometer’s base logging computer onto the field processing computer via a floppy disk. The data was then checked for spikes and erroneous readings. If invalid diurnal data occurred whilst survey data was being acquired the affected section was re-flown. The diurnal data was also checked to see that the change in diurnal readings during the course of the survey did not exceed the specified tolerances described in section 2.9. When this occurred the affected part of the survey line was re-flown. The diurnal data was merged with the aircraft data and used in the verification of the magnetic data. Diurnal data recorded every 5 seconds from the backup base stations was also down loaded from the magnetometer base stations onto the field processing computer directly via a dump cable.

7.3 Altimeter Data

Radar altimeter, barometric altimeter and GPS height data from the aircraft was transferred via magneto-optical disk onto the field processing computer.

7.3.1 Radar Altimeter Data

The radar altimeter is verified to check that a reasonably constant height above the terrain specified in section 2.6 was flown, readings during the course of the survey did not exceed the specified tolerances described in section 2.8 and for equipment reliability. The radar altimeter data is used in the production of topographic maps.

7.3.2 GPS Height Data

The aircraft's height above mean sea level each second was determined by differentially post-processing the synchronised DGPS data from the aircraft and GPS base station. The GPS height of the aircraft is verified to check for data masking and for equipment reliability. The GPS height data is used in the production of topographical maps.

7.3.3 Barometric Altimeter Data

As a backup to the aircraft's GPS height barometric data was also recorded. The barometric height of the aircraft is verified to check for equipment reliability. The barometric data is also used in the processing of the spectrometer data.

7.3.4 Topographical Data

After verification parallax corrections as specified in section 5.1.2.4 were applied and the radar altimeter height was subtracted from the GPS height to give the elevation of the terrain above the GDA94 ellipsoid. It was not considered necessary to make any further corrections as this data is for verification purposes only.

7.3.5 Gridding and Inspection

The topographical data was gridded and grid image enhancements were computed and displayed on screen. These were inspected for inconsistencies and errors and appropriate corrections were made if required.

7.4 Flight Path Data

The flight path data from the aircraft and the GPS base station were transferred via magneto-optical disk onto the field-processing computer. The aircraft's precise location each second was determined by differentially post-processing the synchronised GPS data from the aircraft and GPS base station. The flight path was recovered and plotted daily to ensure it was within specifications described in section 2.8. Any data not within specification was re-flown. The flight path data was then merged with the rest of the aircraft and diurnal data. Both the aircraft and GPS base station recorded the data in the WGS 1984 datum.

7.5 Magnetic Data

The real-time compensated and uncompensated magnetic data from the aircraft recorded every 0.1 second were transferred via magneto-optical disk onto the field-processing computer. The raw, unedited magnetic data was checked to identify noise and spikes. Single reading spikes were manually edited and if the noise exceeded the specified tolerances described in section 2.8 the part of the line affected was re-flown. After the edited magnetic data was merged with the digital flight path the following sequence of processing operations were carried out to allow inspection and verification of the data:

7.5.1 Diurnal Correction

The synchronised digital diurnal data collected by the base station was first subtracted from the corresponding airborne magnetic readings to calculate a difference. The resultant difference was then subtracted from the base value described in section 4.1.3 to produce diurnally corrected magnetic data.

7.5.2 Parallax Correction

The diurnally corrected magnetic data was then corrected for system parallax using the value given in section 5.1.2.4.

7.5.3 Preliminary Gridding and Inspection

The magnetic data was gridded and grid image enhancements were computed and displayed on screen. These were inspected for inconsistencies and errors and appropriate corrections were made if required.

7.6 Spectrometer Data

Spectrometer data from the aircraft was transferred via magneto-optical disk onto the field-processing computer. The data is verified to check that readings during the course of the survey did not exceed the specified tolerances described in section 2.8 and for equipment reliability.

7.6.1 Preliminary Corrections

Standard radiometric data reduction corrections were then applied to the Total Count, Potassium, Uranium and Thorium window data.

7.6.2 Parallax Correction

The corrected window data were then corrected for system parallax using the value given in section 5.1.2.4.

7.6.3 Preliminary Gridding and Inspection

The spectrometer data was gridded and grid image enhancements were computed and displayed on screen. These were inspected for inconsistencies and errors and appropriate corrections were made if required.

7.7 Digital Archives

All raw aircraft data was backed up on magneto-optical disk at the end of each day's survey. Two copies of all verified and edited data were made onto magneto-optical disk also at the end of each day's survey. One copy was sent by courier to the Fugro office in Perth with the other copy remaining at the field processing office.

8 FINAL DATA PROCESSING

Three separate streams of raw data are collected by separate acquisition systems. All three sets of data are treated as discrete units and are post-processed accordingly before being merged.

8.1 Raw Data Collection

8.1.1 Aircraft Data

Data collected by the aircraft includes:

- TMI via the Caesium vapour magnetometer
- 1024 Channel spectrometer
- 3 axis fluxgate magnetometer
- radar altimeter
- pressure
- temperature
- fiducial
- time
- GPS Positioning information (including time and satellite info.)

8.1.2 Magnetic Base Station Data

Whilst the aircraft was collecting data, magnetic diurnal data was collected at the aircraft base.

8.1.3 Global Positioning System Base Station Data

An Ashtech Ranger II 12 channel GPS receiver was used for the GPS base station at the crew headquarters. This instrument recorded variables such as location, time and satellite information to be used later for post-processing of the aircraft location.

8.2 Aircraft Location

The aircraft's location each second was determined by differentially post-processing the synchronised GPS data recorded on both the aircraft and GPS base station. Where small gaps occurred in the differential data, positions were calculated using the GPS velocity data. This data is recorded in the WGS84 datum. Prior to being merged with the magnetic, radiometric and topographic processing stream data, system parallax as specified in section 5.1.2.4 was applied. No datum transformation shift from WGS84 to GDA94 was applied as the difference between the two datums is not considered large enough to have any meaningful effect on the positional accuracy of the survey. For all practical purposes WGS84 and GDA94 positions can be considered identical for this type of survey.

8.3 Magnetic Data Processing

Data collected by each of the raw data sources is checked for spikes and noise by complex procedures. These procedures are summarised below:

a) Apply any spike corrections (including Inmarsat transmissions) to the raw magnetic variables.
b) Interpolate undefined magnetic values.
c) Apply fluxgate corrections and compensate the data with post-processed compensation files.
d) Filter diurnal values and subtract them from individual compensated magnetic readings. The Tennant Creek diurnal base value was then added (see section 4.1.3). Diurnal data collected at the Tanami base was first adjusted by –596 nT to bring it to the same level as the Tennant Creek data.
e) Apply parallax correction (see section 5.1.2.4).
f) Co-ordinate the data with post-processed GPS data as per section 8.2.
g) Correct for regional effects of the earth’s magnetic field by calculating the IGRF value at each fiducial using IGRF model 1995 and secular variation model. A base value of 50940 nT was added.
h) Using the tie lines (flown at 90 degrees to the traverse lines) a set of miss-tie values were determined. These miss-tie values reflected the differences in the magnetic value between the tie lines and the traverse lines over the same geographical point. Using a least squares fit algorithm, which also takes into account the statistical variation inherent in DGPS positioning, a series of corrections were applied to the traverse line data. These allowed the data to be levelled to the same base value.
i) Following this, a Fugro proprietary micro-levelling process was applied in order to more subtly level the data. This process removes sub-gamma pulls evident only under image enhancement algorithms.
j) Compute along line Total Magnetic Intensity 1st Vertical Derivative (1VD) from the final levelled TMI data.

8.4 Radiometric Data Processing

The radiometric data was processed using the standard IAEA window processing technique as summarised below.

a) The 1024 channel data is energy calibrated, as detailed in section 8.4.2.
b) Sum individual energy calibrated crystals to produce a total pack 256 channel spectrum.
c) Apply MNF filtering to the 256 channel data.
d) Window the MNF filtered 256 channel data using the IAEA standard energy windows.
e) Co-ordinate the data with post-processed GPS data as per section 8.2.
f) Apply spike corrections to the radar altimeter, temperature and pressure values.
g) Apply parallax corrections to altimeter, temperature and pressure data (see section 5.1.2.4).
h) Calculate the equivalent terrain clearance at STP (standard temperature and pressure).
i) Remove aircraft background.
j) Remove cosmic background.
k) Remove radon background.
l) Apply stripping ratios.
m) Apply height corrections.
n) Convert to ground concentrations.

8.4.1 Dead-Time Correction

Gamma-ray spectrometers require a finite time to process each pulse from the detectors. While one pulse is being processed, any other pulse that arrives will be rejected. Consequently the ‘live’ time of a spectrometer is reduced by the time taken to process all pulses reaching the multi channel analyser. The Picodas PGAM 1000 system has analogue to digital converters associated with each detector, and as such, the total dead-time, even at ground level is extremely small, and as such was omitted.

8.4.2 Energy Calibration

The spectral drift was checked by monitoring the position of Potassium, Uranium and Thorium peaks on average spectra along flight lines. The peak positions were determined by removing the Compton continuum and applying a gradient search technique on the residual spectrum. The original 1024 channel data was mapped onto the corrected peak positions and a new 256 channel data set was generated by interpolation and summation.
To verify the calibration, spectra was checked by comparing the before and after energy calibration plots. Where any spectra showed errors in recalibration, or any other abnormalities, the lines were reflown.

8.4.3 MNF Filtering

The recalibrated spectra were then smoothed using the MNF (Green et. al, 1988) spectral smoothing technique. Nine components were used in reconstructing the data.

8.4.4 Window Definitions

The MNF smoothed 256 channel data were summed into the standard IAEA windows.

Window	Peak Energy (keV)	Energy Window (keV)	PGAM Channel Window
Total Count	-	410 - 2810	34.9867 - 239.7867
Uranium Low	609	550 - 750	46.9333 - 58.0267
Potassium	1460	1370 - 1570	116.9067 - 133.9733
Uranium	1765	1660 - 1860	141.6533 - 158.7200
Thorium	2615	2410 - 2810	205.6533 - 239.7867
Cosmic	-	3000 - 6000	-

8.4.5 Cosmic Aircraft Background Removal

The cosmic and aircraft backgrounds for each channel are of the form:

N = a + b*C
where

N = combined cosmic & aircraft background in each spectral window
a = aircraft background in the window
C = cosmic channel count
b = cosmic stripping factor

The aircraft background radiation was removed by subtracting the computed aircraft background from the Total Count, Potassium, Uranium and Thorium windows. The effect of cosmic radiation was removed from each window by multiplying the cosmic channel by the cosmic stripping factor for each window and subtracting the result from the window data.

Aircraft Background and Cosmic Stripping Ratio for VH-WGB

Window	Aircraft Background	Cosmic Stripping Ratio
Total Count	65.0	1.3000
Potassium	7.8	0.0790
Uranium	0.8	0.0627
Thorium	1.1	0.0720

8.4.6 Atmospheric Radon

The method of radon removal differs to that of Grasty and Minty (A Guide to the Technical Specifications for Airborne Gamma-Ray Surveys. Record 1995/60 p.34, Australian Geological Survey Organisation) and is proprietary but its effectiveness is evident in the quality of the final product.

8.4.7 STP Altitude

The radar altimeter data was converted to effective height at standard temperature and pressure using the expression:

STPAlt = RAlt * (P/103) * (273 / (T+273))
where:

RAlt = the observed radar altitude in metres
T = the measured air temperature in degrees C
P = the barometric pressure in hectopascals

8.4.8 Spectral Stripping

Spectral stripping was applied to the Potassium, Uranium and Thorium windows. The stripping co-efficients were corrected for STP altitude.

Stripping Ratios for VH-WGB

Stripping	Value	STP adjustment (/m)
Alpha	0.2663	0.00049
Beta	0.4123	0.00065
Gamma	0.7932	0.00069
a	0.0332	0
b	0	0
g	0	0

8.4.9 Height Correction

The background corrected and stripped window data were then corrected for variations in the density altitude of the detector.

STP Altitude Coefficients for Aircraft VH-WGB

Window	Attenuation coefficient (m^{-1})
Total Count	-0.0063
Potassium	-0.0082
Uranium	-0.0078
Thorium	-0.0064

8.4.10 Ground Concentrations

The Total Count window data were then converted to dose rate and the Potassium, Uranium and Thorium windows were converted to ground concentrations using the expression:

C = N/S
where

C = concentration of the radioelement in (nGy/h, % K, ppm U, ppm Th)
N = count rate for each STP height corrected window
S = sensitivity factor

Sensitivity factors for VH-WGB

Window	Factor
Total Count	21.247 nGy/h
Potassium	78.3 %
Uranium	8.2 ppm
Thorium	4.8 ppm

8.5 Digital Elevation Model

Data collected by each of the raw data sources is checked for spikes and then processed as follows:

a) Apply any spike corrections to the raw radar altimeter data.
b) Interpolate undefined values.
c) Apply parallax correction (see section 5.1.2.4).
d) Co-ordinate the data with post-processed GPS data as per section 8.2.
e) Subtract the aircraft's height above ground from the aircraft's height above the GDA ellipsoid and correct for radar altimeter/GPS sensor separation.
f) Convert to Australian Height Datum 1998 (AHD) by using the AUSLIG geoid model corrections for AHD 1998.
g) Using the tie lines (flown at 90 degrees to the traverse lines) a set of miss-tie values were determined. These miss-tie values reflected the differences in the computed topographic height between the tie lines and the traverse lines over the same geographical point. Using a least squares fit algorithm, which also takes into account the statistical variation inherent in DGPS positioning, a series of corrections were applied to the traverse line data.

h) Following this, a Fugro proprietary micro-levelling process was applied in order to more subtly level the data.

8.6 Gridding

The final levelled magnetic, radiometric and elevation data were gridded using the minimum curvature method. A grid cell size of 100 metres, ¼ line spacing, was used. For each gridded parameter, e.g. TMI, TC, DEM, etc., a grid was made of the MGA52 block and the MGA53 block. These were then merged to form a single grid in MGA53. RTP and AGC_1VD grids were computed from the merged MGA53 TMI and 1VD grids respectively. Grids of the RTP and AGC were then made for each zone by trimming the entire area RTP and AGC grids to the TMI grids from zones 52 and 53 respectively.

APPENDIX 1.: LINE LISTING

A line number summary has been included on the CD-ROM. The document file name is:
wiso/app_docs/line_summary.doc.

APPENDIX 2.: LINE DATA

Two copies of line data were provided on CD-ROM and one copy on Exabyte tape. The data on Exabyte were stored in unix TAR format. The line data format conformed to the ASEG-GDF (II)-format. Three sets of line data were provided:

a) Magnetic and elevation data at 0.1 second intervals.
b) Windowed radiometric data at 1.0 second intervals.
c) Raw radiometric 256 channel data at 1.0 second intervals.

Example .DES and .DFN files covering the three types of line data have been included on the CD-ROM.
Directory on CD-ROM: wiso/app_docs
Files:

File name	Description
wiso_mag_trav01.des	Mag and elevation description file
wiso_mag_trav01.dfn	Mag and elevation definition file
wiso_rad_trav01.des	Radiometric window data description file
wiso_rad_trav01.dfn	Radiometric window data definition file
wiso_rad256_trav01.des	Raw radiometric 256 channel data description file
wiso_rad256_trav01.dfn	Raw radiometric 256 channel data definition file

APPENDIX 3.: GRIDDED DATA

Two copies of gridded data were provided on CD-ROM and 1 copy on Exabyte tape. The data on Exabyte were stored in unix TAR format. All grids were in ERMapper .ERS format. Grids were provided for data blocks MGA52, MGA53 and merged grids in MGA53.
The following naming convention was used:

<Survey Name>_<Gridded Parameter>_<Datum> _<Projection>

where:

Survey Name = WISO
Gridded Parameter = TMI, RTP, etc.
Datum = GDA94
Projection = MGA52 or MGA53

The following grids were provided:

a) Total Magnetic Intensity (TMI)
b) TMI Reduced to the Pole (RTP)
c) TMI along line 1st Vertical Derivative (1VD)
d) 1VD with Automatic Gain Control (AGC_1VD)
e) Digital Terrain Model (DTM)
f) Total Count (TC)
g) Potassium (K)
h) Uranium (U)
i) Thorium (Th)

APPENDIX 4.: HEIGHT CROSSOVER DIFFERENCES

A listing of all traverse and tie line crossover height differences has been included on the CD-ROM. The document file name is: wiso/app_docs/xover_summary.doc.

APPENDIX 5.: DATA NOTES

5.1 Diurnal Data

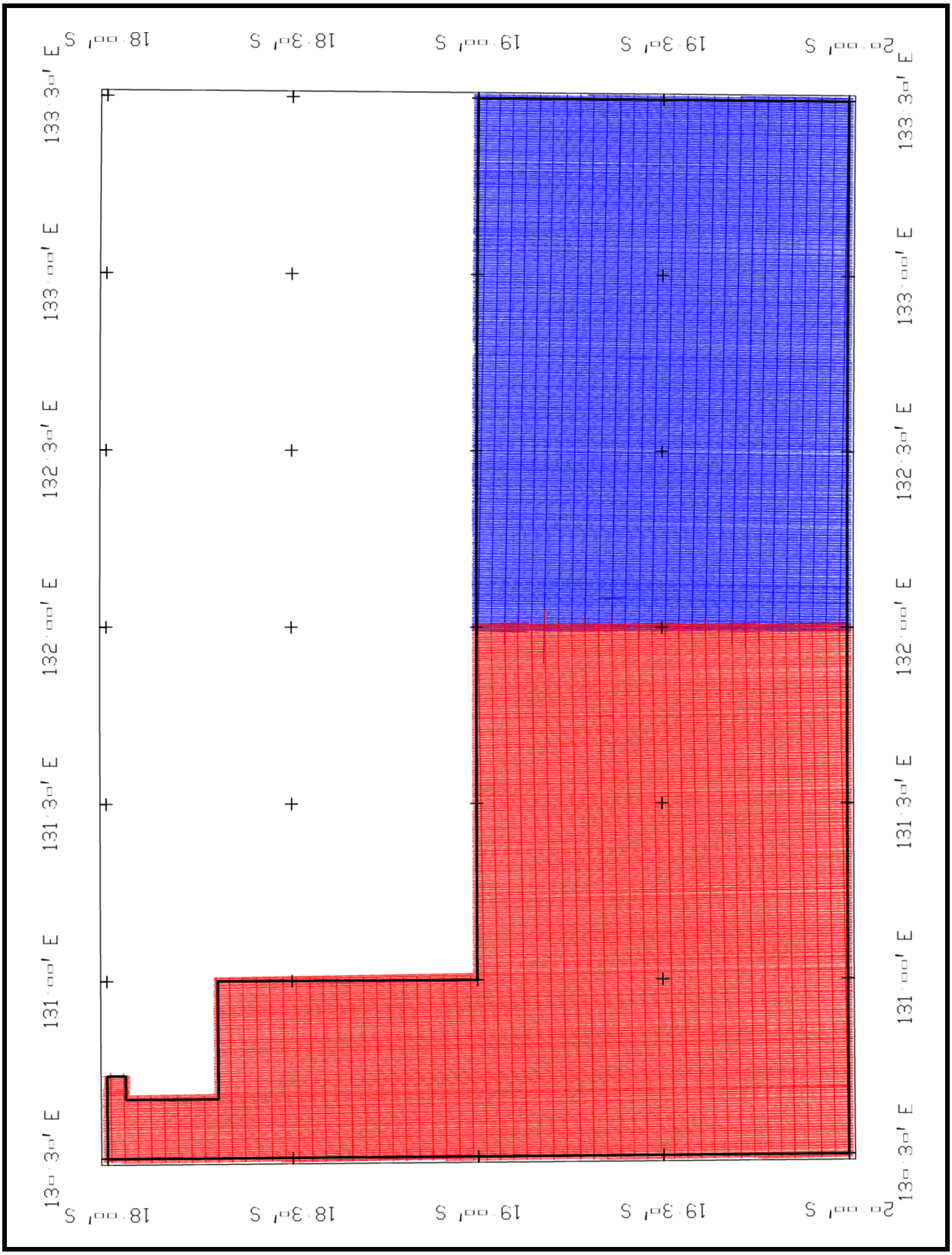
The G-823B was used as the primary magnetic diurnal base station. During flights 18, 52 and 73 it failed when the battery ran out and the G-856 backup data were used. The flights and lines affected were:

Flight	Line
18	11890
18	11900
18	11910
18	11920
18	11930
18	11940
18	11950
18	11960
52	22960
52	27530
73	20470

5.2 Humidity Data

Humidity data was collected and supplied in the located data but was not used in any of the data processing. During flights 57 to 60 the readings appeared much lower than would be expected. The sensor was replaced prior to the start of flight 61.

APPENDIX 6.: FLIGHT PATH PLOT



APPENDIX 7.: QUALITY CONTROL PLOTS

Various quality control (QC) products were produced throughout the survey. These products have been stored on the CD-ROM accompanying this report.
The QC products required were:

1. Cumulative plot of the thorium source test, background removed, Th window.
2. Cumulative plot of the background, Th window.
3. Cumulative plot of the low level test line, height corrected, Th window.
4. Spectral plot of the average spectrum for each flight line.
5. Radar altimeter height deviation map showing all deviations greater .then +/- 10 metres of the nominal terrain clearance.
6. Diurnal map showing every 1 minute period where the diurnal range exceeded 1 nT.
7. Flight path map showing separations greater than:
   1. 1.1 x nominal flight line spacing.
   2. 1.01 x nominal tie line spacing.
8. TMI 8th difference map with a threshold of 0.05 nT

7.1 Thorium Source and Low Level Test Line

Cumulative plots were made of the thorium window data from the thorium source test (background removed), background test and the low level test line (standard radiometric corrections applied). The plot files have been stored in HPGL and DXF formats.

Directory on CD-ROM: wiso/test_line_data
Files:

File name	Description
b_th.[dxf,hgl]	Background test, thorium window
th_th.[dxf,hgl]	Thorium source, thorium window
tl_th.[dxf,hgl]	Low level test line, thorium window

7.2 Flight Line Spectra

Spectral plots were made of the average spectra for each flight line. The plot files have been stored in HPGL and DXF formats.

Directories on CD-ROM: wiso/spectra/[dxf,hgl]
Files:

File name	Description
?????.dxf	Spectral plot in DXF format
?????.hgl	Spectral plot in HPGL format

7.3 100-hourly QC maps

The 4 QC map types were produced on a standard 1:100,000 maps sheet basis. A total of 14 maps covered the survey area. The map plot files were written in DXF and HPGL formats. Each file has in turn been archived as a ZIP file.

The QC map types are:

Name	Description
ar	Height deviation map
di	Diurnal map
pl	Flight path separation map
8th	8th difference map

The 1:100,000 map sheets are:

Name	Name	Name	Name
5058	5059	5060	5061
5158	5159	5258	5259
5358	5359	5458	5459
5558	5559		

Directories on CD-ROM: wiso/qc_maps/[dxf,hgl]
Files (map sheet 5058 has been given as an example):

File name	Description
5058_ar.dxf	Height deviation map
5058_di.dxf	Diurnal map
5058_pl.dxf	Flight path separation map
5058_8th.dxf	8th difference map

APPENDIX 8.: SPECTROMETER CALIBRATIONS

A report on the spectrometer calibrations has been included on the CD-ROM. The document file name is: wiso/app_docs/spect_cal.doc.

APPENDIX 9.: FLYING SUMMARY

A summary of the flying operations has been included on the CD-ROM. The document file name is: wiso/app_docs/flight_summary.xls.