TECHNICAL REPORT ON A FIXED WING AEROMAGNETIC SURVEY

YUKON FLATS
ALASKA

SOLICITATION NUMBER
02CRQ0080

for

UNITED STATES GEOLOGICAL SURVEY

by

GOLDAK AIRBORNE SURVEYS

JULY – AUGUST, 2002

GOLDAK EXPLORATION
AIRBORNE GEOPHYSICS

Goldak Airborne Surveys

25 Duncan Crescent
Saskatoon, Saskatchewan
Canada S7H 4K3

Tel: (306) 249-4474
Fax: (306) 249-4475
Cell: (306) 222-5104

Email: ben@goldak.ca
URL: www.goldak.ca

1. INTRODUCTION

This report describes an airborne geophysical survey carried out in the Yukon Flats region of Alaska on behalf of the United States Geological Survey (USGS). The airborne total field magnetic survey was carried out over the Yukon River Flats north of the community of Central. The survey block was approximately centered on the community of Fort Yukon. The survey took place during July and early August of 2002.

Aircraft equipment operated included three cesium vapor, digitally compensated magnetometers, a dual-frequency GPS real-time and post-corrected differential positioning system, a flight path recovery camera, a VHS video titling and recording system, as well as dual radar and barometric altimeters. All data was recorded digitally in GEDAS binary file format.

Reference ground equipment included a Geometrics G823A cesium vapor magnetometer, a GEM Systems Overhauser Proton magnetometer and a Novatel 12 channel dual-frequency GPS base station.

The community of Fort Yukon is at the approximate center of the survey block, some 350 kilometers northeast of the city of Fairbanks, Alaska.

The initial flight for equipment calibration and test was made on July 2. Thirty-two survey flights were required to complete the data acquisition phase of the project. The survey flights took place between July 2nd and August 1st.

The flight lines for were oriented on an azimuth of 000°/180°T (true with respect to UTM North) with control lines at 090°/270°T. 33779 line kilometers of data was acquired and 32563 line kilometers accepted.

The survey was flown with a traverse line separation of 1609 meters and a control line spacing of 12,900 meters. Aircraft height was specified at 150 meters above ground.

2. SURVEY AREA LOCATION

The Yukon Flats survey area is located approximately 350 kilometers northeast of Fairbanks, Alaska and is centered at N 66° 44   W 143° 59'.

No all-season road access is available to the survey area. There is all season road access to Central and Circle City, approximately 80 kilometers south of the block. An ice road is constructed to Fort Yukon most years during the winter season. During the summer months freight is carried to Fort Yukon by barge. Several small airstrips exist within the survey block.

The general location of the survey area is indicated by the target symbol on the map of Alaska shown below.

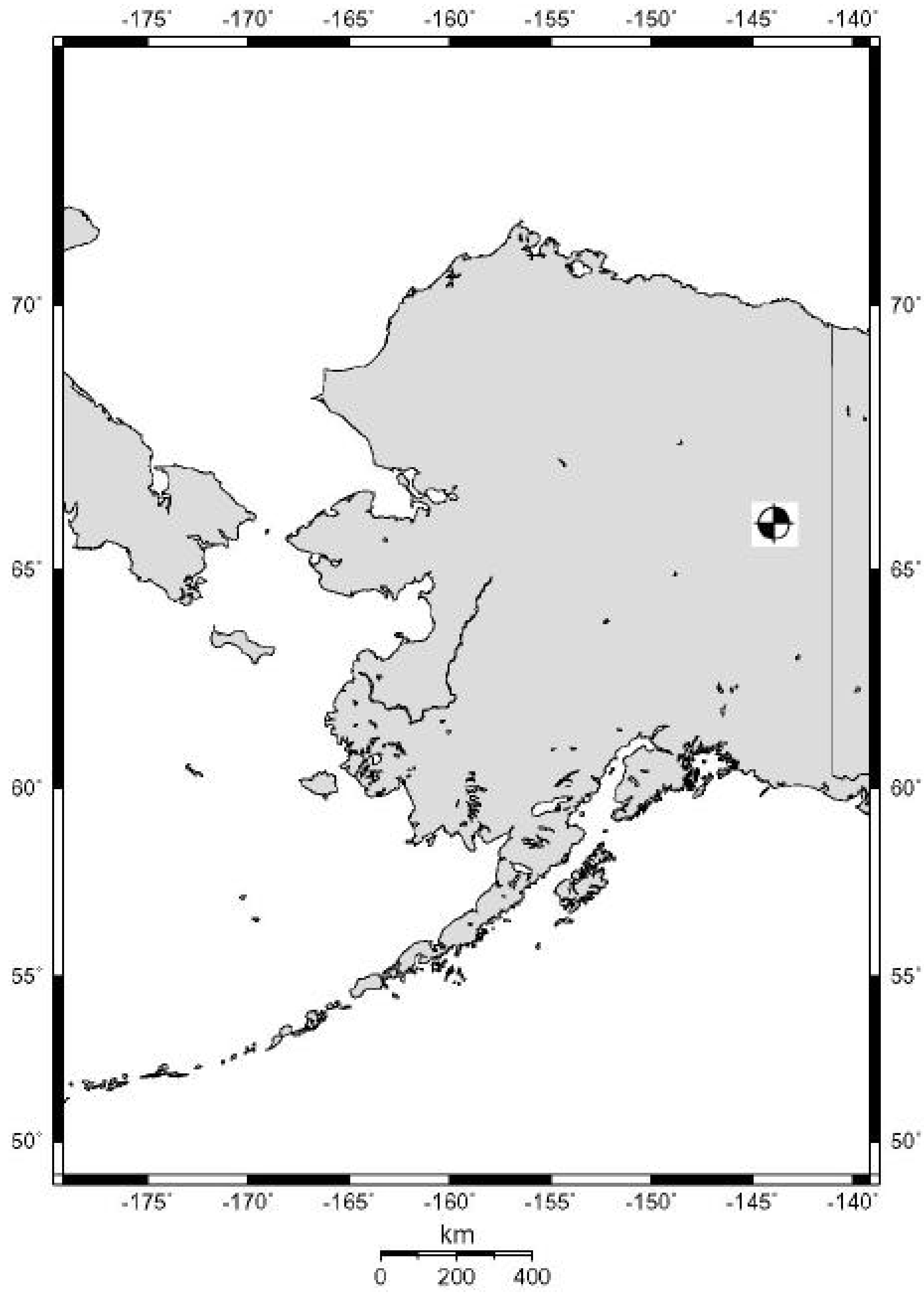

Illustration – General Survey Location Map

Accommodations were made, and the field office setup at the Crabbs Corner gas station, restaurant and general store.

Illustration – Field Office Location

The survey block was defined in contract by the following NAD-27 geographic coordinates.

66.00.00.00	-147.00.00.00
66.00.00.00	-141.00.00.00
67.27.00.00	-141.00.00.00
67.27.00.00	-147.00.00.00

The coordinates were projected for field use to the following WGS-84 UTM Z6N pairs.

499884	7319866
771881	7332892
756334	7493923
499884	7481507

The flight lines were oriented on an azimuth of 090°/270° with respect to UTM north. Orthogonal control lines on an azimuth of 090°/270° degrees were used.

A traverse line separation of 1609 meters (1 statute mile) and a tie line separation of 12,900 meters (8 statute miles) were used.

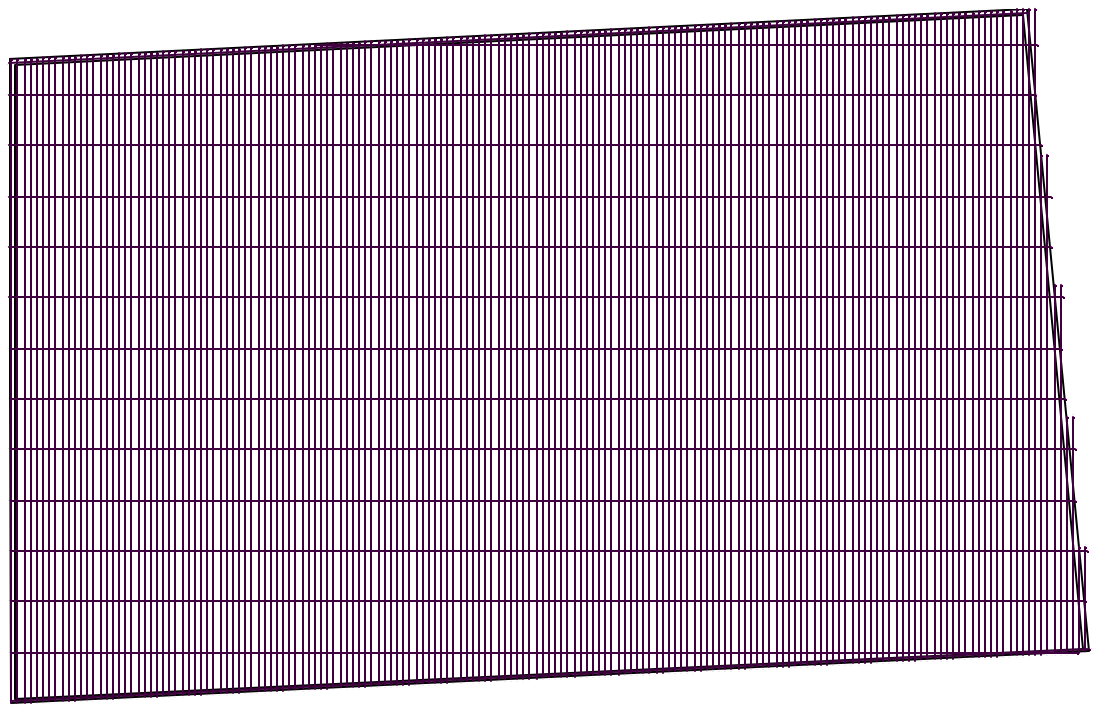

Illustration – Ideal Flight Path

Note that in addition to the east-west tie lines, two additional off-axis “border” tie lines were flown at the south and north ends of the block to ensure full closure of all traverse lines.

The lines were flown at a nominal terrain clearance of 305 meters (1000 feet). The vertical navigation was accomplished using a pre-planned drape altitude surface. This surface was developed using digital elevation data (DEM) supplied by the USGS personnel in Alaska.

3. DATA SPECIFICATION

The nominal traverse line separation was 1609 meters, with a control line spacing of 12,900 meters. The standard tolerance for horizontal line navigation was ± 25% maximum deviation over a 1000-meter distance with a maximum gap between adjacent lines of 150% nominal spacing.

Altitude control was accomplished by GEDAS auto-drape system using a pre-defined altitude drape surface. The surface was developed using DEM data supplied by the USGS.
The specified terrain clearance altitude was 305 meters with a tolerance of ± 61 meters from an ideal drape surface over a 1000-meter distance, with the usual exceptions made for rugged terrain, regulatory compliance or aircraft safety considerations

Diurnal activity tolerance was specified as maximum 2nT deviation from a straight-line chord whose length is 120 seconds in length. This chord length is approximately the time required for the aircraft to pass between two tie lines while flying a traverse. It represents error due to diurnal activity that cannot be leveled by conventional means.

The flight data magnetic noise tolerance was specified as not to exceed ± 0.1 nT over a maximum distance of 1000 meters.

The aircraft maneuver noise was specified as a Figure of Merit of less than 2.0 nT. The FOM was flown with ±5° pitches, ±10° rolls and ±5° yaws on four cardinal headings. The FOM is then the arithmetic sum of the mean peak-to-peak response for all 12 maneuvers.

Further, the maximum magnetic response due to as single maneuver is specified as 3nT. The maximum allowed heading error is 1nT. The initial tests performed meet these specifications.

4. AIRCRAFT AND EQUIPMENT

4.1 Aircraft

The aircraft used was a Piper PA-31 Navajo, registration C-GJBB, owned and operated by Goldak Exploration. The aircraft is fitted with a 3-meter stinger attached to the rear fuselage on the centerline of the aircraft. The attitude sensing fluxgate magnetometer is positioned at the midpoint of the stinger. The aircraft also has magnetometers installed in composite pods on each wingtip. The pods mount the sensors 1.2 meters outboard of the aircraft wingtip. The three magnetometers form a two-axis gradiometer with following dimensions:

Lateral	14.83m
Longitudinal	8.66m

The aircraft has been extensively modified, both mechanically and electrically to minimize the effects of maneuvering on the measured magnetic field. The aircraft has a demonstrated Figure of Merit of less than 0.7 nT as measured to GSC (Geological Survey of Canada) specification. Typical FOMs under less than ideal calibration environments are 0.9 nT for the tail magnetometers. This low level of magnetic noise is considered to be exceptional by experts at the National Research Council.

Illustration - PA-31 Navajo C-GJBB in Horizontal Gradient Survey Configuration

4.2 Magnetometer and Compensation

The airborne magnetometers used are a matched set of Geometrics G-822A optically pumped cesium vapor types with sensitivity of 0.005 nT. The magnetometer's Larmor signal is decoupled and counted by a RMS Instruments AADCII compensator, and data produced at a rate of either 10 Hz with a resolution of 0.001 nT. The data bandwidth is from 0 to 0.9 Hz with an internal noise level of less than 0.002 nT.

The AADCII compensates for magnetic noise due to aircraft motion and heading. Prior to the survey, the aircraft is taken to an area of low magnetic gradient at a high altitude (7000' AGL +) and put through a series of rolls, pitches and yaws on each of the survey's cardinal headings. This is done so that the AADCII can form a model of the aircraft's magnetic characteristics without the near influence of the local geology. The remaining magnetic distortion is quantified by a term known as the Figure of Merit, or FOM. A figure of merit of 2.0 or less is used by the Geological Survey of Canada as standard survey criteria. As stated above, this aircraft has an exceptional typical FOM of approximately 0.9 nT.

The following table represents the digital analysis of the initial compensation and FOM data taken prior to this survey in the vicinity of the survey area within an area of low magnetic gradient. The flight was made on July 1, 2002. The results are typical and are indicative of a good compensation fit to the aircraft maneuver noise.

RMS AADCII Compensator Statistics

	Un-comp Std Dev	Comp Std Dev	Improvement Ratio	Solution Norm
Right Wing	8.436e-01	4.25e-02	22.6	37.8
Left Wing	9.74e-01	4.26e-02	22.9	37.5
Tail Bottom	1.29e-01	3.47e-02	3.7	14.6
Lateral Gradient	2.36e00	7.9e-02	29.9	41.9
Long Gradient	3.45e00	9.82e-02	35.1	38.0
Memory Slot	#2			

Figure of Merit – Tail Magnetometer (MBc)

	North	East	South	West	Sum
Pitch	.07	.09	.08	.05	.3
Roll	.03	.04	.1	.06	.22
Yaw	.04	.10	.08	.03	.25
Sum	.14	.25	.24	.14	**.77**

Figure of Merit – Lateral Gradient (GXc)

	North	East	South	West	Sum
Pitch	.06	.06	.08	.05	.25
Roll	.08	.04	.10	.06	.28
Yaw	.06	.14	.08	.07	.35
Sum	.20	.24	.26	.18	**.75**

Figure of Merit – Longitudinal Gradient (GYc)

	North	East	South	West	Sum
Pitch	.04	.06	.08	.05	.23
Roll	.04	.08	.07	.06	.25
Yaw	.03	.08	.06	.04	.21
Sum	.11	.22	.21	.15	**.69**

A second compensation was necessary after a wingtip magnetometer failed on July 7 and had to be replaced on the survey aircraft. The results of that re-compensation and FOM taken later on July 7 are given below.

RMS AADCII Compensator Statistics

	Un-comp Std Dev	Comp Std Dev	Improvement Ratio	Solution Norm
Right Wing	9.948e-01	4.237e-02	23.5	39.5
Left Wing	1.169e00	4.789e-02	24.4	35.9
Tail Bottom	1.570e-01	3.582e-02	4.4	13.8
Lateral Gradient	2.531e00	1.094e-01	23.1	48.2
Long Gradient	3.534e00	1.923e-01	23.1	48.2
Memory Slot	#3			

Figure of Merit – Tail Magnetometer (MBc)

	North	East	South	West	Sum
Pitch	.13	.15	.11	.13	.52
Roll	.02	.03	.04	.06	.15
Yaw	.04	.06	.06	.04	.2
Sum	..19	.24	.21	.23	**.87**

Figure of Merit – Lateral Gradient (GXc)

	North	East	South	West	Sum
Pitch	.06	.10	.09	.06	.31
Roll	.15	.13	.11	.14	.53
Yaw	.06	.13	.06	.10	.35
Sum	.27	.36	.26	.30	**1.19**

Figure of Merit – Longitudinal Gradient (GYc)

	North	East	South	West	Sum
Pitch	.08	.07	.06	.09	.30
Roll	.15	.10	.08	.13	.46
Yaw	.07	.05	.04	.07	.23
Sum	.30	.22	.18	.29	**.99**

The following plots are graphical representations of the FOM data taken earlier in the year and are also indicative of a good compensation fit to a magnetically clean aircraft.

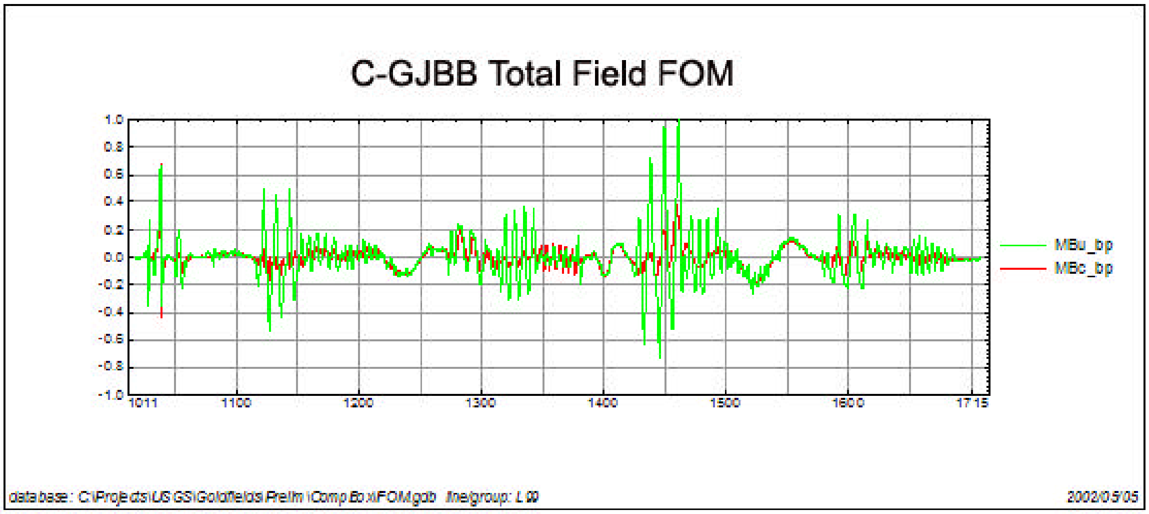

Illustration - C-GJBB Total Field Figure of Merit

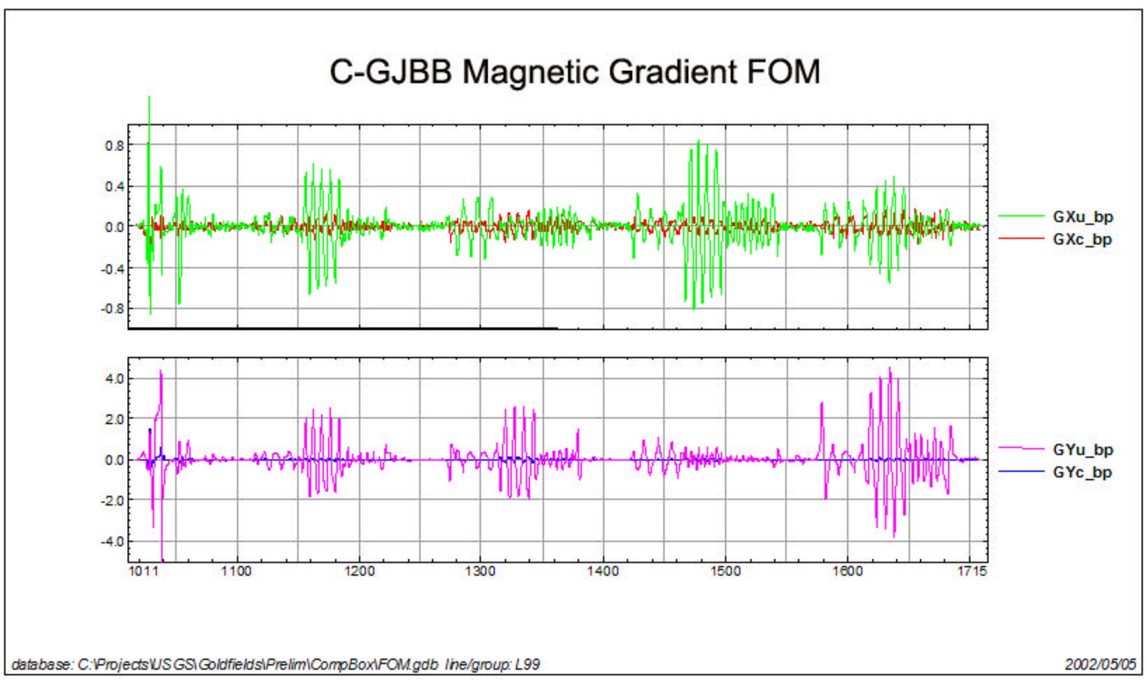

Illustration - C-GJBB Gradients Figure of Merit

4.3 Magnetic Base Station

Two magnetic base stations were used for this survey. One unit was a Geometrics G823B cesium vapor sensor with integral counter and serial interface. A local data logger is used to store the continual field measurements and a radio modem used to transmit the readings to the field office. At the field office the data is plotted graphically and checked automatically for diurnal activity tolerance.

The cesium unit was placed within radio data link range near the village of Central so that the field crew could monitor diurnal conditions in real time.

The other unit used was a GEM Systems GSM-19 Overhauser Proton magnetometer. It was placed near the survey area and was used as the primary diurnal monitor.

The cesium base station was setup on the airport grounds just west of the aircraft parking area at the following WGS-84 UTM Z6N coordinates:

602241E
7274324N

Illustration – Cesium Base Magnetometer Site, Central Airport

The second proton type base magnetometer was set up along a cut line in the bush approximately 46 km east of Central near the community of Circle City. The station was positioned approximately 110 meters north of the road at WGS-84 UTM Z6N coordinates:

629491E
7296824N

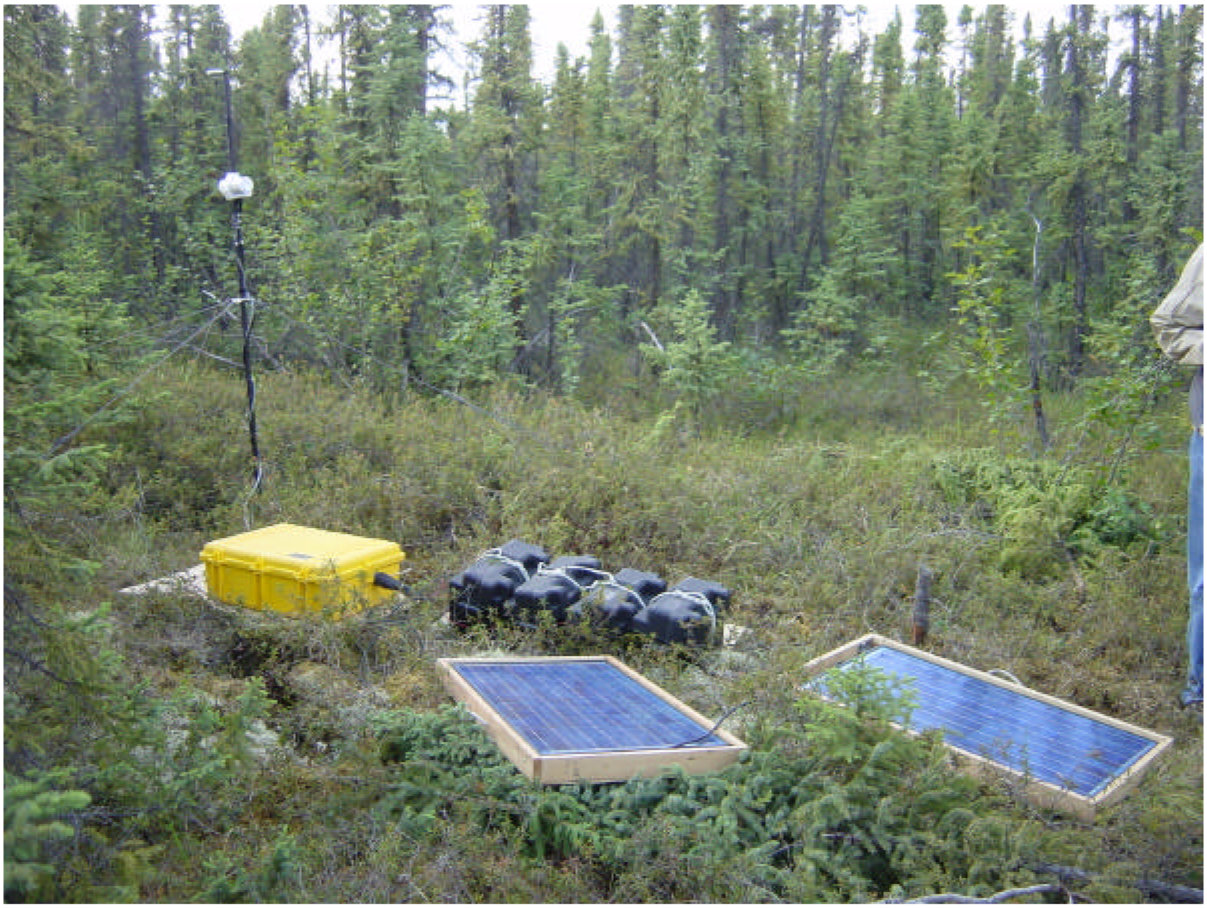

Illustration – Proton Base Magnetometer Site

The base station magnetometers were recorded over 24 hours of quiet magnetic diurnal activity to obtain an average base value.

The mean total field value used to correct with database channel BaseMag1, the cesium magnetometer, was 59332nT.

The mean total field value used to correct with database channel BaseMag2, the proton magnetometer, was 59439nT.

These values were used consistently in all subsequent diurnal corrections to the aircraft data. Both the aircraft data acquisition system and the base magnetometer are synchronized to UTC time derived from the aircraft GPS system and recorded in the form of seconds after midnight.

4.4 VLF-EM System

No VLF-EM system was recorded during this survey.

4.5 GPS Positioning System

The GPS receiver in the survey aircraft is a Novatel 3151R Propak 12 channel dual-frequency differential unit that communicates directly with the GEDAS system. The base station GPS is also a dual-frequency Novatel 3151R Propak whose data is logged by a battery powered industrial portable computer. A survey grade GPS base antenna and choke ring is used to minimize multi-path errors. The system can be used for differential positioning in either real-time, or post-corrected mode.

The positioning system also incorporates a Racal Landstar real-time DGPS system that receives real-time differential corrections from an orbiting geo-synchronous communications satellite. These corrections from this device allow 2-5 meter positioning accuracy in real-time. A GPS base station is also recorded during the survey flight to provide a higher level of accuracy and an independent confidence check to the Landstar RT DGPS system.

GPS signals are occasionally “dithered” by the US Department of Defense for security reasons. This dithering can cause positioning errors of up to 100 meters. In addition to dithering, atmospheric and ionospheric effects typically reduce the accuracy of the non-differential positioning to approximately 10 meters RMS. If a suitable stationary GPS receiver on a known, or assumed position, is used to record the apparent errors in the satellite range data, those errors can be used to correct the moving receiver in the aircraft to a an accuracy of 2-5 meters RMS. This compensation process is called differential correction and can be either applied to the moving receiver in real time for higher dynamic accuracy, or applied later to find out where the aircraft *was* with high accuracy. This is called real-time and post-corrected differential positioning respectively.

For this survey, the base station GPS antenna was located on the roof peak of the field office behind Crabbs Corners as shown below. After 20 hours of simple position averaging, the apparent position in WGS-84 is

Latitude:	65 34 17.679	ρ = 0.150m
Longitude:	-144 48 10.566	ρ = 0.110m
Elevation (ELL):	302.09 m HAE	ρ = 0.334m

The base position was then determined by differentially correcting the acquired GPS data using remote base station data from the CENA CORS station near Central. The position of the CENA base station site is published as:

Station:	CENA
Service:	CORS
Latitude:	65° 29‘ 53.38770”
Longitude:	-144° 40‘ 39.3710”
Elevation:	283.448 m HAE (height above ellipsoid)

The field office base position was determined using the program “GrafNav”. The CENA base station data was used to differentially correct approximately 20 hours of data acquired at our base station location at Crabbs Corners. The resultant differentially corrected master position is used throughout the entire Yukon Flats airborne survey.

The differentially corrected antenna position was computed to be:

Latitude:	**65° 34’17.893”**
Longitude:	**-144° 48’ 10.934”**
Elevation:	**301.64 MSL**

This position agrees to within a meter to the position observed by simple averaging. This is indicative of a differential solution free of systematic errors.

Later, when the data became available on the internet, the local base station position was re-computed for greater certainty. The base position was verified using the CORS base station FAIR located at Fairbanks, Alaska

The station location is published as:

Station:	FAIR
Service:	CORS
Latitude:	64° 58‘ 40.7978”
Longitude:	-147° 29‘ 57.16480”
Elevation:	318.703 m HAE (height above ellipsoid)

The differentially corrected local base station position agreed with both the CENA corrected position as well as the simple averaged solution to within two meters. The noise level on this correction process was higher due to the longer differential baseline distance, but still served as a good confidence check on the first process.

The GPS antenna can be seen on the shorter of the two masts near the roof peak in the illustration below. The longer mast is the VHF radio modem data link antenna.

Illustration – Base Station GPS Antenna and Radio Modem Link

4.6 Radar Altimeter

The radar altimeters used were a Terra TRA-3000 digital unit (database channel RadAlt1) with accuracy of ±3 meters in the range of typical survey altitudes, and a King KRA-10A (RadAlt2) with similar specifications.

4.7 Barometric Altimeter

The barometric altimeter monitored by the system is a Setra model 270 with accuracy of ±1 meters.

4.8 Flight Path Camera

The flight path is recorded by a Panasonic GP-KR222 SV hi-resolution color video camera located in the lower rear fuselage of the aircraft. The video is recorded by a Panasonic AG-1980P SVHS recorder. Data pertaining to position, time, speed, altitude, line number and direction are superimposed in the videotape by a Horita SCT-50 video titler.

4.9 GEDAS Digital Recorder

All data is processed and recorded digitally by our GEDAS system. The GEDAS is an industrial rack-mount Intel Pentium based PC computer operating at 233 MHz with multiple hard-drives, IO ports and ADAC devices.

The GEDAS system records time, magnetic, and VLF data at 10 Hz. All positioning data is recorded at 2Hz. Data files are organized on a flight-by-flight basis in a proprietary binary format. The data is then converted post-flight to a Geosoft compatible format.

Data can be downloaded from the system by either floppy disk or Iomega ZIP disk. Data can be delivered in the field by floppy, ZIP disk, Iomega JAZ disk or CD-ROM.

4.10 Personnel

The following chart illustrates the Goldak Airborne Surveys crewmembers involved in this particular survey.

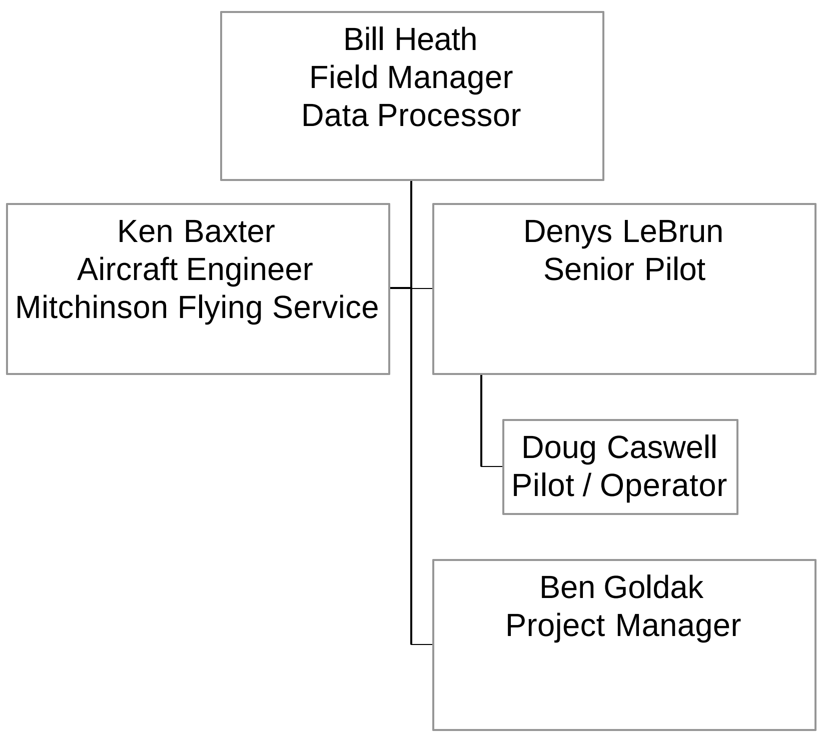

Illustration – Project Personnel

5. DATA PROCESSING AND PRESENTATION

All positions in the database are represented in both the WGS-84 (NAD-83) datum as well as the NAD-27 datum. UTM coordinates are calculated in Zone 6N. All maps are presented in the NAD-27 datum as per contract specification.

Although the line magnetic data is of good quality, and diurnal conditions were light to moderate, the gridded data has many unusual features that do not appear realistic. This is most likely due to data under-sampling caused by an excessively wide line spacing (1600m) for the terrain clearance specified (305 meters). Usually a 1:1 or 2:1 ratio of line spacing to terrain clearance is desirable. In this case, a 5:1 ratio was specified and line-to-line correlation suffers.

5.1 Total Field Leveling and Magnetic Gradient Processing

Conventional tie line leveling was carried out on the data at the Goldak Airborne Surveys office in Saskatoon.

The processing consists of the following basic streams:

Positioning processing
Magnetic leveling
Altimeter processing
Layout and production of maps

All data processing and most of the map layout was done in Geosoft Oasis Montaj. Many custom routines have been developed and used to facilitate the process, particularly in map layout.

Each can be discussed separately although there are many interdependencies.

Positioning Data

This data was acquired using Novatel 12 channel dual-frequency GPS receivers. The real-time positioning is enhanced by the use of the Racal Landstar system that provides RTCM-104 corrections to the aircraft GPS receiver during the flight. This increases 3-dimensional accuracy to approximately 3-5 meters in real time.

Post-processing using Waypoint Consulting GrafNav software was done to enhance the positioning accuracy. This step, depending on baseline distance and ionospheric activity, brings accuracy to the 1-meter level.

Flight path is also verifiable by the times and positions superimposed on the flight-path videotape.

The video overlay generated by the GEDAS data system, displays the following data format:

HH:MM:SS.S	MM-DD-YY
LAT TYPE	LON
UTME	UTMN
LOCX	LOCY
LINE#	HAGL
COG	VEL

Were HH:MM:SS.S is the data system time in UTC as set from GPS time at the last line start. MM-DD-YY is the UTC date. LAT and LON are the latest position update from the GPS in decimal degrees. TYPE is either 'A' for autonomous, or 'D' for a real-time differential type position. UTME and UTMN are the UTM coordinates of the last positioning fix. LOCX and LOCY are the local track coordinates relative to the survey grid origin. LINE# is the line number designation and HAGL is the radar altimeter derived height above the terrain. COG is the GPS indicated track over the ground in degrees true, while VEL is the aircraft velocity in meters per second.

It should be noted that the 10Hz clock display is asynchronous from GPS time and may be subject to drift while on line. The clock is reset at the beginning of every line. The method for determining precise video time is to observe the 10Hz clock at the GPS position change just prior to the event of interest. Note the time of that GPS fix from the data file. Advance the video to the event and note the 10Hz clock again. Subtract the first 10Hz time from the first and add that time to the GPS fiducial time.

Magne**tic Data**

The first steps in verifying the magnetic data took place in the field. The base station data was monitored to ensure compliance with the contract specification. The fourth difference was also monitored carefully to find any sudden offsets or other problems in the data.

Leveling of the data consisted of the following steps:

- Statistical leveling of the tie lines with linear trend
- Statistical leveling of the survey lines with linear trend
- Repeat statistical leveling in steps 1 and 2 using a piecewise linear interpolation over second order spline to model higher order diurnal effects and positioning errors.
- Move flight path to minimize remaining error as described above.
- Manual leveling to remove remaining errors

Statistical leveling refers to applying linear or smoothly varying offsets to the data to minimize the leveling error. This is required since diurnal corrections are not always spatially consistent and the survey area is some distance from the magnetic base station.

Given the evidence of smoothly varying diurnal, the linear and second order trend offsets applied to the flight data is reasonable.

Following the statistical leveling to compensate for diurnal and flight path adjustment all remaining leveling offsets can be considered as errors. The major source of error is altitude control.

When adjusting the data to accommodate mis-closures at tie line intersections the intention is to shift the data location in such a way as to avoid offsets or sharp variations in the data. Further refinement of the leveling network was carried out by using the calculated vertical gradient to estimate the magnetic error at intersections where significant altitude errors were present.

A final set of corrections to the data were made after examination of the resulting magnetic field. The calculated vertical gradient showed areas where gradients had along line trends, clearly indicating problems with the leveling. These along line trends can be caused by altitude errors in the flying of the defined drape surface. Small adjustments at this time were sufficient to finalize the leveling network.

Altitude Data

Part of the GPS positioning processing involves calculation of the height above sea level. This component of the position is the least reliable, however with suitable care should be accurate to within 2-3 meters.

The barometric altimeter is calibrated for the air pressure at the beginning of each flight and allowed to drift from that point. The drift is very similar to the magnetic diurnal in that it varies both in time and in space. It is quite possible that the air pressure would vary significantly from one end of the survey block to the other on a large area.

At this point the derived topography was generated for post-processed GPSZ minus radar altitude, gridded and compared with the known topography.

Map Production

The final task in processing this data was the layout and production of maps in Postscript format. The maps are then converted to a device dependant format. HPGL RTL format is used for the HP 750C+ plotter. Both the postscript and the RTL files are included on CDROM.

5.2 Map Presentations

The contract specifies a presentation scale of 1:100,000.

Nine sheets identified below as A-I are required to cover the survey area for each of the map products. The index map is shown below.

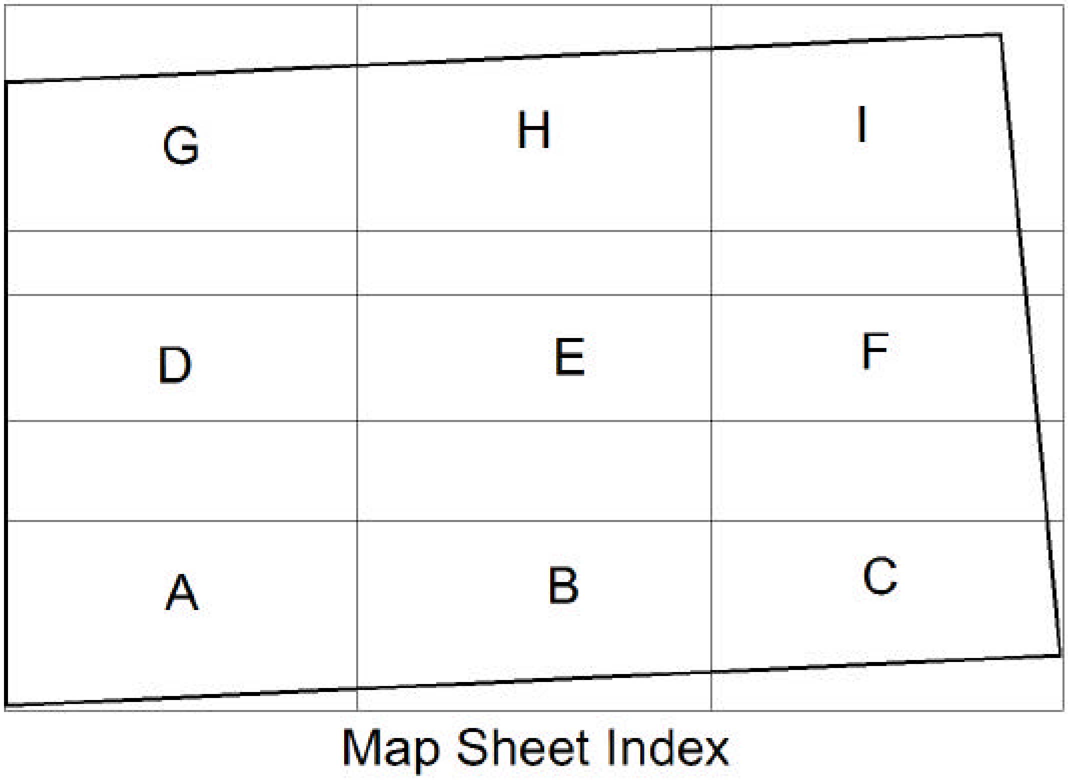

Illustration – Final Map Layout Index Sheet

One copy of a Flight Path map with Total Magnetic Intensity (TMI) contours on clear film was generated at a scale of 1:100,000. The magnetic data was presented with the IGRF2000 regional field removed. TF and CVG grid images are shown below.

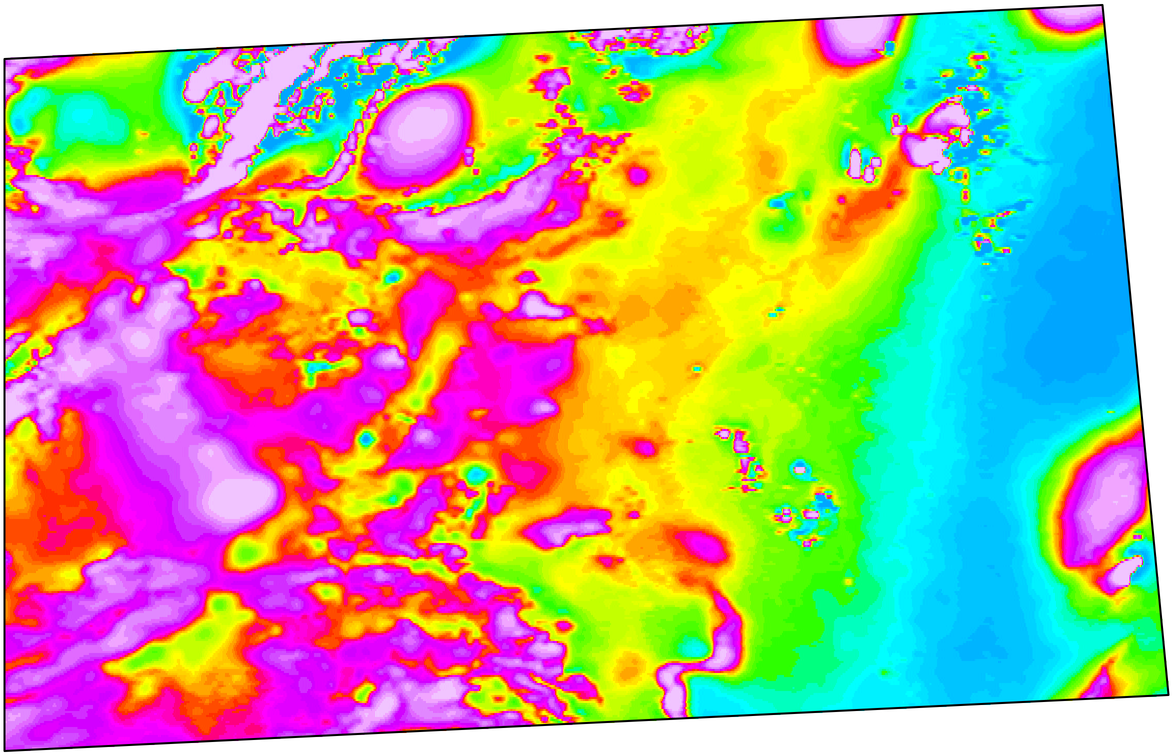

Illustration – Total Magnetic Intensity Image

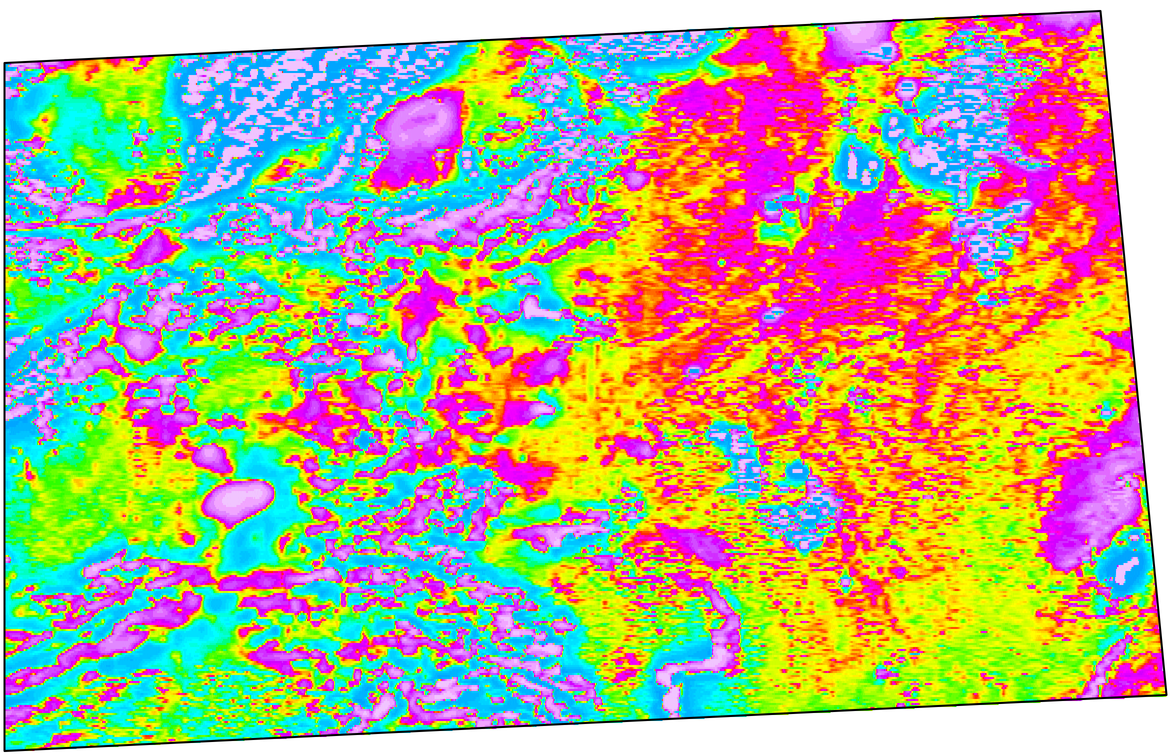

Illustration – Calculated Vertical Gradient Image

5.3 Multi-parameter Analog Profiles

Selected channels have been presented in analog chart style on continuous thermal paper. Included in these channels are Total Field Mag, course and fine scales, longitudinal gradient, as well as lateral and vertical gradients. Also included are the corrected GPS, barometric and radar altitudes as well as the magnetic fourth difference noise for the tail sensor.

5.4 Digital Data Files

All raw and processed data files along with the Geosoft compatible grids are included on CD-ROM disks.

The following is a primary channel definition list for the database. Note that additional temporary, work and special system channels may exist in the database and may be ignored.

BALT	BAROMETRIC ALTIMETER
BaseMag1	DIURNAL BASE MAGNETIC FIELD 1, DE-SPIKED, FILTERED
BaseMag1R	DIURNAL BASE MAGNETIC FIELD 1, RAW
BaseMag2	DIURNAL BASE MAGNETIC FIELD 2, DE-SPIKED, FILTERED
BaseMag2R	DIURNAL BASE MAGNETIC FIELD 2, RAW
BPRESS	BAROMETRIC PRESSURE MEASURED IN AIRCRAFT
DGPSZ	DIFFERENTIALLY CORRECTED GPS ALTITUDE (MSL)
DiurX1	DIURNAL TOLERANCE EXCEPTION LEVEL, BASEMAG 1
DiurX2	DIURNAL TOLERANCE EXCEPTION LEVEL, BASEMAG 2
DLat	DIFFERENTIALLY CORRECTED GPS LATITUDE
DLon	DIFFERENTIALLY CORRECTED GPS LONGITUDE
Fid	LINE FIDUCIAL COUNTER
GHoriz	TOTAL HORIZONTAL GRADIENT (SUM OF SQUARES)
GPSQ	GPS QUALITY INDICATOR
GPSZ0	REAL-TIME GPS ALTITUDE
GPSZCorr	POST-CORRECTION APPLIED TO GPS Z
GPSZDiff	POST-CORRECTION GPS Z NOISE
GSTime	GPS RECORD SYSTEM TIMESTAMP
GT	TEMP TIME CHANNEL, CONTINUOUS ACROSS MIDNIGHT
GTIME	GPS TIME
GXc	LATERAL GRADIENT, COMPENSATED
GXc_Lag	LATERAL GRADIENT, LAGGED
GXn	LATERAL GRADIENT, NORMALIZED
GXn_Lev	FINAL LEVELED LATERAL GRADIENT
GXu	LATERAL GRADIENT, UNCOMPENSATED
GYc	LONGITUDINAL GRADIENT, COMPENSATED
GYc_Lag	LONGITUDINAL GRADIENT, LAGGED
GYn	LONGITUDINAL GRADIENT, NORMALIZED
GYn_Lev	FINAL LEVELED LONGITUDINAL GRADIENT
GYu	LONGITUDINAL GRADIENT, UNCOMPENSATED
GZc	VERTICAL GRADIENT, COMPENSATED
GZc_Lag	VERTICAL GRADIENT, LAGGED
GZn_Lev	VERTICAL GRADIENT, LEVELED
GZn	VERTICAL GRADIENT, NORMALIZED
GZu	VERTICAL GRADIENT, UNCOMPENSATED
HGe	FINAL EAST MAGNETIC GRADIENT
HGel	EAST MAGNETC GRADIENT, LOG SCALED
HGn	FINAL NORTH MAGNETIC GRADIENT
HGnl	NORTH MAGNETC GRADIENT, LOG SCALED
HGr	TOTAL HORIZ GRADIENT AMPLITUDE, SUM OF SQUARES E,N
LAT0	REAL-TIME GPS LATITUDE

Line	LINE NUMBER
LON0	REAL-TIME GPS LONGITUDE
MagFid	AADC MAG RECORD FIDUCIAL COUNTER
MBc	LOWER TAIL MAG, COMPENSATED
MBc_D4	LOWER TAIL MAG, 4TH DIFF NOISE
MBc_DC1	LOWER TAIL MAG, COMPENSATED, DIURNAL 1 CORRECTED
MBc_DC2	LOWER TAIL MAG, COMPENSATED, DIURNAL 2 CORRECTED
MBc_Lag	LOWER TAIL MAG, COMPENSATED, LAGGED
Mag_Lev	TIE LINE LEVELED TOTAL FIELD
MBu	LOWER TAIL MAG, UNCOMPENSATED
MicLev	MICRO-LEVELED LOWER TAIL MAG (Mag_Lev)
MLc	LEFT WING MAG, COMPENSATED
MLc_D4	LEFT WING MAG, 4TH DIFF NOISE
MLc_Lag	LEFT WING MAG, COMPENSATED, LAGGED
MLu	LEFT WING MAG, UNCOMPENSATED
MRc	RIGHT WING MAG, COMPENSATED
MRc_D4	RIGHT WING MAG, 4TH DIFF NOISE
MRc_Lag	RIGHT WING MAG, COMPENSATED, LAGGED
MRu	RIGHT WING MAG, UNCOMPENSATED
MSTime	MAG RECORD SYSTEM TIMESTAMP
MTc	UPPER TAIL MAG, COMPENSATED
MTc_D4	UPPER TAIL MAG, 4TH DIFF NOISE
MTc_Lag	UPPER TAIL MAG, COMPENSATED, LAGGED
MTu	UPPER TAIL MAG, UNCOMPENSATED
ONLINE	IN / OUT GRID LOGICAL FLAG
RadarTopo	RADAR ALTIMETER / GPS DERIVED TOPOGRAPHIC ALTITUDE
RadarTopo_Lev	RADAR TOPO, LEVELED
RALT1A	RADAR ALTIMETER NUMBER 1, ANALOG INPUT
RALT1D	RADAR ALTIMETER NUMBER 1, DIGITAL INPUT
RAlt1A_Lag	RAD ALT 1, LAGGED
RALT2	RADAR ALTIMETER NUMBER 2
RAlt2_Lag	RAD ALT 2, LAGGED
RAlt_Err	RADAR ALTIMETER 1 DIFFERENCE FROM IDEAL
Sense	LINE DIRECTION SENSE, E,N +, W,S –
SurfErr	ALTITUDE DEVIATION FROM IDEAL AUTODRAPE SURFACE
SurfInd	INDICATED AUTODRAPE VALUE, TEST AND DEBUG
SysFid	GEDAS SYSTEM FIDUCIAL NUMBER
Velocity	AIRCRAFT VELOCITY IN M/S
VLFLQ	VLF, LINE QUAD
VLFLQ_Lag	VLF, LINE QUAD, LAGGED
VLFLT	VLF, LINE TOTAL
VLFLT_Lag	VLF, LINE TOTAL, LAGGED
VLFOQ	VLF, ORTHO QUAD
VLFOQ_Lag	VLF, ORTHO QUAD, LAGGED
VLFOT	VLF, ORTHO TOTAL
VLFOT_Lag	VLF, ORTHO TOTAL, LAGGED
VMl	RMS AADC VECTOR MAG, LONGITUDINAL
VMt	RMS AADC VECTOR MAG, TRANSVERSE
VMtf	RMS AADC VECTOR MAG, TOTAL FIELD
VMv	RMS AADC VECTOR MAG, VERTICAL
X	X CHANNEL IN USE
X_27	NAD 27 E
X_84	WGS 84 E
X0	REAL-TIME WGS 84 E
Xtr	X CHANNEL TRIMMED TO BLOCK
Y	Y CHANNEL IN USE
Y_27	NAD 27 N
Y_84	WGS 84 N
Y0	REAL-TIME WGS 84 N
Ytr	Y CHANNEL TRIMMED TO BLOCK

The Geosoft .GDB database is included in the final delivery of digital data. The following channels are also provided in simple uncompressed ASCII .XYZ format. The Geosoft export template used is as follows.

```
EXPORT XYZ]
EXPORT LINE,NORMAL,10,1
EXPORT DLon,NORMAL,10,5
EXPORT DLat,NORMAL,10,5
EXPORT X,NORMAL,10,1
EXPORT Y,NORMAL,10,1
EXPORT X_27,NORMAL,12,1
EXPORT Y_27,NORMAL,10,1
EXPORT fiducial,NORMAL,10,1
EXPORT DATE,NORMAL,10,1
EXPORT Time_HMS,TIME,14,2
EXPORT Ralt1A_Lag,NORMAL,8,0
EXPORT BALT,NORMAL,8,0
EXPORT DGPSZ,NORMAL,12,1
EXPORT BaseMag2,NORMAL,10,2
EXPORT MBc_Lag,NORMAL,10,2
EXPORT MBc_DC2,NORMAL,10,2
EXPORT MBc_DC2_resid,NORMAL,10,2
EXPORT Mag_Lev1,NORMAL,10,2
EXPORT Mag_Lev1_Resid,NORMAL,10,2
EXPORT Mag_Lev2,NORMAL,10,2
EXPORT Mag_Lev2_Resid,NORMAL,10,2
EXPORT MicLev,NORMAL,10,2
EXPORT MicLev_Resid,NORMAL,10,2
WRITEDUMMY  NO
WRITEHEADER  YES
CSV_COMMASEPARATE  NO
CLIPMAP     NO
```

Geosoft formats grids in WGS-84 Z6N projection are included and are defined as follows:

Mag_Lev1	Total Field leveled with less aggressive intersection manipulation. Only instersection adjustments that could be explained by diurnal activity, aircraft altitude errors, etc were made
Mag_Lev1_Resid	Above data with IGRF2000 subtracted.
Mag_Lev2	Total field leveled as above, but with adjustments also made for aesthetics and “reasonable” looking contours.
Mag_Lev2_Resid	Above data with IGRF2000 subtracted.
Mic_Lev	Mag_Lev2 with some directional cosine micro-leveling applied
Mic_Lev_Resid	Above data with IGRF2000 subtracted.

The above grids are provided in Geosoft .GRD format as well as simple uncompressed ASCII .GXF format.

5.5 Flight Path Video

Flight path video for this survey is supplied on VHS tapes, one per flight. Times, positions, direction and speed are overlain on the tape for detailed flight path recovery if required. The video format is described above in the processing discussion.

6. DETAILED EQUIPMENT SPECIFICATIONS

Our detailed equipment technical specifications are as follows:

Aircraft			
C-GJBB	Piper PA-31 Navajo		
	4m composite tail stinger		
	Demonstrated Figure of Merit = 0.9nT		
	Sensor Separation		
	Lateral	582"	14.834m
	Longitudinal	341"	8.661m
Aircraft Magnetometers:			
Manufacturer:	Geometrics		
Type and Model Number:	Cesium G-822A		
Range in nT:	20,000 to 90,000		
Sensitivity in nT:	0.005		
Sampling Rate:	20Hz		
Base Station Magnetometer:			
Manufacturer:	GEM Systems		
Type and Model Number:	Overhauser GSM-19W		
Range in nT:	20,000 to 120,000		
Sensitivity in nT:	0.01		
Sampling Rate:	5Hz maximum (0.5Hz typical)		
Solar Power Supply:	1 - Solarex MSX50		
Real-time Magnetic Compensator:			
Manufacturer:	RMS Instruments		
Type and Model Number:	AADCII		
Range in nT:	20,000 to 100,000		
Resolution in nT:	0.001		
Sampling Rate:	20Hz		
Digital Acquisition System:			
Manufacturer:	Goldak Exploration Technology		
Type and Model Number:	GEDAS		
Sampling Rate:	20Hz		
Data Format:	GEDAS binary		
Positioning Cameras:			
Manufacturer:	Panasonic		
Model:	GPKR402 HRSV		
Lens:	WV-LR4R5 4.5mm		
	FOV at 1000 feet AGL is 1040 x 1300 feet		
Barometric Altimeter:			
Manufacturer:	Setra		

Type and Model Number:	270
Range:	-1000 to 10,000 feet
Resolution:	1 meter

Radar Altimeter 1:

Manufacturer	Thompson CSF
Type and Model Number:	ERT-160
Range:	0-8000 feet
Resolution:	1 meter
Accuracy:	1-2%

Radar Altimeter 2:

Manufacturer	Terra
Type and Model Number:	TRA300 – TRI40
Range:	0-2500 feet
Resolution:	1 meter
Accuracy:	5-7%

Positioning System:

Manufacturer:	Goldak Exploration Technology Ltd.
Type and Model Number:	GEDAS
Displays:	10” color LCD graphical display Graphic LCD pilot indicator

GPS Subsystem:

GPS Receiver:

Manufacturer	Novatel
Type and Model Number:	3151R Propak Dual Frequency

GPS Real Time Differential Receiver:

Manufacturer	Racal
Type and Model Number:	Landstar

GPS Base Station:

Manufacturer	Novatel
Type and Model Number:	3151R Propak Dual Frequency

System Resolution:	1 meter
Overall accuracy:	3 m in real-time, <1m post-corrected

Computers:

Manufacturer:	Compaq
Type and Model Number:	Pentium 400, laptop PC
Manufacturer:	Toshiba
Type and Model Number:	Pentium 200, 100CS laptop PC

Plotters and Printers:

Manufacturer:	Canon
Type and Model Number:	Bubblejet, BJC10 color page printer

Data backup:

Manufacturer:	Iomega
Type and Model Number:	100Mb Zip drive

Manufacturer: Iomega
Type and Model Number: 1.0Gb Jaz drive

Manufacturer: Hewlett Packard
Type and Model Number: Sure Store CD-ROM writer

Software

Manufacturer: Geosoft
Function: Geophysical data processing
Type and Model Number: Oasis Montaj

Manufacturer: Waypoint Consulting
Function: GPS post-processing
Type and Model Number: GrafNav

Manufacturer: Geomatics Canada
Function: GPS post-processing
Type and Model Number: GPSPace

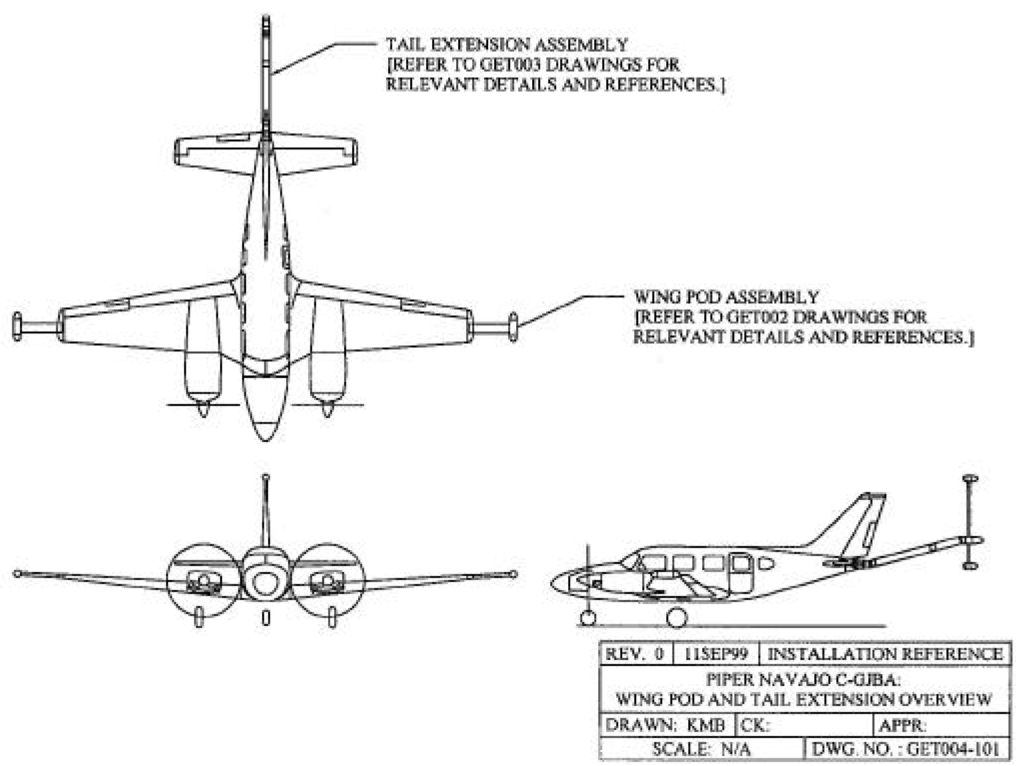

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Illustration – Survey Aircraft 3-View in Tri-Axial Configuration

7. STATEMENT OF QUALIFICATIONS

Ben Goldak

I reside at 25 Duncan Crescent in Saskatoon, Saskatchewan.

I hold a B.Sc. Adv. in Computer Science from the University of Saskatchewan.

I have been active in the field of geophysics since 1980.

I have examined the data referred to in this report and find it to be of suitable quality for purposes of geological interpretation.

I am President of Goldak Exploration Technology Ltd.

Ben Goldak December 29, 2002