APPENDIX A

ACQUISITION AND PROCESSING REPORT

AEROMAGNETIC SURVEY

SAN LUIS VALLEY, CO AND NM

For

United States Geological Survey

Contract No: 04CRSA0844

by

PRJ Inc.
12640 West Cedar Drive, Suite 100
Lakewood, Colorado 80228
Phone: 303/987-1114
FAX: 303/989-0181
e-mail: info@prj.com

I. COMPENSATION & CALIBRATIONS

Aircraft: N4181T
Date: 10-20-04
Pilot: Wayne Hebert
Operator: Dianne Hebert
Location: San Luis Valley, CO

Clover Leaf:

Aircraft Altitude: 400 feet
Positioning: GPS Waypoint
Latitude: 37° 00' 06" N
Longitude: 105° 49' 05" W
Directions: Four Cardinal Headings
North: 52296.0 nT
South: 52296.0 nT
East: 52295.0 nT
West: 52296.0 nT
East-West Error: 1 nT
North-South Error: 0 nT
Total Error Sum: 1 nT

Calibrations:

The radar altimeter has a manufactur's default calibration. To ensure that this calibration is accurate the pilot flies over a know topographical location and checks it against the default calibration that they perform upon the survey data.

The location of the base station was in the same position throughout the survey. The posisiton is as follows:

Latitude: 37°26'28.781"
Longitude: -105°51'58.986"
HAE: 2293.432 meters
Sigma:
North: 1.910 meters
East: 1.893 meters
Up: 2.487 meters

II. EQUIPMENT

A. Survey Aircraft and Crew

The aircraft to employed was a Cessna 320 registration numbe N4181T r, specifically equipped by Airmag Surveys Inc. for the undertaking of airborne magnetic data acquisition. A rigid tail stinger contains the magnetometer sensor and a permanent camera hole in the lower aircraft belly accommodates the video camera system, while the aircraft is fully equipped with sufficient aviation instrumentation to undertake the surveys. The aircraft was completely stripped down after purchase and refurbished with non-magnetic components where possible to minimize both induced and permanent magnetic effects. A more complete description of the aircraft, and its operational characteristics including endurance and climb rates is provided hereafter.

Manufacturer's aircraft specifications indicate a maximum climb rate of 1,825 feet per minute (176 meters per kilometer) at 118 miles per hour at 5,000 feet above sea level at 41 F.

A two-man crew, consisting of an pilot and an electronics technician/data processor was mobilized with the aircraft.

B. Airborne Instrumentation

1. *Magnetometer*

The aircraft is equipped with Geometrics G822A Cesium vapor, optically-pumped magnetometers. These instruments have a sensitivity of 0.01 nT over a range of some 20,000 nT, with a sensor noise level of less than 0.02 nT. The airborne magnetic field was recorded at 0.25 sec intervals (less than 15 meters sample spacing) to a resolution of 0.01 nT and with an acceptable noise level which did not exceed +/- 0.1 nT over more than 10 percent of any line length.

2. *Navigation Systems*

Three separate GPS systems provided redundant positioning for the aircraft. On-board real-time DGPS positioning was provided by an OmniSTAR 3000L navigation system. The primary instrumentation used is the airborne part of a Motorola Mobile DGPS system which was post-flight processed on a daily basis. A Trimble 2000AE GPS recorder provides full independent back up to the above configuration. The airborne GPS data was recorded at 1 sec intervals and positional traces acquired included latitude and longitude, elevation, as well as time and range data for the tracked satellites. Final processed positioning data was an accuracy of better than 5 meters.

The positional data was processed in real time and provided to the pilot as cross track and along track positions relative to the locations of the pre-planned flight lines.

Elevation control, as output of the vertical GPS height relative to the pre-planned drape surface, is provided to the pilot in a similar manner.

3. *Altimeters*

Minneapolis Honeywell 8505 digital radar altimeters, with a range of 0 to 5,000 feet, recording at 4 Hz, are permanently installed in the aircraft. Terrain clearance as measured by the radar altimeter was recorded at 0.25 sec intervals to a resolution of 0.5 foot. The radar altimeter was calibrated over flat terrain at the start of each survey and periodically thereafter as required.

Barometric altimeter data is provided by an FAA certified Rosemont model 800E18 altimeter. Aircraft altitude as recorded by the barometric altimeter will be measured at 0.25 sec intervals to a resolution of 1 foot.

4. *Airborne Data Acquisition System*

Airborne data acquisition was accomplished on a Hewlett Packard Data Acquisition system consisting of the following components:

HP 9000-300 Digital Recorder controller.
HP 53132A Universal Counter.
HP 3457A Multiplexing System
HP 33120A GPS Time synchronization system.
HP 7132A Analog Recorder
IO Tech Serial 488/4 IEEE serial Converter.
Panasonic CF-27 Hardened Digital Recorder Controller.

Digital records of the magnetometer (0.1 sec), radar and barometric altimeters(0.25 sec) and the GPS output (1.0 sec) were made. Time synchronization is provided for all data channels recorded based on the available GPS time signals and digital records included the necessary header and synchronization information, including line numbers, positioning data and time and fiducial marks.

5. *Video Camera and Recorder*

A JVC color video camera and associated recorder system were used. The video camera is mounted in the camera hole, located in the belly of the aircraft, and oriented for an alignment of less than 2 off vertical while in flight. Fiducial marking and positioning overlay information was incorporated in the video recording system, which recorded continuously during data acquisition with annotations of flight and line number, location, fiducial time and recorded magnetic value superimposed.

6. *Fixed Compensation System*

Airmag Surveys Inc. uses a magnetically-cleaned aircraft which, after purchase, has been completely stripped down and extensively modified to remove all magnetic components where possible. This process minimizes any aircraft-induced noise associated with survey maneuvers. A fixed compensation system is installed in the stinger minimizing relative heading effects of the aircraft which is adjusted if necessary for specific survey conditions.

C. Ground Based Instrumentation

1. *Ground DGPS Base Station Receiver*

A Motorola 6- or 8-channel DGPS receiver provided position and range information for the GPS ground station used. At the survey initiation the system is to employed for a continuous 24 hour period provided an initial base station location. Ground GPS positional data is recorded at 1 sec intervals and referenced to the location of the ground station. The base station location was established to an accuracy of 0.5 meters or better and final processed, differentially-corrected aircraft locations have an accuracy of 5 meters or better.

2. *Ground Data Acquisition System*

A Hewlett Packard based computer system, similar to the airborne data acquisition recorder was employed and included an HP 53132A Universal Counter and a Panasonic CF-27 Hardened Digital Recorder-controller.

3. *Base Station Magnetometer*.

The time-synchronized ground magnetic field data was digitally recorded at a 1.0 sec interval with a Geometrics G822A magnetometer and to the same specifications as the airborne data set. Analog recordings of the base station record, with time marks are also provided on a continuous basis on a M-Tek analog recorder, which was operational on a 24-hour basis.

The base station was located within 50 miles (80 km) of all survey points.

4. *Field Data Verification Station*

The Hewlett Packard data acquisition system allows use as a field work station for profile data verification and display for editing and transcription purposes. Full GPS processing software is available in-field to allow the determination of flight line locations during survey operations on a daily basis and the production of page-sized flight path location maps.

III. File Table

1. Raw Data CD-ROM: (* - flight number: 1-43)

a. FLT*.DAT - Raw data for the specified flight in ASCII format.
b. FLT*.DBF - Raw GPS data for the specified flight in data base format.
c. FLT*.TXT – Raw NEIMA Trimble GPS data in comma delimited format for the specified flight. Only the data contained in the $GPGGA word were used.

2. Proccessed Data CD-ROM:

a. ALL.DAT – Profile data in ASCII format of the San Luis Valley Area, CO & NM.
b. TMI.GXF – Total magnetic intensity grid of the San Luis Valley Area, CO & NM.
c. RADAR.GXF – Radar altimeter grid of the San Luis Valley Area, CO & NM.

3. Data Formats:

A. Raw Data CD-ROM:

1. FLT*.DAT:

Columns	Format	Descriptions	Units
1-4	I4	Line Number	
5-6	I2	Flight Direction (see bottom of flight logs)	
7-13	I7	Fiducial	¼ second
14-18	I5	Year	
19-22	I4	Julian Date	
23-26	I4	Radar Altimeter	feet
27-33	I7	Barometric Altimeter	feet
34-43	F10.2	Raw Magnetics	nT
44-45	I2	Place Holder	
46-55	F10.2	Diurnal Magnetics	nT
56-66	F11.6	Latitude	Dec. Deg.
67-77	F11.6	Longitude	Dec. Deg.

B. Processed Data:

1. ALL.DAT:

Colums	Format	Description	Units
1-4	I4	Line Number	
5-12	I8	Flight Direction	degrees
13-23	F11.4	Latitude (NAD 83)	Dec. Deg.
24-34	F11.4	Longitude (NAD 83)	Dec. Deg.
35-45	F11.2	UTM X (WGS 84)	meters
46-56	F11.2	UTM Y (WGS 84)	meters
57-67	F11.2	UTM X (NAD-27)	meters
68-78	F11.2	UTM Y (NAD-27)	meters
79-87	I9	Fiducial	¼ second
88-98	A11	Year/Julian Date	YYYY/DDD

99-110	**A12**	**Time**	**hh:mm:ss.ss**
111-117	**I7**	**Radar Altimeter**	**meters**
118-124	**I7**	**Barometric Altimeter**	**meters**
125-133	**F9.2**	**GPS Elevation**	**meters**
134-142	**F9.2**	**Diurnal**	**nT**
143-151	**F9.2**	**Raw Magnetics**	**nT**
152-160	**F9.2**	**Diurnally Corrected Magnetics**	**nT**
161-169	**F9.2**	**Diurnally + IGRF Corrected Magnetics**	**nT**
170-179	**F10.2**	**Final Leveled Magnetics**	**nT**

V. Processing Report

I. INTRODUCTION

During 10/21/04-12/07/04 an airborne magnetic survey acquired by Airmag Surveys, on behalf of USGS, was processed and mapped by PRJ Inc. of Lakewood, Colorado.

This report describes the processing procedures used and contains a listing of products delivered.

II. DATA PROCESSING PROCEDURES

A. Flight Path Recovery

The navigation system used during the data acquisition included the full recording of GPS locations. A lag test was performed to the data and a one fid shift was applied to the locations. The latitude/longitude data were projected onto a flat surface using the following projection parameters:

Projecton Data:

Project Name:	San Luis Valley Area, CO & NM.
Projection:	UTM
Datum:	WGS84 and NAD27
Central Meridian:	105 west
Spheroid:	Clarke 1866
False Easting:	152,400 meters
False Northing:	0 meters

1. Magnetic Data

1. Data Received

Digital magnetic data from the airborne acquisition systems was received by e-mail. The data were read and converted to a line location file.

2. *Data Editing*

   a. Profile plots of the magnetic data for each line were inspected for noisy or missing data. A small number of isolated spikes was removed from the data.

   b. The data quality was considered good, and no filters were applied.

   c. Cultural noise was identified on the data set, no deculturing of the data was attempted.

3. *Diurnal Correction*

The base magnetometer data were inspected and compared with the observed magnetic data trace.

The following diurnal correction, in addition to the removal of diurnal by the line adjustment procedures, was applied to the data set:

The observed diurnal, corrected for the I.G.R.F. values for the location of the base station, were hi-cut filtered to remove noise and a constant of 51887 was then subtracted from the diurnal. This data was then subtracted from the observed magnetic data.

4. *I.G.R.F.*

The International Geomagnetic Reference Field, updated to the dates of the survey, was calculated and applied to the data set.

5. *Leveling*

Mis-ties at line intersections were calculated and adjusted to minimize mis-tie errors. Initial leveling adjustments were completed using a DC level adjustment to compensate for long wavelength diurnal effects.The data were then interpolated using a minimum curvature approach. (Ref: Program Minc USGS OFR 81-1224). Micro leveling (see Appendix A) was applied to the data to remove small residual mis-ties.

III. Appendices

Appendix A :

Microleveling

Even after standard leveling is applied to magnetic data (e.g., DC least squares adjustment using misties between profile and tie lines), some corrugation is usually evident in the grid made from the data. This corrugation is due to small mismatches between adjacent lines arising from residual heading errors, small differences in flight elevation, and horizontal positioning errors. The corrugation can be removed from the grid by splitting the gridded data into matching low-pass and high-pass components, applying tuned strike suppression filters along the profile and tie line directions to the high-pass component, and reassembling the result with the low-pass component. This destroys short-wavelength geological anomalies oriented along the flight and tie line directions, but these are unrecoverable anyway in the presence of corrugation. Variations of this procedure are standard in the industry, and are known generally as decorrugation.

The remaining problem is to transfer this correction back to the profile data. Simply extracting the profiles from the gridded data yields a result which lacks the short-wavelength content of the original data; the idea is to retain the shorter wavelength components in the profile data, while using the longer wavelength components of the data extracted from the decorrugated grid.

The procedure used is as follows. The spectrum of the difference between the profile data and the extracted profiles is analyzed to design a low-pass filter that reflects the long-wavelength part of the difference, and the filter is applied to the difference. The low-pass difference is then subtracted from the profile data, which is equivalent to replacing the long-wavelength component of the profile data with that of the profile extracted from the grid. This is a variation of the procedure known as microlevelling.

The differences between the profile data before and after microlevelling are quite small, generally less than 1 nT except for DC shifts. However, the final data now interpolates to a grid which is essentially free of corrugation.