

**Logistics
Report**

for a

High Resolution Fixed Wing Magnetic Survey

of

**Portions of the States of Wisconsin,
Minnesota, Michigan and Iowa**

carried out on behalf of

U.S. Geological Survey

Denver, Colorado

by

High-Sense Geophysics Limited



Toronto, Canada
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1. INTRODUCTION

In September 1998, High-Sense Geophysics Limited was contracted by the United States Geological Survey to provide a fixed wing magnetic survey over an area of interest located primarily in the southern half of Wisconsin, and portions of Minnesota, Michigan and Iowa.

The survey was flown between September 15, 1998 and February 21, 1999. A total of 74015 line-kilometers of total field magnetic data, flown at a nominal line spacing of 800 metres, was collected, processed and plotted on-site.

The technical objective of the survey was to provide high resolution magnetic maps, suited for anomaly delineation, detailed structural evaluation and identification of lithologic trends. Fully corrected magnetic maps were prepared by High-Sense's Toronto office after completion of survey activities.

2. LOCATION

Latitude and longitude coordinates, central meridian and zone used to define the blocks are listed below - see accompanying map for relative locations.

Central meridian: 87° W, UTM Zone: 16

Area 1

<u>Corner No.</u>	<u>Latitude</u>	<u>Longitude</u>
1	43° 30' 00" N	91° 20' 00" W
2	43° 48' 00" N	91° 22' 30" W
3	44° 00' 00" N	91° 33' 30" W
4	44° 02' 30" N	91° 39' 00" W
5	44° 02' 30" N	90° 51' 00" W
6	44° 15' 00" N	90° 51' 00" W
7	44° 15' 00" N	90° 18' 00" W
8	44° 26' 00" N	90° 18' 00" W
9	44° 26' 00" N	90° 02' 30" W
10	44° 00' 00" N	90° 02' 30" W
11	44° 00' 00" N	90° 00' 00" W
12	43° 30' 00" N	90° 00' 00" W

Area 2

<u>Corner No.</u>	<u>Latitude</u>	<u>Longitude</u>
1	43° 00' 00" N	91° 12' 30" W
2	43° 17' 30" N	91° 13' 30" W

3	43° 30' 00" N	91° 20' 00" W
4	43° 30' 00" N	90° 00' 00" W
5	43° 00' 00" N	90° 00' 00" W

Area 3

<u>Corner No.</u>	<u>Latitude</u>	<u>Longitude</u>
1	43° 30' 00" N	90° 00' 00" W
2	44° 02' 30" N	90° 00' 00" W
3	44° 02' 30" N	88° 47' 30" W
4	44° 00' 00" N	88° 47' 30" W
5	44° 00' 00" N	88° 15' 00" W
6	43° 45' 00" N	88° 15' 00" W
7	43° 45' 00" N	88° 45' 00" W
8	43° 30' 00" N	88° 45' 00" W

Area 4

<u>Corner No.</u>	<u>Latitude</u>	<u>Longitude</u>
1	44° 00' 00" N	88° 47' 30" W
2	44° 32' 30" N	88° 47' 30" W
3	44° 32' 30" N	87° 22' 30" W
4	44° 00' 00" N	87° 22' 30" W

Area 5

<u>Corner No.</u>	<u>Latitude</u>	<u>Longitude</u>
1	44° 32' 30" N	87° 40' 00" W
2	45° 09' 00" N	87° 40' 00" W
3	45° 52' 30" N	87° 05' 00" W
4	45° 52' 30" N	86° 45' 00" W
5	45° 15' 00" N	86° 45' 00" W
6	44° 32' 30" N	87° 22' 30" W

Area A

<u>Corner No.</u>	<u>Latitude</u>	<u>Longitude</u>
1	42° 29' 30" N	90° 29' 00" W
2	42° 29' 30" N	90° 39' 30" W
3	42° 37' 30" N	90° 43' 30" W
4	42° 40' 30" N	91° 00' 00" W
5	42° 45' 00" N	91° 06' 00" W
6	42° 52' 30" N	91° 07' 30" W
7	42° 55' 00" N	91° 10' 15" W
8	43° 00' 00" N	91° 12' 30" W
9	43° 00' 00" N	90° 29' 00" W

Area B

Corner No.	Latitude	Longitude
1	44° 00' 00" N	87° 52' 30" W
2	44° 00' 00" N	87° 35' 19" W
3	43° 45' 00" N	87° 36' 16" W
4	43° 22' 30" N	87° 46' 19" W
5	43° 09' 34" N	87° 47' 28" W
6	43° 09' 34" N	88° 11' 23" W
7	43° 22' 30" N	88° 11' 23" W
8	43° 29' 02" N	88° 40' 49" W
9	43° 36' 53" N	88° 40' 49" W
10	43° 36' 53" N	88° 19' 56" W

Area C

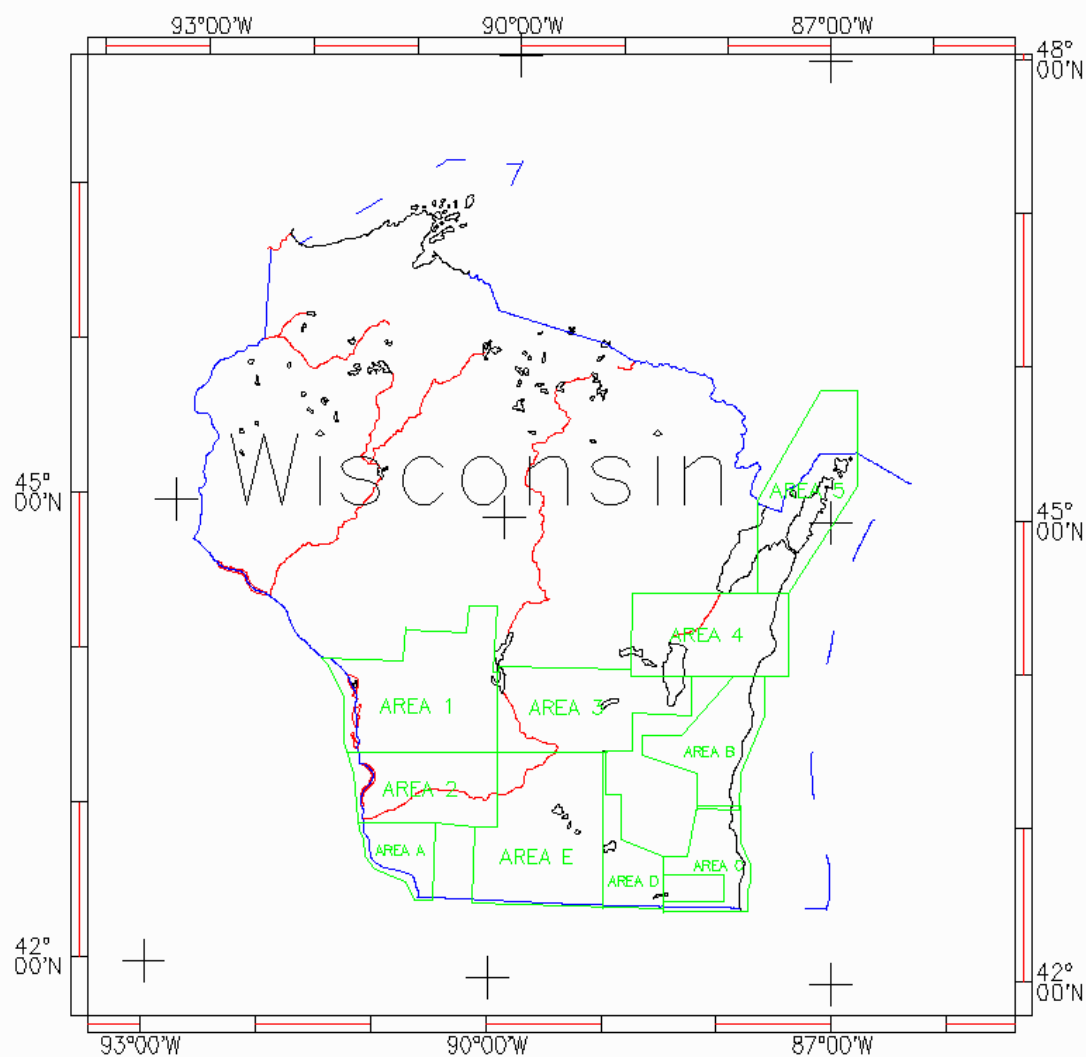
Corner No.	Latitude	Longitude
1	43° 09' 38" N	88° 11' 23" W
2	43° 09' 38" N	87° 47' 28" W
3	42° 54' 30" N	87° 46' 07" W
4	42° 47' 12" N	87° 41' 40" W
5	42° 40' 52" N	87° 41' 40" W
6	42° 37' 30" N	87° 43' 00" W
7	42° 29' 18" N	87° 43' 00" W
8	42° 29' 18" N	88° 27' 47" W
9	42° 32' 45" N	88° 27' 47" W
10	42° 32' 45" N	87° 55' 22" W
11	42° 43' 45" N	87° 55' 22" W
12	42° 43' 45" N	88° 27' 47" W
13	42° 50' 05" N	88° 27' 47" W
14	42° 50' 05" N	88° 15' 08" W

Area D

Corner No.	Latitude	Longitude
1	43° 30' 00" N	88° 58' 42" W
2	43° 13' 29" N	88° 58' 42" W
3	43° 13' 29" N	88° 50' 26" W
4	42° 55' 36" N	88° 50' 26" W
5	42° 50' 05" N	88° 27' 47" W
6	42° 29' 30" N	88° 27' 47" W
7	42° 29' 30" N	89° 02' 30" W
8	43° 30' 00" N	89° 02' 30" W

Area E

Corner No.	Latitude	Longitude
1	42° 29' 30" N	90° 08' 30" W
2	43° 00' 00" N	90° 08' 30" W
3	43° 00' 00" N	90° 00' 00" W
4	43° 30' 00" N	90° 00' 00" W
5	43° 30' 00" N	89° 02' 30" W
6	42° 29' 30" N	89° 02' 30" W

Location Map: Wisconsin Project Area

3. AIRCRAFT AND EQUIPMENT

3.1 Aircraft

The aircraft used was a Cessna 206 fixed wing (C-GNNN) owned and operated by Bruceland Air of Wiarton, Ontario.

3.2 Airborne Geophysical System

3.2.1 Magnetometer

One Geometrics G-8 22A Optically Pumped Cesium Split Beam Sensor was mounted in a fixed wing pod at the end of the wing. The Larmor frequency output was processed by a High-Sense magnetometer counter that provides a resolution of 10 ppb (in a magnetic field of 50,000 nT this resolution is equivalent to 0.005 nT) ten times per second.

3.2.2 Magnetic Compensation

A Billingsley Magnetics TFM100-1E three axis fluxgate magnetometer measured the orientation and rates of change of the aircraft's magnetic field with respect to the Earth's magnetic field. Correction factors were then generated to compensate for permanent, induced and eddy current magnetic anomalies generated by the aircraft.

3.2.3 GPS Navigation

A Novatel 951 twelve channel GPS receiver, which is an integral component of the HS-GFCS-II flight control system, provided precise positioning.

3.2.4 Altimeter

A Terra TRA 3000 radar altimeter was mounted on the aircraft. This instrument operates with a linear performance over the range of 20 to 1500 metres, and records the terrain clearance of the magnetic sensor.

A Rosemount barometric altimeter was also mounted on the aircraft. This instrument operates with a linear performance over the range of -1000 to 15000 feet.

3.2.5 Geophysical Flight Control System

The High-Sense MiniMag Data Acquisition flight control system monitored and recorded magnetometer, altimeter and GPS equipment. Input from the various sensors was monitored every 0.005 seconds for precise coordination of geophysical and positional measurements. GPS positional coordinates and terrain clearance were presented to the pilot by means of an LCD touch screen display. The magnetometer response, 4th difference, and altimeter profile were also shown on the LCD touch screen display for real time monitoring of equipment performance.

3.2.6 Digital Recording

The output of the magnetometer, compensation equipment and altimeter as well as uncorrected GPS coordinates were recorded digitally on disk at a sample rate of ten times per second by the HSG MiniMag Data Acquisition system. Line number, GPS time and system time were also recorded for use during subsequent differential GPS correction.

3.3 Ground Monitoring System

3.3.1 Magnetometer

A Scintrex H-8 magnetometer was operated as a base station to record diurnal variations of the Earth's magnetic field. Readings with a resolution of 0.1 nT were recorded digitally every second, and synchronized with GPS time for accurate correction of the airborne data.

3.3.2 GPS Monitor

A Magnavox 9200 twelve channel receiver with a fixed antenna was also active at the base of operations. Raw satellite data was digitally recorded to enable differential correction of the corresponding airborne data.

3.3.3 Recording

The output of the magnetic and GPS monitors was recorded digitally on a dedicated PC. A visual record of the last four hours of activity is graphically maintained on the computer screen to provide an up to date appraisal of magnetic activity. At the conclusion of each production flight raw GPS and magnetic data were transferred to the main compilation computer.

3.4 Field Compilation System

A Pentium PC computer and a Hewlett Packard Design Jet 350C colour plotter were used for field data processing and presentation. Processing software and procedures were developed by High-Sense Geophysics Limited, and include the Geopak RTICAD imaging system.

4. PERSONNEL

4.1 Field Operations

USGS Representative	: Robert E. Bracken
High-Sense data processors	: Amir Soltanzadeh Steven Green Darrick Wagg
Bruceland pilots	: Will Plageman, Tom Martindale
Bruceland Engineer	: Tom Elmes

4.2 Project Management

USGS, Denver office	: Robert E. Bracken
High-Sense, Toronto office	: Ted Urquhart

5. SURVEY PARAMETERS

Traverse Line spacing	: 800 metres
Control Line spacing	: 12,500 metres
Nominal Terrain clearance	: 1000 feet
Navigation	: Global Positioning System
Traverse Line direction	: North-South, (East West for Area C)
Control Line direction	: East-West, (North-South for Area C)
Measurement interval	: 0.1 sec
Airspeed (nominal)	: 210 km/hr
Measurement spacing (nominal)	: 6.0 meters
Airborne Digital Record	: Radar Altimeter Barometric Altimeter Total Field Magnetism Time (Local and GPS) Raw Global Positioning System (GPS) data Magnetic compensation parameters
Base Station Record	: Ambient Total Field Magnetism Raw Global Positioning System (GPS) data Time (Local and GPS)

6. OPERATIONS AND PROCEDURES

6.1 Flight Planning

Survey block outlines were specified by USGS (section 2.0), and the coordinates used to generate pre-calculated navigation files. These, in turn, were used by the airborne data acquisition system to plan flights at the designated line spacing of 800 metres.

6.2 Base Station

The GPS and magnetic base station site was established at various locations close to the base of operations for each particular area. A total of four locations were used during the course of the survey. A description and exact position of the locations is listed below:

1. *Green Bay Wisconsin:* The base station was set up in a remote section of the airport.

44° 29' 41.98" N 174.6 m asl
88° 07' 50.12" W (Clarke 1866 spheroid)

2. *Manitowoc Wisconsin:* The base station was set up in a remote section of the airport.

44° 07' 19.6176" N 168.4 m asl
87° 41' 03.1164" W (Clarke 1866 spheroid)

3. *Platteville Wisconsin:* The base station was set up in a remote section of the airport.

42° 41' 30.5797" N 278.5 m asl
90° 26' 24.8613" W (Clarke 1866 spheroid)

4. *Janesville Wisconsin:* The base station was set up in a remote section of the airport.

42° 36' 40.1443" N 203.38 m asl
89° 02' 44.1223" W (Clarke 1866 spheroid)

The GPS antenna should be located at an accurately surveyed position point, since positional errors are carried through to the differentially corrected data. Because no suitable control point was available, the location of the GPS antenna was determined by recording 24 hours of GPS data and averaging the resultant antenna coordinates (the assumption being that the deliberate errors introduced by military

selective availability satellite signal distortion will average to zero over an extended period of time).

6.3 Data Compilation

Data recorded by the airborne and base station systems was transferred to the field compilation system. As each flight was completed, the following compilation operations were carried out.

6.3.1 Flight Path Correction

The GPS data was differentially corrected to remove errors introduced by 'selective availability', an intentional accuracy degradation method used by the military. The correction process uses the known fixed location of the base station to calculate the error associated with each satellite. These errors are then removed from the survey GPS data enabling a position to be calculated with an accuracy in the order of three metres, with four or more satellites in view. Satellite visibility and coverage were good throughout field operations. Both GPS receivers were generally tracking a minimum of seven satellites.

The navigational correction process yields a flight path expressed in WGS 84 Latitude-Longitude coordinates. Transformation to local Clarke 1866 (NAD 27) UTM coordinates used the following projection parameters :

	Semi-major axis (a)	Flattening (f)
WGS 84	6378137.0	298.2572201
Clarke 1866 (NAD 27)	6378206.4	294.9786982

Local datum shift applied :

Delta X	:	9
Delta Y	:	-160
Delta Z	:	-176

UTM central meridian = 87° W (Zone 16)

False Easting	:	500,000
False Northing	:	0

6.3.2 Magnetic Corrections

Diurnal variations recorded by the base station were subtracted directly from the aeromagnetic measurements to provide a first order diurnal correction. Aeromagnetic data was compensated for permanent, induced and eddy current magnetic noise generated by the aircraft. Figure of Merit tests were conducted at the beginning of the survey and after each time the orientation of the magnetometer was adjusted (See Appendix A for details).

Control lines flown perpendicular to the traverse lines were used to provide level correction. Residual differences between control and traverse lines were used to carry out a further refinement of diurnal and heading errors. Micro leveling technique was also used to correct any problems not removed by tie line leveling. Any apparent cultural effects noted in the magnetic maps were not removed from either preliminary or final map products.

6.3.3 Map Products and Digital Data

Interim digital data for the blocks were supplied to USGS as the survey progressed. Following processing in the High-Sense Toronto office, copies of the final map products (see below), plus three (2) copies of the digital data (CD-ROM), video cassettes used to assist in tracking the aircraft, and this logistics report were delivered to USGS.

1. Maps at 1:100,000 of the Total Magnetic Field with contours, flight path in triplicate on clear mylar.
2. Maps at 1:100,000 of the radar altimeter with contours, flight path on clear overlay (mylar) in single copy.

Respectfully submitted,

Steven Green, E.I.T.
High-Sense Geophysics Limited
August 25, 1998

APPENDIX A: Figure-of-Merit

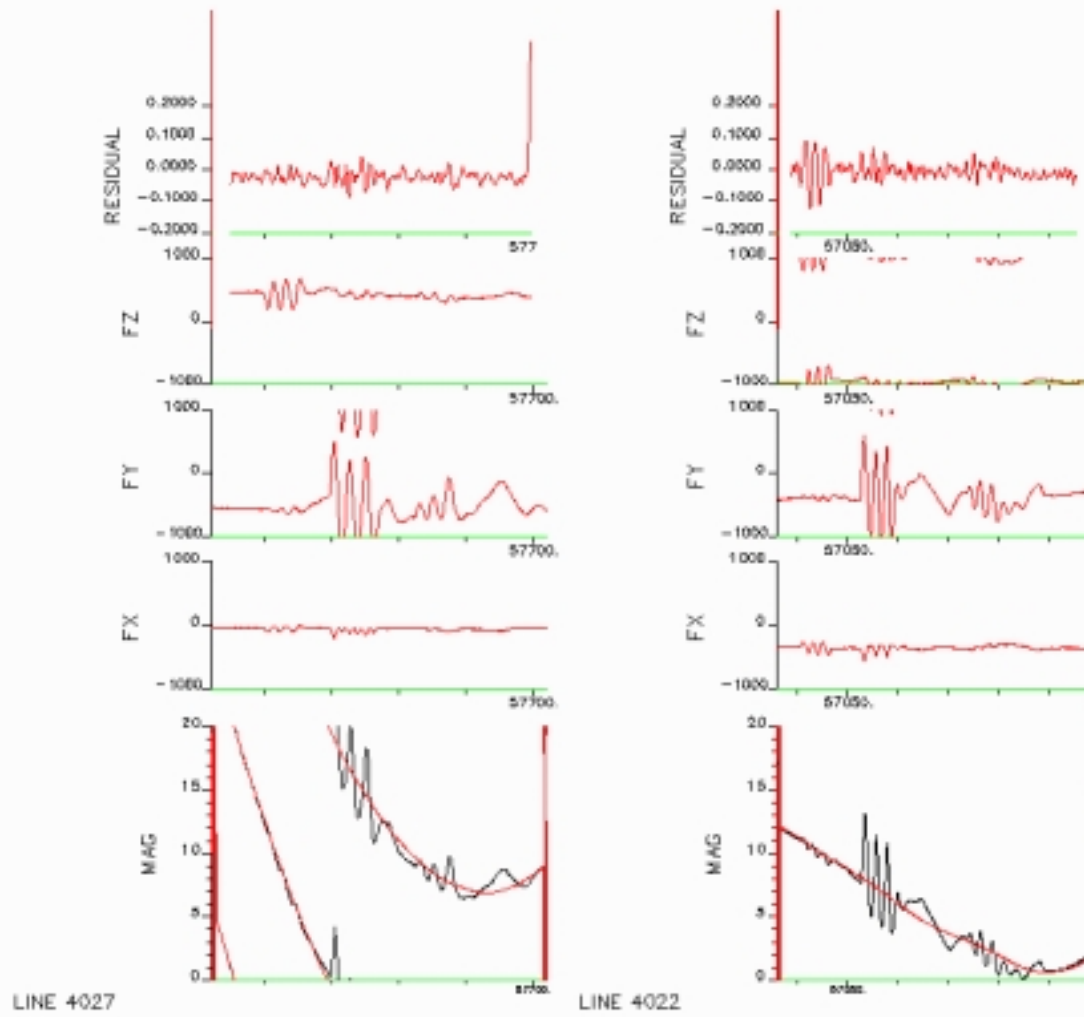
Magnetic Figure-Of-Merit Tests

The airborne magnetic record is corrected using an 18 term post-flight digital compensation system that uses magnetic data from the Barrington 3-axis fluxgate magnetometer to determine the aircraft's attitude and rate of change with respect to the earth's magnetic field. The compensation system identifies the permanent, induced and eddy current magnetic contributions of the aircraft and provides a correction to be applied to the raw magnetic data to remove maneuver noise.

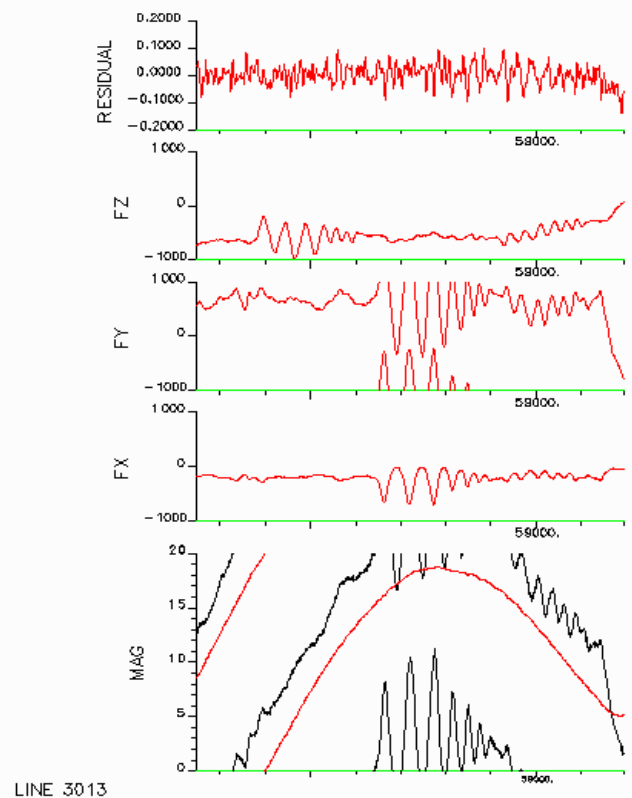
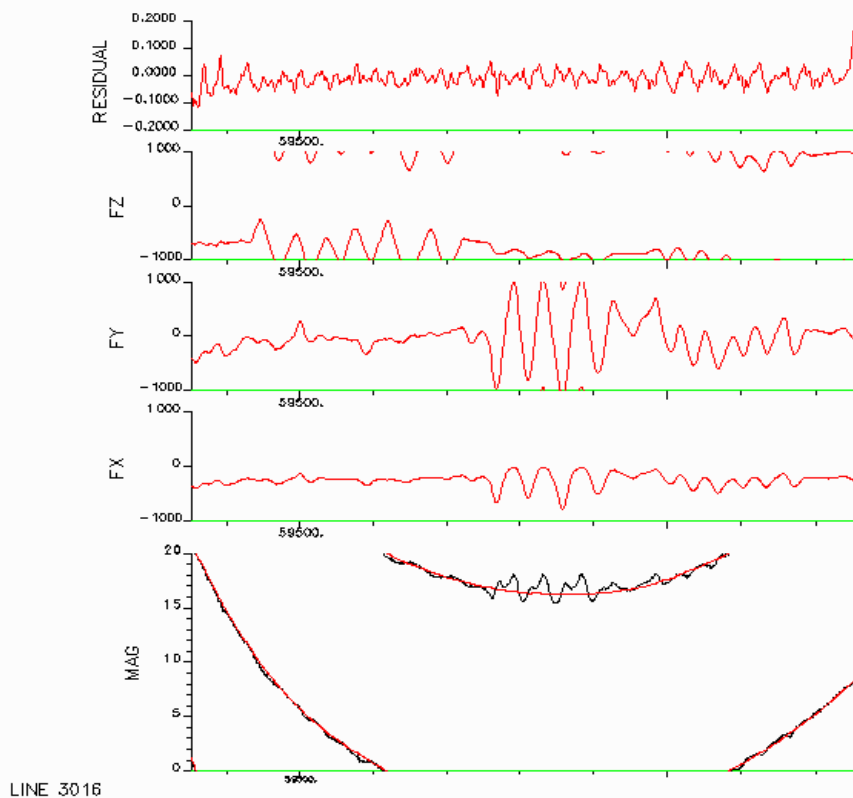
In order to calibrate the compensation system, tests are flown at high altitude to determine the effects of aircraft pitch, roll and yaw. The aircraft flies each of the headings aligned with the direction of the survey flight lines and control lines, performing three sets of pitch roll and yaw maneuvers over periods of approximately six, ten and fourteen seconds. The data is subsequently used to calibrate the compensation system.

The following figures show the results (raw and compensated magnetic signature) of three Figure-Of-Merit tests:

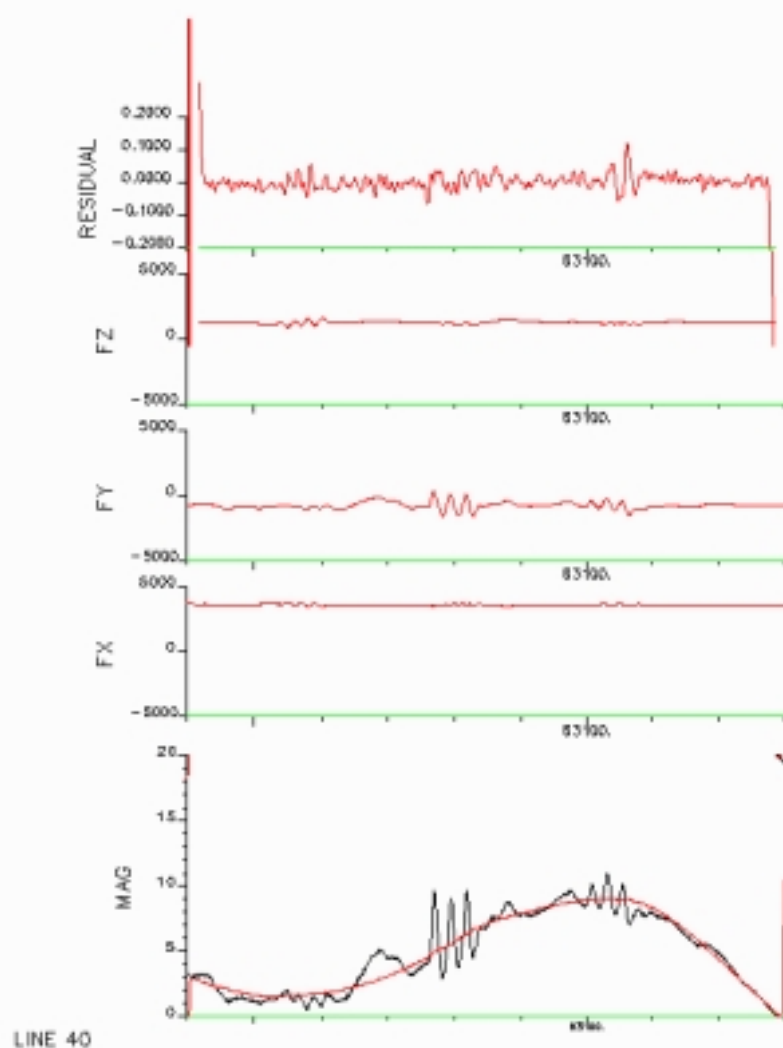
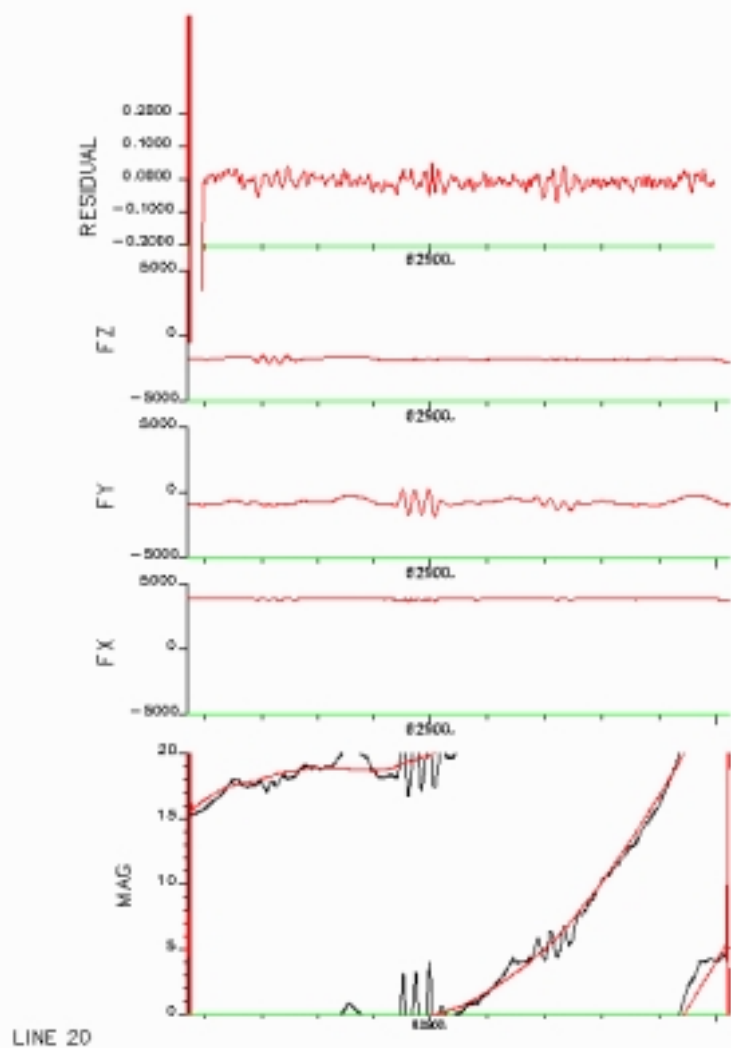
- September 20 – 1.18
- December 18 – 1.37
- February 20 – 1.22



September 20 FOM Results (North: 4027, South: 40)



December 18 FOM Results (East: 3016, West: 3013)



February 20 FOM Results (North: 20, South: 40)