GRAV-MAG-EM

Airborne Survey System

McPHAR INTERNATIONAL
Singapore · India · Canada · South Africa
www.mcpharinternational.com
sales@mcpharinternational.com

Features:

- *A TAGS-6 or GT-2A Airborne Gravity Meter with a spatial resolution of 2.5 to 3 km at 65m/sec survey speed and dynamic range of +/- 500,000 mGal*
- *An AEM-PTP Natural Source Transient Pulse EM system, measuring a frequency spectrum of 200-2200 Hz into 11 discrete bands in the time domain*
- *Tail-stinger mounted high-resolution cesium magnetometer with 1 pT sensitivity and 10 Hz or 20 Hz sampling rate with real-time digital magnetic compensation*
- *Dual-Frequency DGPS navigation & positioning with 20 Hz updates*
- *Radar & barometric altimeters*
- *Typical production rates of 700 to 800 line -km per day*

GRAV-MAG-EM - an airborne gravity, natural source transient pulse EM & magnetometer survey system for offshore and onshore oil & gas

Piper PA-31 Navajo twin-engine survey aircraft - equipped with a GRAV-MAG-EM survey system

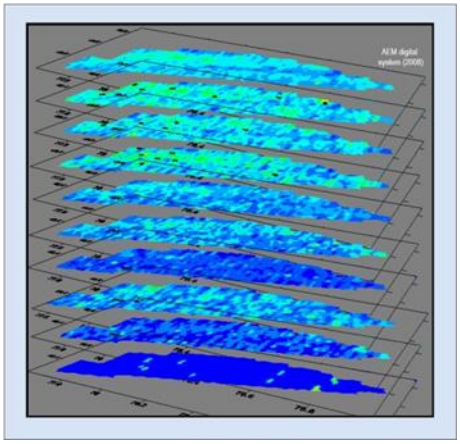
Cessna C208B Grand Caravan turbine engine survey aircraft - equipped with a GRAV-MAG-EM survey system

APPLICATIONS:

- **Locate sedimentary basins**
- **Delineate basin boundaries & structure**
- **Infer location of thickest sedimentary section**
- **Map tectonics, including structural axis, faults, causative sources and discontinuities**
- **Cost effectively place seismic surveys**

Passive Airborne Transient Pulse EM System (Pinemont Technologies)

"Airborne Measurement of Transient Pulses Locates Hydrocarbon Reservoirs" by authors LeSchack and Jackson (Search and Discovery Article #40204 (2006) describes a reliable, cost-effective, environmentally friendly remote sensing tool for finding oil and gas both onshore and offshore. Recently, major improvements have been made to automate the efficient collection of these airborne data, enabling us now to make estimates not only of the reservoirs' horizontal location, but of the depth at which they would likely be encountered.



The AEM/PTP system spectrally decomposes recorded transient energy to provide an indication of anomaly depth.

Passive Airborne Transient Pulse Electromagnetic (AEM/PTP) surveys are based on the following theory: an inherent passive electromagnetic field is present in the earth that can be sensed at the earth's surface from low-flying aircraft. Vertical components of this field contain transient random impulses of energy varying across a wide frequency range, including in the audio range.

Although speculative, it is widely believed that the impulses are related to a combination of the effects of solar plasmas, lightning activity around the world that produces electronic disturbances called "sprites" and "whistlers," seismoelectric potentials within the earth, and REDOX cells generated by vertical hydrocarbon microseepage from reservoirs into the surrounding lithology (Garcia and Jones, 2002; Boissonnas and; Cummer, 1997; Labson, et al., 1985; Vozoff,1972; Pirson, 1969; Ward, 1959, Leonardon, 1948).

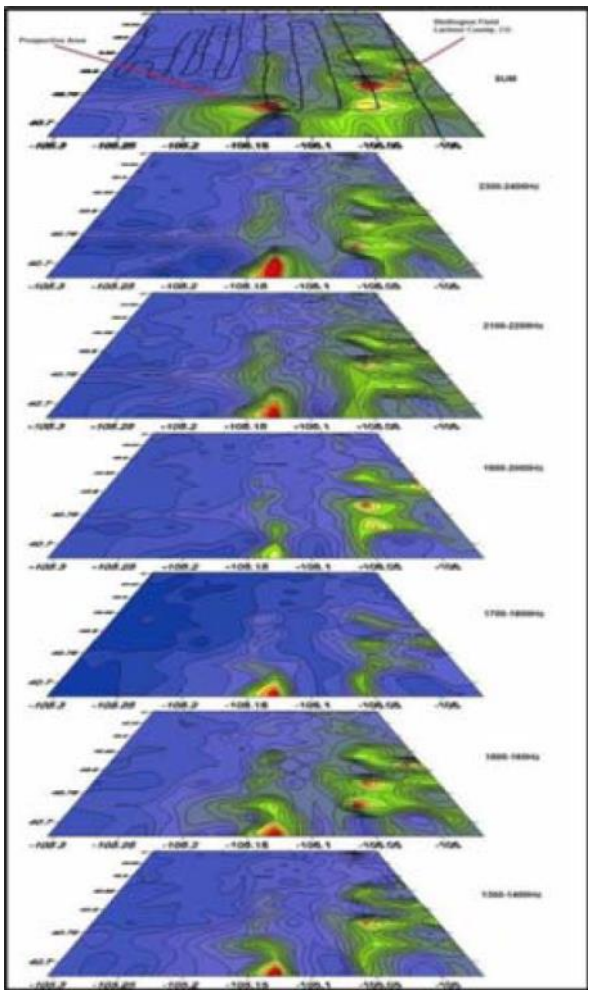
Over 130 proprietary AEM/PTP surveys have already been flown in Australia, Canada, Europe, Kyrgyzstan, New Zealand, and the United States during the past decade, comprising more than 370,000 line-kilometers of survey lines over productive areas, both onshore and offshore.

Developed in 2001 by Jackson, and first flown in 2002 over LeSchack's Devonian prospects in Alberta, more than 40 productive wells through 2007 have been documented as being drilled where Transient Pulse anomalies were present prior to drilling. As far as we know, only four non-productive wells have been drilled on positive AEM/PTP anomalies.

Recent drilling results in central Kentucky in the U.S. using the AEM/PTP technology resulted in 8 productive wells out of 11 holes drilled.

Typical AEM/PTP surveys are flown at low levels above ground or water surface. Both light planes and helicopters may be used as survey platforms. The light-weight portable sensing equipment and antenna are carried entirely within the aircraft. It does not matter if the airframe is made of aluminum or not; transient pulse signals are not attenuated either way.

The AEM/PTP system hardware



Cultural artifacts on the ground, wells, pipelines, utility lines, etc., have no affect on data quality. Flight line spacing is determined based on the size of the expected reservoirs.

The AEM/PTP Survey technology works not only onshore, but offshore also. Surveys have been flown over offshore areas of New Zealand's Tasman Sea, and the North Sea, which was ice covered at the northern extremity of the survey. Ice cover on the water did not appear to affect data quality.

Left: selected Frequency-Depth slices of an A-EM survey flown over an oilfield in Colorado are mapped and stacked by frequency/ depth.
Red indicates highest Transient Pulse activity. Interpretation of the data slices suggest the producing area for this mature field as being between the bottom two slices; i.e., 1280m and 1370m, from the Frequency-Depth Curve (as calibrated for the United States).
The top slice is the Summation of all slices. That slice also shows the flight line path, as well as suggesting an as yet undrilled anomaly.

GRAV-MAG-EM

a highly integrated gravity, EM & high-resolution magneto-meter survey system

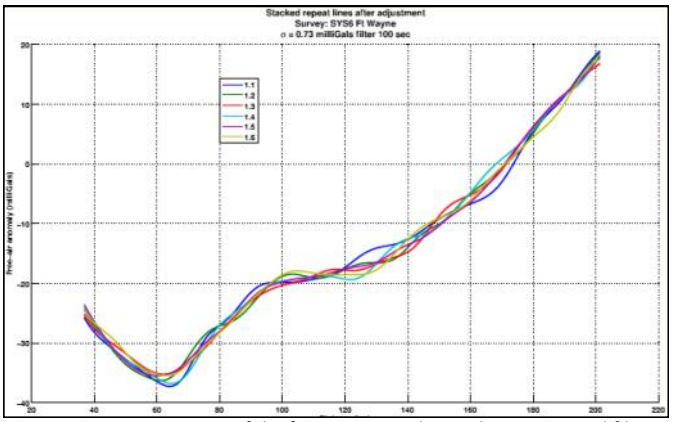
Micro-G LaCoste TAGS-6 Airborne Gravity Meter

TAGS-6 represents the latest in a long line of Lacoste-based airborne gravity systems, stretching back to the first successful airborne gravity flights in 1958 and building on the success of the TAGS system. For over 50 years, Lacoste gravimeters have acquired hundreds of thousands of line kilometers of gravity data during academic, government, and commercial surveys. TAGS-6 blends the latest in GPS and data acquisition technology with the solid foundation of the Lacoste dynamic gravimeter.

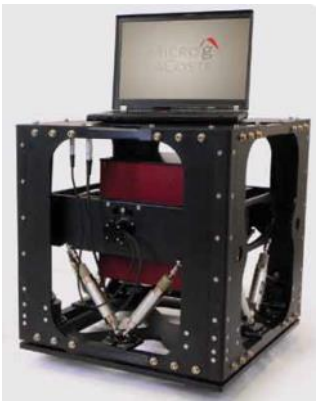
TAGS-6 is an upgrade to the TAGS/ Air III gravity meter, and is designed specifically for airborne operations. The system incorporates a time-tested, low-drift, zero-length-spring gravity sensor mounted on a gyro-stabilized gimbal platform.

The sensor has a dynamic range of ±500,000 milliGals, a resolution of 0.01 milliGals, static repeatability of 0.02 milliGals and an accuracy of 0.6 milliGals or better.

The TAGS-6 data recording rate is 20 Hz.



Six repeat measurements of the free-air anomaly . With a 100 second filter, the standard deviation of the repeats was 0.73 milliGals.



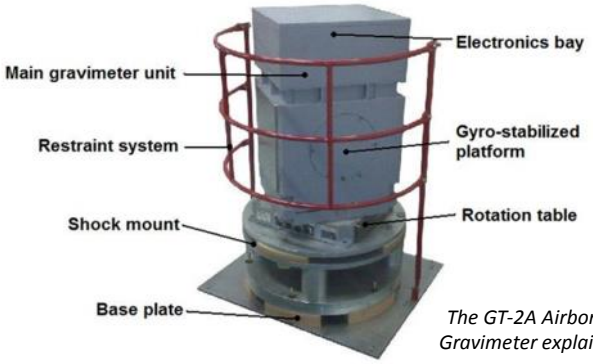
TAGS-6 gravity meter and TAGS-6 gravity meter installed in a Piper PA-31 Navajo aircraft

Canadian Micro Gravity GT-2A Airborne Gravity Meter

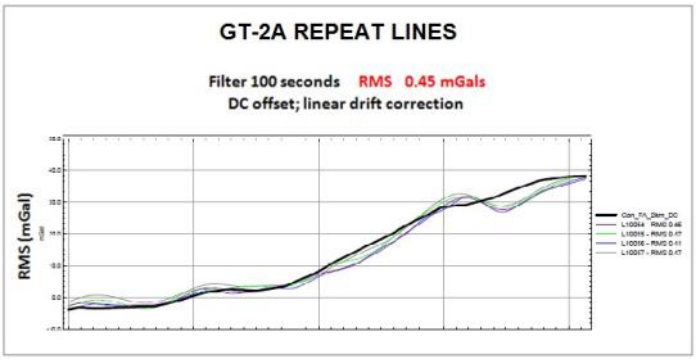
The GT-2A gravimeter is a vertical sensor, GPS-INS, scalar gravimeter with a Schuler-tuned three-axis inertial platform. The vertical accelerometer, or gravity sensing element (GSE) has an axial design with a reference mass on a spring suspension, a photoelectric position pickup and a moving-coil force feedback transducer. The GSE suspension design minimizes the effect of cross-coupling, an undesirable effect which contaminates gravity measurements with components of horizontal accelerations induced by aircraft motion. This feature allows the GT-2A to collect data in the presence of large horizontal accelerations, such as during aircraft turns or during periods of high turbulence.

The sensor has a a dynamic range of 1,000,000 milliGals, a resolution of 0.01 milliGals, and an accuracy of 0.5 milliGals.

The GT-2A data recording rate is 20 Hz.



The GT-2A Airborne Gravimeter explained



Four repeat measurements of the free-air anomaly . With a 100 second filter, the standard deviation of the repeats was 0.45 milliGals.

Airborne Magnetometer

Airborne magnetics is an excellent tool for mapping geological structure in a wide range of tectonic settings, including new and mature basins in both onshore and offshore environments. For this purpose ***GRAV-MAG-EM*** features a Scintrex **CS-3** cesium vapour magnetometer with a sensitivity of better than 1 picoTesla, installed in a rigid-boom "STINGER" extending from the back of the airplane.

CS-3 Cesium Magnetometer

The Larmor frequency outputs of the **CS-3** are processed by a Pico Envirotec **MMS-8** Smart Magnetometer Processor delivering magnetic data at better than 1 pT resolution, at sampling rates up to 100 Hz.

The Scintrex **CS-3** is a self-oscillating, split-beam Cesium Vapor (non-radioactive Cs-133) magnetometer with an ambient range of 15,000 nT to 105,000 nT. Some of its features include; Automatic Hemisphere switching; a sensitivity of 0.0006 nT √Hz rms; a noise envelope of typically 0.002 nT peak-to-peak and 0.1 to 1 Hz bandwidth.

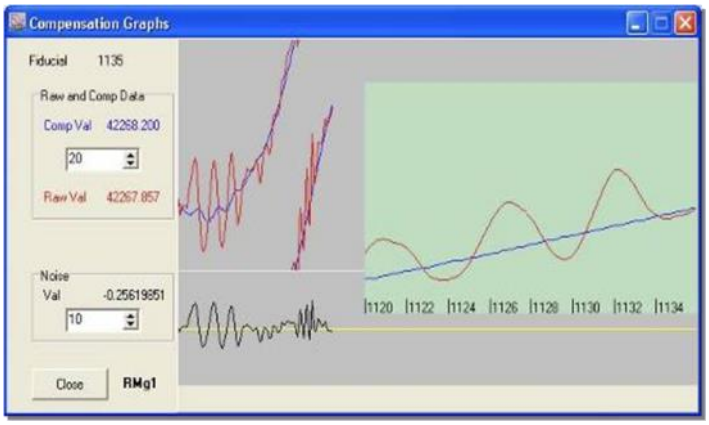
The **MMS-8 Smart Magnetometer Processor** is an intelligent high sensitivity, high resolution magnetometer processor. It is upgradeable to manage and process as many as four cesium magnetometers. It contains a continuous frequency processing input module with a signal decoupler and power control circuitry.

The processor contains synchronization input from GPS 1PPS (pulse per second), to assure precise signal sampling without quantizing errors.

Magnetic compensation is undertaken in real-time or, if required, post mission using Pico Envirotec's **PEIMAGComp** system. **PEIMAGComp** quickly creates a magnetic coefficient file to compensate magnetic data. The source data is usually a PEI binary data file recorded during a compensation test flight, however, data may also be imported from a text file. The input file must contain at least X, Y, Z data from a 3-axis fluxgate magnetometer, raw total field magnetometer data, and X & Y position coordinates for heading calculations. Usually four sets of coefficients are created – one for each of the four cardinal headings.

A Billingsly **TFM-100 (**or equivalent) Tri-Axial Fluxgate Magnetometer measures the aircraft's attitude during flight, and provides X,Y, Z data for recording by the data acquisition system**.** As previously mentioned, these data are used for the calculation of the coefficients necessary for the magnetic compensation.

Billingsley TFM-100 Tri-axial attitude sensor



Magnetic compensation coefficients calculation. Compensation coefficients are used to compensate magnetic data in real time. Compensation coefficients can also be used to compensate magnetic data in post processing

The rigid-boom stinger for the high-sensitivity cesium magnetometer on a Piper PA-31 Navajo aircraft

GRAV-MAG-EM

the magnetometer may be upgraded to a magnetic gradiometer, utilizing 3 magnetometer sensors, mounted on the wingtips and tail of the aircraft

GPS Navigation and Positioning

To provide horizontal and vertical positions during the survey, as well as steering information to the flight crew, a real-time dual-frequency DGPS system is provided.

The **NovAtel DL-V3** L1/L2 GPS Receiver is a general purpose high performance GNSS receiver particularly suited for base station and airborne rover applications. The DL-V3 incorporates NovAtel's OEMV-3 receiver board housed in a rugged aluminum enclosure.

The DL-V3 provides flexible connectivity options through Serial, USB, Ethernet and Bluetooth interfaces.

Features:

- L1, L2, L2C, L5, L-Band and SBAS signal tracking
- GPS only or GPS + GLONASS or GPS + OmniSTAR
- RT-2™, RT-20®, ALIGN®, GL1DE® and 50 Hz firmware options
- Serial, Ethernet, USB and Bluetooth capable
- 2 GB Compact Flash cards to store logged data

Benefits:

- Flexible communication interface broadens deployment options
- Multi-constellation tracking yields higher solution availability and reliability
- Removable memory provided for data security and portability
- Excellent multipath mitigation provides superior tracking performance and increased accuracy in high multipath environments

A navigation guidance system provides 2D and/or 3D steering information to the flight crew, courtesy of a PGU Navigation Display.

NovAtel DL-V3 GPS receiver

PGU Navigation Display

Base Stations and Ground Support

Magnetometer Base Station

A Pico Envirotec PBM-CS3 magnetometer base station with a Scintrex CS-3 cesium vapour magnetometer sensor will be operated continuously throughout the survey operations. The base station will be synchronized with the Differential GPS Base Station and the airborne system by GPS time. The sensitivity of this magnetometer is 0.001 nT (similar to the airborne system). During survey operations, the magnetometer will sample at a rate of once every second.

PBM-CS-3 Base Station Cesium Magnetometer

GPS Base Station

The GPS Base Station will be a NovAtel DL-V3 Triple-Frequency GNSS receiver, comparable to the airborne GPS receiver, complete with tripod-mounted antenna and a long antenna cable. During survey operations, the DLV-3 uses a standard USB Flash Drive for data logging. To process the GPS data and to undertake post-mission differential GPS corrections, NovAtel Waypoint Navigation`s GrafNAV software will be used.

GPS Base Station

Portable Gravity Meter

To perform the gravity measurements to establish a gravity base station at the aircraft base and to tie it in to an IGSN-71 network, McPhar will use a Scintrex CG-5 AUTOGRAV Gravity Meter.

The CG-5 is a microprocessor-based instrument with numerous revolutionary features that permit rapid operation in the field, yet maintaining the high precision of the gravity measurements (the instrument resolution and repeatability are 0.005 mGal).

The CG-5 AUTOGRAV is equipped with solid state memory, so that readings are recorded along with the X, Y and Z coordinates of the survey point, and the time of the measurement.

Scintrex CG-5 AUTOGRAV Gravity Meter

Quality Control, Data Processing & Interpretation

Quality Control

McPhar undertakes QC and preliminary data processing in the field at the survey base. For this purpose all our airborne systems are mobilized with a geophysicist and a PC-based data processing system to support them.

The Field Data Verification Workstation (FWS), as this system is known, can process airborne gravity, magnetic and radiometric data, and produce plots and maps in full-colour, often within hours of the survey flight ending.

The FWS software, which is the core of this facility, permits the Q.C. geophysicist to differentially correct the GPS navigation data; carry out flight path recovery; undertake gravity corrections; perform magnetic compensation and leveling; undertake radiometric corrections and preliminary processing; and generally to perform filtering, gridding and contouring of data, imaging of selected data and plotting to any map scale and layout.

Data Processing

Final data processing is undertaken at our data processing centre, which is staffed by very experienced geoscientists and equipped with a state-of-the-art network of computers, scanners, plotters and other hardware.

The interpretation of geophysical results into meaningful geological parameters is the prime function of any of our interpreters. The many highly qualified geophysicists and technicians on our staff share a strong geological background.

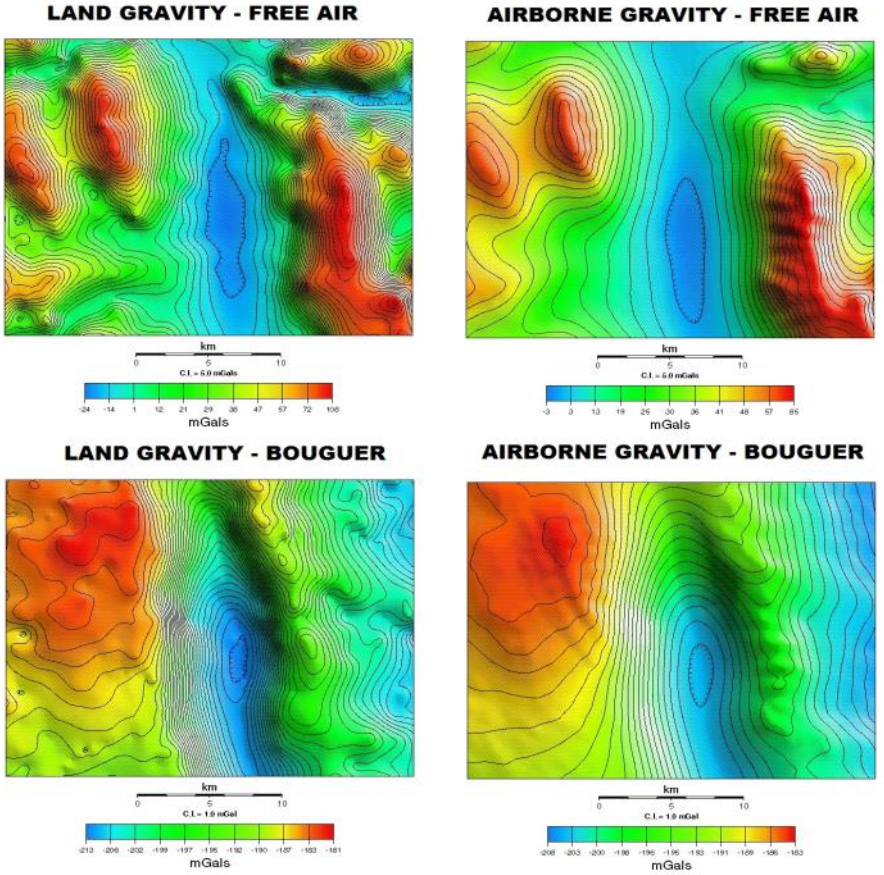
The manipulation of geophysical data is only a means to an end, and the final product of the interpretation is the compilation of a series of maps showing interpreted geological parameters.

The data processing routines and mathematical operators applied to the data are not the end product of the interpretation; they help delineate geologic and economic targets to be discussed in the final report.

We bring many techniques to bear on an interpretation project in order to determine depths to causative sources, to delineate discontinuities and boundaries, and to draw conclusions regarding geological structure beneath the survey. A wide variety of contour and interpretation maps, profiles, cross-sections and models, and a written report are the result of the interpretation.

Processing Software - Several programs are utilized to undertake data QC and to process the acquired GPS, magnetic and gravimeter data to derive z-component, scalar, relative free-air gravity and bouguer values. These software include proprietary in-house programs, Micro-G's AeroGRAV and Geosoft montaj programs.

Mapping & Final Presentation Software - Typically Micro-G LaCoste's AeroGrav, INTREPID and Geosoft montaj software is used for geophysical survey planning, QC and data processing. A single interface provides all of the functionality required to transform raw gravity and magnetic data to final products which meet Client's specifications. Intrepid and/or Geosoft montaj software may then be used to produce the final maps and profiles that are required.



A comparison of airborne and land gravity data over the same survey area – on the left is the Free Air and Bouguer maps of the land gravity data. On the right is the Free Air and Bouguer maps of the airborne gravity data