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# ADVANCES IN GEOPHYSICAL TECHNOLOGY

**THE NORTHERN MINER**

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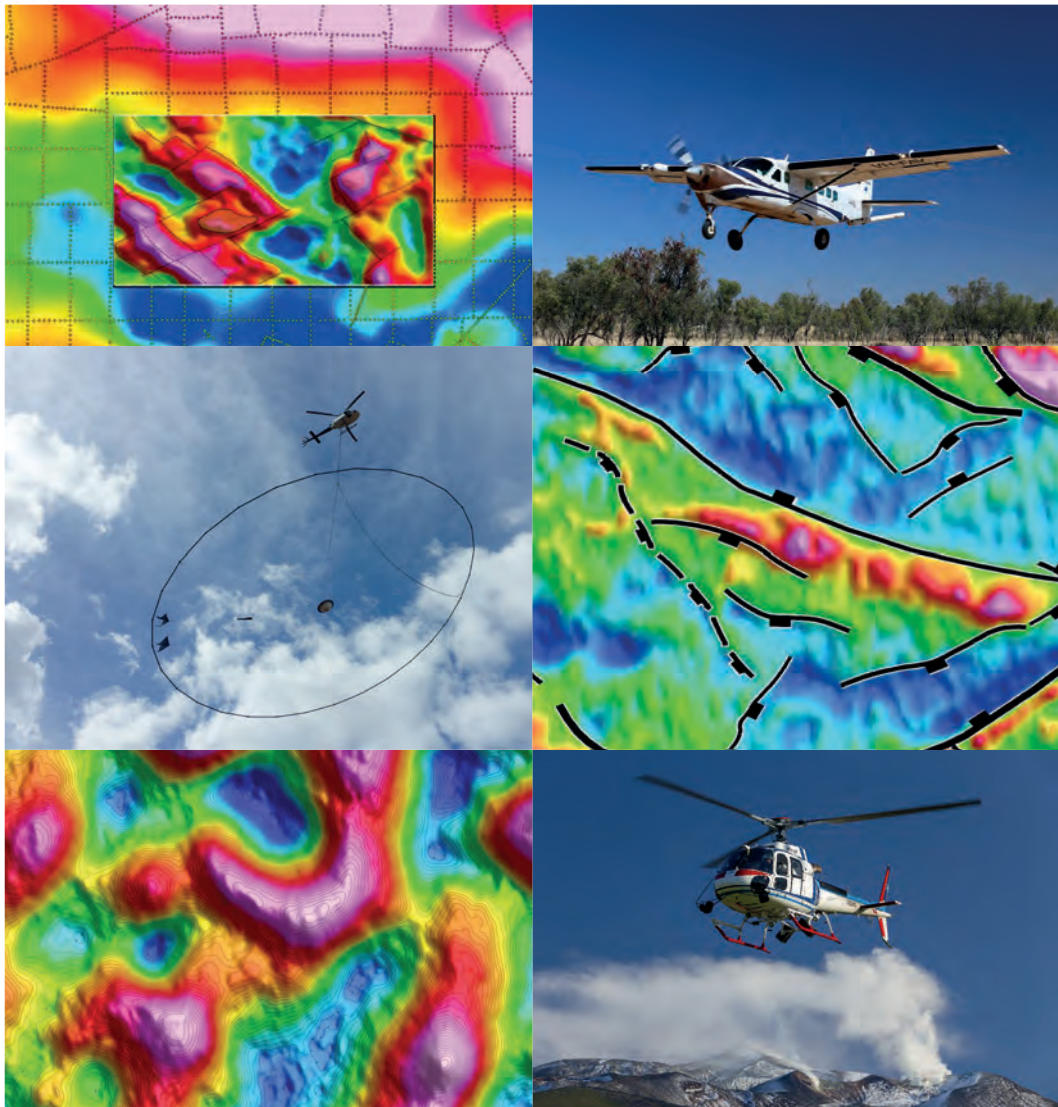
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**Cover photo:**

Geotech's ZTEM system on survey in Peruvian Andes.

Credit: Geotech

# MINERAL EXPLORATION TRENDS AND DEVELOPMENTS IN 2021

By Patrick G. Killeen Ph.D., Geophysical Consultant and retired Research Scientist, Geological Survey of Canada, Ottawa 2021



This is the sixth year that Decennial Mineral Exploration Conferences (DMEC) has served as the patron for Exploration Trends & Developments. DMEC organized the very successful Exploration '17 conference, held in Toronto in 2017, the sixth in the series of conferences which began in 1967. This year DMEC support came from the sponsoring companies listed on pages 14 and 15.

The ETD review originated with the Geological Survey of Canada (GSC), where for more than 50 years GSC scientists prepared an unbiased annual publication on trends and new developments in geophysical exploration for minerals. This marks the 30th year that Patrick Killeen has written the review, originally as a GSC research scientist.

The Canadian Exploration Geophysical Society (KEGS) was the patron of ETD between 2007 and 2016. DMEC and KEGS are committed to the promotion of geophysics, especially as it is applied to the exploration for minerals other than oil; to fostering the scientific interests of geophysicists; and to promoting high professional standards, fellowship and co-operation among persons interested in this industry.

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■ Terraquest's newest addition to its fleet, a Piper-Navajo outfitted for magnetic gradient surveys.. CREDIT: TERRAQUEST



# EXPLORATION TECHNOLOGY IN 2021:

## THE REBOUND — ARE WE THERE YET?

In 2021 the level of exploration activity is reported to have returned to “normal” despite the continued Covid-19 interference with field operations. Companies developed procedures to cope and safely conduct surveys worldwide although operations were somewhat hindered by the shortage of manpower. In part, exploration activity was stimulated by increased demand for “battery metals” used in electric vehicles and other climate change inspired innovations. It was also a year of increased mergers and acquisitions, partnerships, strategic alliances and collaboration. Formation of a rejuvenated global airborne geophysical survey contractor was achieved by combining capabilities of two companies, one from Africa and one from Europe. Numerous companies expanded their home offices, others expanded regional offices and some opened new offices in other countries. Membership in the Canadian industry-led research consortium for development of advanced geophysical software grew and is now sustained by nine major mining companies. Increased exploration activity is evidenced by a survey company reporting a record year and at least three companies adding new aircraft to their fleet.

Just about all aspects of geophysical exploration technology saw improvements, upgrades, updates, added features, or enhancements, as well as some completely new developments in hardware and software. Although R&D continues, several developments started in 2020 were lowered in priority as companies redirected resources to the increased demand for exploration services. R&D in 2020 also led to field testing of prototypes in 2021 and a few projects were postponed to 2022. Several airborne data acquisition and processing systems were developed with at least two including navigation and there are light-weight systems for UAVs. Other R&D was reported on spectral IP, on IP effects in AEM data, on extracting CSEM data from IP surveys and on improving software and calibration for ground EM.

Airborne survey contractors added new equipment to their survey fleets including four new MT systems, and a VLF EM system. Instrumentation for drones/UAVs included new gam-

ma-ray spectrometers, and new magnetometers, both onboard and in towed birds. A new potassium mag was developed for fixed wing aircraft and a version for drones is in development. A newly developed SQUID Full Tensor Magnetic Gradiometer became available in its helicopter-borne version. In AEM, new developments included a TDEM system and a passive EM system using LT SQUIDS. In air mag, there is a new horizontal magnetic gradiometer, and a newly developed hybrid gas/electric drone, aimed at drape flying TEM and MMR surveys. Two companies developed airborne gravity equipment including two new versions of strap-down gravimeters, one for fixed wing and the other for UAVs.

For physical rock properties, a new high throughput gamma-ray core logger was developed using a new type of scintillation detector with twice the density of NaI(Tl). For data acquisition and processing, several companies upgraded their receivers in the field adding more Wi-Fi interfaces and wireless data transfer capabilities including improved and enhanced remote processing. One company reported use of new computing power that increased their data processing speed by a factor of 165. New drillhole logging technology includes use of an atomic clock to eliminate use of synchronization cables in PEM and MMR surveys, a gyro tool, a video camera tool operated with a cellphone and Wi-Fi for 360 degree side views, and two IP tools, one combined with mag and slim enough to log below the drill rods. New ground survey technology includes development of NSEM equipment, field testing of a high-accuracy atomic clock in ground EM surveys, an EM Tx with increased power and efficiency, a 3D resistivity mapping technology for rapid surveys, improved wireless communication equipment, an IP system that shortens data acquisition time and a combined VLF and mag instrument for making measurements while walking without stopping. New for MT surveys were added features and improvements to UMT instruments and software including for remote connectivity and real time data uploading and remote management of MT surveys. ■■■

■ NSGDrones's quadcopter with stinger-mounted magnetometer... CREDIT: NEW-SENSE GEOPHYSICS



# CORPORATE HIGHLIGHTS

In 2021 **Aerogeophysics (AGP)**, a Moscow-based, full service airborne geophysics survey contractor completed several R&D projects and carried out surveys across Russia for resource exploration, petroleum and government mapping projects. Services include high-resolution magnetic, gamma-ray spectrometric, gravity, EM, LiDAR and aerial photography, which may be flown in helicopters, fixed-wing and UAVs.

**ClearView Geophysics** of Brampton, Ont. provides a wide range of ground geophysical surveys and value-added geophysical reports that incorporate other pertinent auxiliary geologic and historic (or new) geophysical data provided by the client. When other datasets such as spectral IP/resistivity, cesium magnetics, airborne and borehole survey results are combined they provide more reliable targeting. Quality control and target selection confidence is also improved when, for example, results from different surveys agree. The complete original and reprocessed auxiliary datasets are provided to the client for digital download from a secure server for up to six months.

**Crone Geophysics & Exploration** of Mississauga, Ont. reported a revival of their international borehole and ground geophysical survey work in 2021 as Covid-19 travel and border restrictions loosened. Advances in software, synchronization, automation and QA/QC controls during the year resulted in increased survey production, better discretization of targets at depth and improved confidence in data quality and interpretation.

**Dias Geophysical** carried out ground surveys in 2021 in Canada, the Dominican Republic, Mali, Mexico, Peru, and the United States with the main exploration targets being copper

and gold. Dias moved into their new corporate headquarters in Saskatoon, Sask., expanded their offices in Vancouver and also established a new office in Mexico. Dias Airborne, also based in Saskatoon, reported a busy year with survey activity in Europe and Canada primarily in exploration for nickel and iron ore.

Saskatoon, Sask.-based **Discovery International Geophysics** expanded operations in 2021 with multiple new hires of geophysicists and senior technical staff and by moving into a new larger facility in Saskatoon to organize and deploy multiple ground and airborne, IP and EM crews to all parts of Canada and the U.S. Low-frequency B-field TEM surveying using the **Supracon** (Jena, Germany) Jessy Deep LT (low temperature, liquid helium) and HT (high temperature, liquid nitrogen) SQUIDs, was a sought-after technology, especially to explore for new sources of battery metals. Discovery continued to offer the DIAS32 CVR technology for its Multipole IP surveying technique, which combines forward and reverse pole-dipole and pole-pole data acquisition in one pass down a survey line. The company also provides the HeliSAM technology in North America as an alternative method for rapid airborne reconnaissance surveying but with the depth of penetration of ground techniques because of the large surface transmitter used. To facilitate rapid and safe installation of large transmitter loops, its new improved HeliWinder is used.

**EON Geosciences** of Montreal continued to provide airborne high-resolution magnetic, gamma-ray spectrometric, gravity, and EM surveys using fixed-wing aircraft and helicopters. In 2021, the company again added a Piper Navajo aircraft to its

*Continued on page 6*

fleet of fixed-wing aircraft.

Airborne geophysical survey company **Expert Geophysics Ltd. (EGL)**, based in Newmarket, Ont., reported a busy 2021. To meet the growing demand for MobileMT surveys worldwide, EGL built four additional MobileMT systems, for a total of eight operational units. The company is now operating two MobileMTm systems, a compact version of the original MobileMT system, outfitted with two magnetic sensors, configured to measure the horizontal gradient of the magnetic field, and one mTEM, time-domain system designed for high-resolution near surface exploration. In 2021, EGL established a subsidiary in Australia to support exploration projects in that region.

Montreal-based **Mira Geoscience** expanded its integrated interpretation software and consulting services for mineral exploration. Its Geophysical R&D Consortium, an industry-led geophysical research collaboration following the model of UBC's Geophysical Inversion Facility, increased its membership. It is now sustained by nine major mining companies, numerous mid-tiers, juniors, geological surveys, and universities. The consortium is focused on delivering software and methods that make the use of advanced geophysics a day-to-day, practical reality for the industry. Membership provides corporate licenses to the Geoscience ANALYST Pro Geophysics software platform, which has modelling and inversion capability, formal interfaces to UBC-GIF and SimPEG codes and inversion of potential fields, resistivity, IP and EM data.

**New Resolution Geophysics (NRG)** headquartered in Cape

Town, South Africa, continued flying helicopters and fixed-wing magnetics, radiometrics, gravity and helicopter time domain EM throughout Africa, the Middle East, Australasia and Europe. The company opened a European headquarters in Spain, to become a regional provider of airborne geophysical services for mineral exploration, environmental, groundwater and geotechnical applications. NRG also added an AS350 B helicopter and an Airtractor AT504; increasing its fleet of dedicated survey aircraft to a total of ten helicopters and four fixed wing.

**NSGDrones**, based in Markham, Ont. was founded in 2019 in a collaboration between the principals of **New-Sense Geophysics** (also from Markham) and **Tundra Airborne Surveys** of St. Catharines, Ont. It offers drone magnetic surveys using a quadcopter with a stinger-based magnetometer mount and a flight time of 50 minutes. The company provides service in both North and South America. In 2021, New-Sense carried out magnetic and radiometric helicopter and fixed-wing surveys in Peru, Chile, Argentina, Canada and the U.S.

Toronto-based **Quantec Geoscience** has partnered with **Australian Geophysical Services (AGS)** to provide its deep imaging technologies in Australia. AGS is a new full service geophysical provider in Australia founded by a former Quantec manager. AGS will provide TITAN 24, SPARTAN MT and ORION 3D DCIP & MT services. The company has also established **Quantec Brasil Geosciences**, based in Brasilia to deliver a range of shallow and deep geophysical services for the Brazilian market. It continues to provide for download educational webinars, on various IP and MT methods.

**Sander Geophysics Ltd. (SGL)** based in Ottawa, provides worldwide airborne geophysical surveys for petroleum and mineral exploration, and geological and environmental mapping. Its services include high resolution airborne gravity, magnetic, EM, radiometric, and methane sensing surveys, using fixed-wing aircraft and helicopters. The company reported a busy year despite the Covid-19 pandemic, which caused a few projects to be delayed due to local restrictions. The company flew numerous combined gravity and magnetic surveys, combined radiometric and magnetic surveys, and combined EM, radiometric and magnetic surveys, as well as standalone magnetic surveys for mineral exploration and a radiometric survey for soil mapping. In 2021 SGL was awarded another large survey consisting of over 270,000 line-km of horizontal gradient magnetic and radiometric data to be flown in India for the **Geological Survey of India (GSI)**. This project also includes training and interpretation.

**Scintrex**, based in Concord, Ont., designer and manufacturer of precision gravity meters and high sensitivity cesium magnetometers, reported that its CG-6 Autograv gravity meter continued to receive very positive customer feedback and favorable independent technical reviews. Product refinements are continually being added to ensure the highest quality and reliability. The Sea III Marine Gravimeter System, manufactured by sister company **Micro-g LaCoste** of Lafayette, Colo., and introduced in 2020, is now in operation in many parts of the world. Sea trials have shown that the system performs well in higher sea states. Recent sea trials and surveys in the U.S., France and China have demonstrated that the Sea III can deliver <0.3 mGal system precision at about 1.2 km spatial resolution.

In June 2021, **Seequent**, headquartered in Christchurch, New Zealand, joined **Bentley Systems** (Exton, PA). The acqui-

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■ Aerogeophysica's strapdown airborne gravimeter in thermal case ready to install on UAV. CREDIT: AEROGEOPHYSICA

sition expanded the portfolios of Bentley and Seequent solutions, enabling their teams to work together to provide more innovative software and services. The group continued its growth trajectory in 2021 with Seequent also acquiring **Aarhus GeoSoftware** (Aarhus, Denmark) in July. The merger has extended Seequent's product offering by adding AGS Workbench, SPIA, Res2DInv, and Res3DInv providing new geophysical data processing capabilities to workflows and helping advance subsurface investigation and modelling.

2021 was a very active year for **Simcoe Geoscience** of Stouffville, Ont. It started with the launch of a new Calgary office and ended in a merger with Hamilton, Ont.-based **Geophysics HM**, a well-known geophysical provider for environmental, geotechnical, geological engineering and mining applications. The company has developed several strategic partnerships including with **More Core Diamond Drilling Services** of Stewart, B.C., giving Simcoe access to 18 drill rigs; and also with an airborne geophysical group. New airborne services include helicopter-borne triaxial magnetics and TDEM surveys. Complete integrated geophysical services with ground, airborne, and borehole capabilities are now offered. By the end of 2021, Simcoe had expanded its geographic area of coverage adding clients in Africa, the Middle East and North America. It also conducted R&D to enhance its processing and interpretation options based on spectral analysis of Alpha IP time series data.


**SJ Geophysics**, based in Vancouver, reported that 2021 was an exceptionally busy year with surveys completed across the globe. The company provides ground-based geophysical data acquisition and consulting services, specializing in 2D/3D DCIP, EM (surface and borehole), MT, gravity, and magnetic surveys. R&D has been focused on development of the next generation Volterra Acquisition System and IP transmitter.

**SkyTEM Surveys** headquartered in Denmark, and with offices in Canada, Africa and Australia, reported a huge rebound in the airborne geophysics market. Although Covid-19 continued to create barriers to travel, the company took the opportunity to grow its offices in each region to meet the demand.

**Southern Geoscience Consultants (SGC)** is headquartered in Perth, Western Australia, with consultants based in Toronto, Vancouver, and Canberra. SGC offers integrated geophysical exploration and data solutions across the entire resource industry including environmental, geotechnical, and groundwater applications. Despite the global impact of Covid, the company reported that 2021 was a record year for both the consulting

and data acquisition (Field Services) parts of the business.

**Terraquest**, of Markham, Ont., has provided high resolution airborne geophysical surveys to government organizations, and the mining and oil and gas exploration sectors for almost 40 years. The company flies gravimetric, total field magnetic, horizontal gradient, radiometric, proprietary Matrix VLF-EM surveys and recently added VLF-EM Resistivity methods. In 2021, a multi-year survey for the USGS was completed. Company-owned aircraft include Cessna 206, Piper Navajo, and a twin turbine King Air C90 with additional fixed wing and helicopters leased as required.

On June 30, 2021, **Xcalibur Multiphysics** completed the acquisition of all businesses and assets of **CGG Multiphysics** from the CGG group. The new combined group, Xcalibur Multiphysics, headquartered in Madrid, Spain, is now a worldwide provider of specialized airborne and marine geophysical services in the mineral, petroleum, and environmental sectors. The company offers these services globally from offices in North and South America, Europe, Africa, and Australia. Its services portfolio is arguably the largest available in the market for magnetics and radiometrics, gravity gradiometry, conventional gravity, and EM, all supported on fixed-wing and helicopter platforms. In addition, the company offers marine gravity and magnetics, specialized modelling software for the oil and gas industry, remote sensing, and data interpretation services. The company is currently undertaking a number of large airborne mapping projects in Africa, the Middle East, and South America. 



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# AIRBORNE GEOPHYSICAL SURVEYING



■ NRG's Xplorer magnetic and radiometric system in Australia. CREDIT: NRG

**EON Geosciences** reported its busiest year to date, with multiple crews operating for the majority of the year flying several large aeromagnetic, gamma-ray spectrometric, and VLF-EM surveys in Quebec for the **Ministry of Energy and Natural Resources (MERN)**, in Alberta for the **Alberta Energy Regulator (AER)**, in several U.S. states for the **United States Geological Survey (USGS)**, and in Norway for the **Geological Survey of Norway (NGU)**.

In 2021 **EGL** completed numerous helicopter-borne surveys using its MobileMT natural field (25 - 20,000 Hz) EM system, which combines the latest advances in electronics, airborne survey system design, and signal processing techniques to produce high quality data. Over 50,000 line-km of MobileMT data were collected in Australia, North America, South America, and Asia in exploration for gold, porphyry copper, silver, and uranium. Eight MobileMT systems, and two lightweight MobileMTm systems are now available for commercial operations worldwide. The company also offers

data processing, data inversion including inverted resistivity-depth models and interpretation services.

Worldwide airborne geophysical surveys and consulting services are offered by Aurora, Ont.-based **Geotech**, and its subsidiaries **Geotech Airborne** (Johannesburg, SA) and **UTS Geophysics** (Perth, WA) using its VTEM helicopter time-domain EM and ZTEM natural field EM systems. Also offered are fixed wing and helicopter-borne magnetic, radiometric and gravity surveys. In 2021 surveys included a large (>4,800 line-km) VTEM time domain EM and magnetic survey for the **Ontario Geological Survey** and the **Ministry of Energy, Northern Development and Mines (MENDM)** in the Saganash Lake area, near Kapuskasing, Ont. A ZTEM natural field EM survey was also commissioned by the **Geological Survey of Sweden (SGU)** in northern Sweden. The company continued a multi-year VTEM survey in parts of Rajasthan and Madhya states for the Government of India's **Atomic Minerals Directorate (AMD)**, in the Department

of Atomic Energy.

**Precision GeoSurveys**, based in Vancouver, B.C., specializes in low level airborne geophysical surveys in remote and mountainous terrain using a combination of owned and chartered helicopters and fixed wing aircraft. High-resolution magnetic, radiometric, and EM data have been collected for clients in Africa, Asia, Europe, South America, and across North America in a wide variety of geological environments. In 2021, Precision flew EM, magnetic, and radiometric surveys across Canada, in the western U.S., and in Europe. The company also reported it has reduced magnetic noise using new software and hardware as well as improvements to its EM technologies.

The following projects were completed by **SGL** in 2021: another season of combined magnetic, radiometric and SGFEM surveys in Ireland, as part of continuing involvement in the **Geological Survey of Ireland's** Tellus project; and in Canada: fixed-wing gravity and magnetic surveys for mineral exploration, fixed-wing radiometric survey for soil mapping,



helicopter gravity and magnetic gradient survey for mineral exploration and a government-funded magnetic gradient, radiometric and VLF survey. Several high resolution helicopter and fixed-wing magnetic and radiometric surveys were flown for the **USGS** to assist in exploration for critical minerals. In addition, SGL started flying a very large (>800,000 line-km) magnetic gradient and radiometric survey in Saudi Arabia.

In 2021 the Heli-GT georeferenced 3-axis magnetic gradiometer system, developed by Toronto-based **SHA Geophysics**, carried out several surveys across North America. Some notable surveys include: a survey in Nova Scotia to identify new gold trends and essential structural controls on known regional gold mineralization; a survey in central Newfoundland in the Corridor of Gold district to map structural lineaments, key to the placement of high-grade gold deposits in the area; and a survey in the Timmins mining district of northern Ontario to map continuity of geology along strike and identify drill targets. The Heli-GT's unique combination of four high sensitivity cesium sensors in a towed bird and accurate pitch, roll and yaw determination allows the measurement of total field as well as magnetic gradients in the true east, north and vertical directions, fully independent of the bird orientation. The Heli-GT data are collected by the DAQNAV airborne data acquisition, navigation and magnetic compensation system developed

by SHA. GT-Grid mapping system takes full advantage of the measured magnetic gradient information. It has been used to process or re-process more than one million line-km of gradient data collected by various airborne survey companies around the world.

As a result of **SkyTEM's** R&D, a fully digital version of SkyTEM306 HP with several new features was introduced in 2021. The MultiMoment mode combined with a dipole-moment of 500,000 Am<sup>2</sup> enables the system to deliver high resolution from surface to large depths of investigation in one operation. In addition, the integrated B-field is particularly useful for mining applications. These new features have made SkyTEM306 HP useful for both groundwater and mineral exploration applications. The company flew globally at capacity in 2021 with a roughly equal split between mineral exploration and groundwater programs. SkyTEM officially began a multi-year program in the U.S. in partnership with **Ramboll**, based in Emeryville, CA, for groundwater mapping for the **California Department of Water Resources (DWR)** based in Sacramento.

The SpectremPLUS system of **Spectrem Air** (Lanseria, South Africa), was deployed on numerous projects in South and southern Africa during 2021 for geological and hydrogeological mapping as well as mineral exploration. The system has a large transmitter dipole moment, allowing the detection of deep targets in conductive terrains, a full duty transmitter square

wave that provides good resolution of shallow targets; and full streaming of the raw data enabling user selection of time gates to optimize processing and interpretation. Spectrem has carried out TEM surveys for the **Council of Geoscience** in the Northern Cape province of South Africa as part of their strategic regional mapping projects, as well as surveys for mineral exploration clients in South Africa. The company also began large regional and infill surveys for Anglo American in southern Angola for mineral exploration.

**Terraquest** continued to provide fixed wing and helicopter geophysical surveys in 2021 while dealing with the challenge of providing safe operations during the Covid pandemic. Almost 160,000 line-km of data were acquired in North, Central and South America for both mineral exploration and government regional mapping programs. Two fixed wing aircraft acquired almost 60,000 line-km high resolution horizontal gradiometer and Matrix VLF-EM data traversing the main strike of the Newfoundland Gold Rush and an AS350 helicopter equipped with a fixed mag boom flew about 25,000 line-km in south-west NL. In South America, a record number of high-resolution horizontal gradiometer magnetic and radiometric surveys were flown with the King Air C90. In Mexico, about 10,000 line-km were flown with a Bell 206L4 outfitted with fixed boom magnetics, radiometrics and VLF-EM. In the U.S., about 65,000 line-km of magnetic and

*Continued on page 10*

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■ SkyTEM Surveys' helicopter and EM loop on survey. CREDIT: SKYTEM CANADA

radiometric surveys were flown for the **USGS**. The company added another Piper Navajo to its fleet, for horizontal gradient magnetic, radiometric and digital Matrix VLF-EM surveys.

**Xcalibur Multiphysics** did significant airborne survey work in mineral exploration for battery metals and gold using its fleet of magnetic and radiometric aircraft, as well as gravity gradient and EM systems deployed on fixed wing or helicopter aircraft. In Australia, despite the logistical challenges of Covid-19, demand for airborne geophysical surveys was very high from government groups and exploration companies. The company reported high activity levels for most of the year with two Falcon, one HeliFalcon, one Tempest, one Magnetic-Radiometric and two Helitem systems. In Canada, demand for airborne geophysical services was high in the gold and battery metals sectors despite the need for quarantine to enter northern communities. The Falcon, HeliFalcon, Helitem, and Resolve systems were almost continuously deployed, with the Tempest system arriving later in the year for government work in the U.S. Airborne EM dominated activity in Brazil with Resolve being used for a large engineering project, and several Helitem surveys being flown for mineral explo-

ration. Elsewhere in South America, the company's Colombian team continued to map the Andes with magnetic and radiometric data. In Africa, there was significant demand for regional aeromagnetic, radiometric, and gravity surveys for government clients. Interestingly, these were carried out with line spacings normally used for high-resolution surveys. This is recognition of the value of high quality data and that these surveys will form the framework for future exploration. To meet the exceptional demand in the African region, Xcalibur Multiphysics acquired three additional aircraft to bring its total fleet to twelve.

#### AIRBORNE DATA ACQUISITION AND PROCESSING

**Aerogeophysica** completed development and testing of AGDAS, a new data acquisition and navigation system. The acquisition module logs and displays data from all devices via the major communication interfaces, including Ethernet/Wi-Fi and Serial/USB. In real-time, a user can view the flight plan, background maps and data quality indicators. The company continued to develop an integrated interpretation system with geophysical inversions of airborne EM, mag and gravity data. Additional available

data (seismic, geologic and drill-hole) can be used as constraints. The newest module uses supervised machine learning algorithms to predict structural horizons based on seismic and airborne gravity and magnetic data.

**Geotech** further developed its AIP (Airborne Inductively Induced Polarization) Mapping code for its VTEM helicopter-borne time-domain EM data. The new version of the AIP code solves for all four Cole-Cole parameters ( $\rho_0, m, \tau, c$ ) (=rho subscript zero, m, tau, c) based on a half-space (non-layered) 1D model assumption. The previous version solved for only three independent parameters ( $\rho_0, m, t$ ) based on a fixed frequency factor ( $c$ ). The new AIP code provides better curve-fits of the EM decays, resulting in better accuracy of the Cole-Cole parameters.

**Mira** has added more geophysical online content to its YouTube channel. There are now over 50 new how-to and tutorial videos highlighting the company's earth modelling, interpretation, and data management software.

The launch of **Seequent's** Leapfrog 2021.1 (geological modelling application) introduced the Geophysics extension, a powerful new capability supporting the import of SEG-Y data, Magnetotelluric grids and inverse distance-weighted interpolation of geophysical data. The company's Oasis montaj core product was updated with new gridding, projections and performance improvements. Extensions have also been updated, including IP and Resistivity for better visualization and QC and processing workflows were updated for increased functionality and usability. Processing speed and quality of airborne geophysical data were improved with the new Airborne QC extension update. Improvements were also made to the Gravity and Terrain Correction Extension algorithms for a more intuitive user interface.

**Spectrem** has implemented an improved sferics filtering routine, which significantly improves data in areas where sferics are a problem. This routine is performed on the raw streamed data, as is the reselection of data channel times and widths, which allows the reprocessing of historical data as well. Collaboration with **Aarhus Geophysics** of Denmark to detect and interpret IP effects in Spectrem data is ongoing.

**TechnoImaging (TI)**, based in Salt

Lake City, Utah, reported a very active 2021 applying its 3D inversion and imaging technology to ground (Gradient Array IP, MT, and Magnetic) and airborne (VTEM, HeliTEM, SkyTEM, HeliFalcon, and Magnetic) survey data. The multi-physics data can be interpreted separately, and jointly inverted, generating 3D conductivity, chargeability, density, magnetic susceptibility, and magnetization vector (which considers remanence) shared earth models. Examples of applications include mapping Banded Iron Formations containing gold in Brazil, porphyry copper and tar sands in the U.S., gold and base metals in Canada, copper, gold, and silver in Australia, gold in Ghana and geothermal sources in Japan. Technolmaging has extended its method of IP data inversion based on the generalized effective-medium theory of IP effect, to airborne EM, making it possible to simultaneously invert airborne data for 3D distributions for both conductivity and chargeability in areas where there is an IP effect.

In 2021, Sydney-based **Tensor Research**

released a new version of their ModelVision magnetic and gravity interpretation system with improvements to its mapping and imaging system, synchronous map zoom and pan, magnetic property, demagnetization, labelling, anisotropy and vector relationships, QuickDepth and RockMod. A new suite of CET perceptually Uniform Colour tables provide alternative colour scales for geoscientists who have difficulty perceiving colour contrast in standard LUTs. LUTs can be designed conveniently with the Colour Table Editor, which produces LUTs compatible with PA Explorer, ER Mapper and Oasis montaj. In 2022 the import tool will be extended to include spheres, circular pipes and elliptic pipes. An auto-recognition system has been designed to take a large dataset generated by the Tensor Research-developed rock property and depth mapping system known as RPD Mapping. The mapping system results from the Cloncurry district in Queensland Australia, recovered compact rock property and depth information from 67,000 line-km of survey data

acquired in the early nineties. The rock property information was used to evaluate targets and prioritize follow up investigations. This AI technique provides a productivity tool that focuses on the shallowest magnetic unconformity and supplies information on depth of cover, magnetic susceptibility, the presence of remanence, possible magnetite destruction zones and quality ratings for the property estimates. The results can be visualised in 2D and 3D as point cloud datasets or converted to a 3D solid model of the interpreted surface. RPD Mapping is applied to magnetic tensor data, which is computed from conventional magnetic survey data. The magnetic tensor provides 3D information that makes it possible to apply AI techniques for the direct recovery of high-resolution geological models of the basement surface over large survey areas. It has been applied to full tensor magnetic data acquired by **Spectrem Air** using the **Supracon** full tensor magnetometer system and may now be applied to data acquired by the

*Continued on page 12*



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■ Expert Geophysics' newly developed MobileMTm system with horizontal magnetic gradiometer. CREDIT: EXPERTGEOPHYSICS

**Dias Airborne**, QMAGT full tensor magnetometer.

**AEROMAGNETIC SURVEYING**

**Aerogeophysica (AGP)** completed a number of combined magnetic and radiometric surveys targeting gold using a new light aircraft. It has a 32 L gamma-ray detector and a magnetometer in a stinger to perform low-flying surveys for high-resolution data. In 2021 AGP flew customized octocopters in low-level combined UAV surveys using a UAV-borne spectrometer with a CsI detector and a towed-bird magnetometer. To create the survey plan, a detailed DTM was first made from an aerial photography survey. The company also released the

Unimaster, an ultra-lightweight magnetometer system with high-sensitivity rubidium vapour sensors. Four channels allow measurement of magnetic gradients and a fluxgate sensor is used for real-time compensation. The magnetometer can be used with UAVs, fixed wing aircraft and helicopters.

**Dias Airborne's** QMAGT SQUID-based full-tensor magnetic gradiometer (FTMG) system surveyed over 12,000 line-km across Canada in 2021. The signal to noise level of the system was reduced by a factor of two through improvements to the mechanical damping system.

Markham, Ont.-based **GEM Systems** is developing an optically pumped Potassium magnetometer system for its

Supergrad GSMP-20S3 which presently has a sensitivity of 0.01pT. Also currently in development is DRONemag, a miniaturized mag sensor that will weigh 500 g. At less than half the weight of the already proven GSMP-35U(B) AirBIRD, the soon to be released 1.5 kg Cardinal bird has 1pT sensitivity, +/-500pT heading error and 0.1nT absolute accuracy. All of GEM's Potassium systems are capable of sampling at up to 20 Hz (standard) and can now be upgraded to 100 Hz by software and to 1000 Hz using software combined with supporting hardware.

In 2021 **RMS Instruments** of Mississauga, Ont., introduced a new, low-cost data acquisition system for high-resolution magnetometry, aimed at applications that do not require real-time compensation of platform effects. The DAS2 Aeromagnetic Data Acquisition & Logging System features the interface and processor for two Cs magnetometer inputs, an embedded dual-frequency GPS receiver supporting L-band corrections, embedded barometric pressure and temperature sensors, and ancillary data capture via high-resolution differential analog inputs and high-speed Ethernet with multiple independent logical connections. Proprietary electronics and firmware ensure perfect synchronization of the magnetometer inputs, critical in gradiometer applications. The light, compact and low-power package is designed to meet the strict requirements of UAV installations. Continuing R&D by RMS on the DAARC500-family of aeromagnetic systems includes proprietary hardware interfaces, improved tools for analysis of



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calibration data sets, and flexible connectivity to ancillary sensors and instrumentation. For magnetic anomaly detection (MAD) new algorithms were developed for efficient real-time estimation of a target's location and magnetic moment based on multiple triggers (or "passes" near the target). The technology is being developed in prototype form for the company's UAV-targeted aeromagnetic compensation systems. This RMS technology for UAV aeromagnetism was used successfully in Autonomous Underwater Vehicle applications.

SGC has been following the developments in UAV-acquired magnetism over the past few years and has now assessed and processed magnetic data from more than ten UAV systems globally. The company reported that demand for its aeromagnetic interpretation training is high with seven two-day short courses scheduled for delivery by mid-2022.

At **Spectrem Air**, development of the SQUID Full Tensor Magnetic Gradiometer is ongoing. The system developed with **IPHT** and **Supracon** is now available for helicopter boom and bird surveys. The project to fully implement the horizontal cryostat system on a fixed wing platform continues. Data processing and interpretation using routines from **Tensor Research** as well as the SimPEG inversion routine implemented by **MIRA Geoscience**, showed very good correlation with drilling results. These routines allow mapping of complex magnetic features, even in terrains where magnetic remanence is prevalent.

In 2021 **Terraquest** acquired an **RMS-AARC510** Adaptive Aeromagnetic Real-Time Compensator system and a new AS350 Survey (TRI) Boom Array from **Lake Central Air Services** based in Gravenhurst, Ont. The system flew 17,000 line-km of high-resolution magnetic survey in southwest Newfoundland at 25m altitude and 30m line spacing. Drilling has confirmed gold mineralization using geological and structural mapping based on the system data.

The **Xcalibur Multiphysics** XMAG system, comprised of wing-tip mounted magnetometers combined with state-of-the-art spectrometers, is flown with a customized Air Tractor aircraft at a very low survey altitude. This combination allows high-resolution data acquisition in a variety of survey environments. The aircraft are degaussed to improve

signal to noise and the navigation system permits extremely accurate flying. Spatial resolution and signal-to-noise ratios improve dramatically when flying height is reduced. Low-level data provides significantly more detailed information for kimberlite detection, base and precious metal exploration, litho-structural and geo-hydrological mapping, and mine planning. In Africa and the Middle

East, demand for the XMAG system was strong with surveys being carried out in Uganda, Togo, DRC, Benin, Zambia, Zimbabwe and South Africa in 2021.

**AIRBORNE ELECTROMAGNETIC SURVEYING**

**Aerogeophysics** launched its newest time-domain EM helicopter system *Continued on page 14*




Discovery  
Drone  
Geophysics

Discovery Geophysics, known as the leader in innovation for geophysical exploration, is evolving into the drone market to assist clients to collect data in the "missing zone" between the ground surveys and airborne surveys.

### Skyfront Perimeter 8 Hybrid Drone



- Hybrid battery + gas engine drone
- 17 kg drone weight
- 7 kg payload capable
- 4 hour flight time
- Stable flight
- Long telemetry range
- Manufactured in Silicon Valley

### Geometrics MagArrow



- UAS Deployable Magnetometer
- Weighs only 1 kg
- Can be easily attached to Skyfront
- GPS, storage and WIFI on board
- Fly faster, up to 10 m/s with samples every 1 cm
- Filters out drone motor noise
- 2 hours of battery life, hot swappable
- Superior Data Quality

### Wingtra One Photogrammetry Drone



- Vertical take-off and landing for dense spaces
- Fully Automatic – Safely collects hundreds of acres with simple, user-friendly inputs
- Immediate access to georeferenced High-Resolution Images
- DSM data output for other drone surveys

# ETD

EXPLORATION TRENDS & DEVELOPMENTS

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## GOLD SPONSORS



named **HorizOND**. It is equipped with a high power transmitter and a fully digital three-channel receiver, which has a new suspension system increasing the signal-to-noise ratio. The transmitter base frequency is 12.5/25 Hz. The system can be easily reconfigured to suit different geological environments. The first commercial survey with the **HorizOND** system was completed in 2021. The company also continued to improve its frequency-domain EM system, which is effective for mineral exploration in resistive environments due to its high sensitivity to small variations in resistivity. The latest version may be towed beneath any helicopter, however the most common configurations are fixed to a specific helicopter or fixed-wing aircraft.

**Dias Airborne** introduced **QAMT** (airborne MT), a passive EM system that uses **LT SQUID** sensors to measure the x, y, and z B-field components. The ability to use these three low-noise components individually in the processing provides higher resolution results. Full base rotation data including three-component B-field and two-component E-field datasets can be combined to produce a range of imaging products that have industry-leading resolution and depth search capability.

**Discovery** offers the **HeliSAM** (Heli-borne sub-audio magnetics) technology for hybrid ground/airborne TEM and MMR surveys in North America in an agreement with Brisbane-based **Gap Geophysics Australia**. **Discovery's** patented **HeliWinder** is used to deploy transmitter wire 90% faster than traditional ground wire deployment methods with corresponding added safety. A new improved lightweight **HeliWinder** is 50% lighter and can handle up to 750 kg of wire from a large helicopter or a light load if operated from a smaller helicopter. The **HeliWinder** is particularly useful in mountainous and heavily forested terrain. Working with Saskatoon-based **Dragonfly**, an established drone manufacturer, the company has developed a state-of-the-art hybrid gas/electric drone, with the ultimate objective of draping flying low speed, low frequency, TEM and MMR **HeliSAM** surveys.

**EGL** initiated commercial surveys with its newly developed **MobileMTm** system, which is a lighter version of the **MobileMT** bird with two **Geometrics** 822A magnetometers, separated by 4 m, configured to measure the horizontal gradient of

the magnetic field. The **MobileMTm** bird is towed on a 55 m longline below a helicopter. It is designed to provide apparent resistivities from near surface to depths of several hundred metres, together with total field and horizontal gradient magnetic data. The **MobileMTm** system was successfully tested over known kimberlites in Ontario. In 2021, the company flew surveys with **mTEM**, its innovative air-

borne time-domain EM system which uses a controlled source primary field. It is used for detailed near surface (0 - 50 m) investigations and is believed to be the only system in the industry able to record clear data in industrial areas with EM noise.

The exploration come-back in 2021 kept **Geotech's** crews fully engaged in surveying and limited its time for field *Continued on page 16*



EXPLORATION TRENDS & DEVELOPMENTS

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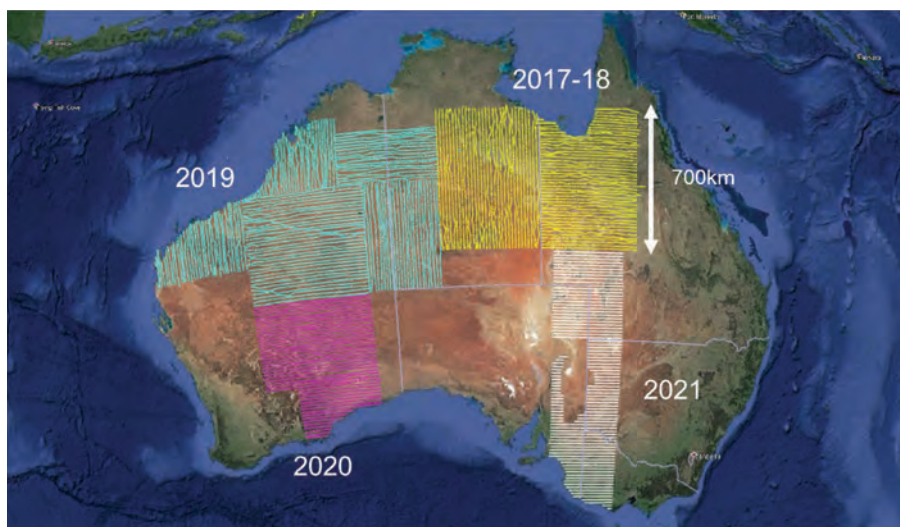
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■ AusAEM surveys from 2017 to 2021 showing over 210,000 line-kms of Xcalibur Multiphysics' Tempest data over six states in Australia. CREDIT: XCALIBUR

testing R&D projects, which are now rescheduled for release in 2022. These developments include a new high speed, full waveform, Streamed Data Acquisition System for its VTEM TDEM systems, a new generation VTEM TDEM transmitter, and its next generation Blackbird TDEM system prototype. In terms of natural field EM systems, the company continued development and testing of its new ZTEM Lite receiver with modular aerodynamic design and its next generation ZTEM 3D system that combines its AirMT prototype and full 3-axis AFMAG tipper measurements in the 22 to 30,000 Hz frequency band.

SGC's Field Services now include four crews offering surface and downhole EM, passive seismic, and ground magnetic data acquisition. Demand for field crews, particularly EM, in Western Australia has been very high due to both increased exploration and Covid-related interstate travel limitations. Downhole EM crews are operating from both surface exploration and active underground mining operations. Additional high-powered transmitters and DigiAtlantis DHEM probes have been purchased to meet demand. SGC was an early investor in the development of LoupeTEM, a state-of-the-art moving-loop EM profiling system for high-efficiency surveys of electrical conductivity. It has many applications in geotechnical investigations such as dam and tailings storage facility seepage mapping and monitoring, water quality and depth to groundwater assessments, shallow conductor mineral exploration and geological mapping, grade control and

underground surveys. To meet increasing demand for near-surface environmental and hydrogeological applications, SGC now has in-house electrical resistivity imaging (ERI) capability with the acquisition of an **ABEM** Terrameter system.

**Spectrem Air** upgraded its EM receiver system to include full tracking of the receiver sensor position and orientation, as well as new enhanced data acquisition. The upgrades include a revised suspension to lower noise levels caused by sensor movement and improved electronics to reduce electronic noise of the system.

Based on increased demand for VLF data acquisition, **Terraquest** commissioned the design and production of a second generation, proprietary digital Matrix VLF-EM system using circuitry and techniques adapted from current EM signal research. It is fully tuneable and can monitor up to four frequencies, recording full parameterization of the VLF-EM signal including total field amplitude, vertical ellipticity (proxy for quadrature), planar ellipticity, tilt angle ellipse (proxy for in-phase), Tipper coefficient and azimuth to VLF transmitter. These data have now been successfully inverted to produce well defined and coherent resistivity products, corroborated by IP and drilling. Final products include resistivity maps, depth slices, vertical sections, 3D databases and voxels in Geosoft format, allowing user selected visualization of the 3D model for enhanced interpretation.

**Xcalibur Multiphysics** offers three EM technologies with unique techni-

cal features and deployment options, Tempest, Helitem and Resolve. The Tempest fixed wing time domain EM system, combines high quality, fully calibrated EM mapping with the efficiency of a fixed wing aircraft. To meet the growing global demand for Tempest surveys, Xcalibur Multiphysics is building two additional Tempest systems, with fabrication and construction started in the third quarter of 2021 with systems to be operational in 2022. In Australia, the Tempest system continued to work on the regional coverage of the AusAEM series of surveys for **Geoscience Australia**. To date it has been contracted to fly over 210,000 line-km across six Australian states. In 2021 two surveys flew over 40,000 line-km in the Goldfields region of Western Australia and the Eastern Resources region bordering QLD, NSW, VIC and SA. These projects illustrate the suitability of Tempest for large regional scale mapping. The system returned to the U.S. in late 2021 to continue hydrogeological mapping along the Mississippi floodplain of various southern U.S. states. The Helitem2 system uses a square transmitter wave which enables early off-time measurement and effective energizing of deep conductive targets. It can operate at base frequencies as low as 6.25 Hz due to an upgraded receiver system. Currently Helitem2 is the only helicopter time-domain EM system operating commercially at this low base frequency. In Australia in 2021, two Helitem2 systems completed surveys in four states including in the Julimar region for nickel-copper-platinum group elements (PGE), in the Pilbara Region for iron ore, in the Paterson region for copper-gold and in South Australia, Queensland and New South Wales for base metals. Helitem surveys were conducted in several provinces and territories of Canada mostly for mineral exploration, nickel being the most common target due to the very low base frequencies of the Helitem and some hydrogeological mapping. In Brazil, several Helitem surveys were completed for mineral exploration in the states of Mato Grosso and Para. The Resolve frequency domain airborne EM system provides accurate near-surface resistivity information, which is particularly important for engineering applications and water exploration, as well as gold exploration in resistive environments. It is well suited to operations in very rough terrain due



to its low weight and geometry. A large engineering project was flown with Resolve in Brazil and it was also deployed in Canada, and the U.S.

**AIRBORNE GAMMA-RAY SPECTROMETRIC SURVEYING**

In 2021, **Radiation Solutions Inc. (RSI)** of Mississauga, Ont., continued to develop and manufacture the most widely-used gamma ray spectrometers worldwide. Successful investigations using the RS-530 (formerly known as DDS-3) UAV-mounted spectrometer, have resulted in increased interest in this technology for numerous applications. The RS-530 uses a 3"x3" (0.39L) NaI(Tl) detector and spectrometer assembly weighing only three kg. It offers enhanced GPS configurations, records K, U, Th, TC and full spectrum (2048 channels) data, allows numerous data file formats, and supplies altitude corrections embedded in the data analysis software. During the summer of 2021, the **British Columbia Geological Survey (BCGS)** successfully conducted numerous geological mapping surveys using the RS-530. The BCGS will present the results at the 2022 AME Roundup in Vancouver.

In 2021 **Terraquest** completed its final year of horizontal magnetic gradient and radiometric surveys for the **USGS** in support of its multiyear "GAP" mapping project. Merged with previous surveys to the west and east, encompassing parts of Missouri, Illinois, Indiana and Kentucky, the data are part of ongoing scientific studies for crustal plate tectonics, earthquakes, environmental and critical mineral assessment. On the east coast, the USGS released results and interpretation of two, contiguous radiometric and horizontal magnetic gradient surveys flown by Terraquest, totalling about 94,000 line-km stretching from the foothills of the South



■ Conducting mag sensor pre-survey QC check with SHA Geophysics' wireless DAQNAV 3D system. CREDIT: SHA GEOPHYSICS

Carolina Piedmont across the coastal plain and flood plains to the Atlantic Ocean. The radiometric surveys were used to determine the source of critical minerals and their transport routes, depositional sites, plus reworking and re-deposition along the Atlantic (details are in **Geological Society of America 2021 publication GSA Today**, Vol. 31 No.11).

**AIRBORNE GRAVITY SURVEYING**

At the beginning of 2021, **Aerogeophysica** tested performance of its new strapdown gravimeter by test flights with the well-known GT gravimeter. The new device showed comparable accuracy and tolerance of disturbing accelerations. Due to its compact size and relatively light weight, the strapdown gravimeter was installed on a heavy UAV for the first test flights.

For the first time in Russia, a multi-parameter commercial survey was carried out combining airborne gravity with EM, radiometric and magnetic sensors. The newest strapdown gravimeter makes it possible to fly with full drape for EM and gamma-ray spectrometric surveys. AGP has also upgraded its GT airborne gravimeter by updating the sensitive gravity element, built-in program, gyros and electronics in a gyroscopic stabilization platform. This modification is named GT-3A.

**NRG** announced a major new development; the NxT generation airborne gravimeter. A new laser ring gyro strapdown Inertial Measurement Unit (IMU) gravimeter has been commissioned, after an extensive test program, by **NRG Exploration** in South Africa. The NxT *Continued on page 18*

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■ Precision GeoSurveys conducting magnetic gradient survey at Oatman, Arizona.  
CREDIT: PAUL BURNETT

system collects sub milligal gravity data with a full wavelength of 2800 m. It does not need a traditional stabilized orientation platform because the orientation is solved mathematically using a triad of gyroscopes. The strapdown unit has greater dynamic range and is less sensitive to turbulence and aircraft attitude changes. The recovery time from external disturbance is extremely quick as there are no mechanical moving parts. The unit is mounted in a patented thermally controlled housing that greatly reduces long term drift. It is now possible to measure accurate low-level grav-

ity simultaneously with either magnetic, radiometric, or electromagnetic data without compromising the tight drape flight pattern required for low level geophysics. Excellent signal to noise ratio is retained while collecting sub mGal accuracy gravity data. The NxT system can be added to enhance either helicopter or fixed wing geophysical platforms.

Several gravity surveys for mineral exploration and geological mapping were flown by SGL in 2021, using fixed-wing aircraft and helicopters. Surveys were flown predominantly in North America, due to local restrictions preventing the

start of some overseas projects. For all surveys, airborne magnetic data were recorded simultaneously with the gravity data using its improved AIRGrav system. AIRGrav provides high accuracy and resolution vertical gravity, as well as providing the two horizontal components. SGL has 12 AIRGrav systems operating worldwide.

**Xcalibur Multiphysics** deployed the **CMG GT-2A** gravity meter to East Africa in 2021 to acquire airborne gravity data to assist with regional geological mapping on a large project. The Falcon family of high sensitivity Airborne Gravity Gradiometry (AGG) systems were designed specifically for use in light aircraft and helicopters and engineered to isolate the instrument from aircraft-induced noise. It arguably offers the highest resolution airborne gravity data for small targets. The company operates six Falcon systems globally and in 2021 surveys were flown in Australia, Africa, Indonesia, Kazakhstan and North America, targeting predominantly gold, followed by oil and gas, iron ore, and base metals. Heli-Falcon AGG systems were also deployed on a large regional geothermal mapping program for **JOGMEC** in Japan, and for high resolution mineral exploration programs in Canada, Australia and South America. Falcon Plus is Xcalibur Multiphysics's premium airborne gravity gradiometer (AGG) system, claiming to produce the lowest noise gravity gradient data compared to other commercially available systems. Primary applications in 2021 were gold exploration in Australia and Canada and other mineral exploration projects worldwide where a helicopter platform is used in rugged areas and where ultra-high resolution gravity data are required. A Falcon AGG system is used to acquire high quality short to medium wavelength gravity data, while simultaneously a sGrav airborne gravimeter is used to acquire high quality long wavelength gravity data. These data streams are integrated to obtain a high-accuracy gravity signal over a broad bandwidth, which significantly improves imaging at depth and increases spatial resolution for near surface geology. Full Spectrum Falcon was deployed in Australia, Africa and North America in 2021 and was in high demand by oil and gas, and other explorers interested in both short and long wavelength gravity information. **END**

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■ Quantec Geoscience crew deploying an MT survey in northwestern B.C. CREDIT: JORDAN SAMPSON

# GROUND SURVEY TECHNIQUES



## PHYSICAL ROCK PROPERTIES & ELEMENTAL ANALYSIS

**Terraplus** of Richmond Hill, Ont., introduced the CORELA, designed by **Crytur** and **Georadis** in the Czech Republic. The CORELA is an advanced gamma-ray core logger designed for high sensitivity and high throughput with easily adjustable sampling interval. Based on the concept of conversion of sequential single point measurements in parallel multipoint processing, multiple core samples can be fully scanned simultaneously by employing multiple detectors. It features GAGG detectors, the next generation of scintillation detectors, with FWHM resolution similar to NaI(Tl) detectors but with double the density and sensitivity. This new detector type allows the CORELA to use smaller detectors while still providing maximum sensitivity and minimizing the weight of the local background radiation shielding.

## GROUND DATA ACQUISITION AND PROCESSING

In 2021, **Condor Consulting**, with offices in Lakewood, Colo. and Vancouver, B.C., reported a marked improvement in market conditions, requiring an expansion of staff for the first time since 2013. Project profiles remained an even mixture of assessing legacy data and new

survey results, with projects in Alaska, across Canada, Nevada, Colorado, the South American Cordillera and Europe. Several clients have taken on the search for battery metals and Condor offered a mixture of traditional and innovative approaches to support this search. To produce geologically realistic outcomes, the company continued to advance joint inversion of disparate but complementary airborne EM data sets as well as airborne EM and ground surveys such as MT, CSAMT and DC resistivity. A number of clients reported exceptional exploration results in 2021, based in part on Condor's assessment of their geophysical survey results, typically integrated with client-provided geology and other geoscience data. An example is the recent result from the **Solaris Resources** Warintza project in Ecuador where the 3D modeling of **Geotech** ZTEM data provided high resolution sub-surface imaging of a high grade porphyry copper-gold system.

**Crone Geophysics** has upgraded many of its Pulse EM receivers to their new standard CDR4s, which contain embedded CPUs, that enable faster processing. Increased data transfer speeds and USB 3 enables streaming of individual sampled data (up to 100 kHz for full-waveform data) to be stored for every component and transferred routinely to high capac-

ity storage for every survey.

**Dias Geophysical** made numerous advances in its processing and inversion capabilities in 2021. For DIAS32 resistivity and IP surveys, convolution neural nets were used to reduce the time needed to analyze time series data for quality control. Dubbed "Friday AI", the software package was created to identify problem sections in resistivity and IP time-series and flag them for downstream processing. For DIASMT/CSAMT/AMT surveys, empirical mode decomposition was integrated with CSAMT processing to improve frequency extraction, and MT processing was improved with wavelet analysis for advanced event detection. In addition, all Dias services are migrating to the Caravel web application to support centralized data integration with PostgreSQL Databases. On the inversion side, parallelization of the company's proprietary frequency domain inversion codes was implemented to support fully scalable cluster inversions for reduced inversion time of both resistivity and magnetic gradiometry data sets. Residual analysis tools were built to assess how well parameters like frequency, dipole size, transmitter-receiver separation, observed stations, etc., fit modelled results. SimPEG inversion

*Continued on page 20*

codes were expanded to support CSAMT acquisition and processing, and a line current source was implemented in the frequency domain inversion code to support the near-field data inversion. At this point, all acquisition services are fully supported with processing and inversion.

The most popular and exclusive geophysical survey technology offered by **Discovery** is LT and HT SQUID TEM surveying. LT SQUID has become more popular lately because of its greater sensitivity, in spite of the extra expense and more difficult logistics of liquid helium. Typical frequencies most often used are less than 5 Hz with 0.25 Hz being most popular and now even down to 0.125Hz, with the recent increased interest in detecting high conductivity metals at depths of a kilometre or more. Discovery also provides higher frequency 3D coil and fluxgate TEM surveys, borehole coil and fluxgate TEM surveys and a wide range of IP survey methods, including 3D enhanced borehole IP, using the DIAS32 CVR technology. A major advantage of the DIAS32 CVR technology is the ability to survey in

any terrain and even across open water. A wide range of transmitters sourced from Australia, the U.S. and Canada are used in these surveys, from 5 kW to 50 kW, depending on the application.

The development of matched filter processing software, Slproc (Step loop processing) for the imaging of multi-fold step loop UTEM5 by Kingston, Ont.-based **Lamontagne Geophysics** continued in 2021. The processing was ported to an in-house HPC compute cluster that increased the processing speed by a factor of 165 over that achieved previously with two high end desktop machines. It is now possible to consider a much greater variety of model signatures. Runs with 1.4 million signatures are now done routinely whereas it was previously limited to less than 100,000 even with weeks of processing. The SLproc code development is also continuing, aimed at joint processing of multiple step loop traverses to obtain sections over strike lengths of several kilometres.

In 2021 **Mira Geoscience** worked with **HiSeis** of Australia to incorporate 2D and

3D seismic data structures and seismic survey designer tools on the Geoscience ANALYST platform. Through the free 3D viewer, SEG-Y 2D and 3D can now be imported and viewed as large seismic cubes with good, interactive performance. Other standard visualization features include arbitrary slicing of the 3D volume, transparency, chair clipping, and co-rendering of seismic attributes. The seismic survey planning tool includes ray path modelling. With the version 3.4 release of Pro Geophysics **Mira** expanded its connection to VP Geophysics Suite with additional inversion styles and drillhole pierce-point constraints. It now supports connection to on-premise, high-performance computing. A waveform designer for TEM data, new options for Maxwell channel files, a new UI for assigning uncertainties, and complete I/O for TEM data are now included. The open-source tool catalogue has a new GUI for gravity, magnetic, and DC/IP 3D inversion (SimPEG), an update to the latest SimPEG v0.5, and implementation of the  
*Continued on page 22*

# HELI-GT

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working permanently

DC/IP survey type in the geoh5py Python API. VPmg heterogeneous inversions are now also available. Geoscience ANALYST Pro continues to offer low-cost geophysical tools, including unlimited numbers of gravity and magnetic inversions with the addition of EM-channel editing and merging, and changing coordinate locations on DC/IP objects.

**Quantec** reported conducting R&D to extract CSEM responses from IP surveys. The company records full-waveform time series in DCIP surveys, which includes the IP response of the subsurface as well as the EM response that is normally rejected in IP processing. Because Quantec processes IP data in the frequency domain, any other part of the subsurface signals can be extracted, including the EM response, which now may be extracted from an array-based IP survey. The EM response is calculated for the very wide frequency band allowed by the acquisition specs. The significance of the data in a particular frequency band and its potential for a joint inversion along with other EM data is currently undergoing R&D in collaboration with another industrial partner. The company continued to improve and enhance its remote processing capabilities to reduce survey costs. By making better use of expanding internet interactivity it can allow the data processor to work from home eliminating the cost of an extra man on a survey crew. The company manufactured 22 more QRT-160

data receiver modules to increase survey capacity. The QRT-160 provides full frequency MT data recording for SPARTAN surveys. The robust receiver is also core to multi-parameter TITAN 160 DCIP and MT 2D surveys and for full frequency array-based MT in conjunction with Distributed IP. It is also used for full 3D ORION DCIP and MT surveys. New to the QRT-160 is a Wi-Fi interface that allows data logger configuration via any browser-enabled device. Many new Quality Control features are built into the QRT-160, such as sensor impedance, self-potential, on-demand state of health testing, as well as wireless data transfer. The Wi-Fi interface will be retrofitted to existing equipment as they cycle through for routine maintenance. The company also developed upgrades and retrofits for the existing low frequency MT coil inventory to increase the specifications on the coils to full broad bandwidth. To proactively identify and fix equipment that needs attention, Quality Control tools now include two smart devices, the QSIM and Spider, which can capture component information such as serial numbers and sensor impedances. Improved battery and magnetic field sensor technologies also reduce costs and enhance data quality.

#### DRILLHOLE METHODS

**Abitibi Geophysics** reported that the development of the ARMIT B-field borehole EM system was upgraded to include

simultaneous dB/dt and B-field measurements. The project is now rescheduled for field testing in 2022.

The high reliability and accuracy of **Crone Geophysics'** new atomic clock under adverse field conditions means that Borehole Pulse EM surveys with fluxgate or coil sensors (B or dB/dt) as well as MMR surveys can be done confidently without a connecting synchronization cable. Underground borehole surveys can also benefit from this more accurate clock.

Denver, Colo.-based **Mount Sopris Instrument (MSI)**, along with technical partner **Advanced Logic Technology (ALT)** of Luxembourg, have made modifications and enhancements to their borehole IP tools addressing the needs of the mining community. In addition to standard current injection/release times of 100, 250 and 500 mS, the new generation QL40-IP-2G tool now has user-selectable injection/release times ranging from 100 to 2000 mS, with chargeability measured at two spacings (40 and 160 cm) and simultaneous full-wave digitizing of electrode voltage at each spacing. The 24 bit / 0.5 mS ADC with real-time filtering and processing provides 1.2 microvolt resolution with an output impedance of 1.4 M-Ohm. Real-time IP inversion produces best-fit relaxation curves and relaxation time decay plots.

In 2021, **MSI** and **DGRT Australia** started delivery of a new fully digital 43 mm diameter HDMI (1280 x 960) quality downhole video camera. Users of the MSICAM360 can operate the system with a cell phone, tablet, or personal computer and uphole control unit with Wi-Fi. Rated at 200 Bar and 70°C, this new downhole tool runs on compact, small-footprint portable and semi-portable single-conductor wireline winches common in the mineral exploration industry. Video processing allows front facing and full 360-degree side views to be recorded simultaneously.

MSI, working with Australian based partner **Axis Mining Technology** is now renting and selling the Champ Navigator multi-functional north-seeking solid-state downhole gyro tool in the U.S. The Champ family of tough, rugged, and reliable borehole gyro tools are memory north seekers, single or multi-shot and high speed with continuous operation and rig alignment in five minutes. These systems are run on cable and wirelines, on drill rods, in overshots, etc. and can be pumped into boreholes.

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**SJ Geophysics'** new 32 mm version of its Volterra Borehole System first introduced in 2020, achieved regular use in commercial surveys in 2021. The now shorter and lighter Volterra-BH system can survey below the drill rods, allowing boreholes at risk of collapse to be surveyed safely and efficiently, as well as horizontal and up-dip oriented boreholes.

#### GROUND ELECTROMAGNETIC METHODS

In 2021, Toronto-based **Advanced Geophysical Operations and Services (AGCOS)** completed the development of its natural and controlled-source EM technology (NCSEM), an integrated high-precision, high-sensitivity EM exploration system for mining exploration and geological mapping to a depth of 2 km. The company reported that NCSEM, combined with its proprietary field array has proven its effectiveness in small- and large-scale surveys. It is a portable, scalable and robust technology that can in a single pass, map deep geological structures, which control mineralization as well as solve com-

plex tasks such as detecting multiple thin quartz veins. AGCOS also supplies turnkey multifunction EM data acquisition systems with support for up to 18 ground EM methods that can be configured to deploy any array and any combination of methods. It continued to further improve and upgrade its multifunction EM receivers GEPARD (AMT/MT, MVP, CSAMT, FDEMS-IP, TDEM, IP, Resistivity, SIP, VLF, SP), low, mid and high-power transmitters (1 A to 300 A), sensors, software and accessories to simplify field operation, increase productivity and streamline data acquisition and processing algorithms with enhanced QC/QA procedures.

**Crone Geophysics** provided borehole/surface Pulse-EM surveys throughout 2021 and continued to improve the system. Improvements include a new atomic transmitter clock that is currently undergoing late stage field testing prior to large scale production in early 2022, allowing very accurate synchronization between transmitter and receiver even in heavy canopy cover, valleys and underground where GPS signals are weak or non-exis-

tent. Paired with older generation 4.8 kW transmitters or integrated into the new 20 kW transmitter and CDR3/4 receivers, these atomic clocks enable more precise synchronization while eliminating most environmental effects. For high-sensitivity B-field Pulse EM surveys, lower noise SQUID sensors have been acquired and are currently undergoing field testing.

Development of the UTEM 5 transmitter series by **Lamontagne Geophysics** began a new phase in 2021 with the prototyping of a new model (U5XTX) boasting an increase in both maximum output voltage across the loop from 630 V to 830 V and in output power from 11 kVA to 14 kVA. The new model is particularly suited for the light wire gauge transmitter loops of 1500 m size or more used in deep borehole UTEM surveying. The last of the UTEM 4 transmitters in service were replaced in 2021 by the more efficient UTEM 5 transmitters models U5MTX (8 kVA) and U5HTX (11kVA). The UTEM 5 transmitters have a power efficiency of more than 90% due to their high frequency switchmode

*Continued on page 24*



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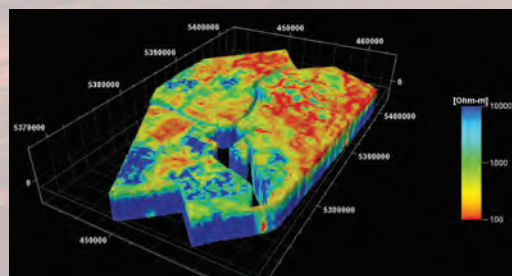
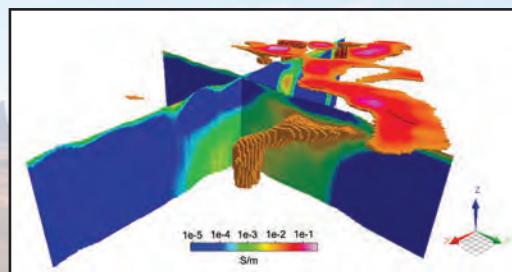
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regenerative four quadrant operation that recovers energy from the large loop load during current reversals.

**SJ Geophysics** completed multiple surface EM surveys in 2021 using the Volterra-EM system with high sensitivity induction magnetometers and the Volterra EM Transmitter (EMTX). Research was focused on improving the signal processing software and instrument calibrations, resulting in improved data quality.

#### INDUCED POLARIZATION

In 2021 **Crone Geophysics** introduced its innovative bi-directional Mark 7 field system technology making the E-SCAN 3D resistivity mapping capability highly cost effective. It allows rapid surveying of large exploration areas with field crews often as small as two persons (vs conventional 10-12 persons of 3D Res/IP surveys). This makes 3D survey costs less than that of traditional non-3D line surveys. This is achieved while delivering the same deep, high resolution 3D earth models that have been the hallmark of E-SCAN 3D technology since its commercial introduction in **Geological Survey of Canada** geothermal mapping programs in 1982.

Quebec City-based **Instrumentation GDD (GDD)** continued to optimize the technology around the GDD Wireless Communication Module for 2D and 3D IP surveys with multiple receivers. The company's R&D has developed a new module based on Raspberry PI that not only allows wireless full-wave reading and recording in real time, but also reduces costs and improves productivity while acquiring IP data in the field. The new module completely replaces the PDAs, which were normally installed with each IP receiver deployed in the

field when operating in multi-Rx mode. The senior geophysicist and operator of the module will have instant control of the receivers from one single operating device running the Windows 10-compatible Multi-Rx Software. This new module provides a unique, cost-effective solution suitable for all types of IP projects in terms of scale, environment, investigation depth and type of mineralization, and is compatible with all generations of GDD IP transmitters and receivers.

In 2021 **IRIS Instruments** (Orleans, France) focussed on development of a solution to significantly shorten the IP data acquisition time in the field. It involves a package that includes a high-power transmitter, a receiver and dedicated software. Recent technological advances implemented in IRIS' receiver (ELREC TERRA) and high-power transmitter (TIP), show this new solution will offer a substantial advantage to companies conducting mineral exploration.

In 2021 **Simcoe** doubled its ability to serve exploration clients with the addition of extra Alpha IP systems to its geophysical equipment stable. It also added ground CSAMT, TDEM, gravity and magnetics services, to offer an enhanced set of solutions to clients. During the year, the company carried out over 750 line-km of ground Alpha IP surveys and over 3000 line-km of ground magnetics with many high definition targets leading to discoveries. The Alpha IP survey efficiency now reportedly ranks among the highest in the industry with 2 to 3 line-km per day capability, completing projects faster with higher definition targeting.

**SJ Geophysics** carried out multiple Volterra-3DIP and Volterra-3DIP/MT surveys in 2021. The number of active dipoles deployed per survey was consis-

tently larger than in previous years with new strategies developed to manage the increased data collected. Development of the company's own IP transmitter moved forward with multiple field tests completed in the summer.

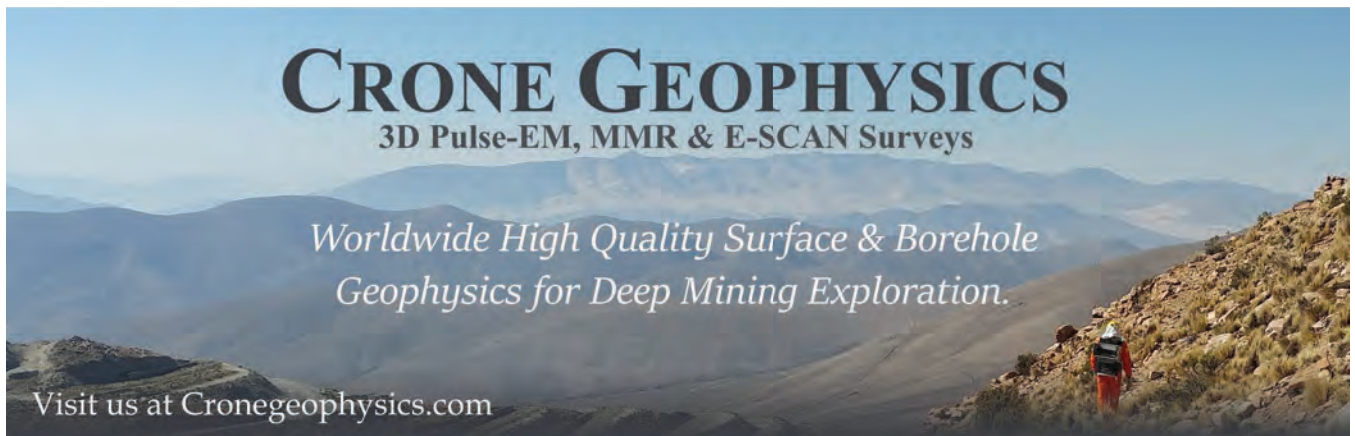
#### GROUND MAGNETIC SURVEYING

**GEM** produces the GSMV-19W dual-sensor walking VLF-only system where "walking" refers to continuous measurements without stopping. In a new development, the walking Overhauser magnetometer GSM-19W is being combined with the walking VLF GSMV-19W. This new model GSM-19WVW produces magnetic data and data from 2 VLF stations simultaneously with a sampling rate of up to 1 Hz.

#### MAGNETOTELLURIC

**AGCOS's** wideband MT technology supplied with its GEPARD multifunction EM receivers was further upgraded for collection of reliable data in the 43 kHz-DC frequency band even in very noisy rural and industrial environments. It uses a flexible configuration of extremely low-noise, high-sensitivity AMT (AMS-11, AMS-12, AMS-14, AMS-15), MT (AMS-37) and wideband MT (AMS-27 & AMS-47) induction coils and fluxgate sensors. This MT technology can be deployed with any array, sensor, or channel configuration, either as a stand-alone or remote reference, and integrated with other EM methods to increase accuracy and certainty of interpretation results.

**Dias Geophysical** completed ground CSAMT surveys in Canada and the U.S. in 2021 using the new DIASMT system integrated with low-noise MFS07e induction coils. The receivers are single channel and GPS synchronized, which allows full flexibility in sensor layout and survey design.



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The DIAS32 receivers allow acquisition from low frequency MT to 5,000 Hz with a sampling rate of up to 19,200 Hz. The system is easily paired with the DIAS32 3D IP system to efficiently enhance depth search for the resistivity parameter.

Toronto-based **Phoenix Geophysics** continued to add features and improvements to its Ultra-Wideband Magnetotellurics (UMT) instrumentation and data processing software. One new feature is the addition of CSEM/CSAMT to the new generation equipment platform. A new transmitter driver, the TXD, synchronizes transmitter waveforms with UMT receiver logs (such as MTU-5C or RXU-8A). It can continuously log current output waveform and drive a Phoenix transmitter with any broadband EM waveform. EMpower V2 is being released to handle both MT and CSEM/CSAMT data types, along with new firmware with enhanced features for CSEM/CSAMT, supported by all types of UMT receivers. A receiver will record time series data that can be processed within seconds to geophysical data. All Phoenix instruments now support remote connectivity to a server. A whole range of new applications is being reported by users around the world using a remote server. These include real time data upload to a distant server, availability of Remote Reference Data from any connected computer, real time QC of permanent stations, and remote management of an AMT/MT survey. One example reported at the **Balkan Geophysical Society Congress** in 2021 was the improved efficiency of a geothermal MT survey completed in Turkey using a remote management MT survey approach where the duration of each station data collection (number of nights) could be revised from the office without going to the field. The company also released a new model of channel boards that comes with improved protection against nearby lightning strikes, an improved low pass filter to attenuate high frequency noise, quieter electronics that improve efficiency at collecting MT signals and better power management. Existing users of the Phoenix UMT system can request an upgrade of channel boards on their equipment, field assistance, online training courses and 24/7 technical support. In 2021 it supplied over 70 wideband MT and CSAMT systems.

**Quantec** reported that SPARTAN MT was used in several projects with very tightly spaced MT stations to provide enhanced resolution for nickel and plat-

inum/palladium exploration imaging. TITAN MT can also provide detailed MT resistivity mapping. In 2021 TITAN MT was deployed at 25 m and 50 m dipole spacing, which rivals CSAMT surveys for detail, but provides enhanced depth capability to 1500 m and greater, which is far deeper than standard CSAMT depths of 500 m.

**SJ Geophysics** continued to improve

the Volterra-MT system to carry out stand-alone MT and combined 3DIP/MT surveys. The AMT/MT signal processing software was updated in 2021 to improve signal-to-noise and processing efficiency, as well as to add new QC capabilities. Inversion modelling is offered using the MARE2D inversion software developed by the **Scripps Institution of Oceanography**, based in LaJolla, CA. 

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## Abbreviations (for acronyms used in the text)

A	Ampere	DMEC	Decennial Mineral Exploration Conferences	KW	kiloWatt	QC	Quality Control
ADC	Analog to Digital Converter	DTM	Digital Terrain Model	LiDAR	Light Detection And Ranging	R	Resistivity
AEM	Airborne EM	E	Electric Field	LT	Low Temperature	SimPEG	Simulation and Parameter Estimation in Geophysics
AFMAG	AMT	EM	Electromagnetic	LUT	Look Up Table	SIP	Spectral IP
AI	Artificial Intelligence	FDEM	Frequency Domain EM	MMR	Magnetometric Resistivity	SP	Self Potential
AMT	Audiofrequency MT	FWHM	Full Width Half Max	ms	millisecond	SQUID	Superconducting Quantum Interference Device
B	Magnetic Field	GAAG	Gadolinium Aluminum Gallium Garnet	MT	MagnetoTelluric	TDEM	Time Domain EM
BH	BoreHole	GIF	Geophysical Inversion Facility	MVP	Magnetovariational Profiling	TEM	Transient EM (= TDEM)
CET	Centre for Exploration Targeting, University of Western Australia	GPS	Global Positioning System	NaI	Sodium Iodide	Tx/Rx	Transmitter/Receiver
CPU	Computer Processing Unit	GUI	Graphical User Interface	NCSEM	Natural and CSEM	UAV	Unmanned Airborne Vehicle (Drone)
CSAMT	Controlled Source AMT	HPC	High Performance Computing	NFEM	Natural Field EM	UBC	University of British Columbia
CSEM	Controlled Source EM	HT	High Temperature	NSEM	Natural Source EM	USB	Universal Serial Bus
CsI	Cesium Iodide	Hz	Hertz = cycles per second	nT	nanoTesla	V	Volt
CVR	Common Voltage Reference	IMU	Inertial Measurement Unit	PDA	Personal Data Assistant	VLF	Very Low Frequency
dB/dt	rate of change of B with time	IP	Induced Polarization	PEM	Pulse EM	Wi-Fi	Wireless Network Protocol
DC	Direct Current	kHz	kiloHertz	PGE	Platinum Group Elements		
DHEM	Drill Hole EM	kVA	kiloVoltAmpere	pT	picoTesla		
				QA	Quality Assurance		

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The screenshot displays a software interface with multiple data tables. The primary table is titled 'SURFACE MINING EQUIPMENT' and is organized into sections: 'Loaders, Wheel', 'Loaders, Rubber', 'Loaders, Backhoe', 'Loaders, Crawler', 'Excavators, Backhoe', 'Excavators, Crawler', 'Scrapers, Coal', 'Scrapers, Rubber', and 'Scrapers, Crawler'. Each section contains a table with columns for equipment name, capacity, and various cost metrics. The interface includes standard software navigation elements like a toolbar and window titles.



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**GEOTECH**  
AIRBORNE GEOPHYSICAL SURVEYS

**COMPANIES OFFERING AIRBORNE GEOPHYSICAL SURVEYS IN CANADA AS A CONTRACT SERVICE 2022**

Compiled by P.G. Killeen, 9759 Hwy 509, Ompah, ON K0H 2J0

(15/April/2022)

<b>COMPANY (President or Senior Officer)</b>	<b>ADDRESS OF MAIN OFFICE</b>	<b>TELEPHONE NO/FAX NO, E-MAIL/WEBSITE</b>	<b>TYPES OF SURVEY OFFERED*</b>
Dias Airborne (Jonathan Rudd)	Unit 2-3111 Millar Avenue Saskatoon, SK, S7K 6N3	416-795-1263 sales@diasgeo.com	H: AM (Full tensor magnetic gradiometer) Natural field EM; QAMT
Discovery Int'l Geophysics (Dennis Woods)	147 Robin Crescent, Saskatoon, SK S7L 6M3	306-249-4422 www.discogeo.com	H: HeliSAM: (TD, 2.5-7.5 Hz) Inductive Ground Loop Tx Galvanic Grounded Bipole
EON Geosciences Inc. (Khaled Moussaoui)	4018 boul. Côte -Vertu St-Laurent QC H4R 1V4	Tel: 514-341-3366 Fax: 514-341-5366 info@eongeosciences.com www.eongeosciences.com	FW: AM, AG, CAM/AR, VLFEM Horizontal Gradiometer H: AM, AG, FEM, TEM, CAM/AR, VLFEM CAM/AEM/AR, CAM/AEM
Expert Geophysics Ltd. (Andrei Bagrianski)	19 Lionel Heights Cres., Toronto ON M3A 1L8	647-402-8436 info@expertgeophysics.com www.expertgeophysics.com	Natural Field EM: MobileMT, CAM/AEM
Flux Geophysics Ltd. (Seyd Shah)	3-304 Stone Road West Guelph, ON N1G 4W4	519-767-1767 Cell: 519-362-5307 www.fluxgeo.com	Magnetics
Geodata Solutions Inc. (Mouhamed Moussaoui)	1054 des Pervenches Laval QC H7Y 2C7	Tel: 514-867-9990 Fax: 450-689-1013 mmoussaoui@geodatasolutions.ca www.geodatasolutions.ca	FW: AM, CAM/AR H: AM, CAM/AR
Geophysics GPR International Inc. (Claude Robillard)	2545 Delorimier Street, Suite 100 Longueuil QC J4K 3P7	Tel: 450-679-2400 Fax: 514-521-4128 Claude.Robillard@GeophysicsGPR.com www.GeophysicsGPR.com	H: AM, AR, Transverse, Longitudinal, Vertical Gradiometry VLFEM, Geophex FEM, GPRTEM
Geosphair Aviation Inc. (Olivier Ayotte)	767 Mont-Royal East Montreal QC H2J 1W8	Tel: 514-585-4314 Fax: 514-527-6726 Olivier_Ayotte@yahoo.com www.Geosphair.com	FW: AM, CAM/AR,VLFEM
Geotech Ltd. (Jim Morrison)	245 Industrial Parkway N Aurora ON L4G 4C4	Tel: 905-841-5004 Fax: 905-841-0611 info@geotech.ca www.geotech.ca	H-TEM: VTEM, AeroTEM Natural Field EM (AFMAG): ZTEM, AirMt, H-FEM: Impulse, CAM/AEM, CAM/AEM/AG, CAM/AR FW: CAM/AG, CAM/AR, CAM/ZTEM/AG, ZTEM Transverse, Longitudinal and Tri-Axial Magnetic Gradiometer

**\*NOTATION: AM - Aeromagnetic; CAM/AEM - Combined Aeromagnetic/Airborne EM; CAM/AR - Combined Aeromagnetic/Airborne Radiometric etc.; VLFEM - Very Low Frequency EM, AG - Airborne Gravity, AGG-Airborne Gravity Gradiometry, FEM - Frequency Domain EM, H-Helicopter, FW-Fixed Wing, TEM - Time Domain EM, UAV - Unpiloted Airborne Vehicle**

**COMPANIES OFFERING AIRBORNE GEOPHYSICAL SURVEYS IN CANADA AS A CONTRACT SERVICE 2022**

Compiled by P.G. Killeen, 9759 Hwy 509, Ompah, ON K0H 2J0

(15/April/2022)

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GeoVision Geosciences Inc. (Richard Osmond)	23678 108th Loop, Maple Ridge, BC, V2W 1B2	604-805-0314 rosmond@globecopper.com	H: CAM/VLFEM
MPX Geophysics Ltd. (Daniel McKinnon)	355 Harry Walker Parkway Newmarket ON L3Y 7B3	905-947-1782 Info@MPXGeo.com www.MPXGeo.com	FW: AM, CAM/AR, VLF-EM H: AM, CAM/AR, VLF-EM, AG FEM TEM
New-Sense Geophysics Ltd. (Glenn Slover)	195 Clayton Drive Unit 11 Markham ON L3R 7P3	Tel: 905-480-1107 Fax: 905-480-1207 info@new-sense.com www.new-sense.com	FW: Horizontal AM, CAM/AR, VLFEM H: CAM/AR, VLFEM
Novatem Inc. (Pascal Mouge)	1087, Chemin de la Montagne Mont-Saint-Hilaire QC J3G 4S6	Tel: 450-464-1655 Cell: 514-966-8000 Mouge@NOVATEM.com www.NOVATEM.com	H: COLIBRI AM, CAM/AEM, CAM/AR, CAM/AEM/AR; NOVATEM TEM & Resistivity FW: CAM/AR
Precision GeoSurveys Inc. (Harmen Keyser)	Hanger 42, Langley Airport 21330 56 <sup>th</sup> Ave. Langley BC V2Y 0E5	604-484-9402 info@precisiongeosurveys.com www.precisiongeosurveys.com	H: AM, CAM/AEM, CAM/AR Biaxial & Tri-axial Gradiometer, TEM, FEM FW: AM, CAM/AR, VLFEM

**\*NOTATION: AM - Aeromagnetic; CAM/AEM - Combined Aeromagnetic/Airborne EM; CAM/AR - Combined Aeromagnetic/Airborne Radiometric etc.; VLFEM - Very Low Frequency EM, AG - Airborne Gravity, AGG-Airborne Gravity Gradiometry, FEM - Frequency Domain EM, H-Helicopter, FW-Fixed Wing, TEM - Time Domain EM, UAV - Unpiloted Airborne Vehicle**

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(15/April/2022)

Prospectair Geosurveys Inc. (Alain Tremblay)	15 chemin de l'Étang Gatineau QC J9J 3S9	Tel: 819-661-2029 Fax: 866-605-3653 contact@prospectair.ca www.prospectair.ca	H-TEM: ProspecTEM H: AM, AR, CAM/TEM, CAM/AR, CAM/TEM/AR
Sander Geophysics Ltd. (Stephan Sander & Luise Sander)	260 Hunt Club Road Ottawa ON K1V 1C1	Tel: 613-521-9626 Fax: 613-521-0215 surveys@sgl.com www.sgl.com	FW: AM, AR, AG, FEM, VLFEM, CAM/AR, CAM/AG, CAM/AG/AR, CAM/FEM, CAM/AG/FEM, CAM/AR/FEM, CAM/AG/AR/FEM, CAM/AR/VLFEM Scanning LiDAR, Methane Sensing Transverse, Longitudinal, Vertical & Triaxial Gradiometer H: AM, AR, AG, VLFEM, CAM/AR, CAM/AG, CAM/VLFEM, Scanning LiDAR, Methane Sensing, Transverse & Vertical Gradiometer
SHA Geophysics Ltd. (Scott Hogg)	85 Curlew Drive, #104 Toronto ON M3A 2P8	Tel: 416-444-8245 Fax: 416-444-4409 scott@shageophysics.com www.shageophysics.com	H: CAM-AR-VLFEM, Triaxial Magnetic Gradiometer
SkyTEM Canada Inc. (Mandy Long)	36 King St. East, 4 <sup>th</sup> Floor Toronto ON M5C 3B2	647-256-6716 mlo@skytem.com www.skytem.com	H: SkyTEM 304, 312, 306HP, 312HP CAM/AR, CAM/AEM, Single, multi and dual moment TEM
Terraquest Ltd. (Howard A. Barrie)	301-2900 John Street Markham ON L3R 5G3	Tel: 905-477-2800 Fax: 905-477-2820 info@terraquest.ca www.terraquest.ca	FW: AM, Transverse, Longitudinal, Vertical Gradiometer, CAM/AR, VLFEM (Matrix), AG (CMG GT2A) H: AM, CAM/AR, Matrix VLFEM, CAM/AEM
Triumph Surveys (Steve Balch)	1 Rosetta Street, Unit 7, Georgetown, ON, L7G 3P1	905-407-9586 steve@itriumph.ca www.itriumph.ca	Various
Xcalibur Multiphysics Canada (Davin Allen)	2505 Meadowvale Blvd. Mississauga ON L5N 5S2	Tel: 905-812-0212 Fax: 905-812-1504 davin.allen@xcaliburmp.com www.xcaliburmp.com	H: AM, TEM, CAM/TEM, (HELITEM2) CAM/AR, CAM/TEM/AR, AGG (HELIFALCON), CAM/AGG, FEM, CAM/FEM, (RESOLVE) CAM/FEM/AR, Gradient AM (MIDAS) FW: AM, CAM/TEM, (TEMPEST) CAM/TEM/AR, CAM/AR, Gradient AM/AR (XMAG) AGG (FALCON, FALCON PLUS, FULL SPECTRUM FALCON, FTG), AG, CAM/AGG, CAM/AG

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Compiled by P.G. Killeen, 9759 Hwy 509, Ompah, ON K0H 2J0

(15/April/2022)

<b>COMPANY</b> (Country) Telephone No. Web site	<b>AIRCRAFT</b> Fixed Wing = FW Helicopter = H Unpiloted Aerial Vehicle = UAV (Positioning)	<b>AEROMAGNETIC</b> T=Total Field, G=Gradient L, TT, V=Longitudinal, Transverse & Vertical	<b>AIRBORNE ELECTROMAGNETIC</b> (Time domain = TD) (Frequency domain = FD)	<b>AIRBORNE RADIOMETRIC (R), GRAVITY (G) &amp; GRAVITY GRADIENT (GG) Remote Sensing (RS)</b>
Aerogeophysica Inc. (Russia) T: 7-495-641-1230 www.aerogeo.ru	Antonov-An-26,An-2 FW Ilyushin-II14 H Kamov-KA25,26 (Ashtec GPS/Glonass)	Scintrex & Geometrics Cs Vapour (T, VG, LG)	6 Freq. Coax/coplanar FW AGP AEM H Towed Bird 4 Freq. Explorer HEM	Picodas PGAM 1000 R (50 l) Picodas/PEI GRS 410 (33.6 l) AGP G
Aerophysics (Mexico) T: 52-555-590-9928	Cessna 206, FW Piper PA-31 Navajo H Leased (PNAV-GPS + Video)	Cs Vapour Helimag PMAG 3000 (T)	Explorer HEM H Towed Bird 5 Freq. Coaxial/coplanar	Picodas PGAM 1000 R 256 chan (16 l or 33 l down, 4 l up)
Bell Geospace, Inc. (USA) T: 281-591-6900 www.bellgeo.com	Basler BT-67 FW Cessna 208B	Geometrics G822A Cs Vapour (T)	NA	Lockheed Martin FTG GG Full Tensor Gravity
Dias Airborne (Canada) T :416-795-1263 sales@diasgeo.com	Chartered helicopter	QMAGT Full-Tensor Gradiometer	QAMT-AFMAG-MT	NA
Discovery Int'l Geophysics {Canada) T: 306-249-4422 www.discogeo.com	Chartered helicopter	Geometrics Cs Vapor (T)	HeliSAM: {TD, 2.5-7.5 Hz) Inductive Ground Loop Tx Galvanic Grounded Bipole	NA
EDCON-PRJ Inc. (USA) T: 303-980-6556 www.edcon-prj.com	Dragon Fly Ultralight FW Leased H	Geometrics Cs Vapour (T)	NA	NA
EON Geosciences Inc. (Canada) T: 514-341-3366 www.eongeosciences.com	Piper PA-31 Navajo; FW King Air A90 Cessna 206 Piper Cheyenne II Leased H (DGPS, RT-DGPS, Digital Video)	Scintrex & Geometrics Cs Vapour (T, TTG)	E-THEM TD H Hummingbird FD Herz Totem-2A VLFEM	RSI RSX-5 1024 chan R (32 l down, 8 l up) CMG GT-1A/GT-2A G



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Expert Geophysics Ltd. (Canada) T: 647-402-8436 www.expertgeophysics.com	Leased H	Geometrics Cs Vapour (T)	Natural Field EM: MobileMT H	NA
Geo Data Solutions Inc. (Canada) T: 514-867-9990 www.geodatasolutions.ca	Piper PA-31 Navajo; ASTAR 350, Bell 206 Robinson R44 (RT-DGPS) FW H	Geometrics & Scintrex Cs Vapour (T, TTG)	Totem-2A VLFEM	RSI RSX-5 (16 l down, 4 l up) R
Geophysics GPR International Inc. (Canada) T: 450-679-2400 www.geophysicsgpr.com	Hughes 300 R44 Bell 206B/L ASTAR BA, B2, B3, Lama H	Geometrics Cs Vapour (T, LG, TTG, VG)	GEOPHEX HEM GEM-2A Towed Bird Multi Freq. Coaxial/Coplanar VLFEM GPRTEM H	Pico Envirotec (16 l) R
Geosphair Aviation Inc. (Canada) T: 514-585-4314 www.geosphair.com	Piper PA-31 Navaho x 1; Super-Cub x 1 (DGPS, RT-DGPS, DVideo) FW	GEM System K Vapour (T,TTG,VG)	Totem-2A VLFEM	Medusa MS-4000 R
Geotech Ltd. (Canada) T: 905-841-5004 www.geotech.ca	Cessna 206 x 1 Cessna 208B x 4 PAC750-XL x 1 Koala AW119 x 2 AS350-B3 x 13 (DGPS, GLONASS + DVideo) FW H	Geometrics G823A Cs Vapour (T, LG, TTG) (T, LG, Triaxial) FW H	Geotech VTEM TD (systems configured for shallow to deep penetration) AFMAG ZTEM AirMt AeroTEM TD IMPULSE FD TD FW/H H H	RSI RSX-5 1024 chan (32 l down, 8 l up) CMG GT-2A R G
GeoVision Geosciences Inc. (Canada) T: 604-805-0314 rosmond@globecopper.com	Leased H	GEM System GSMP-30A	VLFEM	NA

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<b>GyroLAG</b> (South Africa & Botswana) T: NA www.gyrolag.com	Maule M5-235C X 1 FW Trojan (1) Sycamore (1), Geoduster (1)-gyrocopter Agnav Guia/Linav (2) Novatel-DGPS (3)	Fluxgate (T, Vectors, TTG)	'SP' experimental device	MS 4000 (4 l Csl) R  TAGS-6 G  NIR,VIS,TIR, LiDAR RS
<b>MagSpec Airborne Surveys Pty Ltd</b> (Australia) T: 61-8-6260-2041 www.magspec.com.au	Cessna 210 FW Cessna 206 PAC750XL  Leased H (Novatel L1/L2 + GLONASS)	Geometrics G822A Cs Vapour (T, G, TTG )	N/A	RSI RS-500 R CMG GT-2A G
<b>Microsurvey Aerogeofísica e Consultoria Científica Ltda</b> (Brazil) T: 55-21-2445-1773 www.microsurvey.net	Cessna 208B FW EMB 820C x 2 Piper PA-31 Navajo	Scintrex Cs Vapour (T, G)	Ms Relief VLFEM  SP-4 MT with 3 Coils	Picodas/PEI GRS 410 R (33.6 l) RSI RS-500 256-512 chan (16 l down, 4 l up) Exploranium GR-820 256 chan (16 l, 32 l or 48 l) Lockheed Martin FTG GG Full Tensor Gravity
<b>MPX Geophysics Ltd.</b> (Canada) T: 905-947-1782 www.mpxgeo.com	Cessna 206 FW Piper PA-31 Navajo Piper Aztek Leased H (DGPS RT-DGPS, Video)	Scintrex & Geometrics Cs Vapour (T, G, TTG)	PTHEM TD MICROTEM TD	RSI RS-500 R 256-512-1024 chan (50.4 l down, 12.6 l up)

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New Resolution Geophysics (South Africa) T: 27-21-789-0509 www.airbornegeophysics.com	Pilatus PC6 x 2 FW (DGPS) Reims-Cessna F406 Caravan II Airtractor AT504 AS350 series x 10 H (DGPS)	Scintrex CS-3 (T, LG, TTG, VG)	Xcite TD x 6 H	RSI RSX-4 x 8 R CMG GT-2A x 2 G
New-Sense Geophysics (Canada) T: 905-480-1107 www.new-sense.com	Leased: Piper PA-31 Navajo FW Cessna 206 Leased Bell 206 (stinger) H ASTAR (stinger)	Scintrex CS-3 (T, LG)	NA	RSI RSX-5 x 7 R (16 l down, 4 l up)
Novatem Inc. (Canada) T: 450-464-1655 C: 514-966-8000 www.novatem.com	Cessna 208 Caravan FW Piper PA-31 Navajo x 4 Leased ASTAR series H	Geometrics Cs Vapour (T, LG, VG)	NOVATEM TD H	RSI RSX-5 x 7 R (16 l down, 4 l up)
Precision GeoSurveys Inc. (Canada) T: 604-484-9402 www.precisiongeosurveys.com	Cessna 206 FW Piper PA-31 Navajo Bell 206, Airbus AS-350 H (GPS, DGPS)	Scintrex & Geometrics Cs Vapour, & GEM K Vapour (T,G) (with attitude correction)	TEM, FDEM, VLFEM H	Nuvia GRS-10 + AGRS R Medusa + Exploranium GR820
Prospectair Geosurveys Inc. (Canada) T: 819-661-2029 www.prospectair.ca	EC120B, R44 H (RT-DGPS)	Geometrics Cs Vapour (T,G)	ProspectEM TD H	RSI RSX-5 R (16 l down, 4 l up)

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Prospectors A. S. Ltda. (Brazil) T.: 55-21-2502-2526 www.prospectorsbr.com	Piper Chieftain x 2 FW Cessna 208B x 2 H Leased	Geometrics Cs Vapour (T, LG, TTG)	AeroTEM TD H	RSI RS-500 R 3 x (40 l down, 8 l up)  CMG GT-2A G
Sander Geophysics Ltd. (Canada) T: 613-521-9626 www.sgl.com	Cessna 208B x 8 FW BN Islander x 2 DHC6 x 1 H Airbus AS-350B3 x 2 H (DGPS, RT-DGPS + DVideo)	Geometrics Cs Vapour Sander SGMAG (T, LG, TTG, VG, Triaxial) FW  (T,TTG, VG) H	SGFEM FD FW  Herz Totem-2A VLFEM	Exploranium GR820 R (256 chan) (60 l) RSI RS-500 256-512 chan 50 l down, 8 l up Sander AIRGrav G
SHA Geophysics Ltd. (Canada) T: 416-444-8245 www.shageophysics.com	Leased H (GPS)	Scintrex CS-3 Cs Vapour (T, LG, TTG, VG, Triaxial)	Totem 2A VLFEM	Pico Envirotec R 256 chan (32 l down, 4 l up)
SkyTEM Canada Inc. (Canada) T: 647-256-6716 www.skytem.com	Leased H (GPS)	Geometrics Cs Vapour sensors (T)	TD: SkyTEM 304 & 312 (Dual moment), 306HP (multi moment), 312HP (single moment)	Medusa R 256-512 chan; (16 l down, 4 l up)
Spectrem Air (RSA) T: 27-11-659-1518 www.spectrem.co.za	Basler BT-67 FW (DGPS) Chartered H	Scintrex CS-3 (T) Jessy Star SQUID FTMG Vertical or horizontal cryostat mode	SpectremPLUS TD 100% duty cycle FW	Exploranium GR820 R (32 l)
Terraquest (Canada) T: 905-477-2800 www.terraquest.ca	King Air C90 FW Cessna 206 Navajo PA-31 Leased H (DGPS + DVideo)	Scintrex & Geometrics Cs Vapour (T, LG, TTG, VG)	Matrix digital FW/H VLFEM	RSI RSX-500 R Pico Envirotec (32 l down, 8 l up)  CMG GT-2A G

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Thomson Aviation (Australia) T: 61-2-6960-3800 C: 61-4-9999-1963 www.thomsonaviation.com.au	PAC 750XL x 2 FW Cessna 210 x 4 Cessna 208B Fletcher FU24 Piper PA-31 Navajo x 2 UAV FW/H; Leased H (NovAtel OEMV-1VBS)	Geometrics G822A & G823A Cs Vapour (T, G)	BIPTM TD H	RSI RS-500 R (up to 67.2 l) CMG GT-2A G
UTS Geophysics (Australia) T: 61-8-9479-4232 www.uts.com.au	Same aircraft as Geotech Ltd.			
Xcalibur Multiphysics Canada (Canada) T: 905-812-0212 www.xcaliburmp.com	Cessna 208B FW Basler BT 67 AT 502 Chartered Helicopters H (DGPS, RT-DGPS, DVideo)	CGG DAS FW Scintrex & Geometrics Cs Vapour (T, LG, TTG, VG, Triaxial) (T, LG, TTG, VG, LTTVG H Triaxial)	TD; TEMPEST FW TD; HELITEM <sup>2</sup> H (3 axis Rx (x-y-z), concentric, 8-40 ms pulse width, square Tx waveform, 6.25-30 Hz, 200k-600k NIA), MULTIPULSE FD; RESOLVE (6 Freq. 400 Hz - 140,000 Hz, 1 coaxial & 5 coplanar coil sets) or RESOLVE (5 freq. 900 Hz – 56,000 Hz, 2 coaxial & 3 coplanar coil sets)	Exploranium GR 820 FW R RSI RS-500 (256/512 chan) Exploranium GR 820, H R RSI RS-500 (256/512 chan) FALCON, FALCON FW GG PLUS, FULL SPECTRUM FALCON, FTG CMG GT-1A, GT-2A, FW G sGrav FALCON H GG

Manufacturer (Country)	(TD=Time Domain FD=Freq. Domain $\phi$ =Phase S=Spectral)	Transmitter Model No.	Cycling Time or Frequency	Transmitted Power	Transmitter Power Source (MG=Motor Generator)	Transmitter Weight	Receiver Model No.	Sensitivity or Accuracy	Voltage Range	Microprocessor Controlled/Data Memory	Receiver Weight
Advanced Geophysical Operations and Services Inc. (Canada)	TD, FD, $\phi$ IP & SIP	AT-100	DC - 50kHz, 50% & 100% duty	100 W	12V battery	4 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 $\mu$ V / 1% typical	0.1 $\mu$ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD, FD, $\phi$ IP & SIP	KR-10	DC - 50kHz, 50% & 100% duty	500 W	12V-60V battery	5 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 $\mu$ V / 1% typical	0.1 $\mu$ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD	AT-3000	DC-30Hz, 50% duty	3 kW	12V-150V battery	12 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 $\mu$ V / 1% typical	0.1 $\mu$ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD	AT-3000R	DC-30Hz, 50% duty	3 kW	12V-150V battery, MG	28 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 $\mu$ V / 1% typical	0.1 $\mu$ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD, FD, $\phi$ IP & SIP	AT-4000	DC - 50kHz, 50% & 100% duty	4 kW	12V-150V battery, MG	28 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 $\mu$ V / 1% typical	0.1 $\mu$ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD, FD, $\phi$ IP & SIP	KR-30	DC - 50kHz, 50% & 100% duty	37 kW	3-phase MG	35 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 $\mu$ V / 1% typical	0.1 $\mu$ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD, FD, $\phi$ IP & SIP	KR-75	DC - 50kHz, 50% & 100% duty	75 kW	3-phase MG	55 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 $\mu$ V / 1% typical	0.1 $\mu$ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery
	TD, FD, $\phi$ IP & SIP	KR-175	DC - 50kHz, 50% & 100% duty	175 kW	3-phase MG	205 kg	GEPARD-4 (4ch) GEPARD-8 (8ch)	0.1 $\mu$ V / 1% typical	0.1 $\mu$ V to 10V	Intuitive GUI/SD Card up to 128Gb	7 kg with internal battery

Manufacturer (Country)	(TD=Time Domain FD=Freq. Domain $\phi$ =Phase S=Spectral)	Transmitter Model No.	Cycling Time or Frequency	Transmitted Power	Transmitter Power Source (MG=Motor Generator)	Transmitter Weight	Receiver Model No.	Sensitivity or Accuracy	Voltage Range	Microprocessor Controlled/Data Memory	Receiver Weight
IRIS Instruments (France)	TD & FD	VIP 3000		3000 W	45 - 450 Hz 1 phase	16 kg					
	TD & FD	VIP 4000	0.0625 - 4 Hz	4000 W	45 - 450 Hz 1 phase	16 kg	ELREC 6	0.01 mV/V0.6% typ. accuracy	10 $\mu$ V to 10V	Yes/2500stations	8 kg
	TD & FD	VIP 5000		5000 W	45 - 800 Hz 1 or 3 phases	23 kg	ELREC 10	0.01 mV/V0.6% typ. accuracy	10 $\mu$ V to 15V	Yes/3200stations	9 kg
	TD & FD	VIP 10000		10000 W	45 - 800 Hz 1 or 3 phases	35 kg					
Instrumentation GDD Inc. (Canada)	TD	Tx III-4800V-10A	DC 1,2,4,8 and 16 seconds	1800 W	120 V, 50-60 Hz	27 kg	GRx2-2 channels	Voltage: Resolution 1 $\mu$ V, Accuracy $\leq$ 0.15%	$\pm$ 10 $\mu$ V to $\pm$ 15V for any channel	Archer 2 PDA-512Mb RAM Allegro 2 PDA-512Mb RAM	1.6 kg
	TD	Tx II-4800V-15A	DC 1,2,4,8 and 16 seconds	3600 W	240 V, 50-60 Hz	32 kg	GRx8mini-4 or 8 channels		$\pm$ 10 $\mu$ V to $\pm$ 15V for any channel	Archer 2 PDA-512Mb RAM Allegro 2 PDA-512Mb RAM	3.1 kg
	TD	Tx4-4800V-20A	DC 1,2,4,8 and 16 seconds	5000 W	240 V, 50-60 Hz	40 kg	GRx8-32-8,10,16,24 or 32 channels	Chargeability; 1 $\mu$ V/V, Accuracy $\leq$ 0.4%	$\pm$ 10 $\mu$ V to $\pm$ 15V for any channel	Archer 2 PDA-512Mb RAM Allegro 2 PDA-512Mb RAM	7.0 kg
	TD	Tx4-4800V-20A	DC 1,2,4,8 and 16 seconds	10000 W	240 V, 50-60 Hz	2 x 40 kg	Post-processing IP software				
	TD	Tx4-4800V-20A	DC 1,2,4,8 and 16 seconds	20000 W	240 V, 50-60 Hz	4 x 40 kg					
	TD	EM-IP Tx Controller	1 second on and above			2 X Li Ion batteries	4 kg				
	TD	TRM	Higher frequencies								

Manufacturer (Country)	(TD=Time Domain FD=Freq. Domain $\phi$ =Phase S=Spectral)	Transmitter Model No.	Cycling Time or Frequency	Transmitted Power	Transmitter Power Source (MG=Motor Generator)	Transmitter Weight	Receiver Model No.	Sensitivity or Accuracy	Voltage Range	Microprocessor Controlled/Data Memory	Receiver Weight
Phoenix Geophysics (Canada)	TD, FD, $\phi$ IP, SIP, CSAMT	T3	TD: 0.0625 Hz -30 Hz , FD: 0.125 Hz to 10 kHz TD: 50% FD: 100% duty cycle, external drive optional	3000 W	Battery or any single-phase generator	12 kg, mounted on backpack	V8 Multifunction Rx.			Yes/flash memory 512 MB (upgradeable)	7 kg
	TD	T4	5A, 50% duty cycle, 2.7* microsec 40A, 50% duty cycle, 27* microsec *loop size dependent	2.8 kW, max 130 V input, fast turn-off for EM operations	12 V batteries in series (24V-72 V)	10 kg, mounted on backpack					
	TD, FD, $\phi$ IP, SIP & CSAMT	TXU-30A	TD: Up to 60 A, 0.0625 Hz-30 Hz, 50% FD: 20 A @ 1000 V, 0.125 Hz to 9.6 KHz, 100%	20 Kw	Any 200-240 V commercially available 3-phase generator external drive optional	50 kg					
	CSAMT Tx Driver	TXD	CSAMT: 1 Hz-10k Hz	N/A	12V battery	4 kg					
Walcer Geophysics Ltd. (Canada)	TD & FD	IPT-1 & TX KW10	IPT-1: FD: "A" & "B" Models DC - 4 Hz TD: "A" Model- 2 sec. on / 2 sec. off "B" Model - Seconds on / off; in 1,2,4 & 8 seconds TX KW10: 1 sec., 2 sec., 4 sec., 8 sec.	IPT-1 75 - 1200V in 5 steps 3 mA - 10 Amps TX KW10 100 - 3200V in 10 steps 0.05 - 20 Amps Tested to 10.5 kVA	MG-1, MG-2, MG-6 and MG-12 Variable power 400 Hz/3 phase	IPT-1 18 Kg TX KW-10 44 kg					
Zonge International	TD & FD $\phi$ IP & SIP	GGT-3	DC to 8 kHz	3 KVA	ZMG-4 3 Kw MG 400 Hz	30 kg	ZEN 6 channels	20 mV	Max +- 2.5 V	Yes/60 Mhz ARM processor/channel Mass Storage; 8 GB/channel Data Storage; 16 Gbytes/channel	3 kg
	TD & FD $\phi$ IP & SIP	GGT-10	DC to 8 kHz	10 KVA	5, 7.5 & 10 Kw MG 400 Hz	51 kg	ZEN 2 channels	20 mV	Max +- 2.5 V	Yes/60 Mhz ARM processor/channel Mass Storage; 8 GB/channel Data Storage; 16 Gbytes/channel	3 kg
	TD & FD $\phi$ IP & SIP	GGT-30	DC to 8 kHz	30 KVA	32 KVA MG 400 Hz	93 kg	GDP-32 6 channels	0.03 $\mu$ V	0.1 $\mu$ V to 32 V AGC	Yes/32 MB/RAM 4 GB/HD	13.2 kg incl. batt.



Manufacturer (Country)	(TD=Time Domain FD=Freq. Domain $\phi$ =Phase S=Spectral)	Transmitter Model No.	Cycling Time or Frequency	Transmitted Power	Transmitter Power Source (MG=Motor Generator)	Transmitter Weight	Receiver Model No.	Sensitivity or Accuracy	Voltage Range	Microprocessor Controlled/Data Memory	Receiver Weight
Zonge International	TD & FD	NT-20	DC to 512 kHz	480 W	Batteries	5 kg	GDP-32 16 channels	0.03 $\mu$ V	0.1 $\mu$ V to 32 V AGC	Yes/32 MB/RAM 4GB HD	19 kg incl. batt.
	TD & FD	ZT-30	DC to 512 Hz	3.6 Kw	Batteries	8 kg	GDP-32 16 channels	0.03 $\mu$ V	0.1 $\mu$ V to 32 V AGC	Yes/32 MB/RAM 4GB HD	19 kg incl. batt.

Manufacturers and Principal Distributors of Mining Geophysical Equipment & Software in Canada 2022;  
 Compiled by P.G. Killeen, 9759 Hwy 509, Ompah, ON K0H 2J0

(15/April/2022)

COMPANY	TELEPHONE (FAX)	E-MAIL/WEBSITE	SENIOR OFFICER
ADVANCED GEOPHYSICAL OPERATIONS AND SERVICES INC. (AGCOS) 162 Oakdale Road, North York, ON M3N 2S5	416-747-8800 (416-747-5761)	info@agcos.ca www.agcos.ca	Igor Ingerov
CRONE GEOPHYSICS & EXPLORATION LTD 2135 Meadowpine Blvd. Mississauga ON L5N 6L5	905-814-0100 (905-814-8617)	info@cronegeophysics.com www.cronegeophysics.com	William (Bill) Ravenhurst
DUALEM INC. 540 Churchill Ave Milton ON L9T 3A2	905-876-0201 (905-876-2753)	inbox@dualem.com www.dualem.com	Rick Taylor
GEM SYSTEMS INC. 135 Spy Court Markham ON L3R 5H6	905-752-2202 (905-752-2205)	info@gemsystems.ca www.gemsystems.ca	I. Hrvoic
GEONICS Limited Unit 8, 1745 Meyerside Dr Mississauga ON L5T 1C6	905-670-9580 (905-670-9204)	geonics@geonics.com www.geonics.com	Miro Bosnar
GEOSENSORS INC. 66 Mann Ave Toronto ON M4S 2Y3	416-483-4691 (416-483-9909)	scott.holladay@geosensors.com	Scott Holladay
GEOTECH LTD. 245 Industrial Parkway North Aurora ON L4G 4C4	905-841-5004 (905-841-0611)	info@geotech.ca www.geotech.ca	Jim Morrison
ICEFIELD TOOLS CORP. P.O. Box 30085 Whitehorse YK Y1A 5M2	867-633-4264 (867-633-4217) 1-877-423-3435	info@icefieldtools.com www.icefieldtools.com	Erik Blake
IDEON TECHNOLOGIES INC. 1015-12471 Horseshoe Way Richmond BC V7A 4X6	1-888-704-3366	info@ideon.ai www.ideon.ai	Gary Agnew
IFG CORPORATION 26 Bramsteele Rd., Unit 2 Brampton ON L6W 1B3	905-451-5228 (905-451-2877)	info@ifgcorp.com www.ifgcorp.com	Detlef Blohm
INSTRUMENTATION GDD INC. 860 Boulevard de la Chaudière, St. 200 Québec QC G1X 4B7	418-877-4249 (418-877-4054)	gdd@gdd.ca www.gdd.ca	Pierre Gaucher
KROUM VS INSTRUMENTS LTD. 2206-701 Don Mills R Toronto ON M3C 1R9	416-421-6313	kroum@kroumvs.com www.kroumvs.com	Kroum Stamenkov
LAMONTAGNE GEOPHYSICS LTD. 115 Grant Timmins Dr Kingston ON K7L 4V4	613-531-9950 (613-531-8987)	lamont@kos.net www.lamontagnegeophysics.com	Yves Lamontagne
MARINE MAGNETICS 135 Spy Court Markham ON L3R 5H6	905-709-3135 (905-479-9484)	info@marinemagnetics.com www.marinemagnetics.com	Melissa Marlowe
MIRA GEOSCIENCE LTD #309 – 310 Victoria Avenue Westmount, Quebec, H3Z 2M9	514-489-1890 (514 489-5536)	info@mirageoscience.com www.mirageoscience.com	John McGaughey
NUVIA DYNAMICS INC. 5548 Timberlea Blvd. Unit # 1 Mississauga ON L4W 2T7	905-760-9512 (905-760-9513)	info@nuvia-dynamics.com www.nuvia-dynamics.com	Sandip Goswami
PATERSON, GRANT & WATSON LTD. 155 University Ave, St. 1710 Toronto ON M5H 3B7	416-368-2888 (416-368-2887)	pgw@pgw.ca www.pgw.ca	Stephen Reford
PHOENIX GEOPHYSICS LTD. Unit 3, 3781 Victoria Park Ave Scarborough ON M1W 3K5	416-491-7340 (416-491-7378)	yavram@phoenix-geophysics.com www.phoenix-geophysics.com	Yann Avram

COMPANY	TELEPHONE (FAX)	E-MAIL/WEBSITE	SENIOR OFFICER
RADIATION SOLUTIONS INC. 5875 Whittle Road Mississauga ON L4Z 2H4	905-890-1111 (905-890-1964)	sales@radiationsolutions.ca www.radiationsolutions.ca	Jens Hovgaard
RMS INSTRUMENTS LTD. 6877-1 Goreway Dr Mississauga ON L4V 1L9	905-677-5533 (905-677-5030)	rms@rmsinst.com www.rmsinst.com	Onorio Rocca
SCINTREX LTD. 222 Snidercroft Rd Concord ON L4K 2K1	905-669-2280 (905-669-6403)	Scintrex@scintrexltd.com www.scintrexltd.com	Ed Quinton
SEEQUENT INC. 207 Queens Quay West-Suite 810 Toronto ON M5J 1A7	416-369-0111 778-379-6778	sales@seequent.com www.seequent.com	Jo Knight
SENSORS & SOFTWARE INC. 1040 Stacey Court Mississauga ON L4W 2X8	905-624-8909 (905-624-9365) (1-800-267-6013)	sales@sensoft.ca www.sensoft.ca	TBD
SHA GEOPHYSICS LTD. 85 Curlew Drive, #104 Toronto ON M3A 2P8	416-444-8245 (416-444-4409)	scott@shageophysics.com www.shageophysics.com	Scott Hogg
SJ GEOPHYSICS LTD. 11966 95A Ave. Delta BC V4C 3W2	604-582-1100	info@sjgeophysics.com www.sjgeophysics.com	Syd Visser
W. SODIN (GRAVITY) LTD. Unit 18, 95 West Beaver Creek Rd Richmond Hill ON L4B 1H2	905-886-8632 (905-886-4477)		Wolf Sodin
SOUTHERN GEOSCIENCE CONSULTANTS (SGC) 19 Beethoven Court Toronto ON M2H 1W1	416-407-6355	Robert.Hearst@SGC.com.au www.sgc.com.au	Robert Hearst
TERRAPLUS INC. 120 West Beaver Creek Rd. Unit 15 Richmond Hill ON L4B 1L2	905-764-5505 (905-764-8093)	sales@terraplus.ca www.terraplus.ca	Claude B. Meunier
WALCER GEOPHYSICS LTD. 2106 Regional Rd 3 Enniskillen ON L0B 1J0	905-263-8767 (905-263-8766)	awalcer@rogers.com www.walcergeophysics.com	Alex Walcer

AIRBORNE EQUIPMENT					GROUND ELECTROMAGNETIC			GROUND EQUIPMENT (non-EM) Sus=susceptibility/G Meter=Gravity Meter							
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software	
ADVANCED GEOPHYSICAL OPERATIONS AND SERVICES INC. (AGCOS)						GEPARD-4 & 8	<u>Receivers:</u> GEPARD-4 & 8 <u>Transmitters:</u> AT-100, AT-3000, AT-3000R, AT-4000, KR-10, KR-30, KR-75 and KR-175 <u>Electrical Sensors</u> ACE-84, ALCE-84A, ASCE-84AG. <u>Induction Coils:</u> AMS-11,12, 14 15, 27, 37, 47 <u>TDEM Loops:</u> MTEM-200, FTEM-100 & LTEM-25  <u>Precision Tripods:</u> TRI-3/30, -3/50, -1/30, -1/50, -1/30/1, -1/50/1		GEPARD-4 & 8 AT-100, AT-4000, KR-10, KR-30, KR-75, KR-175	AMS-11,12,14, 15, 27, 37, 47	GEPARD-4 & 8 AT-100, 4000 KR-10, 30, 75, 175				1. EM and Seismic software for modeling, data processing, editing, visualization and interpretation 2. Shallow Marine EM Receivers for coastal shelf 2AUSS-07A (2Ch) and 5AUSS-07A (5ch) and, SMMT (2ch) 3. Precision Field Tripods for induction mag sensor installation
DUALEM							DUALEM-1, 2, 21, 4, 42, 421 and 642								

AIRBORNE EQUIPMENT					GROUND ELECTROMAGNETIC			GROUND EQUIPMENT (non-EM) Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VL FEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
GEM SYSTEMS	GEM-DAS (Real time data display & Acquisition Software Compensation (post-processing or real-time)	Manned aircraft: GSMP-35A Complete Towed Birds: GSMP-35A(B) (MagBIRD) GSMP-35GA(B) (GradBIRD) GSMP-35GA3(B) (Tri-AxialBIRD) UAV: GFMP-35U (DRONEMag) GFMP-35U(B) (AirBIRD) GFMP-35UG(B) (AirGRAD)	Manned aircraft: GSM-90AV			GSMV-series: (VLF only) 19, 19W GSM-P series: (VLF attachment) 35V, 35GV (GSMP=potassium) GSM-series: (VLF attachment) 19V, 19WV, 19GV, 19GWV (19=Overhauser) 19TV, 19TWV, 19TVG, 19TGV (19T=proton) (G=gradiometer; W=walking mode)								

AIRBORNE EQUIPMENT					GROUND ELECTROMAGNETIC			GROUND EQUIPMENT (non-EM) Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
GEONICS					BH 43 BH 43-3D EM 39 EM 39S MAG 43-3D	EM-16 Tx27	PROTEM 67,47,57-MK2, CM, 67-Plus CMX EM61-MK2 EM61-MK2-HP EM61-HH-MK2 EM61-LX2 EM61-Lite EM63 Flex Array GTEM				EM16R EM31-MK-2 EM31-S EM-31-8 EM34-3 EM38DD EM38B EM38-MK2 EM38-4			DAT(31,34,39,38MK2,61MK2) DAS 70-AR2 Logger INV EM-31-8 INV EM-38-4
GEOSENSORS	Custom	Multi-channel High-Rate Processors	Custom FDEM, TEM Helicopter Towed Bird & Fixed Mount				EM Sensors							
ICEFIELD					MI-03, MI-03N Borehole surveying & magnetics									

AIRBORNE EQUIPMENT					GROUND ELECTROMAGNETIC			GROUND EQUIPMENT (non-EM) Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
IFG					Density Caliper Tilt Orientation Systems Resistivity Conductivity IP Magnetic Temperature Gamma									
INSTRUMENTATION GDD INC.					SSW System: Probes 25 mm+ EM Conductivity Mag Suscept For Ni, Fe, etc.		TDEM Rx 3 or 8 channels EM-IP Tx controller TRM+Tx4 5Kw 2400V-20A Beep Mat		Tx: Tx III 1.8Kw Tx II 3.6Kw Tx 4 5,10,20 Kw EM-IP Tx controller TRM (higher frequencies) Rx: GRX 2- 32 channels SCIP Tester: Resistivity and chargeabilit y Borehole option				MPP- Probe: Mag suscept. and EM conduct	IP and EM post processing software
KROUM VS INSTRUMENTS LTD.	KANA8 SDAS1- PPC	KMAG4												

AIRBORNE EQUIPMENT					GROUND ELECTROMAGNETIC			GROUND EQUIPMENT (non-EM) Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
LAMONTAGNE GEOPHYSICS														S
MARINE MAGNETICS					Magnum Magnetometer					Sentinel Base Stn. Mag.				
MIRA GEOSCIENCE LTD.														GOCAD Mining Suite Geoscience ANALYST Geoscience INTEGRATOR VP suite inversion codes UBC-GIF inversion codes Training
NUVIA DYNAMICS INC.	IMPAC	IMPAC-M (integrated) PEICOMP-magnetic compensation	P-THEM	AGRS				PGIS-2 PGIS-2-1 PGIS-2-2 RADScout (drone installation)		PBM (diurnal variation station)				Praga4 (Spectrometer Processing)
PATERSON, GRANT & WATSON LTD.														S



AIRBORNE EQUIPMENT					GROUND ELECTROMAGNETIC			GROUND EQUIPMENT (non-EM) Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VL FEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
PHOENIX GEOPHYSICS LTD.							MTU-5C & 8A (CSAMT/AMT/MT) RXU-8A (CSAMT/AMT/MT) V8 (AMT/CSAMT /TD/FD/IP) T3 (CSAMT /TD/FD/IP-Tx) T4 (TDEM-Tx) TXU-30-A (CSAMT /TD/FD/IP-Tx) TXD (CSAMT TX Driver)		V8 T3 TXU-30 A		V8			EMpower (for AMT/MT/CSAMT) S EMpower (for TD EM) S
RADIATION SOLUTIONS INC.				RS-500 Series: RSX-4 (16L) RSX-5 (16L + 4L) RS-501 I/F Console RS-600 Series: RS-602 I/F Console RS-605 I/F Console RS-700 Series: RS-705 I/F				Handheld: NaI: RS-120, RS-125, RS-230BGO Portable: RS-330NaI RS-332BGO  Vehicle Mount: RS-600 Series: RS-602 I/F Console RS-605 I/F Console RS-700						

AIRBORNE EQUIPMENT					GROUND ELECTROMAGNETIC			GROUND EQUIPMENT (non-EM) Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
RADIATION SOLUTIONS INC.				Console RSX-0.5 (2L) RSX-1 (4L) RSX-3 (6L) Drone detection spectrometer DDS-3 (0.39 l)				Series: RS-705 I/F Console RSX-0.5 (2L) RSX-1 (4L)						
RMS INSTRUMENTS	DAARC 500 DAS 500 PDU 500 GP 300	DAARC 500 AARC 500 AARC 510, AARC 51/52(UAV) Compensator Geometrics-Cs mags	Herz Totem-2A (VLFEM)			Herz Totem-2A (VLFEM)				Geometrics Cs & Proton Mags				S ExportDARR C Support GP 300 Graphic Printer & Chart Recorder GP300 Support software

AIRBORNE EQUIPMENT					GROUND ELECTROMAGNETIC			GROUND EQUIPMENT (non-EM) Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
SCINTREX		CS-3 CS-VL								ENVI-CS		CG-6 RG-1 Gravilog A10 FG-5X gPhone-X		Training Custom/Design- Consulting S Airborne Gravity Meter TAGS-7 Ship Borne Gravity Meter SEA-III

AIRBORNE EQUIPMENT					GROUND ELECTROMAGNETIC			GROUND EQUIPMENT (non-EM) Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
SEEQUENT														S Geosoft, Leapfrog, GeoStudio collaborative tools and technologies Oasis montaj Magnetics, Gravity, IP, EM, Radiometrics, UXO, UAV VOXI Geophysical Inversion Leapfrog Geological Modelling Target, Target For ArcGIS Data Management Training

AIRBORNE EQUIPMENT					GROUND ELECTROMAGNETIC			GROUND EQUIPMENT (non-EM) Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
SENSORS & SOFTWARE							GPR: PulseEKKO/ PulseEKKO- Borehole NOGGIN BackTrak IceMap							S
SHA GEOPHYSICS	DAQNAV acquisition & navigation													S magnetic comp; AGG mag modeling
SJ GEOPHYSICS					Voltarra BHEM -IM MAG -FLUXGATE MAG -MAGNETICS Voltarra DHIP		Voltarra EM Voltarra EMTX (transmitter)		Voltarra-IP					
SODIN												100 100T 200 200T		
SOUTHERN GEOSCIENCE CON														ImageRobot S
TERRAPLUS		Gradient mag UAV/Drone System	GSM-90 AV VLF	RS-500 series	QL40 Series ABI-2G, OBI-2G FWS, GR, SGR ELOG, IP, DLL3, CAL, DEV, OCEAN, FTC, IND, MGS, SFM Heat Pulse Flow Meter,	GSMV-19 GSM Series 19V, 19WV, 19GV, 19GWV, 19TV, 19TWV, 19TGV 19TWGV	ProEx-GPR GroundExplorer -GPR GDP-3224 GGT-3, -10, -30 XMT-32 AMT/6 TEM/3	Hand-held Nal RS-120 RS-125 RS-230 BGO portable- RS-330	Elrec Pro Elrec 6 Distributed IP System Tipix VIP-3000 VIP-4000 VIP-5000	GSM-19 GSM-19W GSM-19G GSM-19GW GSM-19T GSM-19TW GSM-19TG GSM-19TGW	Syscal Kid Syscal Junior Syscal R1 Syscal Pro Ohm-Mapper		KT-10 v2 KT-10 Plus v2 KT-10R v2 KT-10R Plus v2 KT-10S/C KT-10	Geode ES-3000 StrataVisor SeisImager WellCAD Reflex Res2DINV Res3DINV

AIRBORNE EQUIPMENT					GROUND ELECTROMAGNETIC			GROUND EQUIPMENT (non-EM) Sus=susceptibility/G Meter=Gravity Meter						
COMPANY	Data Acquisition	Magnetometers	EM	Scint. Spectrometers	Drill hole	VLFFEM	EM	Scint. Spectrometers	IP	Magnetometers	Resistivity	G Meter	Suscept Meters	Other & Software
TERRAPLUS					GyroShot MI5 RCAM-1000		Stratagem Numis Lite, - Poly GEM-2 Promis	Nal RS-332 BGO RS-700 series RT-50 oreXpress PSR+	VIP-10000 IP/L QL-ELOGIP KT-20 IP	GSMP-35 GSMP-35G			Plus S/C KT-10R Plus S/C KT-10R S/C KT-20 KT-20 Plus KT-20 S/C KT-20 Plus S/C	Full Wave Designer Full Wave Viewer RadExplorer Object Mapper IX1D Surfer