Jan Kristiansen and co-pilot Nick Taylor fly one of Sander's three Cessna Grand Caravans near Ottawa. Reliable single-engine turbine-powered aircraft like the Caravan are starting to find their niche with geophysical companies around the world in places where twin-engine piston-powered aircraft have traditionally dominated. Mike Reyno Photo

Flying The Lines

Airborne geophysical surveying is a lively market.

By Mike Reyno

The amounts of oil, gas and metallic minerals, both known and undiscovered, that exist in the earth are limited. As established reserves become exhausted, new ones must be found. To meet the challenge, scientists continually develop more sophisticated exploration techniques. Earlier in this century, the search for natural resources was restricted to deposits observable on the surface. But as technology advanced, buried deposits could be found by aircraft carrying special geophysical surveying equipment.

Founded in 1956 by George Sander, PhD, PEng, Sander Geophysics Ltd. (SGL) is one of a small number of companies specializing in high-resolution airborne surveys for the oil and mining industries. SGL carried out its first airborne geophysical surveys in 1958, and by 1967 they had become the company's mainstay. In 1970 it purchased its first aircraft, a Bell 47G-3. In 1975 it purchased its first fixed-wing aircraft, a Cessna 402.

"Today, SGL offers the full range of data enhancement programs and provides complete interpretational services by experienced geoscientists," said Sander. "We acquire the data, process it, reduce it and put it into a readable format." He likes to describe the company, based on the north side of Ottawa's Macdonald-Cartier International Airport, as a geophysical firm that flies aircraft rather than as an aviation company that is involved in engineering.

Since 1990, SGL has compiled more than 1.9 million line kilometres (lkm) of airborne geophysical surveys. It employs 65 people, a third of whom are aviation-oriented, and maintains a fleet of three Cessna 208B Grand Caravans, one Britten-Norman BN2B-21 Islander, one Cessna 404 Titan, one Cessna 402B, and one Beechcraft Queen Air, each equipped for magnetic and radiometric surveys with extensive modifications to reduce their magnetic effect. SGL specializes in surveys using magnetic total field, radiometric, gravity, magnetic gradient or VLF-EM.

Sander said survey flying was on the increase for the 15 or so aerial survey companies worldwide, until the precipitous drop in world commodity prices over the past two years. "The industry has slowed down over the past 12 months, which has forced some survey companies out of business as rates continue to fall," Sander said. "Up to then we were all flying record numbers of hours. But as a result the market has become very competitive because of the drop in commodity prices. It is unusual for prices to be down right across the board, but there are some signs that they may be on the way up."

Nevertheless, the demand for aerial surveying remains relatively steady for SGL, which finds itself working outside of Canada at least 60 to 70 percent of the time. "We have gained extensive experience in working the diverse geographical environments around the world. We have flown surveys in high mountains, offshore, over deserts, tropical jungles

SGL operations manager Malcolm Imray (right) and company chief pilot Jan Kristiansen in front of the company's facility at Ottawa's Macdonald-Cartier International Airport. *Mike Reyno Photo*

and over the Arctic tundra," Sander said. Last year alone, SGL flew more than 5,000 hours for the first time in its history, conducting airborne surveys primarily for governments in Africa (12,000 lkm), Greenland (72,000 lkm), Qatar (58,900 lkm), Argentina (209,100 lkm), Canada (103,000 lkm), US (40,000 lkm) and France (113,600 lkm).

The Fleet

SGL Operations Manager Malcolm Imray, who is also a pilot and aeronautical engineer, told *WINGS Magazine* that the company's diversified fleet of aircraft allows it to conduct aerial surveys in almost all conditions anywhere in the world. "The type of aircraft chosen for a specific survey contract should match the job's criteria in a safe and efficient manner - rate of climb of the aircraft in survey mode, endurance, communications and available maintenance facilities at the survey location. Each has advantages over the others, depending on the area to be surveyed and the type of survey to be conducted." Radiometric surveys, for example, require much better contour flying than magnetic total field surveys. The company's piston-powered Queen Air, 402 and 404 can cover much more territory in a given period than the fixed-gear Grand Caravans and Islander, but cannot contour as well. The turbine-powered Caravans cannot match the endurance of the piston engines at low altitudes but are more tolerant of frequent power changes.

Sander notes that piston-powered aircraft are still common in the industry due to their availability and low acquisition costs. The company's long-term plan however, is to move to an all-turbine fleet for increased reliability and worldwide fuel availability. Despite the higher demand for twin-engine pistons, turboprop aircraft like the single-engine Caravan are finding their niche among a growing number of geophysical companies. "But some customers still insist on using multi-engine aircraft even though multi-engine safety is really a myth in many circumstances for us, since we are so close to the ground that should something go wrong the pilot may not have enough time to reconfigure the airplane and try to climb." In 1996, SGL acquired the first of its three Grand Caravans, which Imray said have worked out well for survey flying. When *WINGS* visited the company in late April, two of the Caravans were being readied for a three-month job in Greenland. "Since the Caravan has a single engine, fixed landing gear and no single-engine control speed limitations, it has proven itself to be very safe, efficient, easy to maintain and easy to fly for surveying that requires low airspeeds, drape flying over rough topography or flight at high altitude. It also has the capability to carry the loads that we may sometimes require, such as the heavy crystal packs that are used to detect gamma radiation emitted from the ground, with full fuel - we couldn't do that with any of our other aircraft."

Each survey aircraft is fitted with a rigid aluminum and composite material tail stinger designed to accommodate a magnetometer sensor. The stinger can be easily removed and the aircraft returned to its original configuration. There is a camera window in the belly of the aircraft and provisions for survey and navigation systems have also been made. Where applicable, airframes have been extensively modified to reduce the magnetic signature of the aircraft by replacing ferromagnetic parts with parts made from special non-magnetic stainless steel or aluminium. Several wiring changes have also been made to the electrical system to reduce magnetic field variations around the aircraft.

Survey Flying

With a worldwide customer base, the most challenging flying sometimes comes in just getting to the job site, which can take more than a week of travel. SGL has designed and integrated its own ferry tanks on all its aircraft. For example, with long-range ferry tanks installed the Caravan can fly up to 11 hours before refuelling. On transatlantic flights crews typically fly Newfoundland-Greenland-Iceland-Scotland, or from St. John's to the Azores to the Canary Islands if going to Africa or to Portugal if going to the Middle East.

"Crews can be over water for up to 10 and a half hours at times," said SGL Chief Pilot Jan Kristiansen. "The hardest part is reestablishing ourselves once we are at the location we will be operating from. We have to get to know ATC and keep them apprised of what we're doing, have the necessary permits and ensure that we get to know the area in general." When one of the company's Caravans was operating in Portugal two years ago, it was intercepted twice by Portuguese Air Force F-16s. "Sometimes not everyone gets the necessary documentation!"

Kristiansen said that while the term 'survey flying' may sound mundane, it is really quite challenging. "It is one of the most challenging types of

Raising Awareness

Through the advent of the International Airborne Geophysics Safety Association (IAGSA) in 1995, aviation and exploration companies have come together to work toward enhancing the overall safety level in airborne geophysics. IAGSA's chief operating officer, Norman Bobbitt, said survey flying presents a different set of hazards from other types of operations, but it wasn't until recently that the association could determine the overall safety record. "We're still coming to grips with the activity rate," said Bobbitt. "It's good to know how many accidents there are in a year, but we still don't know the level of flying activity, so we can't compare ourselves with the rest of the industry at this time. But we anticipate having accurate data by the end of this year from all member companies."

As IAGSA gathers information, it has become evident that many accidents closely resemble a previous one. Bobbitt said the association's main goal is to develop recommended practices that address some of the recognized problem areas. "The practices that have been developed can help prevent accidents. However, for this initiative to achieve its potential, these recommended practices must be broadly implemented and consistently applied." He added that each survey should be subjected to a thorough risk assessment to identify potential hazards. But Bobbitt acknowledges that complying with IAGSA's standards carries a short-term price tag. "This could mean that a supplier that would like to follow IAGSA's recommended practices will be competing against others that do not make the necessary investment and commitment to high safety standards. Companies that do not invest in safety initiatives such as those recommended by IAGSA, may produce some technical or financial benefits for the client of a particular survey but it will inevitably lead to more accidents and higher costs for the industry as a whole."

Bobbitt believes that most accidents in geophysical survey flying to date could have been prevented, and he hopes that a set of recommendations outlined in the association's Safety Policy Manual will help lower the accident rate. IAGSA itself has no power to enforce these practices, so it has developed a recommended Survey Contract Annex for use by exploration firms and agencies contracting the services of airborne geophysics companies. The use of this Annex makes the safety standards and practices part of the contractual requirements, covering such areas as survey height, turning procedures, minimum safe survey speed, flight following, flight and duty times, fuel, use of oxygen, and survival equipment, to name a few. "By bringing aviation and non-aviation companies together we can both have a better understanding of what aircraft are capable of doing. They can then understand why an aircraft can't fly at 50 feet AGL or that a pilot can't fly safely alone for eight hours a day."

With its head office in Ottawa, IAGSA currently has 12 members, 12 associate members and 14 non-voting members from numerous countries.

In most cases survey aircraft are required to fly low and slow in order to gather accurate data. The company's single Islander has the ability to fly constant speeds in mountainous terrain. In this case it was flying a survey over a geyser in Yellowstone National Park in the US.
SGL Photo

flying one can be involved in when compared to the rest of the industry. The only way to gather accurate high-resolution data is to fly slow and low enough to improve the resolution of the data required." However, some surveys don't require such slow speeds and low altitudes, allowing the company to increase production since it can fly faster to produce more line kilometres of data on a given flight and reduce the number of hours on a survey. Typically, though, surveys are flown in a grid pattern at 300-500 feet AGL in lines from two to as much as 230 kilometres long, 50 to 500 metres apart, back and forth depending on the customer's requirements. And it is all hand flown. The use of autopilot is hampered by several factors: "The magnetic noise created by the servo motors interferes with the signal to be measured and the close proximity to the ground during most surveys would provide little if any time for a pilot to recover from a 'runaway' autopilot condition. Duty cycle limitations of the pitch and pitch trim servos are not conducive to frequent pitch commands. And the turbulence associated with low-level flying would more than likely prohibit the use of an autopilot system."

Despite the apparent risks, SGL has never suffered an accident. The company's safety policy extends to its founding membership of the International Airborne Geophysics Safety Association. Kristiansen credits the company's own training standards and philosophy for its safety performance. "Many survey companies are flying single-pilot operations that can last up to six hours at a time, but we always fly with a two-pilot crew on surveys that typically last five to eight hours with pilots alternating control."

Aircraft used for airborne geophysics have traditionally been smaller types with relatively simple navigation systems. But Imray says that the more accurately the actual flight path of the survey aircraft can be recovered, the more useful is the resulting data. In the past the navigation system was used primarily for point-to-point navigation. For survey flying, pilots had to follow lines drawn on topographic maps and aerial photographs, usually with the aid of a navigator, and a frame or strip film was used to record the ground track. After the flight, the geophysicist had to then painstakingly cross-reference the photos with the flight path of the aircraft. "Later, some companies had successes with radio navigation equipment such as Doppler radar, Omega and LORAN, but still none of these systems on their own accurately satisfy the needs of airborne surveying," Kristiansen said. "Inertial navigation systems were also used. But it wasn't until the advent of GPS that survey companies could get constant and accurate reference to position, and SGL has become an industry leader in this."

A survey field team normally comprises one AME, two pilots and one geophysicist. AME Leo Breault cleans the windshield on C-GBENKO in Guinea while Doug Gerrard and Jan Kristiansen and geophysicist Kelly O'Conner take a moment for the camera.
SGL Photo

Sander's R&D division developed its own specialized navigation systems for airborne remote sensing applications. "Based on Real Time Differential GPS (RTDGPS), GPSNav has been specifically designed by Sander to allow for precise navigation to an accuracy of five metres in three dimensions anywhere in the world, while SGDrape allows for precise navigation in mountainous terrain," Imray said. The GPSNav steers pilots to the start of a specific line in the survey area, directs them along the survey line and to the next line or any other specified line. The computer compares the planned altitude with the current altitude and notifies the crew of any deviations using a meter in the cockpit that is combined with a cross-track meter. Steering information, up/down, left/right is displayed on a modified ILS indicator above the instrument panel.

Survey Flying Not For Everyone

Experienced long-term survey pilots are hard to find since it is an aviation field that few people know about. Entry-level pilots have at least 1,000 hours TT and start out in the right seat in any one of the company's aircraft. IFR experience is also important for ferrying aircraft, although all survey flying is day VFR. Captains have a minimum of 2,500 hours TT and at least 500 hours PIC time. All pilots undergo SGL's own extensive internal training program plus training at FlightSafety.

While survey flying can be a challenging and often rewarding career, it is not for everyone. "Survey flying is something you like or don't like," said SGL Chief Pilot Jan Kristiansen. "You have to be a well-rounded person who can handle the long periods away from home." A survey pilot will commonly spend six to eight months of the year away from home. "However, we try not to keep anyone out in the field for more than three months at a time, so we rotate crews back to Canada. In this job you don't want to have any imperious reasons to return to Canada after a few weeks of work." He says that there are three categories of pilots who come to SGL: people who cannot handle the long periods away from home, but are good pilots; pilots who don't mind it for a year or so, using experience here as a stepping stone to further their aviation career; and those who love the type of business we're doing and are quite happy to fly a Cessna 404 or Caravan – they like the variety of the sometimes exotic places that they can go to. "It's hard to tell what kind of survey pilot they are going to be until they join the company." In order to keep pilots as long as possible, SGL pays them handsomely for the type of work that they are doing.

While SGL undertakes surveying jobs in all corners of the globe, Kristiansen said it is rare for it to operate from isolated locations. "Most of the areas that we have flown into are well serviced. We're not flying into unprepared strips and living in tents for three months at a time." In a given year a pilot could be flying in maritime, tropical, mountainous or Arctic conditions depending on where the company is working, and could fly from 600 to as much as 1,000 hours a year.

Above – SGL's aircraft have operated in most corners of the world, in this case Bolivia where the company was flying surveys for the government with its Cessna 404 Titan C-GBWE. SGL Photo

Right – Suzie Santaguida, Tim Daly and Malcolm Argyle of SGL look over a survey map. Mike Reyno Photo

Positions are calculated using GPS, and altitudes can be determined from RTDGPS, or from an accurately calibrated barometric altimeter. During a typical survey flight both pilots will concentrate on flying the aircraft during takeoff and landing, but during the survey operations one crew member concentrates on flying while the other operates and monitors the geophysical and navigation equipment. "Operation of the geophysical equipment is essentially automatic," said Kristiansen. "The operator enters the number and direction of the line to be flown. All other functions are computer-controlled."

SGDrape enables flight crews to maintain an optimal drape during survey flying in hilly or mountainous terrain. Drape flying is used where the terrain gradient exceeds the maximum climb or descent gradient capability of the aircraft. The pilot has to start climbs early and accept higher-than-specified terrain clearance (radar altitude) during descents. "The term is descriptive if one considers the analogy of a tarpaulin draped over the terrain to be flown," Imray explained. "The tension on the tarpaulin is analogous to the climb/descent gradient capability of the aircraft and determines how low into the valleys the tarpaulin will fall. The final shape of the tarpaulin defines a flyable surface." A Digital Terrain Model (DTM) is modified to reduce all slopes to within the capabilities of the individual survey aircraft to climb and descend. The flight crew matches the aircraft's altitude with the DTM with the assistance of the GPSNav. "The system removes a lot of the guesswork from the selection of survey altitudes in rough topography, thereby enhancing the quality of the final data and improving the safety of the survey operation," said Kristiansen.

Without the drape flying program, crews would be hard pressed to fly adjacent lines at a consistent altitude. Decisions must be made as to when to start climbing when approaching rising terrain, how deep to descend into the valley, how steeply to descend off a ridge and what altitudes to fly parallel to a ridge to enable control lines to intersect with all the primary lines. Crews must also fly the aircraft, watch for other aircraft and obstacles, and monitor the survey instruments. "The task of defining the right drape altitude is much better performed by a computer using a DTM." A DTM is obtained for the survey area, it is then verified and corrected using up-to-date base maps. The DTM is then adjusted to reduce all slopes to a maximum of the safe rate of climb and descent which the survey aircraft can maintain. "This system offers a significant safety advantage because the rate of climb is limited before the start of the survey operations to that which can be safely maintained. The system tends to reduce the pilot workload and fatigue, leaving more time for the flight crew to attend to other tasks," Imray said. SGL limits its survey operations to daylight VFR conditions, allowing the crew to maintain a careful lookout for uncharted obstacles and avoid situations where the aircraft may be unable to maintain a safe altitude and airspeed.

After each flight, the data gathered is transferred from the aircraft and copied into a computer in the field office. "Flight path videos are also reviewed by the field operations manager to check for so-called 'cultural' effects (man-made anomalies)," Sander said. The field team is then able to produce preliminary contour or colour maps and data profiles as a test of the data quality. "Once all of the data has been compiled from a survey job it can still take several months from start to finish before we can present the data to the customer."

Maintaining The Fleet

Maintaining an aircraft that can be as far as 15,000 kilometres away from home is no easy task for a small company such as SGL, but it has proven itself as running a first-class maintenance facility with eight AMEs and two apprentices. In February, SGL won Transport Canada's Roland Groome Award for 1998 for demonstrating that its day-to-day maintenance operations are of exceptionally high standard. "We try to maintain a high standard in our facility and constantly look at how we can make improvements," said SGL Maintenance Director Terry Long. "A big help is management's philosophy of ensuring that we only operate safe aircraft wherever they may be working in the world."

Long said the most difficult thing about maintaining geophysical survey aircraft is that they can often be gone for three or more months at a time. "An AME typically accompanies a survey team and is able to perform daily maintenance inspections, 100- and 200-hour inspections, engine changes, etc., depending on the available facilities. However, we try to do heavy maintenance here in Ottawa before the aircraft heads out for the next job." Long said the challenge is to determine how many hours the aircraft will be flying before certain parts will reach time expiry. "If we know that an aircraft will fly 250 hours on a job and a part expires in 175 hours, we will change the part before leaving instead of having to change it on the road."

As much as a third of SGL's profits are poured into research and development for such things as improving the range of its aircraft or better ways to gather data. In recent years, SGL has been developing an airborne gravimeter. A year and a half ago, SGL turned its maintenance facility into a specialized shop for structures and welding. "We can now design and integrate systems to our aircraft to improve their usefulness," said Long. For example, SGL recently designed and integrated an internal fuel tank for the Caravan, extending its endurance significantly. "We are always looking at ways that we can do things better."