Technical Report

Alberta Methane Field Challenge: Airborne Methane Survey

Alberta
2019

for

Petroleum Technology Alliance Canada

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1. Executive Summary

Sander Geophysics Limited (SGL) conducted a fixed-wing airborne methane survey as part of the Alberta Methane Field Challenge (AMFC) for the Petroleum Technology Alliance Canada through the Alberta Upstream Petroleum Research Fund. Please refer to Appendix I for a company profile of SGL. The primary project objective was to assess the real-world performance of new ground based and airborne methane sensing technologies in comparison with conventional optical gas imaging-based leak detection surveys. The leak detection was done of a controlled release site and selected existing oil and gas infrastructure. SGL was the only airborne team participating.

The survey was initially flown with lines oriented orthogonal to the direction of wind and spaced at 250 m. This was changed to loops centred along the direction of wind offset by 250 m on each pass. A drape surface was created taking into account the terrain and the performance of the aircraft at the expected altitudes and estimated temperatures. The survey was flown with a target clearance of survey 77 m above ground level.

The survey was flown using SGL's Britten-Norman Islander, registration C-GSGX operating from Rocky Mountain House Airport, Alberta. Please refer to Appendix II for a description of the aircraft employed. Production flights commenced on November 14 and data acquisition was completed on November 24, 2019. A total of 7 flights (1001 to 1007) were carried out and a total of 5 SGL staff were employed on the field operations. The survey was completed without significant incident.

Final processing of the data was completed at SGL's head quarters in Ottawa, Canada. Digital data products were delivered to the client December 20, 2019. A total of 2 SGL staff were involved on the data reduction.

2. Field Operations

Operational Base

Operations were conducted from Rocky Mountain House Airport in Rocky Mountain House, Alberta. The survey consisted of 7 production flights, from November 14, 2019 to November 24, 2019.

Mobilization of the SGL crew and equipment to Rocky Mountain House began with the arrival of the Britten-Norman Islander on November 10, 2019. The field office was located the Canalta Rocky Mountain House Hotel. The Rocky Mountain House Airport features a single 5513 foot asphalt runway and has fuel and hangar facilities available. Mobilization was completed on November 12, 2019.

Pre-survey wind instrument calibration tests were flown from Macdonald–Cartier International Airport, in Ottawa, Ontario in advance of the survey.

When not survey flying the aircraft was parked on the apron adjacent the terminal. Each survey flight departed and returned to this location.

The survey flying was completed on November 24, 2019. Demobilization started immediately and was completed on November 25, 2019.

Field Personnel

Table 1 shows a list of SGL technical personnel who participated in the field operations.

Table 1: Survey field crew

	Name	Dates in Field
Crew Chief	Colin Terry	November 11 to November 25
Data Processor	Mike McManus	November 11 to November 25
Chief Pilot	Randall Forwell	November 10 to November 25
First Officer	Martin Stirajs	November 10 to November 25
Aircraft Maintenance Engineer	Roger Knott	November 16 to 18 and 22 to 24

3. Project Objectives

The primary project objective was to assess the real-world performance of new ground based and airborne methane sensing technologies in comparison with conventional optical gas imaging-based leak detection surveys. The leak detection was done of a controlled release site and selected existing oil and gas infrastructure. SGL was the only airborne team participating. The specific objective of the airborne technology was to locate and quantify methane sources released from specific production sites in the region of Rocky Mountain House, Alberta. Locations were targeted to facility level identification for the airborne data. This included repeat surveys of a controlled release at one location at multiple release rates across all flights.

4. Technology Description

Sander Geophysics Limited (SGL) offers direct detection of hydrocarbon gases that naturally seep into the air. These gases can be related to active hydrocarbon systems, industrial activity, biogenic processes and landfills. SGL uses ultra sensitive high resolution sensors mounted in a survey aircraft to record methane gas concentrations in the air. These airborne data can then be used to map ground level gas flux rates, matching measured data to known methane sources.

Intake air is collected by an inlet port mounted externally on the survey aircraft and is pumped through a particle separator filter to an off-axis integrated cavity output spectroscopy (OA-ICOS) analyzer recording at up to 20 Hz.

The position recovery uses NovAtel multi-frequency GNS (GPS) receivers in the aircraft and on the ground, processed using SGL's proprietary GPSoft navigation processing system, resulting in a horizontal position accuracy of better than 0.2 m and a vertical position accuracy of better than 0.3 m.

Proprietary processing is used to calculate the equivalent ground flux rate from the measured airborne data. Working with Shell Global Solution B.V., SGL has successfully measured methane gas flux over varied terrain including arid regions and jungle.

5. AMFC Participation Summary

Sander Geophysics Ltd. surveyed for the entire planned duration of the AMFC. Survey flights were made on November 14, 15, 18, 20, 21, 22, and 23. No flight was possible on November 16 due to an aircraft maintenance issue. No flights were possible on November 17, 19, and 24 due to weather including snow, reduced visibility, and high winds.

A pre-planned drape surface was prepared for the survey to guide the aircraft over the topography in a consistent manner, as close to the minimum clearance as possible. The drape surface was prepared with digital elevation model (DEM) data obtained from the Shuttle Radar Topography Mission (http://srtm.usgs.gov/) for the area in question. The DEM included an extension beyond the survey boundary to allow the aircraft to achieve the drape clearance before coming on line.

The drape surface created used a climb and descent rate of 5 %. Interpolation or extrapolation was used to calculate climb and descent rates for the smooth surface for all locations. The temperature component used for the calculation was based on published weather history. The gentle drape surface created was below the maximum climbing and descending capabilities of the survey aircraft and guided the aircraft as close to the target height above the terrain as possible in all locations whilst retaining reasonable safety margins.

The flight path was initially prepared as blocks of straight lines orthogonal to the wind direction covering geographically clustered sites of interest. This method was used for the first two flights and part of the third. Starting with the third flight flight paths were planned as spirals beginning downwind of the site circling upwind and moving farther upwind with each pass. Sites were listed as "mandatory" or "available" for each day of surveying and were prioritized as such.

All flight path guidance were pre-planned for as many possible wind directions with the plan designed for the most probable wind direction for any given day set up the morning of the flight based on the most recent weather forecast. The actual path flown was decided in flight based on the wind direction.

6. Learnings and Areas of Improvement

The primary challenge faced for this survey was in adapting the airborne surveying methodology for a project optimized around ground surveying. Using an aircraft enables rapid coverage of large areas and eliminates the need to gain ground access. An airborne survey can be flown in a grid pattern to provide regularly spaced (unbiased) data sets, unlike a ground survey in which data acquisition usually is restricted to roads. The typical airborne methodology screens all potential sources existing within an area, without bias, and allows identification of the strongest emitters, promoting targeted remedial actions.

Poor weather encountered during the scheduled project time line also limited the quality of data collected for inversion. Normally, production flights would not be flown on days with forecast unstable winds, extending the length of the survey until surveying was complete, but providing better quality data to compute methane source locations flux rates. This was not possible under the constraints of the Alberta Methane Field Challenge schedule and the goal of comparing airborne and ground measurements. Flights were made even in forecast unstable wind conditions in order to collect as much data as possible in the time available. In some cases the change in wind conditions was large enough that the flight path had to be changed partway through surveying in order to sample downwind of the sites.

The wind stability is less of a concern in cases where the atmospheric methane concentration is of interest in itself and not only as an indication of local source emission rates. The wind stability limitation comes from the inversion of that data to locate and quantify the source. The inversion depends on a steady state assumption so wind direction, speed, and turbulence may only vary within certain limits. As such much of the data was unsuitable for inversion and inversion efforts were focused on sites for which the wind conditions were the most stable, even where still outside typical limits.

The early winter conditions also lead to a low atmospheric boundary layer which made flying within that layer more challenging. This was handled by flying later in the day allowing the layer depth to increase. It would be less of a concern in other times of the year.

Since most participants in the project used ground based systems this project was necessarily optimized around ground access restricted to roads, restricted to only specific sites each day, with direct access available to each site of interest. The selection of sites was optimized for ground travel instead of air, reducing the possible efficiency of flights. To address this situation the survey plan was designed as multiple blocks, each covering one or more sites. This results in more time being spent turning and ferrying between blocks but allowed the mandatory sites to be surveyed each day.

Two flights performed in this way allowed only enough time in the flight to survey the mandatory sites instead of all available sites. In addition, changing wind conditions required switching line directions partway through a block in order to continue surveying downwind of the site.

At this point SGL switched to the spiral flight path strategy. Each site was surveyed individually by circling it multiple times. Each loop was offset by 250 m in the upwind direction from the previous loop. This made it possible to survey all mandatory and available sites in each flight by reducing the time lost during turns, though it did not help with the unusable data during ferry between sites. Further, this strategy makes it more likely that the aircraft will transect plumes even in the case of unstable wind. This flight path mimics the path of some ground systems, and so fails to take advantage of the strengths of airborne surveying.

The reversible jump Markov chain Monte Carlo method used quantifies the emission rate attributable to a specific site by fitting it to the data while simultaneously fitting an unknown number of other methane sources at unknown locations, given a model of background methane and error. It is best suited to cases where the number and locations of sources are unknown. In the case where an unbiased area is surveyed, multiple sources are equally well constrained except where approaching the edges of the area. For the sites surveyed in the Alberta Methane Field Challenge sometimes concentrations originating from sources upwind of the site were greater than concentrations appearing to come from the site. This complicated interpretation. These large concentrations could not be modelled as background or error and so required fitting upwind sources outside area of the surveyed data, and tended to obscure the possible emissions from the site of interest. SGL attempted to partially mitigate this issue by performing multiple runs of the reversible jump Markov chain Monte Carlo inversion taking the maximum a posteriori solution from the previous run and feeding it as initial conditions, separately answering first "how much methane is most likely emitting from this site if this site is emitting methane" followed by "is the concentration more likely attributable to the site or to other sources".

It should be noted that circling an area is useful when using a mass balance approach to interpretation as opposed to the reversible jump Markov chain Monte Carlo method, especially in combination with data collected at multiple altitudes within the atmospheric boundary layer. It was not possible to target multiple altitudes due to the low atmospheric boundary layer at the time of year of the survey.

To improve the process and results in future we suggest several changes. In order to take advantage of the strengths of airborne surveying the restriction to survey specific sites each day could be relaxed. While this will make it more difficult to do direct comparison of ground and airborne data, this is already an issue due to sources being intermittent and changing weather conditions on a timescale of less than a day. This scheduling change would allow the area including all sites of interest as well as other possible methane sources to be efficiently surveyed, allowing more flights to be performed over the same area to mitigate the effects of unstable wind conditions. The placing of specific sites within the context of an area surveyed would also improve the inversion process. The limitation of requiring stable wind conditions for the inversion process could be improved through ongoing research on that topic.

35 different sites were surveyed including the controlled release site. Some sites were surveyed more than once. The wind conditions were considered stable enough for an emission rate estimate for 11 site surveys, four of which were of controlled release site 30 at different times. Of these, 6 had methane concentrations attributable to the site of interest and a quantifiable estimated emission rate. The remaining 5 were determined to have site emissions that could not be resolved from other sources either because there were no detectable emissions or the emissions were obscured due to other sources upwind of the site of interest.

One flight had an equipment issue causing the 4 sites plus the controlled release site for that flight to have no emission rates determined. Unstable wind conditions prevented estimation of emission rates for the remaining site surveys. This information is shown in Table 2.

Table 2: Emission Rate Results

Date	Flight	Site	Calculated Emission Rate
2019-11-14	1001	30	unavailable due to equipment issue
2019-11-14	1001	7	unavailable due to equipment issue
2019-11-14	1001	11	unavailable due to equipment issue
2019-11-14	1001	1	unavailable due to equipment issue
2019-11-14	1001	2	unavailable due to equipment issue
2019-11-14	1001	51	unavailable due to equipment issue
2019-11-15	1002	30	unavailable due to unstable wind
2019-11-15	1002	28	unavailable due to unstable wind
2019-11-15	1002	29	unavailable due to unstable wind
2019-11-15	1002	3	unavailable due to unstable wind
2019-11-15	1002	32	unavailable due to unstable wind
2019-11-15	1002	12	unavailable due to unstable wind
2019-11-15	1002	6	unavailable due to unstable wind
2019-11-18	1003	46	unavailable due to unstable wind
2019-11-18	1003	19	unavailable due to unstable wind
2019-11-18	1003	54	unavailable due to unstable wind
2019-11-18	1003	55	unavailable due to unstable wind

Date	Flight	Site	Calculated Emission Rate
2019-11-18	1003	30	unavailable due to unstable wind
2019-11-18	1003	36	unavailable due to unstable wind
2019-11-18	1003	44	unavailable due to unstable wind
2019-11-14	1001	30	unavailable due to equipment issue
2019-11-14	1001	7	unavailable due to equipment issue
2019-11-14	1001	11	unavailable due to equipment issue
2019-11-20	1004	30	90.02 SCFH for controlled release 1
2019-11-20	1004	30	418.39 SCFH for controlled release 2
2019-11-20	1004	30	unavailable due to unstable wind for controlled release 3
2019-11-20	1004	33	site emissions could not be resolved from other sources
2019-11-20	1004	24	727.96 SCFH
2019-11-20	1004	31	1113.81 SCFH
2019-11-20	1004	30	unavailable due to unstable wind for controlled release 3
2019-11-20	1004	33	site emissions could not be resolved from other sources
2019-11-20	1004	24	727.96 SCFH
2019-11-20	1004	31	1113.81 SCFH
2019-11-20	1004	21	site emissions could not be resolved from other sources
2019-11-21	1005	15	unavailable due to unstable wind
2019-11-21	1005	20	unavailable due to unstable wind
2019-11-21	1005	22	unavailable due to unstable wind
2019-11-21	1005	21	unavailable due to unstable wind
2019-11-21	1005	30	site emissions could not be resolved from other sources for controlled release 1
2019-11-21	1005	30	site emissions could not be resolved from other sources for controlled release 2
2019-11-21	1005	30	unavailable due to unstable wind for controlled release 3
2019-11-21	1005	30	unavailable due to unstable wind for controlled release 4
2019-11-21	1005	30	unavailable due to unstable wind for controlled release 5
2019-11-21	1005	15	unavailable due to unstable wind
2019-11-21	1005	20	unavailable due to unstable wind
2019-11-22	1006	49	unavailable due to unstable wind
2019-11-22	1006	39	unavailable due to unstable wind
2019-11-22	1006	17	unavailable due to unstable wind
2019-11-22	1006	30	unavailable due to unstable wind
2019-11-22	1006	18	unavailable due to unstable wind
2019-11-22	1006	34	1370.49 SCFH
2019-11-22	1006	41	site emissions could not be resolved from other sources
2019-11-22	1006	40	unavailable due to unstable wind
2019-11-22	1006	22	unavailable due to unstable wind
2019-11-23	1007	47	unavailable due to unstable wind
2019-11-23	1007	52	792.93 SCFH
2019-11-23	1007	40	unavailable due to unstable wind
2019-11-23	1007	34	unavailable due to unstable wind
2019-11-23	1007	41	unavailable due to unstable wind
2019-11-23	1007	48	unavailable due to unstable wind
2019-11-23	1007	17	unavailable due to unstable wind
2019-11-23	1007	30	unavailable due to unstable wind

7. Final Products

The final data products includes columnar data delivered as plain text. This data may also be delivered as maps as shown. A report including the sources interpreted from the reversible jump Markov chain Monte Carlo inversion is also included. An example for site 24 follows, with coordinate information removed.

Data Product Example

UTC_Time(s)	Latitude	Longitude	Height(m)	CH4(ppmv)	Altitude(m)	WindEast(m/s)	WindNorth(m/s)	WindUp(m/s)
80949.32			1043.4459	2.0115	86.15	1.367	3.904	0.242
80950.28			1043.3870	2.0141	88.47	1.378	3.718	0.151
80951.25			1043.2578	2.0132	89.10	1.306	3.599	0.217

Figure 1: Excerpt from data delivery for site 24. 470 lines not shown.

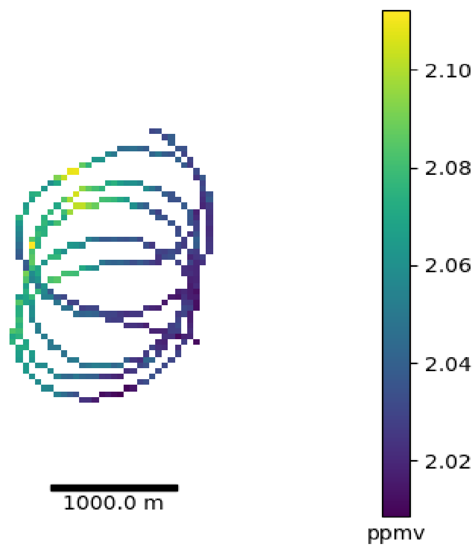


Figure 2: Methane concentration in ppmv measured around site 24.

Interpretation Product Example

Methane source found at a maximum a posteriori location and emission rate of latitude ________°, longitude ________°, and 727.96 SCFH. This source is attributed to site 24.

8. Performance and Cost Implications

The performance and cost of an airborne methane survey can be considered in terms of $ cost per unit mass of attributable mass emission rate mapped within a defined area. In these terms an airborne survey provides a cost effective screening technology to identify larger emitters. In the case of surveying only specific sites the area is small and therefore does not take advantage of the benefits of the airborne surveying.

SGL

Appendix I

Company Profile

ABOUT US

Sander Geophysics Limited (SGL) provides worldwide airborne geophysical surveys for petroleum and mineral exploration, and geological and environmental mapping. Services offered include high resolution airborne gravity, magnetic, electromagnetic, and radiometric surveys, using fixed-wing aircraft and helicopters.

SGL head office in Ottawa, Canada

Dr. George W. Sander (1924-2008) founded SGL in 1956 to provide ground geophysical surveys. The first airborne surveys were performed as early as 1958, and by 1967 airborne geophysical surveys were the company's main focus. Operations have expanded steadily since SGL was founded 60 years ago. The company is led by co-Presidents Luise Sander and Stephan Sander.

WORLDWIDE OPERATIONS

SGL's head office and aircraft maintenance hangar are located at the International Airport in Ottawa, Canada. Sander Geophysics has operated on every continent including Antarctica, over diverse conditions ranging from the tropics to deserts, mountains and offshore.

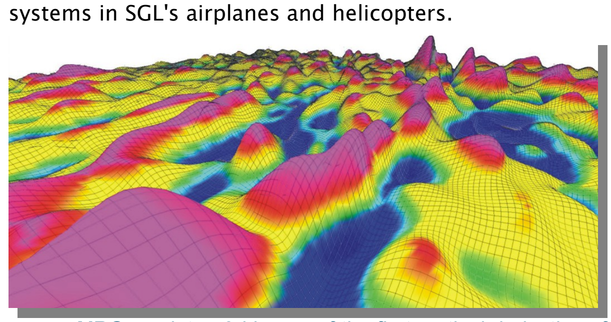
Facilities at the head office include a state of the art data processing department with an integrated digital cartographic department and a fully equipped electronics workshop for research, development and production of geophysical instruments. A Transport Canada Approved Maintenance Organization (AMO) for fixed-wing aircraft and helicopters allows most aircraft maintenance and modifications to be performed in-house.

SERVICES

AIRBORNE SURVEYS

- **Gravity (AIRGrav)**
- **Magnetic Total Field**
- **Magnetic Gradient**
- **Electromagnetic**
- **Gamma-ray Spectrometer**
- **Scanning LiDAR**

SGL offers gravity surveys with **AIRGrav** (Airborne Inertially Referenced Gravimeter), which was designed specifically for the unique characteristics of the airborne environment and is the highest resolution airborne gravimeter available. **AIRGrav** can be flown in an efficient survey aircraft during normal daytime conditions and is routinely flown in combination with magnetometer systems in SGL's airplanes and helicopters.



***AIRGrav** data: 3d image of the first vertical derivative of terrain corrected Bouguer gravity*

DATA PROCESSING

Immediate data processing is part of SGL's standard quality control procedure, and provides clients with rapid results for evaluation while a survey is in progress. Sander Geophysics offers a full range of data enhancement programs and integrated interpretation services by experienced geoscientists. Available products in digital and/or hard copy include:

- **Contour, colour or shaded relief maps of any parameter or combination of parameters**
- **NASVD processed gamma-ray spectrometer data**

- **Filtered line or grid products such as vertical or horizontal gradients, frequency slices, high/low-pass or band-pass filtered, amplitude of the analytic signal, reduction to the pole, upward or downward continuation**
- **Computed depth to basement**
- **Calculated digital terrain models**
- **Two- or three-dimensional modelling**
- **Cultural editing**
- **Complete geophysical interpretative reports**

ENVIRONMENTAL MONITORING

The company also provides environmental monitoring services using gamma-ray spectrometers and specialized processing to detect and quantify natural and anthropogenic radiation.

HEALTH & SAFETY

Sander Geophysics is a founding and active executive member of the International Airborne Geophysics Safety Association (IAGSA), which promotes the safe operation of helicopters and fixed-wing aircraft on airborne geophysical surveys.

SGL has developed and implemented a Safety Management System (SMS) and comprehensive Health, Safety and Environment (HSE) policies that govern all aspects of company operations. Safety initiatives include:

- **Project-specific Aviation Risk Analysis (ARA) and Personnel Risk Analysis (PRA) for all surveys**
- **Real-time satellite tracking of SGL aircraft**
- **HSE and first aid training for all field personnel**
- **Low-level flight and aircraft simulator training for pilots**
- **Advanced safety training appropriate to the survey location, such as water-egress, wilderness survival, etc.**

SGL's excellent safety record reflects the quality and experience of its survey crews. This, combined with management's ongoing commitment to safety, helps to ensure that Sander Geophysics is a safe and reliable choice for airborne geophysical surveys.

PERSONNEL

Sander Geophysics has over 160 experienced permanent employees, including geophysicists, software and hardware engineers, aircraft maintenance engineers and pilots.

AIRCRAFT

SGL owns and operates thirteen aircraft, including eight Cessna Grand Caravans and a Twin Otter all equipped for geophysical surveys.

The Grand Caravans have been modified to allow the installation of a tri-axial magnetic gradiometer system. The company's fleet also includes a de Havilland DHC-6 Twin Otter for airborne magnetic, gravity, radiometric and frequency-domain EM surveys, and two AS350 B3 helicopters equipped for gravity, magnetic and radiometric surveys. Extensive modifications have been made to all of the survey aircraft to accommodate geophysical instruments and to reduce the aircraft's magnetic field. Typical Figures of Merit (FOM) for Sander Geophysics' fixed-wing aircraft are less than 1 nT. The company's aircraft are flown and maintained by licensed and experienced permanent employees of Sander Geophysics.

SGL aircraft

RESEARCH & DEVELOPMENT

Nearly one-third of the company's resources are devoted to developing new and more efficient instrumentation for airborne geophysical surveying, and to further refine its full suite of software for geophysical data processing.

Appendix II

GEOPHYSICAL SURVEY AIRCRAFT

BRITTEN-NORMAN BN2B-21 ISLANDER

Registration	C-GSGX	C-GSGR
Serial #	596	2107

The BN2B Islander is an all metal, high wing, twin-engine, short take-off and landing aircraft powered by two fuel injected engines which drive constant speed, fully feathering propellers. The aircraft has fixed tricycle landing gear, extendable flaps and manually adjustable trim tabs on the rudder and elevator. The aircraft is equipped with de-icing equipment and sufficient avionics for instrument flying. Because of its low take-off speed, high wing, ample propeller clearance, and sturdy fixed landing gear, the Islander is capable of operating from relatively short and rough airstrips. Its excellent low speed capabilities enable it to safely contour much steeper terrain than most other fixed-wing aircraft. Supplementary fuel can be added for transoceanic flight.

GEOPHYSICAL SURVEYING

The aircraft has an aluminium and composite 2.5 m tail stinger designed to accommodate the magnetometer sensor and wiring. The stinger can be easily removed and the aircraft returned to its original configuration. There is a camera hole in the belly and provisions for numerous other survey and navigation systems. The electrical system has been modified to reduce the magnetic field variations around the aircraft.

BRITTEN-NORMAN BN2B-21 ISLANDER SPECIFICATIONS

Crew Capacity:
- 2 pilots, 1 operator (optional)

Fuselage:
- semi-monocoque

Wings:
- cantilever, high wing
- outboard ailerons
- single-slotted inboard flaps

Tail:
- conventional stabilizers
- elevator and rudder with trim tabs

Power Plant:
- 2 Lycoming IO-540, 300 hp, six cylinder, horizontally-opposed air-cooled, fuel-injected, reciprocating engines, overhaul 2,000 hours
- Hartzell two-blade, fully-feathering, constant-speed propellers, overhaul 2,400 hours or 10 years

Systems:
- dual flight controls, IFR instruments and avionics
- full airframe and propeller de-icing
- 2-axis autopilot

Dimensions:

Wing span	53 ft	16.15 m
Exterior length (plus stinger)	35 ft 8 in	10.90 m
Exterior height	13 ft 9 in	4.18 m
Interior usable length	15 ft 2 in	4.62 m
Interior usable width	3 ft 7 in	1.09 m
Interior height	4 ft 2 in	1.26 m

Weights:

Empty	4,190 lb	1,901 kg
Maximum take-off	6,600 lb	2,994 kg

Performance (sea level, standard day, maximum take-off weight):

Range at 60% power (plus reserve)	760 nm	1,408 km
Cruise airspeed at 60% power	121 kt	224 km/h
Fuel flow at 60% power	25.5 US gal/h	97 l/h
Stall airspeed, landing configuration	40 kt	74 km/h
Service ceiling	17,200 ft	5,242 m
Minimum required runway length	2,000 ft	610 m
Two engine rate of climb	1,130 ft/min	344 m/min
Maximum sustained climb gradient	700 ft/nm	115 m/km
Single engine rate of climb	223 ft/min	69 m/min
Usable fuel capacity	189 US gal	715 l

Type of Aviation Fuel: 100LL Avgas
Maximum Endurance: 6 hours, 40 minutes plus 45 minutes reserve at 60% power

GEOPHYSICAL CAPABILITIES

AIRGrav, SGL airborne gravimeter
Magnetic total field
Gamma-ray spectrometer, up to 42 litres (2560 in^3) of detector crystals
SGMethane, methane gas sensing

Additional Features:
- Tail stinger, 2.5 m long, 21 cm in diameter, capable of housing a 5.5 kg sensor
- HF radio
- Video camera mount with glass covered opening in the aircraft belly
- Two instrument racks, standard 48 cm (19 in) width
- Radar altimeter, 0-3,000 m
- Electrical power capacity, 28 VDC at 140 amp
- GPS receiver and antenna plus data link for real-time corrections

v3.0