TECHNICAL REPORT ON AN AIRBORNE GEOPHYSICAL SURVEY OF THE ST. ALBAN'S REGION, NEWFOUNDLAND

FOR THE

GEOLOGICAL SURVEY OF NEWFOUNDLAND

BY

GOLDAK AIRBORNE SURVEYS

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Goldak Airborne Surveys
2 Hangar Rd.
Saskatoon, Saskatchewan
Tel: (306) 249-4474
Fax: (306) 249-4475

Email: info@goldak.ca
URL: www.goldak.ca

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1 INTRODUCTION

This report describes an airborne geophysical survey conducted in the St. Alban's region, Newfoundland. This high sensitivity aeromagnetic and airborne gamma-ray spectrometric survey was carried out by Goldak Airborne Surveys (Goldak) on behalf of the Geological Survey of Newfoundland (GSNL) between October 16th and November 26th, 2015.

Aircraft equipment operated included three cesium vapour magnetometers, an array of three 1024 channel NaI gamma-ray detectors with a total downward looking volume of 50.4 L and a total upward looking volume of 12.6 L, a GPS/GLONASS real-time and post-corrected differential positioning system, a flight path recovery camera, a digital video titling and recording system, as well as radar and barometric altimeters. All data were recorded digitally in GEDAS binary file format.

Reference ground equipment included two GEM Systems GSM-19W Overhauser magnetometers and a Novatel 12 channel GPS/GLONASS base station which was set up at the base of operations for differential post-flight corrections.

Twenty-seven flights (including test and calibration sorties) were required to complete the survey. A total of 8183 line kilometres of high resolution magnetic and gamma-ray spectrometric data were collected, processed and plotted.

The traverse lines were flown at a spacing of 150 metres with control lines flown at a separation of 1000 metres. Nominal terrain clearance was specified at 90 metres above ground. Mean terrain clearance was 133 metres. Gander, Newfoundland was used as the base of operations throughout the entire survey.

All installations and equipment specifications are described in more detail in Section 4 of this report. Daily operational logs were kept and are included as Appendix B of this report.

2 SURVEY AREA LOCATION

The St. Albans survey block was centered over the town of St. Alban's, NL with the midpoint roughly at 48° 52' N, 55° 45' W. This total survey area contained 8183 line kilometers of data (7090 km of traverse lines and 1093 of control lines).

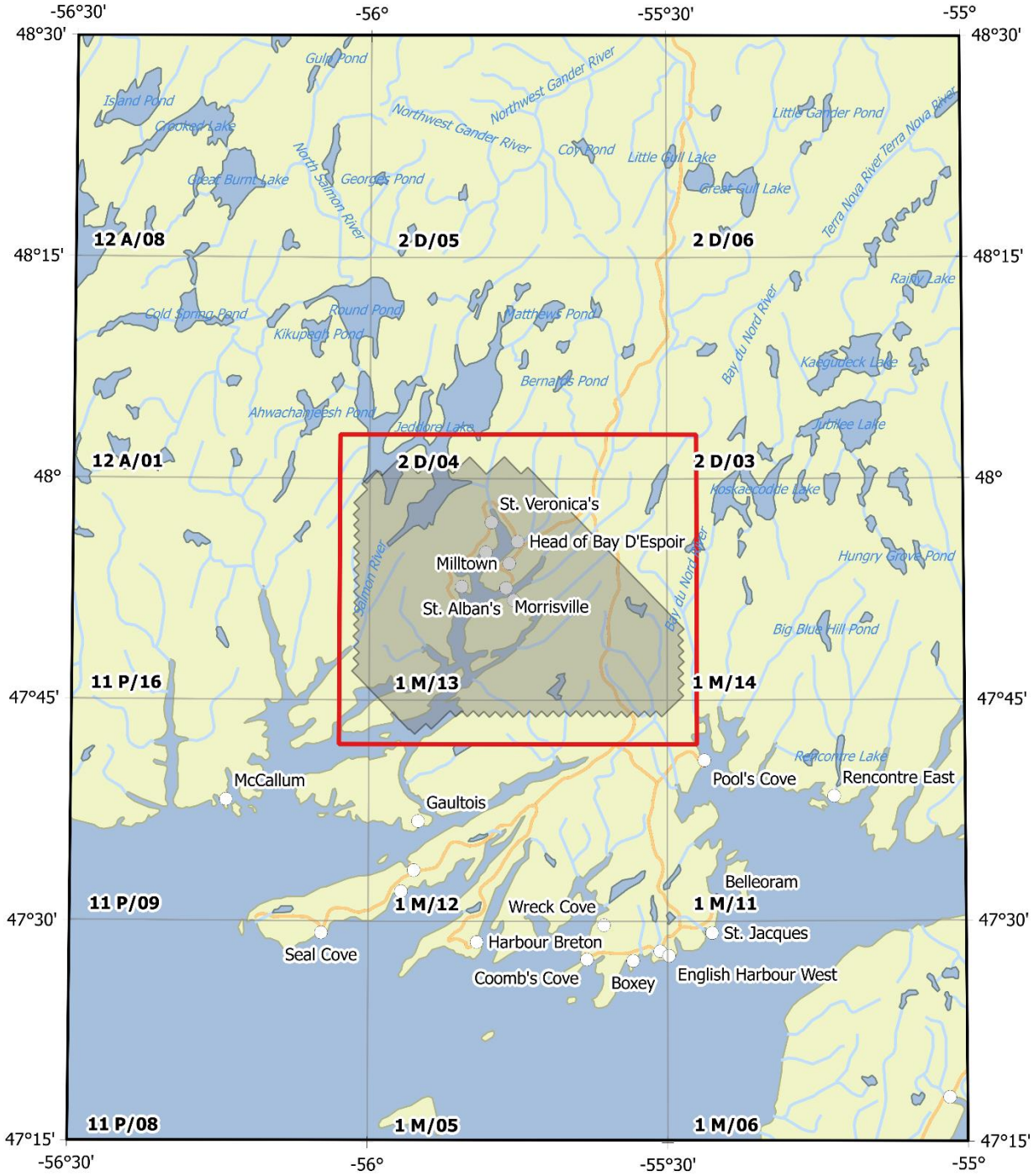


Figure 1 - Location of the St. Alban's Region Survey Block

The St. Albans region survey area was defined by the following NAD83 UTM zone 21N coodinates:

Vertex	Easting	Northing
1	580036	5285445
2	580119	5285532
3	580772	5284909
4	582170	5286255
5	582853	5285589
6	585186	5287907
7	585898	5287198
8	586643	5287928
9	587354	5287218
10	588097	5287960
11	588802	5287260
12	589427	5287900
13	590129	5287190
14	590878	5287917
15	591607	5287226
16	592331	5287968
17	593058	5287241
18	593788	5288001
19	594493	5287309
20	595238	5288024
21	595950	5287312
22	596671	5288063
23	597403	5287369
24	598130	5288104
25	598844	5287398
26	599583	5288134
27	600285	5287455
28	601031	5288176
29	601738	5287462
30	602472	5288199
31	603171	5287492
32	603929	5288238
33	604631	5287540
34	605272	5288171
35	605968	5287453
36	606717	5288209
37	607427	5287501
38	608177	5288251
39	608851	5287543
40	609614	5288287
41	610328	5287572
42	611073	5288322
43	611781	5287622
44	614392	5290231
45	613683	5290925
46	614424	5291683
47	613702	5292390
48	614349	5293015
49	613640	5293736
50	614390	5294474
51	613687	5295169

Vertex	Easting	Northing
52	614332	5295800
53	613620	5296506
54	614253	5297138
55	613539	5297854
56	614308	5298586
57	594411	5318464
58	593577	5317614
59	591455	5319730
60	589220	5317519
61	587102	5319637
62	584986	5317513
63	582856	5319633
64	580629	5317419
65	578505	5319530
66	576069	5317100
67	575361	5317798
68	573694	5316145
69	574412	5315438
70	572735	5313744
71	573428	5313025
72	572691	5312269
73	573393	5311583
74	572755	5310936
75	573454	5310236
76	572825	5309605
77	573539	5308889
78	572786	5308156
79	573497	5307436
80	572861	5306805
81	573556	5306103
82	572829	5305356
83	573528	5304642
84	572888	5304028
85	573611	5303302
86	572881	5302570
87	573576	5301863
88	572949	5301218
89	573628	5300520
90	572887	5299767
91	573605	5299057
92	572957	5298424
93	573664	5297727
94	572925	5296987
95	573633	5296273
96	573007	5295640
97	573716	5294929
98	572970	5294189
99	573665	5293482
100	572832	5292620
101	580036	5285445

Table 1 – St. Alban's Region Survey Area Coordinates

3 CONTRACT SPECIFICATIONS

3.1 Line Spacing

Traverse Lines:

- bearing - N 135°E UTM
- spacing - 150 metres
- allowed min separation - 100 metres
- allowed max separation - 200 metres

Control Lines:

- bearing - N 45°W UTM
- nominal spacing – 1000 metres
- minimum overfly distance 1000

3.2 Altitude

Altitude control was accomplished via a smooth drape constructed using STRM elevation data.

Target nominal altitude: 90 m NTC (nominal terrain clearance)

Mean terrain clearance: 133 m

Tolerance: a maximum 30m difference between traverse lines and control lines. To accomplish this, actual height deviations from the drape surface were not to exceed an envelope of +/- 15 metres at all times.

3.3 Flying Speed

Ground speed of the aircraft was to be between the range of 200 km/h and 270 km/h

3.4 Diurnal Specifications

A maximum tolerance of 3 nT (peak to peak) deviation from a long chord equivalent to a period of 60 seconds was not to be exceeded. Additionally, the diurnal was not to exceed a 0.5 nT deviation over 15 seconds.

3.5 Precipitation Limitations

No survey flying should be undertaken during or for 3 hours after measurable precipitation. In the event of precipitation yielding more than 2 cm of ground soaking rain, flying should be suspended for at least 12 hours after the end of precipitation.

3.6 Magnetic Noise

The magnetic noise was not to exceed 0.1 nT in the 4th digital difference.

All data was fully examined in the field and home office and was deemed to have met the above specifications.

4 AIRCRAFT AND EQUIPMENT

4.1 Aircraft

Type:	Cessna 208 Caravan
Registration:	C-GLDX
Cruise Range:	1800 km
Cruising Speed:	330 km/h
Tyical Survey Speed:	270 km/h
Survey Duration:	6 hours plus reserve
Max Climb Gradient:	13%
Max Descent Gradient:	16%
Aviation Fuel:	Jet A
Fuel Consumption:	150 litres per hour
Oil Consumption:	0.2 liters per hour total
Typical Figure of Merit:	0.7
Tail Stinger:	3 m composite
Wingtip Pods:	1 m composite
Gradiometer Separaton:	18.274 m lateral / 11.233 m longitudinal

A single Cessna 208 Caravan, registration C-GLDX owned and operated by Goldak Airborne Surveys, was used on this survey. The aircraft magnetometers are installed in the 3-meter stinger attached to the rear fuselage and in the 1-metre composite pods attached to each wing-tip. The attitude sensing fluxgate magnetometer is positioned at the midpoint of the stinger. The three magnetometers form a two-axis gradiometer.

The aircraft has been extensively modified, both mechanically and electrically, to minimize the effects of maneuvering on the measured magnetic field. This aircraft has typical a Figure of Merit result of less than 0.7 nT as measured to Geological Survey of Canada (GSC) specification.

Figure 2 - Aircraft C-GLDX

4.2 Airborne Systems

4.2.1 Data Acquisition System

Manufacturer:	Goldak Exploration Technology Ltd.
Type and Model Number:	GEDAS
Sampling Rate:	10 Hz
Data Format:	GEDAS binary

All magnetic and positioning data are processed and recorded digitally by our GEDAS system. The GEDAS is an industrial rack-mount Intel Pentium based PC computer with multiple hard-drives, IO ports and ADAC devices.

The GEDAS system records GNSS navigation records at 1Hz. Magnetic, radar altimeter and barometric altimeter data are recorded at 10 Hz. All data is tightly synchronized to GPS time with an accuracy of ± 1 millisecond. Each data packet, on arrival to the data system is stamped with a system time with a resolution of 1 millisecond. Data files are organized on a flight-by-flight basis in a proprietary binary format. The data can then imported directly into Geosoft® via a custom import routine.

4.2.2 Magnetometers and Compensation

Aircraft Magnetometers:

Manufacturer:	Geometrics
Type and Model Number:	Cesium G-822A
Range in nT:	20,000 to 90,000
Sensitivity in nT:	0.005
Sampling Rate:	10 Hz

Real-time Magnetic Compensator:

Manufacturer:	RMS Instruments
Type and Model Number:	AADCII or AARC
Range in nT:	20,000 to 100,000
Resolution in nT:	0.001
Sampling Rate:	20Hz

The airborne magnetometers used are a matched set of Geometrics G-822A optically pumped cesium vapour types with sensitivity of 0.005 nT. The magnetometer's Larmor signal is decoupled and counted by a RMS Instruments AADCII compensator, and data are produced at a rate of 10 Hz with a resolution of 0.001 nT. The data bandwidth is from 0 to 0.9 Hz with an internal noise level of less than 0.002 nT.

Compensation mathematically "corrects" the magnetic data for noise due to aircraft motion and heading. Prior to the survey, the aircraft is taken to an area of low magnetic gradient at a high altitude (7000' AGL +) and put through a series of rolls, pitches and yaws on each of the survey's cardinal headings. The data collected from these maneuvers can then be used to form a model of the aircraft's magnetic characteristics without the near influence of the local geology.

The remaining magnetic distortion is quantified by a term known as the Figure of Merit, or FOM. The Geological Survey of Canada uses a figure of merit of 1.5 or less as standard survey criteria.

Three compensation flights were completed over the course of the survey. The results of these flights are posted in Appendix A.

4.2.3 Radiometric System

Manufacturer:	Radiation Solutions Inc.
Type and Model Number:	RS-500 Digital Gamma-ray Spectrometer
Detector Volume:	50.4 L downward, 12.6 L upwards
Channels:	1024
Sampling Rate:	1 Hz

4.2.4 GNSS Positioning and Navigation

Navigation System:

Manufacturer	Goldak Exploration Technology Ltd.
Type and Model Number	GENAV
Displays	10" Color LCD data display
	3D Autodrape LCD pilot display

GNSS Receiver:

Manufacturer	Novatel
Type and Model Number:	OEMV dual-frequency ProPakV3 (x1)
System Resolution:	<1 meter
Overall accuracy:	3 m in real-time, <1m post-corrected
Number Channels:	120
Signal Tracking:	GPS L1, L2, L2C, L5
	GLONASS L1, L2
	Galileo E1, E5

INS Receiver:

Manufacturer	Novatel
Type and Model Number	SPAN-CPT

The GNSS receiver in the survey aircraft was a GPS and GLONASS capable Novatel OEMV ProPakV3 12 channel dual-frequency differential unit that communicates directly with the GEDAS system. This unit is used for navigation purposes and also logs data for post-flight differential corrections.

GNSS signals can be affected by atmospheric and ionospheric effects which typically reduce the accuracy of the non-differential positioning to approximately 10 metres RMS. If a suitable stationary GPS receiver, on a known or assumed position, is used to record the apparent errors in the satellite range data, those errors can be used to correct the moving receiver in the aircraft to an accuracy of 1 meter RMS. This compensation process is called differential correction and can be applied to the moving receiver in real time for higher dynamic accuracy, or applied later to find out where the aircraft *was* with high accuracy. These are called real-time and post-corrected differential positioning respectively.

4.2.5 Radar Altimeters

Radar Altimeter 1:

Manufacturer	Thompson
Type and Model Number:	CFS 530A
Range:	0-8000 feet
Resolution:	1 meter
Accuracy:	2%

Radar Altimeter 2:

Manufacturer	Terra
Type and Model Number:	TRA3000 – TRI40
Range:	40-2500 feet
Resolution:	3 metres
Accuracy:	5-7%

4.2.6 Barometric Altimeter

Manufacturer:	Setra
Type and Model Number:	270
Range:	-1000 to 10,000 feet
Resolution:	1 meter

4.2.7 Visual Flight Path Recovery

Flight Path Camera:

Manufacturer:	Panasonic
Model:	GPKR402 HRSV
Lens:	WV-LR4R5 4.5mm
Field of view at 300m AGL	317 x 396m

Video Titler:

Manufacturer:	Horita
Model:	SCT-50
Type:	video overlay with 10Hz clock

Digital Video Recorder:

Manufacturer:	Toronto Micro-Electronics
Model:	MDVR301
Type:	digital MPEG

The flight path was captured by a Panasonic GP-KR402 HRSV hi-resolution color video camera located in the lower rear fuselage of each aircraft. The video was recorded to a removable hard drive by a Toronto Micro Systems MDVR digital recorder, and then burned to dual layer DVD post flight.

4.3 Ground Systems

4.3.1 Magnetic Base Stations

Base Station Magnetometers:

Manufacturer:	GEM Systems
Type and Model Number:	Overhauser GSM-19W
Range in nT:	20,000 to 120,000
Sensitivity in nT:	0.01
Sampling Rate:	1 Hz (5 Hz maximum)

Base Station Data Loggers:

Manufacturer:	Acumen
Type and Model Number:	Data Bridge SDR-CF Serial Data Recorder
Media Type:	Compact Flash

Figure 3 - Base Magnetometer Installation

For this survey two magnetic base stations were installed. Multiple stations are useful both as a hardware back up and to discern any cultural effects from either unit. In both installations the base station employed was a GEM Systems GSM19W Overhauser type proton precession magnetometer with GPS time base. Each setup was configured to log data both internally and externally to a compact flash card using an Acumen DataBridge SDR serial data recorder. The station closest to the base of operations was also equipped with a VHF radio link to the processing office so that diurnal conditions could be monitored in real time. Station BaseMag 1, which included the VHF radio link, was installed in a wooded area approximately 1 km west of the Comfort Inn Motel, Gander. Station BaseMag 2 was installed in a wooded area approximately 1.5 km east of the Gander airport. The installation details are as follows:

Station	Longitude	Latitude	Elevation	Reference Value
BaseMag 1	-54º 37' 33.0''	48º 57' 14.7''	124 m	51644 nT
BaseMag 2	-54º 32' 4.0''	48º 57' 1.7''	131 m	51725 nT

Table 2 - Base Magnetometer Stations

4.3.2 GNSS Base Station

Base GNSS Reciever:

Manufacturer	Novatel
Type and Model Number:	OEMV dual-frequency ProPakV3 (x1)
System Resolution:	<1 meter
Overall accuracy:	3 m in real-time, <1m post-corrected
Number Channels:	120
Signal Tracking:	GPS L1, L2, L2C, L5
	GLONASS L1, L2
	Galileo E1, E5

The base station receiver unit, like the airborne units, was a GPS and GLONASS capable Novatel OEMV ProPakV3 whose data were logged by a battery-powered, industrial portable computer. A survey-grade GNSS base antenna designed to minimize multi-path errors was set up on the roof of the Comfort Inn, Gander. The precise position of the antenna was determined by collecting 9 hours of data then submitting the data to the NRCan's online Precise Point Positioning (PPP) service. The following WGS84 coordinate was delivered:

Longitude	-54º 37' 8.3029''
Latitude	48º 57' 5.5597''
Ellipsoidal Height	143.501 m

Table 3 - Base GNSS Position

Figure 4 - Base GNSS Antenna Installation

4.4 Field Office Systems

4.4.1 Field Data Verification, Logging and Plotting

Processing Computer:

Manufacturer:	Lenovo
Type and Model Number:	ThinkCentre / Intel i5 3.4 GHz

Data Logging Computers:

Manufacturer:	Lenovo
Type and Model Number:	ThinkPad / Intel i5 3.4 GHz

Plotters and Printers:

Manufacturer:	Canon
Type and Model Number:	Inkjet

Data backup:

Manufacturer:	Sony
Type and Model Number:	DVD+-R / CDRW
Manufacturer:	Western Digital
Type and Model Number:	1.5 TB external HDD

4.4.2 Software

Manufacturer:	Geosoft®
Function:	Geophysical data processing
Type and Model Number:	Oasis Montaj v 7.2

Manufacturer:	Waypoint Consulting
Function:	GPS post-processing
Type and Model Number:	GrafNav v 8.50

Manufacturer:	MatLab
Function:	Geophysical data processing
Type and Model Number	2015b

Manufacturer:	Scott Hogg & Associates
Function:	Offline Magnetic Compensation
Type and Model Number:	CompCal v 1.1

5 PERSONNEL

The following Goldak personnel were involved in the St. Albans project:

Owner / President	Ben Goldak
Project Manager / Data Processor	Glen Carson
Logistics Coordinator	Bill Heath
Office / Finance	Brenda Doherty
Aircraft Engineer	Daniel Leppington
Pilot	Jay Mathieson
Co-pilot	Kurtis Schindel
Field Data Processor	Abbas Shaikh

Table 4 - Project Personnel

6 DATA PROCESSING

6.1 Positioning Data and Altitude Data

Processing of the positioning data takes place in the field and is performed on a post-flight basis. The following procedures are included in positioning and altitude data processing:

1. The raw airborne GPS data are corrected using the corresponding GPS base station data and NovAtel® Inc.'s Waypoint® GrafNav® GNSS Post-Processing software suite.
2. The corrected GPS World Geodetic System 1984 (WGS84) longitude, latitude and altitude are merged into a Geosoft® database with aircraft flight data and re-projected to the local UTM Zone 21 NAD83 datum. Velocity is then calculated from the corrected positions. Corrected UTM co-ordinates are trimmed to online.
3. The primary radar altimeter data is lagged by 0.9 seconds and the secondary radar altimeter data is lagged by 3.0 seconds.
4. The digital elevation model is calculated by subtracting the radar altimeter data from the GPS altitude data.
5. Quality-control procedures described in section 7.2 are performed.

6.2 Magnetic Data

6.2.1 Initial Field Processing

Processing of the magnetic data begins in the field where the raw magnetic, positioning and altitude data from the aircraft acquisition systems is first imported into a Geosoft® Oasis montaj™ database on a line basis. The magnetic base station data, logged during the corresponding flight time, were then merged with the flight data for display and quality control checks.

1. A system latency correction, determined from the pre-survey lag test of 0.4 seconds for the tail magnetometer data and 0.3 seconds for the wing-tip magnetometer data, is then applied.
2. A diurnal correction derived from the local magnetic base station data is applied to account for temporal variations in the total magnetic field.
3. The raw, measured magnetic gradients are normalized using the known aircraft sensor separations and aircraft direction to give consistently signed gradient values in units of nT/m. A correction matrix, derived from the attitude data, is then applied scaling them to provide true longitudinal and transverse gradient values parallel to and perpendicular to the ideal line direction.
4. Quality-control procedures described in section 7.2 are performed.

6.2.2 Control-Line Levelling

The intention of control-line levelling is to apply a smoothly-varying function to the measured data, which results in nearly identical values at the intersections of traverse and control lines. The most significant component of the correction is to accommodate the diurnal variation of the magnetic field. Other sources of error are altitude errors, GPS positioning errors and system drift.

Levelling of the total field data consists of the following steps:

1. Calculation of the positions of the survey-line–control-line intersection points and the extraction of mismatch values of the magnetic data between the line and control lines at these points.
2. An iterative application of corrections, based of best-fit, first-order linear trends of mismatch values (with outliers removed), on the traverse and control lines until the resulting corrections approach zero.
3. An iterative application of long-wavelength corrections on traverse and control lines determined by applying median and low-pass filters to the remaining intersection mismatches (with outliers removed) and then using Akima spline interpolation between the now-filtered intersection

mismatch values. This enhances and isolates correction "features" that span several intersections. The lengths of the filters are based on the traverse-line–control-line intersection separations. In this case, the initial filter lengths spanned 10 control-line intersections on survey lines and 50 survey-line intersections on control lines. The number of intersections spanned is reduced in increments to an appropriate minimum until the correction approaches zero.

4. Calculation of the first vertical derivative from the gridded data of the intermediate levelled total field using a 2-D fast Fourier transform (FFT) operator.
5. An altitude correction derived by multiplying the calculated vertical gradient by the aircraft's deviation from the planned surface height is then applied to the original unlevelled magnetic data.
6. Steps 1 to 3 are then repeated using the altitude-corrected magnetic data.
7. Manual inspection of the remaining intersection mismatches and reducing it to zero (where appropriate) by applying the necessary corrections to either the survey or tie lines. Special attention is paid to ensuring that the overall correction profiles are as smooth as possible and that there is no line-to-line correlation in the correction profiles, which implies a misapplied correction.
8. The second vertical derivative of the total field grid is analyzed to ensure that the corrections are sufficient and appropriate. Features that appear along the survey lines in the second vertical derivative may be the result of over-correction or under-correction. In either case, the solution is to revise the correction profile at those intersections.

6.2.3 Calculation and Removal of the International Geomagnetic Reference Field

The International Geomagnetic Reference Field (IGRF) was calculated using the 2015 model year with a constant date of November 5, 2015 (roughly the mid-point of the survey) as the reference date. A constant altitude of 300 m, the mean altitude over the course of the survey, was specified as the elevation. This value was subtracted from the tie-line levelled data to obtain the residual magnetic field data.

6.2.4 Microlevelling of the Magnetic Data

After control line levelling, any residual flight line noise or "corrugation" in the magnetic field data was further reduced using Paterson, Grant & Watson's microlevelling technique. This technique first involves the generation of line-to-line noise profiles by applying frequency domain sixth-order, high-pass Butterworth filter and a directional cosine filter perpendicular to the flight-line direction to the gridded data. This "decorrugation" grid is then sampled back into the database. The initial noise profile data is then limited to a user-defined maximum amplitude and then filtered using a Naudy–Dreyer non-linear filter to obtain the microlevelling correction. Finally, the correction and gridded microlevelled data are inspected to ensure no geological signal was removed and an overall improvement in the gridded data was achieved.

The following parameters in Paterson, Grant & Watson's "Miclev" routine were used:

- Decorrugation wavelength cutoff: 2000 m
- Decorrugation grid cell size: 100 m
- Naudy filter length: 1000 m
- Naudy filter tolerance: 0.0001
- Amplitude limit: 1.0 nT

6.2.5 Processing of Measured Magnetic Gradients

Processing of the magnetic gradient data consists of the following steps:

1. Attitude correction, as described in section 5.3.1, is performed before levelling the gradient information. The effect of attitude on a particular measurement is dependent on the magnitude of the local gradient and the degree of deviation from straight and level flight. This compound effect cannot be accounted for by tie-line levelling of the data, as it is both non-systematic and at a much shorter wavelength than the tie-line separation. Correcting the data for attitude before levelling insures that levelling corrections are kept to a minimum.
2. Horizontal gradients are calculated from the gridded total field data, sampled into the database and subtracted from the measured, rotated gradients.
3. A 31 second median filter followed by a 31 second low-pass filter is applied to the difference and then added back to the measured gradient. This ensures that the lower wavelengths accurately represent the regional field, which is otherwise difficult to achieve.

6.2.6 Gradient-Enhanced Gridding of the Residual Magnetic Intensity

Gradient enhancement of the residual magnetic intensity was achieved using Goldak's Gradient Variable Trend (GVT) gridding algorithm, which utilizes the horizontal gradients to guide the between-line interpolation of the data to generate a more realistic image free of artifacts and irregularities present grids generated from minimum curvature algorithms.

6.2.7 Calculation of the Vertical Derivative Grids

The first and second vertical derivative grids were calculated directly from the gradient-enhanced residual magnetic intensity grid using the Geosoft MagMap grid processing suite.

6.2.8 Gridding of the Measured Magnetic Gradients

The final measured lateral and longitudinal horizontal gradient data was gridded using minimum curvature methods.

6.3 Radiometric Data

The processing methodology was as described in the IAEA Airborne Gamma Ray Spectrometer Surveying Report (IAEA 1991). In this case, no energy calibration or dead-time correction was done as the dead time is typically much less than 0.1% with the Radiation Solutions Inc. system.

6.3.1 Spectral Noise Reduction

Statistical noise reduction in the radiometric data was accomplished using Goldak's GET NASVD software package. In the process, groups of observed spectra are first scaled to yield a constant variance in each channel. These adjusted groups of spectra are then factorized to component matrices using a singular value decomposition (SVD) routine such that:

$$N = USV^T$$

where,

N = adjusted data matrix of size n samples by m channels

S = m by n matrix where the diagonal elements are the ranked singular values of N

U = orthogonal n by n matrix

V = orthogonal m by m matrix the columns of which are the principle components of N

The bulk of the original signal is contained in the lower order components while the higher order components can be regarded as statistical noise. By reconstructing the data using only the lower order

components, "smoothed" spectra are produced with less statistical noise. Count rates in the total count, potassium, thorium and uranium windows are then extracted from these noise-reduced spectra and imported to an Oasis montaj™ database for further processing.

6.3.2 Filtering of the Cosmic and Upward Uranium Channels

Variations in the cosmic channel are of long wavelength and usually attributed to changes in altitude or atmospheric conditions. A 200 point low-pass filter is applied on a flight-by-flight basis to the cosmic channel to allow for a smooth correction, free of statistical noise in the process described in section 5.4.3. Similarly, the upward uranium channel, used in the correction of atmospheric radon, is highly susceptible to statistical noise due to generally low count rates. A 30 point low-pass filter, again on a flight-by-flight basis, is applied to the upward-looking uranium channel.

6.3.3 Cosmic and Aircraft Background Corrections

Radiation in the 3 to 6 MeV range, the cosmic channel, is attributed to non-Earth sources and can be considered as pure noise, in that it has no relationship with the desired geological signal. As such, it can be measured independently and used to remove the cosmic component in lower energy windows.

Theory suggests that the cosmic measurement should increase linearly as altitude increases, provided there is no contamination from radon. Methodology for the removal of the cosmic background involves a cosmic calibration flight where measurements are taken at a variety of heights from 3500 to 12 000 feet altitude. Linear regressions are derived for each of the regions of interest relative to the cosmic channel. The slope yields the "cosmic stripping ratio" and the y intercept is, in theory, the aircraft background.

The correction applied is then expressed as

$$N_i = (a_i * C) + b_i$$

where,

N_i = cosmic correction in the i'th channel;
a_i = cosmic stripping ratio in the i'th channel;
C = counts in cosmic window (3 to 6 MeV);
b_i = aircraft background in the i'th channel.

In practice, the aircraft background derived in this fashion can be unreliable, likely because of the small number of data points in each flight and some non-linearity in the relationship between counts in the cosmic and ROI (region of interest) windows at lower altitudes. It is also difficult to obtain a data set that is untainted by radon contamination. As an alternative, an iterative process was used to determine the final aircraft backgrounds. Initially, a background value of zero is assumed for each channel and cosmic and radon corrections are applied. Then, the overwater repeat lines are averaged for each aircraft and added to the background. The process is repeated until the overwater values average zero.

The coefficients determined by the above process are as follows:

i	a_i	b_i
TC	1.147	76.0
K	0.065	20.7
U	0.051	1.0
Th	0.074	-4.5
UpU	0.014	0.1

6.3.4 Radon Background Corrections

Radon concentrations vary from flight to flight and are affected by weather and topography. A variety of methods can be used to model and remove this signal. The upward detector, which is mostly shielded from geologic signal by being centred above 4 downward detectors, is used to estimate the contribution of

atmospheric radon into the downward uranium channel, U_r, and overwater tests are used to determine the ratio between radon in the uranium window and radon contributions to the other windows.

After cosmic and background corrections have been applied, the signal detected over water is solely due to atmospheric radon. Overwater "backgrounds" are flown at the beginning and end of every flight to collect data with a variety of ambient radon concentrations.

These data are averaged and analyzed to solve the following equations by linear regressions:

$$u_r = a_U * U_r + b_U$$

$$K_r = a_K * U_r + b_K$$

$$Th_r = a_{Th} * U_r + b_{Th}$$

$$TC_r = a_{TC} * U_r + b_{TC}$$

where,

u_r	=	the radon component in the upward U window;
K_r , U_r , Th_r , TC_r	=	the radon components in the various windows of the downward detectors
a_i	=	the calibration constants determined by linear regression;
b_i	=	the now near-zero backgrounds after removal of aircraft and cosmic backgrounds.

The coefficients determined by the above process are as follows:

i	a_i
TC	15.486
K	0.836
Th	0.078
u	0.290

The radon contribution to the downward uranium window, U_r, can be determined from:

$$U_r = \frac{(u - a_1 * U - a_2 * Th + a_2 * b_{Th} - b_U)}{(a_U - a_1 - a_2 * a_{Th})}$$

where,

u	=	count rate in the upward uranium window;
U , Th	=	count rates in the uranium and thorium windows;
a_U	=	ratio of upward uranium counts to downward uranium counts in the overwater data;
a_{Th}	=	ratio of thorium counts to downward uranium counts in the overwater data;
b_U , b_{Th}	=	the small non-zero background in the uranium and thorium channels after removal of cosmic and aircraft backgrounds;
a_1 , a_2	=	covariance coefficients that relate counts in the downward uranium and thorium channels to counts in the upward uranium channels.

The above a_1 and a_2 coefficients are determined in the following process:

The signal measured in the upward uranium window is made up of a contribution from atmospheric radon and a geologic component due to radioactive sources in the ground. This component (u_g) has a linear relationship with the downward uranium (U_g) and thorium (Th_g) given by

$$u_g = a_1 * U_g + a_2 * Th_g$$

Values of u_g, U_g and Th_g are found by analyzing the differences in count rates in each window for adjacent sections of survey lines. Differences between count rates are found at some interval, m, in the upward and downward uranium and thorium channels. Where the overall radioactivity was decreasing, as evidenced by the difference in the total count window, the sign of the differences was reversed.

$$U_g = (U_n - U_{n+m})$$

$$Th_g = (Th_n - Th_{n+m})$$

$$u_g = (u_n - u_{n+m})$$

The differences then are accumulated over the entire survey to determine the calibration factors for upward uranium to downward uranium and thorium for sources in the ground by solving the simultaneous linear equations:

$$\sum(u_g * U_g) = a_1 * \sum(U_g)^2 + a_2 * \sum(U_g * Th_g)$$

and

$$\sum(u_g * U_g) = a_1 * \sum(U_g * Th_g) + a_2 * \sum((Th_g)^2$$

where the summation is carried out over all (n) points in the database

The coefficients determined by the above process are as follows:

a_1	0.06
a_2	0.04

6.3.5 Spectral Stripping Corrections

The spectra of the potassium, uranium and thorium series overlap. Because of this, each spectral window contains counts due to each of the other windows. This can be corrected by "stripping" the data using coefficients derived by obtaining measurements over concrete pads with known radioelement concentrations. Each crystal pack was tested prior to the survey with Goldak's calibrated test pads. The first 3 coefficients vary with height above ground; the attenuation values used are standard values from the IAEA reports.

	Average	DPU 5407	DPU 5621	DPU 5442	Δ / m
α	0.29210	0.29353	0.29242	0.29242	0.00049
β	0.44315	0.44087	0.44778	0.44778	0.00065
γ	0.80326	0.80358	0.80551	0.80551	0.00069
a	0.05333	0.05289	0.05680	0.05680	
b	-0.00064	-0.00046	-0.00051	-0.00051	
g	-0.00045	-0.00085	-0.00159	-0.00159	

Given the background corrected count rates in the potassium, uranium and thorium windows (N) and stripping matrix (S) the stripped count rates in each window (A) can be calculated as follows:

$$A = S^{-1}N$$

or

$$\begin{bmatrix} K_{strip} \\ U_{strip} \\ Th_{strip} \end{bmatrix} = \begin{bmatrix} 1 & \gamma & \beta \\ g & 1 & \alpha \\ b & a & 1 \end{bmatrix}^{-1} * \begin{bmatrix} K_{bg} \\ U_{bg} \\ Th_{bg} \end{bmatrix}$$

which yields:

$$K_{strip} = \frac{Th_{bg} * (\alpha * \gamma - \beta) + U_{bg} * (a * \beta - \gamma) + K_{bg} * (1 - a * \alpha)}{\det(S)}$$

$$U_{strip} = \frac{Th_{bg} * (g * \beta - \gamma) + U_{bg} * (1 - b * \beta) + K_{bg} * (b * \alpha - g)}{\det(S)}$$

$$Th_{strip} = \frac{Th_{bg} * (1 - g * \gamma) + U_{bg} * (b * \gamma - a) + K_{bg} * (a * g - b)}{\det(S)}$$

where,

$$\det(S) = 1 - g * \gamma - a * (\gamma - g * \beta) - b * (\beta - \alpha * \gamma)$$

6.3.6 Calculation of Effective Height

The height of the detectors must be corrected to standard temperature and pressure (STP) height to account for the attenuating properties of changes in air density on count rates. This effective height, h_e, is calculated from the formula below:

$$h_e = h * \left(\frac{273.15}{T + 273.15}\right) * \left(\frac{P}{1013.25}\right)$$

where,

h	=	the observed height above ground level (AGL) in metres;
T	=	temperature in degrees Celsius;
P	=	barometric pressure in millibars.

6.3.7 Height Attenuation Correction and Conversion to Radioelement Concentrations

Prior to the survey the aircraft was flown over the Geological Survey of Canada–approved Danielson test range, located approximately 100 km south of Saskatoon, Saskatchewan, to determine its respective system sensitivities and height attenuation coefficients. These parameters are installation specific and relate to the detector crystal packs used, the aircraft and the location of the equipment within the aircraft. A calibrated meter was used to traverse the test range while the aircraft was flying over at several altitudes. The data are background corrected by immediately flying over nearby water at the same height. They are then stripped and reduced to survey height. The system sensitivities are the ratios of counts to the measured concentrations. The attenuation coefficient is then derived from the exponential relationship between the stripped counts at the various heights.

The calculated altitude attenuation coefficients are as follows:

Total Counts (c/s/m)	-0.00699
Potassium (c/s/m)	-0.00894
Uranium (c/s/m)	-0.0067
Thorium (c/s/m)	-0.00727

The calculated system sensitivities are as follows:

Total Counts (c/s/nGy/h)	29.2094
Potassium (c/s/%)	77.5891
Uranium (c/s/ppm)	8.9501
Thorium (c/s/ppm)	4.8147

The survey data in each window are first reduced to the observed count rate at standard temperature and pressure (STP) height and then scaled by the sensitivity to determine the final ground concentration, *C*, using the following equation

$$C = \frac{n_0 e^{-\mu(H-h)}}{S}$$

where,

n_0 = stripped count rate;
e = Euler's constant
μ = window attenuation coefficient;
H = nominal survey terrain clearance;
h = standard temperature and pressure (STP) height above ground of observation;
S = sensitivity.

6.3.8 Calculation of the Elemental Ratios

Because corrected count rates frequently go to zero or even negative values over water, a simple mathematical ratio is not meaningful and is not useful in the calculation of elemental ratios. The standard procedure is to sum neighbouring points until some threshold, equivalent to 100 counts, is met in both the numerator and denominator and then calculate the ratio. If the threshold isn't reached within 50 samples, then the point is ignored. This minimizes the statistical error in the data and cleans up the "blow-ups" that would occur when the denominator went to zero. Additionally, no ratio is calculated at locations where the potassium concentration is less than 0.25%.

The ratio grid was derived in a similar fashion from the grids of elemental concentrations. In this case, the values are summed at an increasing radius from the centre point until the threshold is met or a maximum radius of 1000 m is reached. At each step, 4 more points were added to the sum, to account for the circular symmetry. No ratio was calculated where the potassium counts were less than 100.

6.3.9 Generation of the Ternary Radioelement Image

The ternary map is produced by scaling the distribution of uranium, potassium and thorium against cyan, magenta and yellow, respectively. In this case, the data were processed using Goldak's ternary image generation utility, which normalizes the data and applies an optimum colour distribution. The algorithm used is as described in Broome et al. (1987).

7 QUALITY CONTROL

7.1 Tests and Calibrations

The full results of the tests and calibrations described below can be found in Appendix A.

a) Compensation Figure of Merit

Aircraft movements induce spurious magnetic fields, which are removed from the magnetic data by the compensator. The efficiency of this removal can be evaluated by conducting a test called a Figure of Merit (FOM). The aircraft flies a series of 3 manoeuvres of ±10° rolls, ±5° pitches and ±5° yaws in each of the traverse- and control-line directions in a magnetically quiet zone (low magnetic gradient). The peak-to-peak amplitudes of the responses obtained on the magnetometer compensated channel are determined for each of the 3 manoeuvre types and for each of the 4 directions. The 12 values are then summed giving the Figure of Merit.

Compensation figure of merit tests were performed by both aircraft after their initial arrival on site and before survey operations commenced. In addition, the calibration and tests were repeated after any significant change to the aircraft or its systems which may have altered its magnetic properties.

In all calibration and subsequent tests performed by the aircraft, the resultant figures of merit for the tail and wing-tip sensors were below the specified threshold of 1.5 nT.

b) Heading Test

To verify system accuracy and acceptable heading error a heading test was performed over the GSC Moorewood calibration range. The aircraft performed 3 passes in each cardinal direction directly over a predefined point and the aircraft measured total field was compared between opposing passes.

For all tests performed the calculated heading errors were minimal.

c) Lag Test

To verify the magnetic system latency, the survey aircraft conducted lag tests. These tests involve flying multiple passes in each of the 4 cardinal headings over a known magnetic feature and comparing the position of the observed magnetic peaks with the known position of the target.

The aircraft flew this test over a tower located 22 km southwest of Saskatoon, Saskatchewan prior to survey commencement.

The calculated system latencies from this tests were determined to be consistent with previous tests performed by this aircraft.

d) Radar Altimeter Calibration

The radar altimeter calibration and verification were performed by acquiring altitude data from several passes of increasing altitude over the runway at the Saskatoon airport. The radar altimeters of both aircraft were confirmed to have a linear relationship with and within acceptable range of the GPS height.

e) Cosmic Calibration

High-altitude cosmic calibration flights were performed by the aircraft prior to and after the survey. In this test, the aircraft climbed from 1500 m to 3600 m in increments of 300 m and accumulated approximately 10 minutes of data at each altitude. The resultant data determined the linear relationship between counts in the cosmic window and each region of interest window.

f) Radiometric Test Range

The aircraft performed a calibration flight over Goldak's radiometric test range at Danielson, Saskatchewan, to determine the radiometric system sensitivities and altitude attenuation factors. The aircraft repeated a 10 km test line and an adjacent over-water line (for background corrections) at altitudes of 60 to 270 m in 30 m increments.

Simultaneously, actual ground concentrations were measured by a ground crew equipped with a calibrated hand-held RSI™ RS-230 BGO spectrometer. At 8 pre-determined stations along the survey test line, four 180-second sample accumulations were acquired, each approximately 20 m apart. The processed measurements are then averaged giving the ground concentrations in each window for the test line.

g) Radiometric Pad Test

To determine the stripping ratios of each detector, calibrations were done at Goldak's hangar using pads calibrated by Bob Grasty (Grasty and Hovgaard 1996). Four concrete pads, 3 embedded with the ROI radioelements and one "bare" pad for background corrections, were placed beneath detector packs installed in the aircraft. Data were then accumulated for approximately 20 minutes. The averaged count rates are then used to compute the 6 stripping ratios for each spectrometer.

7.2 Daily Field Quality Control

a) Positioning Data

In a Geosoft® Oasis montaj™ database, the corrected GPS data are inspected for gaps and positioning error as indicated by anomalous velocity changes or vertical offsets. The real-time positions are compared to the post-corrected positions for integrity check.

Flight path is examined to detect horizontal deviations that exceed tolerances. Computed velocity is inspected and confirmed to be within tolerances.

The radar altimeter and barometric altimeter data are inspected for anomalous conditions. The computed digital elevation model is compared against known topographical data. Vertical navigation is checked for deviations from the pre-determined flight surface that exceed tolerances.

b) Magnetic Data

Goldak Airborne Surveys' data acquisition system is designed to allow the second pilot to monitor data quality at all times. Both pilots have been trained to operate the equipment and recognize data problems. Automated systems are also in place to draw their attention to anomalous conditions. In addition, the field processor is continually monitoring the magnetic base station via radio link to be on the alert for poor diurnal conditions. The field processor maintains scheduled communication with the aircraft for flight-following purposes and to update the flight crew on weather and diurnal conditions.

After a survey flight, the magnetic and measured gradient data are inspected on a line-by-line basis for gaps, spikes and other anomalous conditions. Magnetic noise levels are monitored using the fourth digital difference and visually. The magnetic base station data are examined for deviations that exceed the contract stated peak-to-peak magnitude and chord lengths. Reflights are assigned where necessary.

A frequency domain plot of the uncompensated and compensated magnetic data is generated through fast Fourier transform on a line-by-line basis and inspected. Through this, the general ongoing performance of the magnetic compensation can be evaluated and any aircraft system-induced magnetic noise can be easily discerned.

Grids of the total field and horizontal gradient data, along with flight path plots, are examined daily to visually compare the correlation of data between lines and across flights.

c) Radiometric Data

On-site, weather conditions were continuously monitored to ensure that no radiometric survey took place within 4 hours after measurable precipitation or 12 hours after heavy precipitation.

Prior to each survey flight, the field crew performed the two following system verification tests. The results of these system verification tests are plotted in Appendix A

Source Tests:

> While the aircraft sat stationary, a ^{232}Th source was placed in a cradle and attached to the aircraft beneath the spectrometer detector pack and data were collected for 2 minutes. The sample was then removed and data were again collected for 2 minutes for background determination. The results analyzed and plotted to ensure consistent sensitivities throughout the survey.

System Resolution Test:

> A ^{232}Th source was used determine the full width–half amplitude (FWHM) of the 2615 keV photopeak, expressed as a percentage, as a measure of system performance. In all tests performed, FWHM of the photopeak remained below the contract specified threshold of 6%.

Before and after each radiometric survey flight, a repeat line was flown as an additional measure of system consistency throughout the survey as well as consistency between aircraft.

During a survey flight, the flight crew is presented with a diagnostic display of the of the radiometric acquisition system showing a combined spectra and status of each detector crystal. In the event of anomalous system state or error, a visual alert is displayed.

Post flight, the radiometric data are imported into a Geosoft® Oasis Montaj™ database and viewed in profile format. The data are checked for any gaps, erroneous detector crystal states or stabilization errors. Any records that show an error in detector state are removed and scheduled for reflight if needed. Rough background correction estimates are removed from the ROI channels and the data are displayed in grid format to check for coherence.

A complete archive of the spectra is maintained from the spectrometer console data. An RSI software package can be used with these archives to correct any stabilization problems that may be subsequently found.

7.3 Quality Control in the Home Office

a) Review of field processed data

At the home office, the results of the field processing are reviewed at regular intervals throughout the survey and following completion.

b) Review of the final processed data

The results of the levelling of the magnetic data are reviewed on a line-by-line basis through inspection of the total correction profile and intersection mismatch values. Final grid products are visually and statistically inspected for overall quality and validity.

8 FINAL PRODUCTS

8.1 Digital Profile Data

Databases containing the magnetic and radiometric profile data were delivered in Geosoft® .GDB format. The fields included in each respective database are as follows:

Channel Name	Description	Units
FLIGHT	Flight number	-
AIRCRAFT	Aicraft Registration	-
LINE	Line number	-
LINETYPE	L - survey line , T - tieline	-
LINENAME	LINETYPE & LINENUMBER	-
DATE	Flight date	YYYY/MM/DD
TIME	UTC seconds after midnight	s
LONG	NAD83 longitude	D:M:S
LAT	NAD83 latitude	D:M:S
EASTING	NAD83 UTM Z21N easting	m
NORTHING	NAD83 UTM Z21N northing	m
GPSALTR	Raw GPS altitude	m
GPSALT	Final GPS altitude	m
RALT1RAW	Raw primary radar altimeter	m
RALT2RAW	Raw secondary radar altimeter	m
RALT	Final Radar altimeter	m
BALT	Barometric altimeter	m
SURFACE	Flight Surface	m
DEMRAW	Raw digital elevation model	m
DEMLEV	Levelled digital elevation model	m
TMAGUCOM	Uncompensated tail mag	nT
TMAGCOM	Compensated tail mag	nT
TMAGLAG	Lagged, compensated tail mag	nT
LMAGUCOM	Uncompensated left mag	nT
LMAGCOM	Compensated left mag	nT
LMAGLAG	Lagged, compensated left mag	nT
RMAGUCOM	Uncompensated right mag	nT
RMAGCOM	Compensated right mag	nT
RMAGLAG	Lagged, compensated right mag	Δ nT
HG_OUCOM	Uncompensated orthogonal gradient	Δ nT
HG_OCOM	Compensated orthogonal gradient	Δ nT
HG_OLAG	Lagged, compensated orthogonal gradient	Δ nT
HG_LUCOM	Uncompensated longitudinal gradient	Δ nT
HG_LCOM	Compensated longitudinal gradient	Δ nT
HG_LLAG	Lagged, compensated longitudinal gradient	Δ nT
MAGHCOR	Height correction	nT
MAGTLCOR	Tie-line levelling correction	nT
MAGMLCOR	Microlevelling correction	nT
IGRF	IGRF	nT
SRVMAGLEV	Levelled mag	
SURVMAGRES	Final residual mag (TMAGLAG + MAGHCOR + MAGTLCOR + MAGMLCOR - IGRF)	nT
HG_OROT	Rotated othogonal gradient	nT / m
HG_LROT	Rotated longitudinal gradient	nT / m
HG_OLEV	Final othogonal gradient	nT / m
HG_LLEV	Final longitudinal gradient	nT / m
HG_EAST	Final horizontal gradient, east component	nT / m
HG_NORTH	Final horizontal gradient, north component	nT / m
FLUXTRAN	Transverse fluxgate	nT
FLUXLONG	Longitudinal fluxgate	nT
FLUXVERT	Vertical fluxgate	nT
DIURNAL1	Base station 1 mag	nT
DIURNAL2	Base Station 2 mag	nT
PITCH	Aircraft pitch (nose up +ve)	°
ROLL	Aircraft roll (left wing up +ve)	°
YAW	Aircraft yaw (CCW from line dir +ve)	°
AZIMUTH	Aircraft azimuth	°

Table 5 - Final Magnetic Database Channels

Channel Name	Description	Units
FLIGHT	Flight number	-
AIRCRAFT	Aicraft Registration	-
LINE	Line number	-
LINETYPE	L - survey line , T - tieline	-
LINENAME	LINETYPE+LINENUMBER	-
DATE	Flight date	YYYY/MM/DD
TIME	UTC seconds after midnight	s
LONG	NAD83 longitude	D:M:S
LAT	NAD83 latitude	D:M:S
EASTING	NAD83 UTM Z21N easting	m
NORTHING	NAD83 UTM Z21N northing	m
GPSALT	Final GPS altitude	m
RALT	Final Radar altimeter	m
BALT	Barometric altimeter	m
HEIGHT_STP	Standard temperature/pressure height	m
TEMPERATURE	Temperature	°C
BAROPRESS	Barometric pressure	kPa
R_LIVE_DN	Downward detector livetime	ms
R_SPECTRUM_DN	Downward spectra	1024 ch. array
R_LIVE_UP	Upward dectector livetime	ms
R_SPECTRUM_UP	Upward spectra	1024 ch. array
R_COSMIC	Raw cosmic count	cps
R_TOT	Raw total count	cps
R_POT	Raw potassium count	cps
R_URA	Raw uranium count	cps
R_THO	Raw thorium count	cps
R_UPU	Raw upward uranium count	cps
NASVD_TOT	NASVD processed total count	cps
NASVD_POT	NASVD processed potassium count	cps
NASVD_URA	NASVD processed uranium count	cps
NASVD_THO	NASVD processed thorium count	cps
NASVD_UPU	NASVD processed upward uranium count	cps
RADON	Computed radon background	cps
F_NADR	Natural air absorbed dose rate	nGy/h
F_POT	Final corrected potassium concentration	%
F_URA	Final corrected uranium concentration	ppm
F_THO	Final corrected thorium concentration	ppm
F_RUK	Equivalent uranium / potassium	ppm/%
F_RUT	Equivalent uranium / equivalent thorium	ppm/ppm
F_RTK	Equivalent thorium / potassium	ppm/%

Table 6 - Final Radiometric Database Channels

8.2 Maps

1:50,000 scale, UTM Zone 21N, NAD83 datum maps were delivered digitally in Geosoft .MAP and Adobe .PDF formats.

Ten sheets were produced with the following themes and names:

Map	Sheet Number	Grid Layer
2014-04	1	Residual magnetic intensity
2014-05	2	First vertical derivative of the magnetic field
2014-06	3	Percent potassium
2014-07	4	Equivalent uranium
2014-08	5	Equivalent thorium
2014-09	6	Ratio of equivalent thorium to percent potassium
2014-10	7	Ratio of equivalent uranium to percent potassium
2014-11	8	Ratio of equivalent uranium to equivalent thorium
2014-12	9	Ternary radioelement image
2014-13	10	Natural air absorbed dose rate

Table 7 - Final 1:50,000 Scale Maps

8.3 Gridded Data

Grids in UTM Zone 21N, NAD83 datum coordinates of the following data were delivered in Geosoft .GRD format:

Data	Cell Size (m)	File Name
Residual magnetic intensity	37	MAG_RES.grd
Calculated 1st vertical derivative	37	MAG_RES_1VD.grd
Calculated 2nd vertical derivative	37	MAG_RES_2VD.grd
Horizontal gradient, north direction	37	HG_NORTH.grd
Horizontal gradient, east direction	37	HG_EAST.grd
Digital elevation model	37	DEM.grd
Natural air absorbed dose rate	37	NADR.grd
Percent potassium	37	POT.grd
Equivalent uranium	37	URA.grd
Equivalent thorium	37	THO.grd
Ratio of equivalent uranium to equivalent thorium	37	RUT.grd
Ratio of equivalent uranium to percent potassium	37	RUK.grd
Ratio of equivalent thorium to percent potassium	37	RTK.grd

Table 8 - Final Grids

8.4 Flight Path Video

Flight path video for this survey was supplied on external hard drive, archived by flight, in a proprietary format. Software required to view the video is included on. Times, positions, direction and speed are overlain on the tape for detailed flight path recovery if required.

APPENDIX A – TEST AND CALIBRATION RESULTS

A.1 Compensation Figure of Merits

Compensation / Figure of Merit Test Analysis

Project	St. Alban's, NL
Flight	11
Aircraft	C-GLDX
Date	2015-10-16
Julian Day	289

Pilot	Mathieson
Copilot	Schindel
Processor	Shaikh

Test Summary

MB FOM	0.69
MR FOM	1.44
ML FOM	0.71
GX FOM	0.83
GY FOM	0.57

Test Location	Gander, NL
Reason for Comp / FOM	Initial Comp/FOM

Air Time	1
Test Time	
Ferry Time	1

FOM Analysis

Bottom Tail Magnetometer (MBc)					
	North	East	South	West	Sum
Pitch	0.08	0.09	0.09	0.09	0.35
Roll	0.04	0.02	0.05	0.03	0.14
Yaw	0.04	0.04	0.06	0.06	0.20
Sum	0.16	0.15	0.20	0.18	0.69

Right Wing Magnetometer (MRc)					
	North	East	South	West	Sum
Pitch	0.12	0.15	0.15	0.15	0.57
Roll	0.05	0.06	0.09	0.06	0.26
Yaw	0.1	0.11	0.22	0.18	0.61
Sum	0.27	0.32	0.46	0.39	1.44

Left Wing Magnetometer (MLc)					
	North	East	South	West	Sum
Pitch	0.06	0.09	0.1	0.12	0.37
Roll	0.04	0.03	0.04	0.03	0.14
Yaw	0.03	0.04	0.08	0.05	0.20
Sum	0.13	0.16	0.22	0.20	0.71

Lateral Gradient (GXc)					
	North	East	South	West	Sum
Pitch	0.06	0.04	0.05	0.06	0.21
Roll	0.04	0.03	0.04	0.05	0.16
Yaw	0.07	0.11	0.15	0.13	0.46
Sum	0.17	0.18	0.24	0.24	0.83

Longitudinal Gradient (GYc)					
	North	East	South	West	Sum
Pitch	0.02	0.04	0.05	0.04	0.15
Roll	0.03	0.04	0.03	0.05	0.15
Yaw	0.06	0.05	0.09	0.07	0.27
Sum	0.11	0.13	0.17	0.16	0.57

Table 9 - C-GLDX Compensation Figure of Merit, October 16

Compensation / Figure of Merit Test Analysis

Project	St. Alban's, NL
Flight	24
Aircraft	C-GLDX
Date	2015-11-22
Julian Day	326

Pilot	Mathieson
Copilot	Schindel
Processor	Shaikh

Test Summary

MB FOM	0.67
MR FOM	1.73
ML FOM	0.66
GX FOM	1.31
GY FOM	0.75

Test Location	Gander, NL
Reason for Comp / FOM	Starter generator reapired

Air Time	1.3
Test Time	0.6
Ferry Time	0.7

FOM Analysis

Bottom Tail Magnetometer (MBc)					
	North	East	South	West	Sum
Pitch	0.09	0.09	0.09	0.12	0.39
Roll	0.03	0.03	0.05	0.03	0.14
Yaw	0.03	0.03	0.03	0.05	0.14
Sum	0.15	0.15	0.17	0.20	0.67

Right Wing Magnetometer (MRc)					
	North	East	South	West	Sum
Pitch	0.14	0.15	0.18	0.19	0.66
Roll	0.07	0.07	0.13	0.09	0.36
Yaw	0.12	0.16	0.19	0.24	0.71
Sum	0.33	0.38	0.50	0.52	1.73

Left Wing Magnetometer (MLc)					
	North	East	South	West	Sum
Pitch	0.07	0.08	0.1	0.12	0.37
Roll	0.02	0.02	0.06	0.04	0.14
Yaw	0.04	0.04	0.04	0.03	0.15
Sum	0.13	0.14	0.20	0.19	0.66

Lateral Gradient (GXc)					
	North	East	South	West	Sum
Pitch	0.09	0.08	0.09	0.09	0.35
Roll	0.08	0.06	0.08	0.09	0.31
Yaw	0.1	0.17	0.19	0.19	0.65
Sum	0.27	0.31	0.36	0.37	1.31

Longitudinal Gradient (GYc)					
	North	East	South	West	Sum
Pitch	0.06	0.04	0.05	0.06	0.21
Roll	0.05	0.04	0.05	0.07	0.21
Yaw	0.07	0.06	0.1	0.1	0.33
Sum	0.18	0.14	0.20	0.23	0.75

Table 10 - C-GLDX Compensation Figure of Merit, November 22

A.2 Radar Altimeter Calibrations

Radar Altimeter Calibration Analysis

Project	GSNL - St. Albans
Flight	3
Aircraft	C-GLDX
Date	Oct 3. 2015
Julian Day	279

Pilot	Mathieson
Copilot	
Processor	Heath

Radar Stack Summary

Runway Height	501
Tail Height	1.6

Test Location	Saskatoon -15-33
Radar 1 Type	Thompson-CFS ERT160
Radar 2 Type	Terra TRA-30

Radar 1 Scale Factor	0.996
Radar 2 Scale Factor	

Radar Stack Analysis

PASS (ft)	GPSAlt	RAlt 1	RAlt 2	Hgt AGL	RAlt 1 Scale	RAlt 2 Scale
1	578.5	76.3		75.9	0.995	
2	653.1	150.3		150.5	1.001	
3	717.3	216.9		214.7	0.990	
4	774.3	272.7		271.7	0.996	
5	836.6	336.6		334	0.992	
6	857.1	354.4		354.5	1.000	

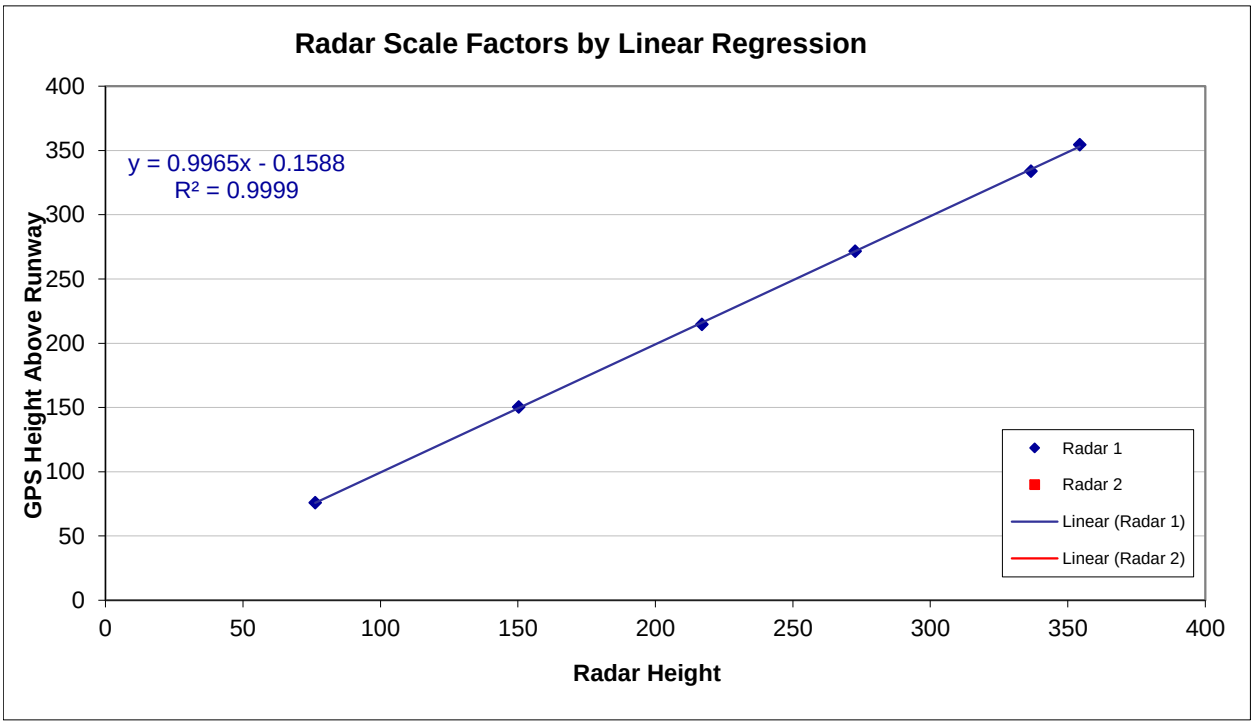


Table 11 - C-GLDX Radar Altimeter Calibration, October 3

A.3 Heading Test

Heading Test Analysis

Project	GSNL - St Albans
Flight	31
Aircraft	C-GLDX
Date	2015-12-05
Julian Day	339

Pilot	Mathieson
Copilot	
Processor	Carson

Heading Test Summary

MB Mean Offset	-1.74
MB Mean N/S Error	0.16
MB Mean E/W Error	0.97
MB Mean Error	0.56
MR Mean Offset	-6.00
MR Mean N/S Error	1.77
MR Mean E/W Error	0.76
MR Mean Error	1.27
ML Mean Offset	-1.58
ML Mean N/S Error	1.22
ML Mean E/W Error	2.19
ML Mean Error	1.71

Test Location	Morewood, ON
Station Offset	638.70

Air Time	1
Test Time	0.3
Ferry Time	0.7

Heading Test Analysis

Bottom Tail Magnetometer (MB)							
Pass	Direction	Time	Meas TF	Base TF	Offset (nT)	Heading Error (nT)	Heading
1	N	54408.1	53787.63	54427.43	-1.11	0.14	N-S
2	S	54568.0	53788.79	54428.74	-1.25		
3	N	54723.1	53785.53	54426.00	-1.78	0.15	N-S
4	S	54878.2	53782.74	54423.36	-1.92		
5	N	55182.0	53777.83	54418.70	-2.17	0.19	N-S
6	S	55337.1	53778.07	54418.76	-1.99		
7	E	55639.5	53781.97	54421.61	-0.95	1.35	E-W
8	W	55819.7	53779.37	54420.37	-2.30		
9	E	55971.5	53778.60	54418.75	-1.45	0.87	E-W
10	W	56146.0	53776.08	54417.10	-2.32		
11	E	56302.1	53773.94	54414.10	-1.46	0.68	E-W
12	W	56483.1	53774.49	54415.33	-2.15		

Right Wing Magnetometer (MR)							
Pass	Direction	Time	Meas TF	Base TF	Offset (nT)	Heading Error (nT)	Heading
1	N	54408.1	53782.18	54427.43	-6.55	2.01	N-S
2	S	54568	53785.50	54428.74	-4.54		
3	N	54723.1	53780.41	54426.00	-6.90	1.53	N-S
4	S	54878.2	53779.29	54423.36	-5.37		
5	N	55182	53772.61	54418.70	-7.40	1.78	N-S
6	S	55337.1	53774.45	54418.76	-5.61		
7	E	55639.5	53776.86	54421.61	-6.05	0.46	E-W
8	W	55819.7	53776.08	54420.37	-5.59		
9	E	55971.5	53773.60	54418.75	-6.45	0.84	E-W
10	W	56146	53772.79	54417.10	-5.61		
11	E	56302.1	53768.95	54414.10	-6.45	0.98	E-W
12	W	56483.1	53771.17	54415.33	-5.47		

Left Wing Magnetometer (ML)							
Pass	Direction	Time	Meas TF	Base TF	Offset (nT)	Heading Error (nT)	Heading
1	N	54408.1	53787.05	54427.43	-1.68	1.42	N-S
2	S	54568	53789.78	54428.74	-0.27		
3	N	54723.1	53785.23	54426.00	-2.08	0.91	N-S
4	S	54878.2	53783.49	54423.36	-1.17		
5	N	55182	53777.20	54418.70	-2.81	1.34	N-S
6	S	55337.1	53778.59	54418.76	-1.47		
7	E	55639.5	53780.41	54421.61	-2.50	1.99	E-W
8	W	55819.7	53781.16	54420.37	-0.51		
9	E	55971.5	53777.36	54418.75	-2.69	2.15	E-W
10	W	56146	53777.86	54417.10	-0.53		
11	E	56302.1	53772.55	54414.10	-2.85	2.44	E-W
12	W	56483.1	53776.22	54415.33	-0.41		

Table 12 - C-GLDX Heading Test, December 5

A.4 Lag Test

Lag Test Analysis

Project	St Albans and Mineville
Flight	4
Aircraft	C-GLDX
Date	2015-10-06
Julian Day	

Pilot	Mathieson
Copilot	
Processor	Carson

Lag Test Summary

MB Average Lag	0.63
MR Average Lag	0.49
ML Average Lag	0.49

Test Location	Near Saskatoon SK
Feature Easting	370601
Feature Northing	5767236

Air Time	
Test Time	
Ferry Time	

Lag Test Analysis

Bottom Tail Magnetometer (MB)						
Pass	Direction	Peak X	Peak Y	Velocity	From Tower	Lag
1	S	370591	5767185	74.29841086	52.30	0.70
2	N	370611	5767284	80.28662256	48.56	0.60
3	S	370592	5767189	74.28843523	48.44	0.65
4	N	370612	5767286	78.95389427	51.12	0.65
5	S	370591	5767187	75.41572766	50.39	0.67
6	N	370608	5767279	77.84199757	43.04	0.55
7	E	370648	5767226	76.66565436	47.70	0.62
8	W	370554	5767248	78.37494362	48.87	0.62
9	E	370651	5767227	76.27234223	50.31	0.66
10	W	370552	5767248	77.51955906	50.85	0.66
11	E	370650	5767231	76.46055005	48.74	0.64
12	W	370556	5767247	79.55341759	46.69	0.59

Right Wing Magnetometer (MR)						
Pass	Direction	Peak X	Peak Y	Velocity	From Tower	Lag
1	S	370594	5767200	74.29840373	37.44018441	0.50
2	N	370608	5767268	80.28663214	32.50945102	0.40
3	S	370594	5767196	74.288609	41.01523988	0.55
4	N	370608	5767271	78.95390411	35.33087959	0.45
5	S	370593	5767194	75.41554383	42.84596433	0.57
6	N	370607	5767271	77.84218772	35.27377057	0.45
7	E	370640	5767228	76.73864983	40.03491278	0.52
8	W	370561	5767246	78.37515209	41.03732873	0.52
9	E	370636	5767230	76.27230103	35.06707907	0.46
10	W	370567	5767245	77.51960195	35.35138998	0.46
11	E	370642	5767232	76.46071261	41.14017623	0.54
12	W	370564	5767245	79.55362906	38.73632355	0.49

Left Wing Magnetometer (ML)						
Pass	Direction	Peak X	Peak Y	Velocity	From Tower	Lag
1	S	370594	5767200	74.29840373	37.44018441	0.50
2	N	370608	5767268	80.28663214	32.50945102	0.40
3	S	370594	5767196	74.288609	41.01523988	0.55
4	N	370608	5767271	78.95390411	35.33087959	0.45
5	S	370593	5767194	75.41554383	42.84596433	0.57
6	N	370607	5767271	77.84218772	35.27377057	0.45
7	E	370640	5767228	76.73864983	40.03491278	0.52
8	W	370561	5767246	78.37515209	41.03732873	0.52
9	E	370636	5767230	76.27230103	35.06707907	0.46
10	W	370567	5767245	77.51960195	35.35138998	0.46
11	E	370642	5767232	76.46071261	41.14017623	0.54
12	W	370564	5767245	79.55362906	38.73632355	0.49

Table 13 - C-GLDX Lag Test, October 6

A.5 Radiometric Test Range

Calibraton Range Flight

Aircraft	G-GLDX
Date	2015-10-06
Project	St Albans & Mineville

Pilot	Mathieson
Copilot	Schindel
Processor	Carson

Calibraton Results

Alititude Attenuation Coefficients	
Total Counts (c/s/m)	-0.006987
Potassium (c/s/m)	-0.008938
Uranium (c/s/m)	-0.006696
Thorium (c/s/m)	-0.007272

Sensitivities	
Total Counts (c/s/nGy/h)	29.2
Potassium (c/s/%)	77.6
Uranium (c/s/ppm)	9.0
Thorium (c/s/ppm)	4.8

Test Data

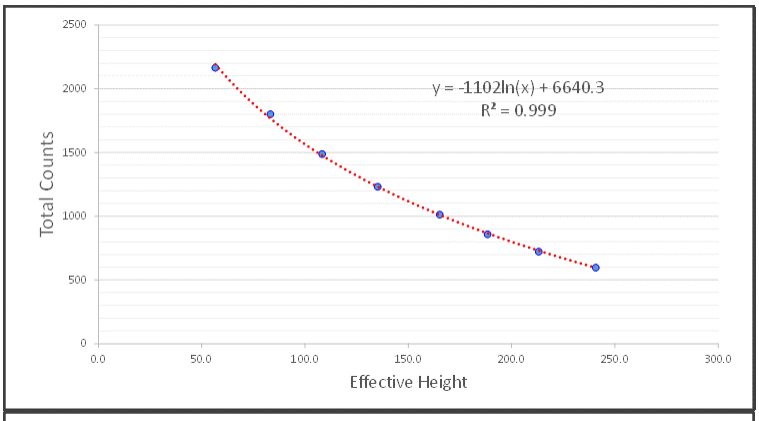
Test Line Data						
Radar Alt (m)	Effective Height (m)	GPS Alt (m)	TC (c/s)	K (c/s)	U (c/s)	Th (c/s)
63.5	56.5	659.5	2788.0	289.5	76.8	70.0
93.7	83.2	688.3	2425.2	244.6	68.6	60.4
122.2	108.3	717.8	2113.4	203.8	64.3	52.9
153.0	135.2	748.3	1858.5	173.2	56.7	46.7
187.5	165.2	781.5	1641.1	148.9	54.6	40.4
214.4	188.3	808.3	1488.5	131.2	49.9	37.6
243.3	213.1	837.5	1353.3	117.7	47.2	33.2
275.7	240.7	869.3	1229.9	105.2	44.6	30.7

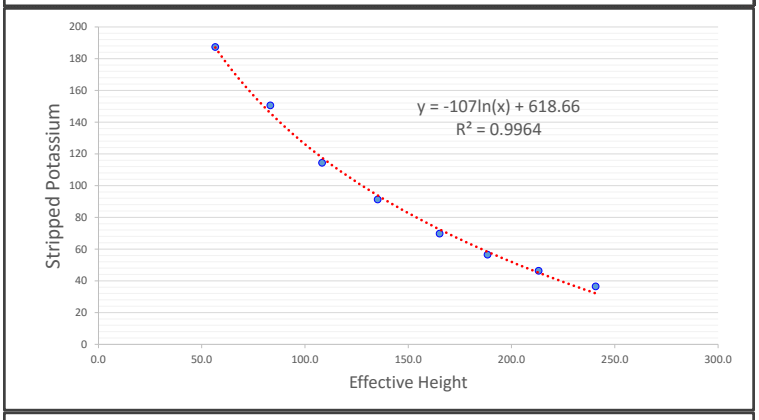
Background Line Data						
Radar Alt (m)	Effective Height (m)	GPS Alt (m)	TC (c/s)	K (c/s)	U (c/s)	Th (c/s)
93.2	83.1	649.1	619.9	51.8	30.1	14.4
122.3	108.7	679.4	626.6	52.3	30.4	14.4
151.1	134.1	708.2	630.1	51.2	31.7	14.7
181.5	160.6	738.0	626.1	51.7	30.3	15.0
213.1	187.9	769.8	623.8	52.1	29.5	15.1
244.1	214.5	800.4	632.3	51.9	30.9	15.5
272.9	239.2	829.1	629.0	51.8	30.3	15.4
303.6	265.2	860.7	634.2	52.5	30.4	16.2

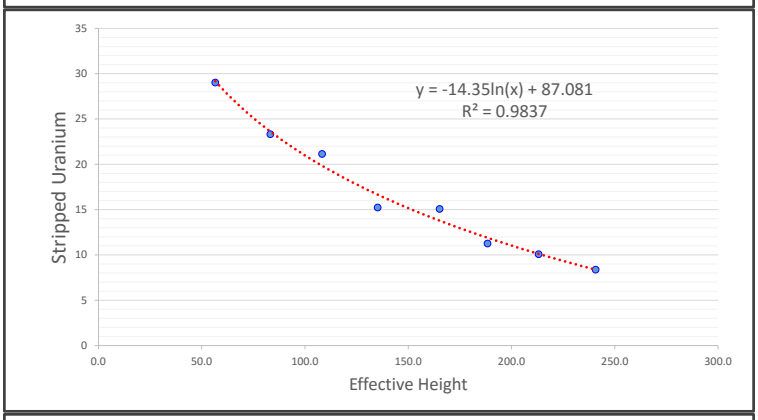
Ground Truth Concentrations	
Total Counts (nGy/h)	47.3
Potassium (%)	1.4
Uranium (ppm)	2.1
Thorium (ppm)	7.1

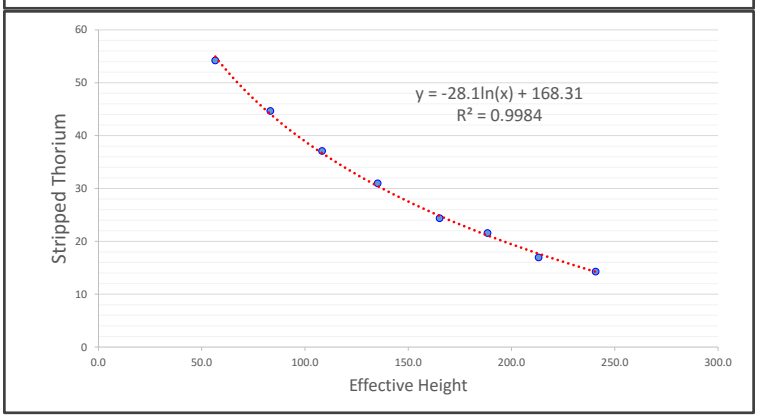
Table 14 - C-GLDX Radiometric Test Range, October 6

Result Plots : ROI Counts vs Effective Height









A.6 Ground Pad Calibration

Ground Pad Calibration

Project	St Albans & Mineville
Flight	N/A
Aircraft	C-GLDX
Detectors	5407 / 5621 / 5442
Date	2015-09-23

Pilot	N/A
Copilot	
Processor	Carson

Calibration Results

DPU 5407 Stripping Ratios	
α	0.2935
β	0.4409
ϒ	0.8036
a	0.0529
b	-0.0005
g	-0.0009

DPU 5621 Stripping Ratios	
α	0.2924
β	0.4478
ϒ	0.8055
a	0.0568
b	-0.0005
g	-0.0016

DPU 5442 Stripping Ratios	
α	0.2924
β	0.4478
ϒ	0.8055
a	0.0568
b	-0.0005
g	-0.0016

Test Data

	Known Pad Concentrations			
Window	BG (Bare)	K	U	Th
K (%)	0.86	9.77	1.02	0.82
U (ppm)	0.99	0.9	53.7	2.15
Th (ppm)	2.64	2.57	3.43	121

	DPU 5407			
Window	BG (Bare)	K	U	Th
K (c/s)	144.3	293.8	208.4	184.5
U (c/s)	27.2	27.0	103.5	55.3
Th (c/s)	25.5	25.3	30.1	115.3

	DPU 5621			
Window	BG (Bare)	K	U	Th
K (c/s)	136.5	267.8	192.0	173.2
U (c/s)	27.5	27.2	93.2	52.5
Th (c/s)	26.0	25.8	30.2	106.6

	DPU 5442			
Window	BG (Bare)	K	U	Th
K (c/s)	136.5	267.8	192.0	173.2
U (c/s)	27.5	27.2	93.2	52.5
Th (c/s)	26.0	25.8	30.2	106.6

Table 15 - C-GLDX Radiometric Pad Test, October 6

A.7 Cosmic Calibration

Cosmic Calibration

Aircraft	G-GLDX
Date	2016-01-22
Project	St Albans & Mineville

Pilot	Mathieson
Copilot	Schindel
Processor	Carson

Calibration Results

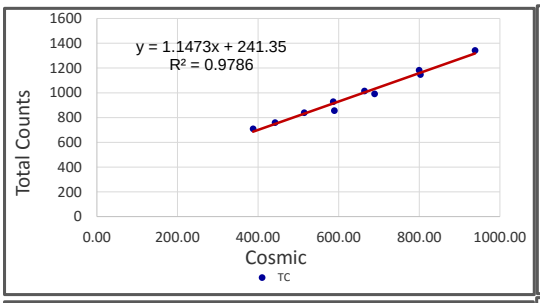
	Slope	Intercept	R^2
TC	1.1473	241.3460	0.9786
K	0.0645	32.8385	0.9700
U	0.0513	9.4975	0.9727
Th	0.0737	-2.6543	0.9990
UpU	0.0143	2.2163	0.9768

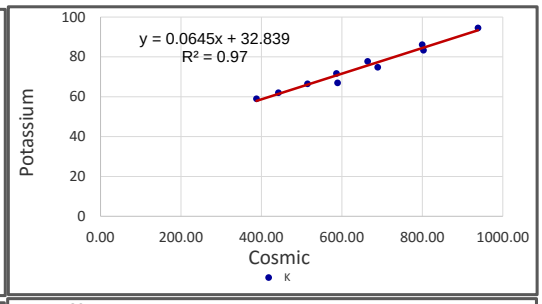
Test Data

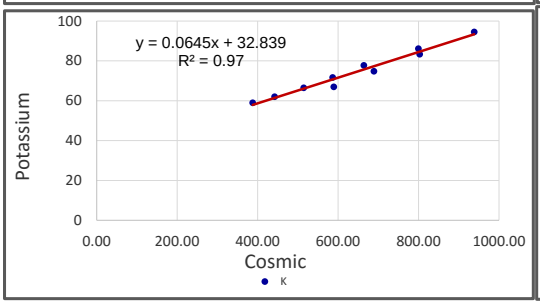
Line	GPS Alt	Cosmic	TC	K	U	Th	UpU
1	1621	387.97	709.86	58.96	30.66	26.18	8.02
2	1935	442.11	759.75	61.97	32.96	30.25	8.95
3	2266	514.73	839.63	66.46	36.21	35.66	9.56
4	2558	586.58	929.01	71.67	40.47	40.57	10.57
5	2801	663.96	1014.66	77.72	43.68	45.83	11.83
6	3163	799.94	1182.04	86.10	51.17	56.09	14.07
7	3481	938.52	1342.22	94.51	59.08	67.09	15.92
8	3184	802.79	1147.74	83.29	50.42	56.61	13.52
9	2891	689.30	991.84	74.77	42.92	48.08	11.67
10	2594	589.31	856.64	66.94	36.50	40.06	9.86

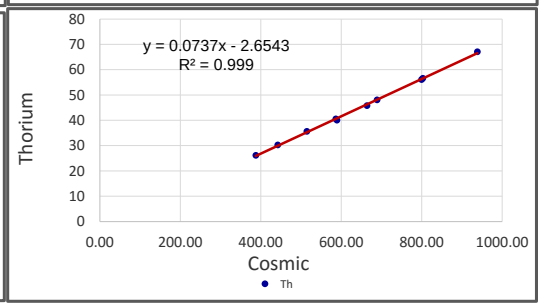
Table 16 - C-GLDX Cosmic Calibration, January 22

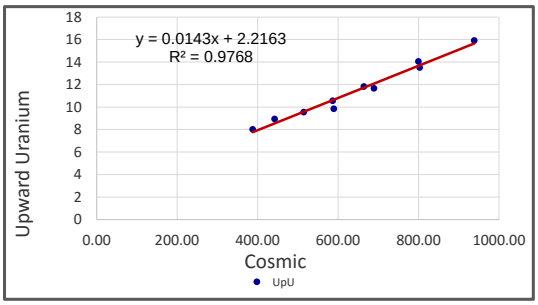
Result Plots











A.8 Daily System Resolution Tests

Radiometric System Resolution Tests

Project	St Albans & Mineville
Flight	N/A
Aircraft	C-GLDX
Detectors	5407 / 5621 / 5442
Date	2015 10-16 to 11-26

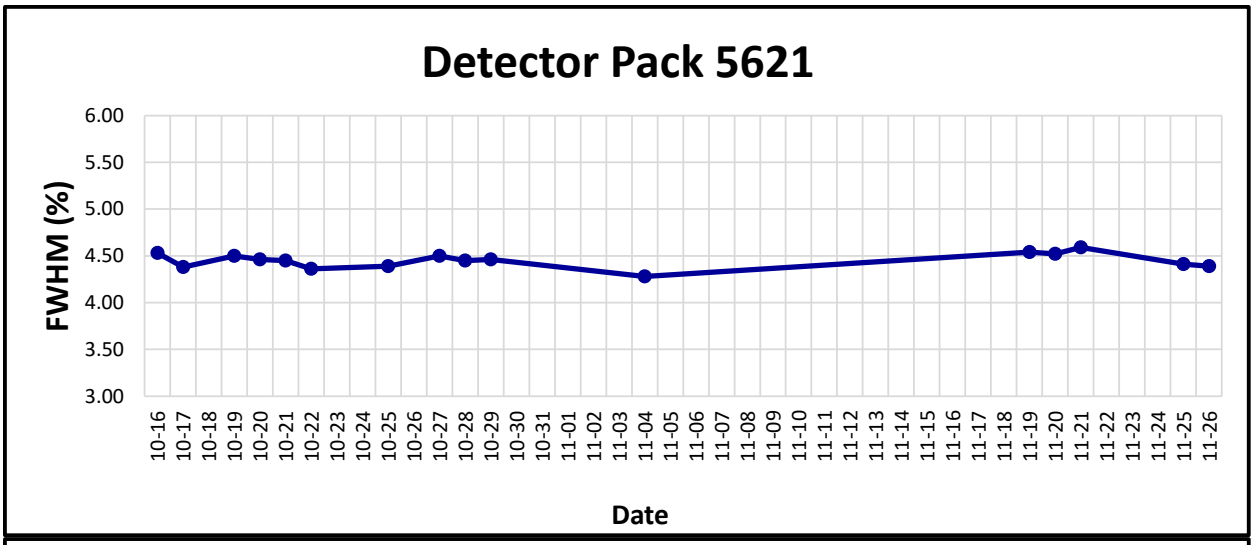
Pilot	N/A
Copilot	N/A
Processor	Carson

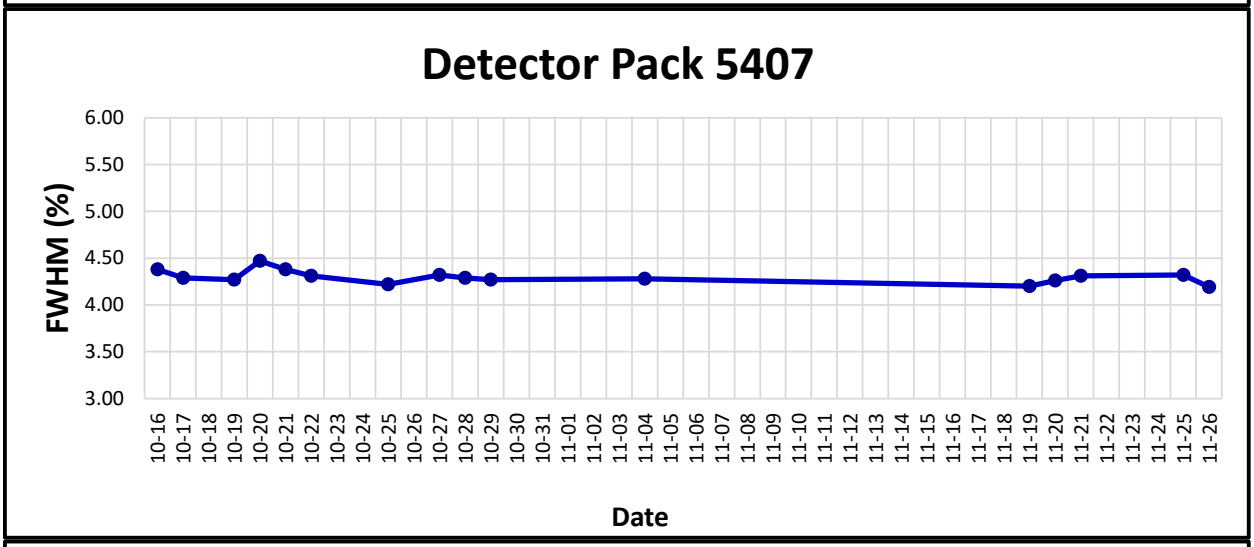
Test Data

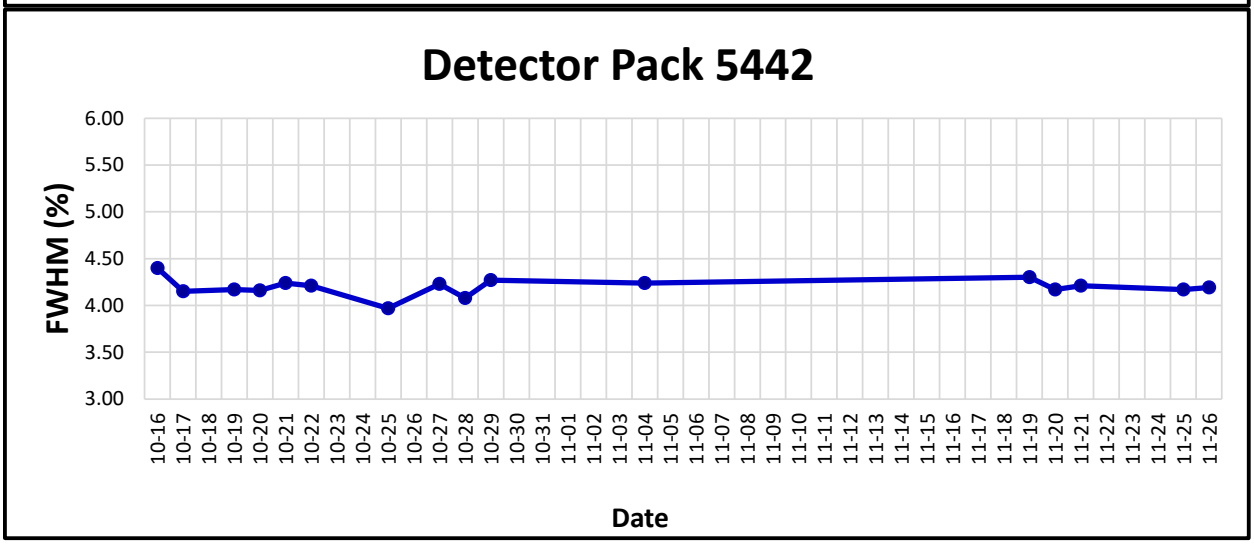
Date	DPU1 FWHM	Err	DPU2 FWHM	Err	DPU3 FWHM	Err
2015-10-16	4.53	0.64	4.38	0.52	4.40	0.58
2015-10-17	4.38	0.61	4.29	0.49	4.15	0.70
2015-10-19	4.50	0.57	4.27	0.68	4.17	0.67
2015-10-20	4.46	0.63	4.47	0.58	4.16	0.64
2015-10-21	4.45	0.65	4.38	0.59	4.24	0.69
2015-10-22	4.36	0.62	4.31	0.62	4.21	0.65
2015-10-25	4.39	0.58	4.22	0.57	3.97	0.53
2015-10-27	4.50	0.63	4.32	0.65	4.23	0.60
2015-10-28	4.45	0.56	4.29	0.56	4.08	0.57
2015-10-29	4.46	0.51	4.27	0.60	4.27	0.48
2015-11-04	4.28	0.59	4.28	0.59	4.24	0.52
2015-11-19	4.54	0.61	4.20	0.63	4.30	0.69
2015-11-20	4.52	0.74	4.26	0.58	4.17	0.55
2015-11-21	4.59	0.63	4.31	0.63	4.21	0.55
2015-11-25	4.41	0.69	4.32	0.60	4.17	0.57
2015-11-26	4.39	0.69	4.19	0.59	4.19	0.59

Table 17 - C-GLDX Daily System Resolution Tests

Test Plots By Date

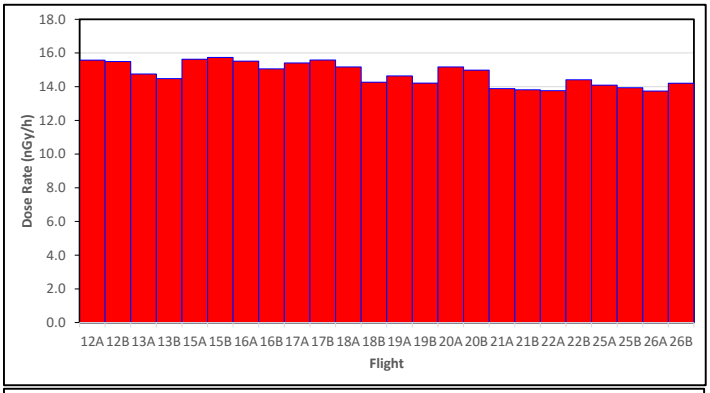


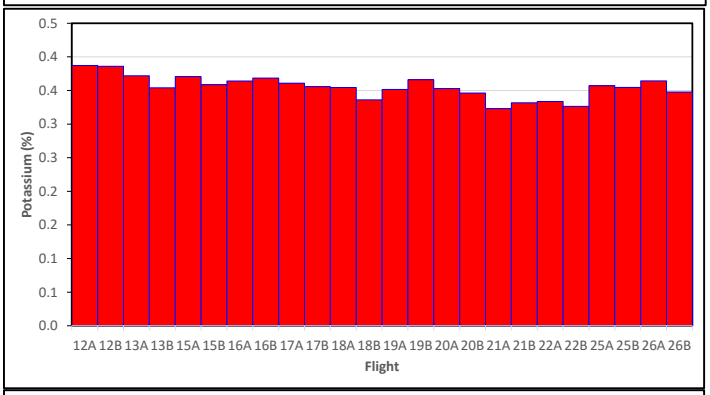


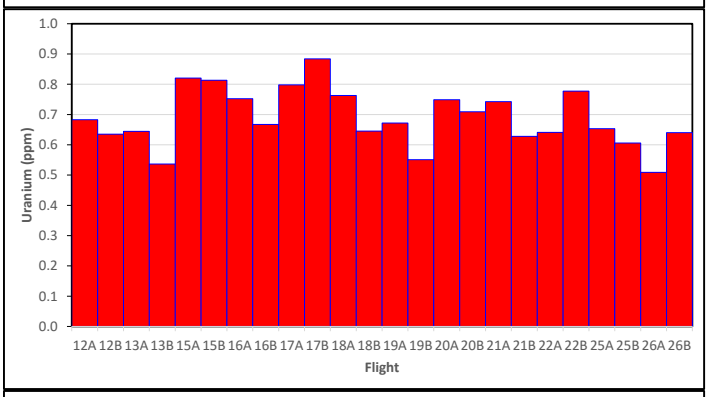


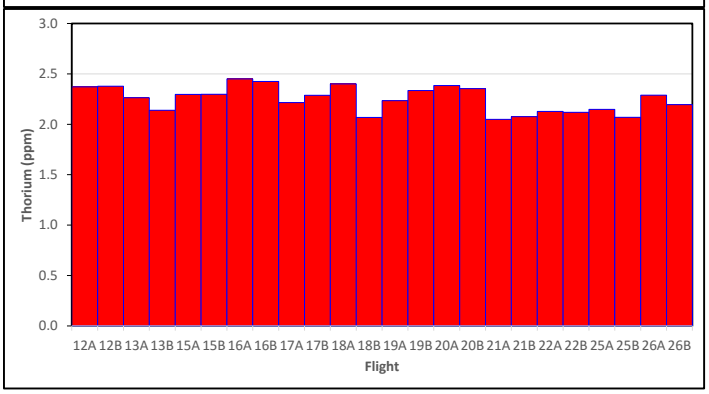
A.9 Daily Radiometric Repeat Line

Repeat Line Concentrations by Flight



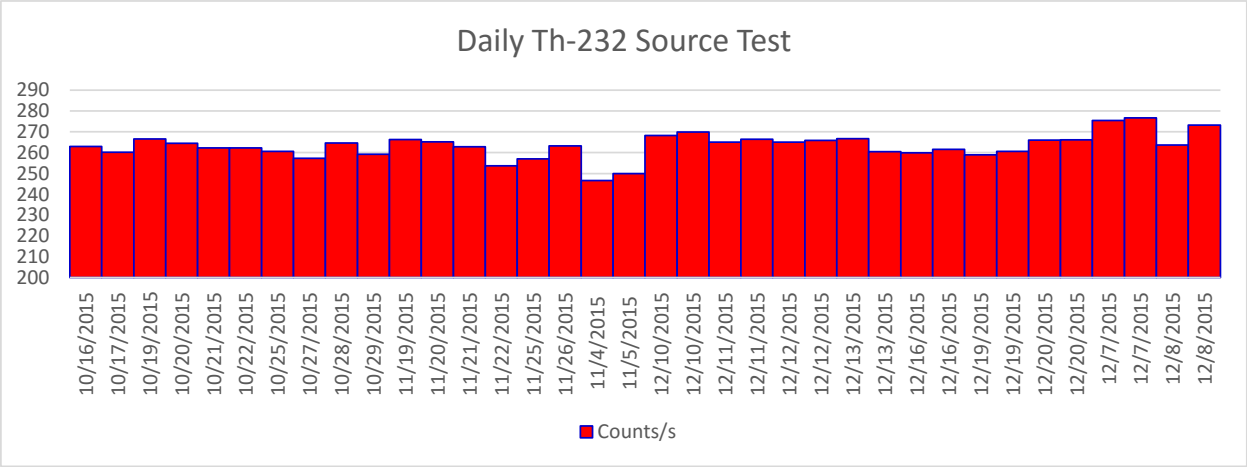






A.10 Daily Source Tests

Daily Source Test by Date



APPENDIX B – OPERATIONS REPORTS

Goldak Airborne Surveys Operations Report

GSNL St. Albans

October 12 to October 18

2015

Aircraft and Crew	
Aircraft:	C-GLDX
Pilot:	Mathieson
Copilot:	Schindel
Processor:	Shaikh
Base:	Room- 121 Comfort Inn, Gander, NL
Contact:	780-903-4599

Summary	
Project Total	**9636**
Remaining	**9152**
Flown this week	**484**
Flown to date	**484**

			Flight Times (h)				Production (km)			Unservicability (%)				
	Flight	Aircraft	Ferry	Test	Survey	Total	Flown	Accepted	Rejected	Weather	Diurnal	Equipent	Crew	Notes
Mon October 12		C-GLDX								100				Low clouds
Tues October 13		C-GLDX								100				Low clouds
Wed October 14	10	C-GLDX	1.1			1.1				70				Low clouds / rain / Comp Flight - rejected
Thurs October 15		C-GLDX								100				Low clouds
Fri October 16	11	C-GLDX	1.0			1.0								Comp flight - passed
	12	C-GLDX	1.2		2.3	3.5	484	484						
Sat October 17		C-GLDX								100				Low clouds / rain
Sun October 18		C-GLDX												
Weekly Total			**3.3**	**0**	**2.3**	**5.6**	**484**	**484**	**0**					
Total to Date			**3.3**	**0**	**2.3**	**5.6**	**484**	**484**	**0**					

Goldak Airborne Surveys Operations Report

GSNL St. Albans

October 19 to October 25
2015

Aircraft and Crew	
Aircraft:	C-GLDX
Pilot:	Mathieson
Copilot:	Schindel
Processor:	Shaikh
Base:	Comfort Inn, Gander, NL
Contact:	780-903-4599

Summary	
Project Total	**9636**
Remaining	**6059**
Flown this week	**3093**
Flown to date	**3577**

			Flight Times (h)				Production (km)			Unservicability (%)				
	Flight	Aircraft	Ferry	Test	Survey	Total	Flown	Accepted	Rejected	Weather	Diurnal	Equipent	Crew	Notes
Mon October 19	13	C-GLDX	1.3		4.0	5.3	706	706						
Tues October 20	14	C-GLDX	1.3			1.3				100				Flight terminated due to low clouds
Wed October 21	15	C-GLDX	1.2		4.3	5.5	807	807						
Thurs October 22	16	C-GLDX	1.1		4.3	5.4	937	937						
Fri October 23		C-GLDX								100				Low clouds / rain
Sat October 24		C-GLDX								100				Low clouds / rain
Sun October 25	17	C-GLDX	1.3		4.0	5.3	725	643	82					Rain in survey area - flew tie lines

Weekly Total	**6.2**	**0**	**16.6**	**22.8**	**3175**	**3093**	**82**
Total to Date	**9.5**	**0**	**18.9**	**28.4**	**3659**	**3577**	**82**

Goldak Airborne Surveys Operations Report

GSNL St. Albans

October 26 to November 01
2015

Aircraft and Crew	
Aircraft:	C-GLDX
Pilot:	Mathieson
Copilot:	Schindel
Processor:	Shaikh
Base:	Gander, NL
Contact:	780-903-4599

Summary	
Project Total	9636
Remaining	3474
Flown this week	2585
Flown to date	6162

			Flight Times (h)				Production (km)			Unservicability (%)				
	Flight	Aircraft	Ferry	Test	Survey	Total	Flown	Accepted	Rejected	Weather	Diurnal	Equipent	Crew	Notes
Mon October 26		C-GLDX								100				Low clouds / rain
Tues October 27	18	C-GLDX	1.3		4.1	5.4	858	858						
Wed October 28	19	C-GLDX	1.3		4.2	5.5	855	855						
Thurs October 29	20	C-GLDX	1.3		4.1	5.4	872	872						
Fri October 30		C-GLDX								100				Rain / gusting wind
Sat October 31		C-GLDX								100				Turbulence / gusting wind
Sun November 01		C-GLDX								100				Turbulence
Weekly Total			3.9	0	12.4	16.3	2585	2585	0					
Total to Date			13.4	0	31.3	44.7	6244	6162	82					

Goldak Airborne Surveys Operations Report

GSNL St. Albans

November 02 to November 08
2015

Aircraft and Crew	
Aircraft:	C-GLDX
Pilot:	Mathieson
Copilot:	Schindel
Processor:	Shaikh
Base:	Comfort Inn, Gander, NL
Contact:	780-903-4599

Summary	
Project Total	**9636**
Remaining	**2759**
Flown this week	**715**
Flown to date	**6877**

			Flight Times (h)				Production (km)			Unservicability (%)				
	Flight	Aircraft	Ferry	Test	Survey	Total	Flown	Accepted	Rejected	Weather	Diurnal	Equipent	Crew	Notes
Mon November 02		C-GLDX								100				Low clouds / rain
Tues November 03		C-GLDX								100	60			Rain / active diurnal
Wed November 04	21	C-GLDX	1.2		4.3	5.5	715	715						
Thurs November 05		C-GLDX										100		Aircraft starter generator problem
Fri November 06		C-GLDX										100		Aircraft starter generator problem
Sat November 07		C-GLDX								100		100		Turbulence / Aircraft starter genrator problem
Sun November 08		C-GLDX										100		Aircraft starter generator problem

Weekly Total	1.2	0	4.3	5.5	715	715	0
Total to Date	14.6	0	35.6	50.2	6959	6877	82

Goldak Airborne Surveys Operations Report

GSNL St. Albans

November 09 to November 15
2015

Aircraft and Crew	
Aircraft:	C-GLDX
Pilot:	Mathieson
Copilot:	Schindel
Processor:	Shaikh
Base:	Comfort Inn, Gander, NL
Contact:	780-903-4599

Summary	
Project Total	9636
Remaining	2759
Flown this week	
Flown to date	6877

			Flight Times (h)				Production (km)			Unservicability (%)				
	Flight	Aircraft	Ferry	Test	Survey	Total	Flown	Accepted	Rejected	Weather	Diurnal	Equipent	Crew	Notes
Mon November 09		C-GLDX										100		Waiting on replacedment starter generator
Tues November 10		C-GLDX								100		100		Rain / Waiting on replacedment starter generator
Wed November 11		C-GLDX										100		Waiting on replacedment starter generator
Thurs November 12		C-GLDX										100		Waiting on replacedment starter generator
Fri November 13		C-GLDX										100		Waiting for start generator fixed
Sat November 14		C-GLDX								100		100		Rain/ Turbulance / Waiting on replacedment starter generator
Sun November 15		C-GLDX								100		100		Rain / Flurries / Waiting on replacedment starter generator

Weekly Total	0	0	0	0	0	0	0
Total to Date	14.6	0	35.6	50.2	6959	6877	82

Goldak Airborne Surveys Operations Report

GSNL St. Albans

November 16 to November 22
2015

Aircraft and Crew	
Aircraft:	C-GLDX
Pilot:	Mathieson
Copilot:	Schindel
Processor:	Shaikh
Base:	Gander
Contact:	780-903-4599

Summary	
Project Total	9636
Remaining	1802
Flown this week	957
Flown to date	7834

			Flight Times (h)				Production (km)			Unservicability (%)				
	Flight	Aircraft	Ferry	Test	Survey	Total	Flown	Accepted	Rejected	Weather	Diurnal	Equipent	Crew	Notes
Mon November 16		C-GLDX								100		100		Flurries / Waiting on replacement starter generator
Tues November 17		C-GLDX								100		100		Low clouds / Starter generator installed and tested
Wed November 18		C-GLDX								100				Low clouds / Freezing rain
Thurs November 19		C-GLDX								100				Low clouds / Freezing drizzle / Fog
Fri November 20		C-GLDX								100				Low clouds / Freezing drizzle / Fog
Sat November 21	22	C-GLDX	1.2		4.4	5.6	957	957						
Sun November 22	23	C-GLDX	1.2			1.2				100				Flight terminated due to low clouds
	24	C-GLDX	0.7	0.6		1.3								Comp/FOM flight, MB=0.67. GX=1.31, GY=0.75
Weekly Total			3.1	0.6	4.4	8.1	957	957	0					
Total to Date			17.7	0.6	40	58.3	7916	7834	82					

Goldak Airborne Surveys Operations Report

GSNL St. Albans

November 23 to November 29
2015

Aircraft and Crew	
Aircraft:	C-GLDX
Pilot:	Mathieson
Copilot:	Schindel
Processor:	Shaikh
Base:	Gander, NL
Contact:	780-903-4599

Summary	
Project Total	**9636**
Remaining	**-191**
Flown this week	**1993**
Flown to date	**9827**

			Flight Times (h)				Production (km)			Unservicability (%)				
	Flight	Aircraft	Ferry	Test	Survey	Total	Flown	Accepted	Rejected	Weather	Diurnal	Equipent	Crew	Notes
Mon November 23		C-GLDX								100				Low clouds / Turbulence / Rain
Tues November 24		C-GLDX								100				Low clouds / Turbulence / Rain
Wed November 25	25	C-GLDX	1.2		4.5	5.7	921	921						
Thurs November 26	26	C-GLDX	1.2		3.3	4.5	619	619						
	27	C-GLDX	1.0		2.7	3.7	453	453						Survey completed.
Fri November 27		C-GLDX												
Sat November 28		C-GLDX												
Sun November 29		C-GLDX												

Weekly Total	3.4	0	10.5	13.9	1993	1993	0
Total to Date	21.1	0.6	50.5	72.2	9909	9827	82