Helicopter Vector IFR

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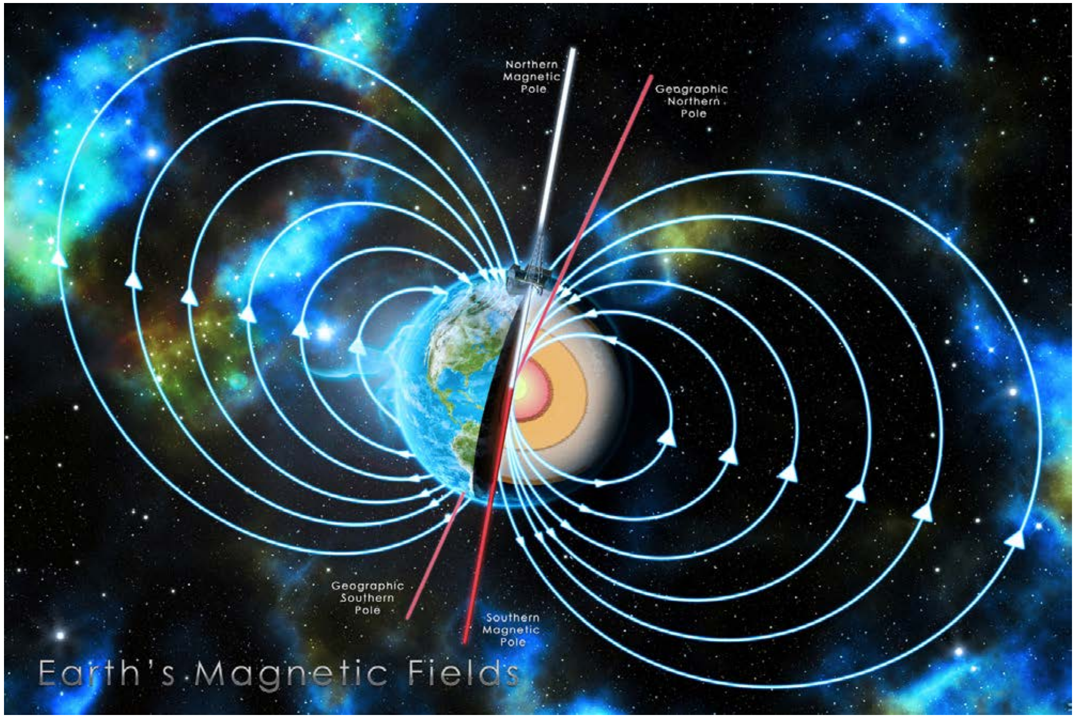
MWD Relies on the Earth's Magnetic Field

MWD tools measure the orientation of the tool with respect to the Earth's field.



Knowledge of the Earth's field is needed to determine the orientation of the tool with respect to true (or grid) north.

The field is defined by the total field strength, declination and dip.

Uncertainty in these values is one of the main factors limiting the accuracy of MWD surveys.

Three Components of Earth's Field

1. Secular Variation

Long slow changes in the earths magnetic core.
Typical Size: Fractions of a deg/year
Corrected by: Global Magnetic Models

2. Diurnal Variation

Rapid daily variations caused by solar wind and earth rotation.
Typical Size: 0.2 degs (Randomized)
Corrected by: Field Monitoring

3. Crustal Variation

Permanent local effects caused by deep, magnetic basement rock
Typical Size: 1 degree
Corrected by:

In Field Referencing (IFR)

Why IFR is needed?

- If not accounted for, localised crustal anomalies can cause errors in MWD surveys, and is one of the largest uncertainty components in the MWD error model
- Can be a degree or more in declination
  - extreme case: Canada 3° declination variation in 11km
- Satellite data improving global models, but resolution not good enough for borehole surveys
- Must be measured in the field
- Initially used in North Sea, but becoming more commonplace

Accuracy of Magnetic Models

	2-sigma Accuracy			
	IGRF	BGGM	HDGM	IFR
Total Field (nT)	314	260	214	100
Dip (deg)	0.48	0.40	0.32	0.20
Declination (deg)	1.21	1.01	0.84	*0.37
Resolution (km)	399	400	28	1.0
Update (year)	5	1	1	from ref

*dependent on latitude. This figure based on >50° North

IFR Measurement Methods

- **Conventional Aeromag** –
  - total field, inversion & downward continuation, wide area of data.
  - either off the shelf data or specially commissioned.
- **Land IFR Survey** –
  - robust, reliable but slow
- **Dynamic Vector Survey** –
  - in1998, the BGS, Shell and Tech 21 developed a method to directly measure the magnetic vector at sea.
  - multiple evolutions of system – now at version 5.
- **Dynamic Vector Helicopter Survey – would it be possible?**

Land IFR Survey

- Use Proton Magnetometer to check that survey point is magnetically clean – no local magnetic gradients
- Measures total field.

Magnetic Theodolite

- Use theodolite to measure dip and declination angles.

Direct Measurement of Vector

- In 1998, the BGS, Shell and Tech 21 developed a method to directly measure the magnetic vector at sea

No longer need a wide area survey area.

The local drilling footprint or even a single well route can be surveyed at surface.

Much of the North Sea mapped in this way

Method and equipment has evolved since the first surveys

Dynamically Measuring the Earth's Magnetic Vector

Since the vessel is always moving, cannot use the land theodolite technique.

Dynamic method requires:

- Hi Spec attitude sensor
- Hi Spec Tri-axial magnetometers
- Rigid Mounting Frame
- Calibration, time synchronisation and Data Processing Software

Latest Evolution of Marine IFR

Why Helicopter IFR?

- No more trudging through deep snow or bog!
- No more fighting off clouds of insects
- No more trucks stuck in the lease roads
- No more upset landowners asking why you’re in their field

Working with helicopters has to be more FUN!

Helicopter IFR

Would it be possible to modify the dynamic method to use in a helicopter?

Step 1: How close can the sensors be to the helicopter?

- Using a local helicopter company, tested complete frame with all sensors running, and total field magnetometer nearby.
- Initial tests at the airfield failed. Discovered that concrete in heliport contained steel rebar
- Acquired permission to use a large field at a local farm to run the tests again

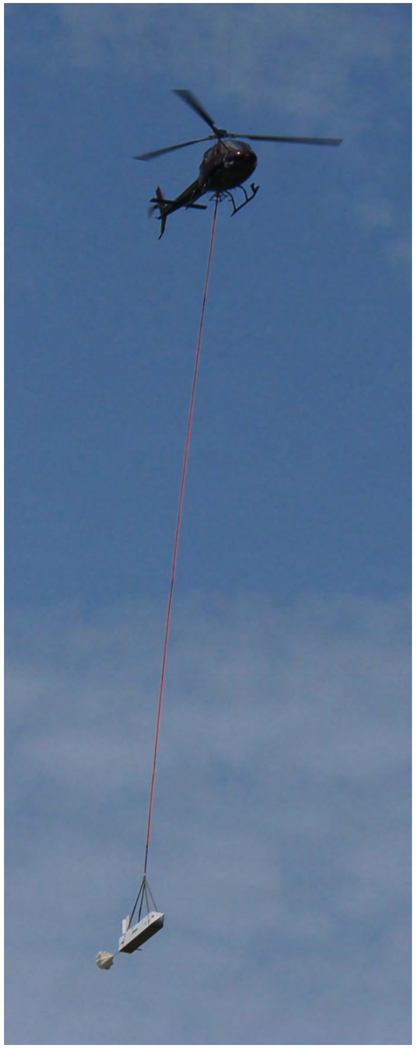
Helicopter IFR

- Tested on ground at varying distances, at different approach angles. Engines off/on.
  <u>No influence until <20m</u>

- Tested in air, hovering over sensors at varying heights and angles.
  <u>No influence until <20m</u>

SUCCESS!

Helicopter IFR



Step 2: Aerodynamic tests

- **Aeronautic design company assisted with the design of underslung bird on 30m line**
- **Constructed and tested a wooden prototype containing the sensor frame**

It did not fly straight!

Tested several modifications

SUCCESS!

Test Flights

Helicopter IFR

Step 3: Commission custom design of bird & modify control system for on-board helicopter use

- **Bird built from fibreglass to custom design incorporating modifications from proving flights**
- **Control box redesigned as carry-on load, with new automation control system and pilot alarm**

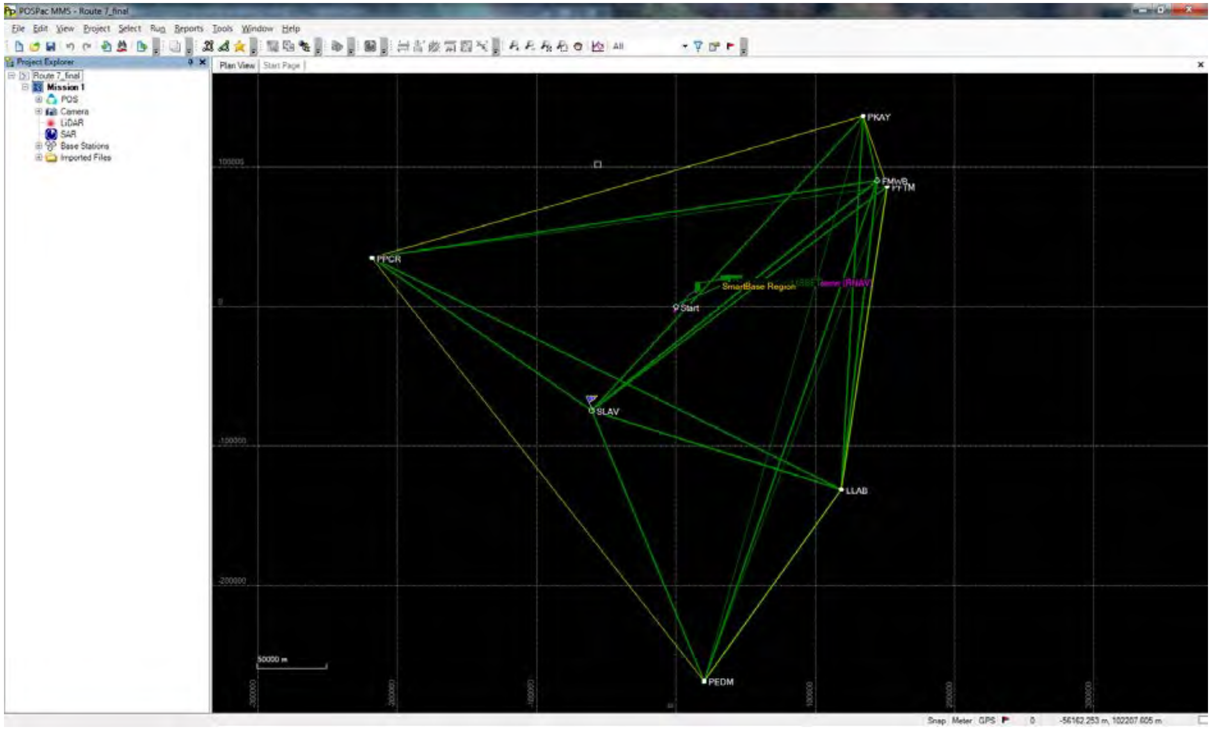
Helicopter IFR

<u>Step 4: Survey Trial (Q3 2013)</u>

- **First survey trial in the Moray Firth**
- **Ground shots for QC**
- **Area already surveyed by marine system 2 years before, therefore good for comparison**

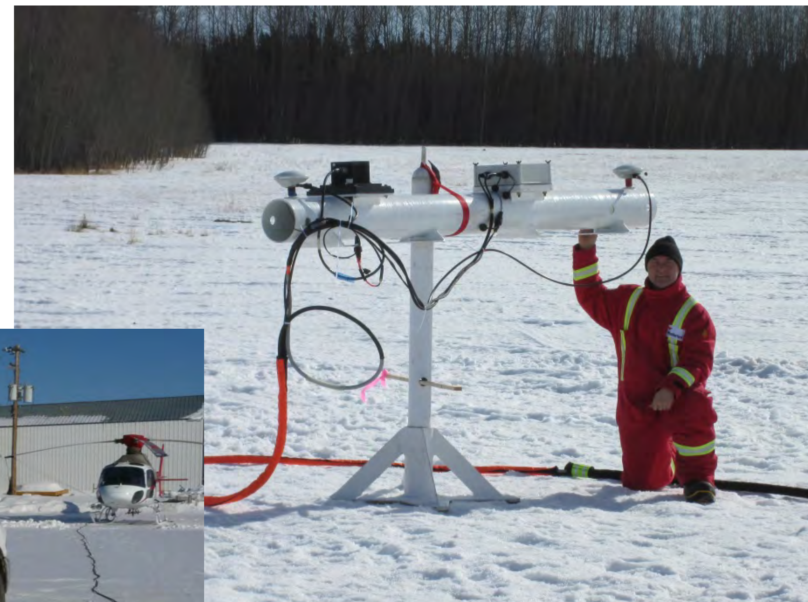
Helicopter IFR - Method

- **Trajectory Processing**
  - Post-processing Kalman smoother combines INS, GPS and GPS base station data to maximise heading accuracy



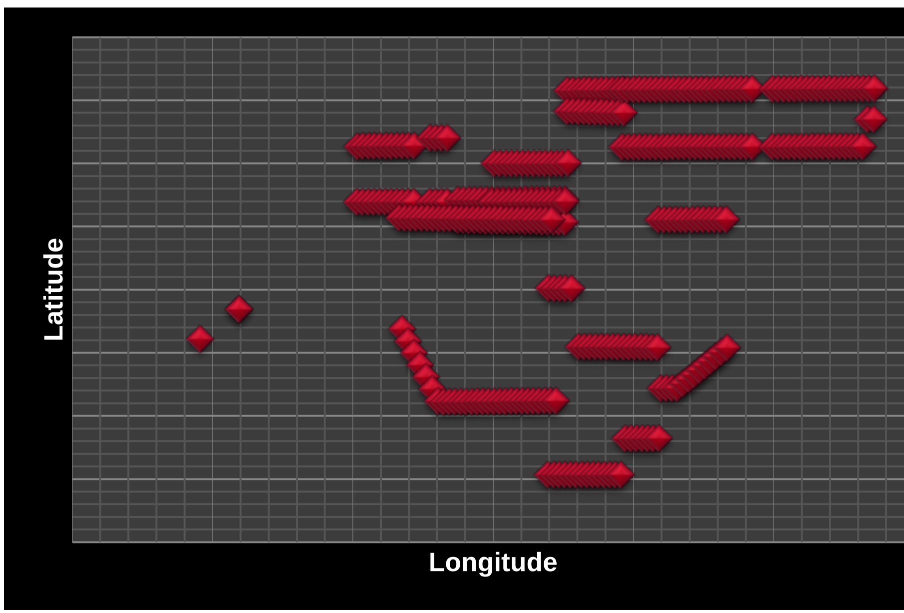
Helicopter IFR - Method

- **Calibration**
  - GPS system, INS & magnetometers to remove scale factor and bias errors



Helicopter IFR - Method

- **Data Acquisition**
  - plan waypoint routes for pilot to fly lines at specified interval spacing



Helicopter IFR - Method

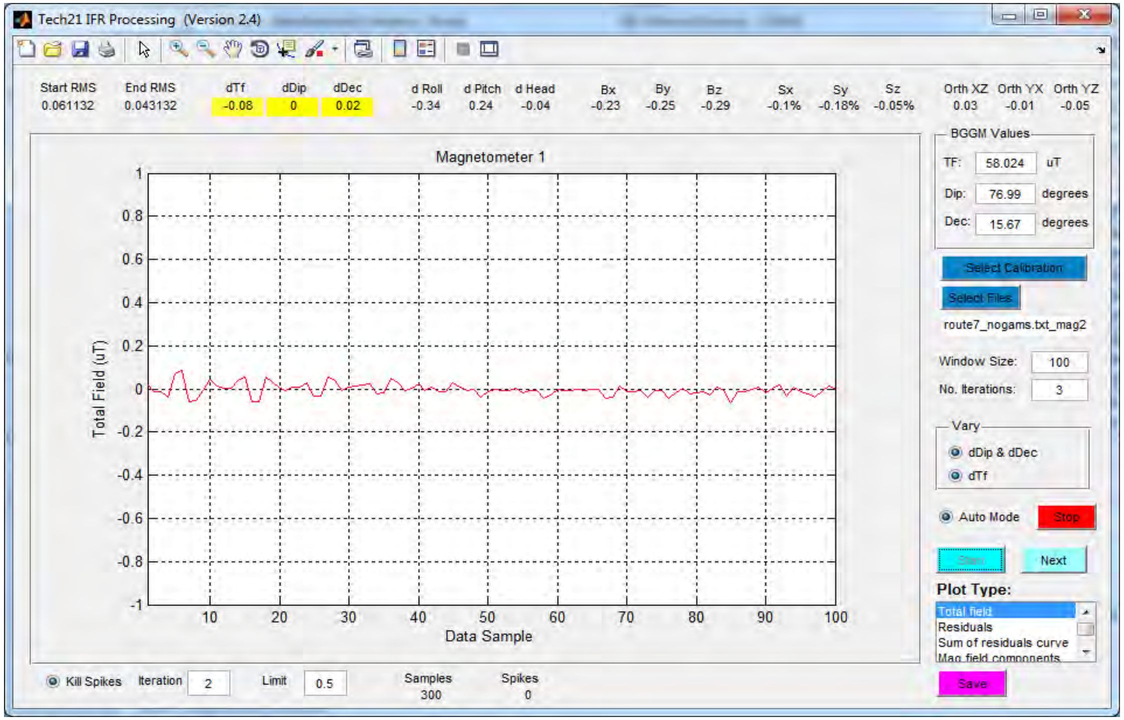
- **In Flight Calibration**
  - circles to acquire 360° data

Helicopter IFR - Method

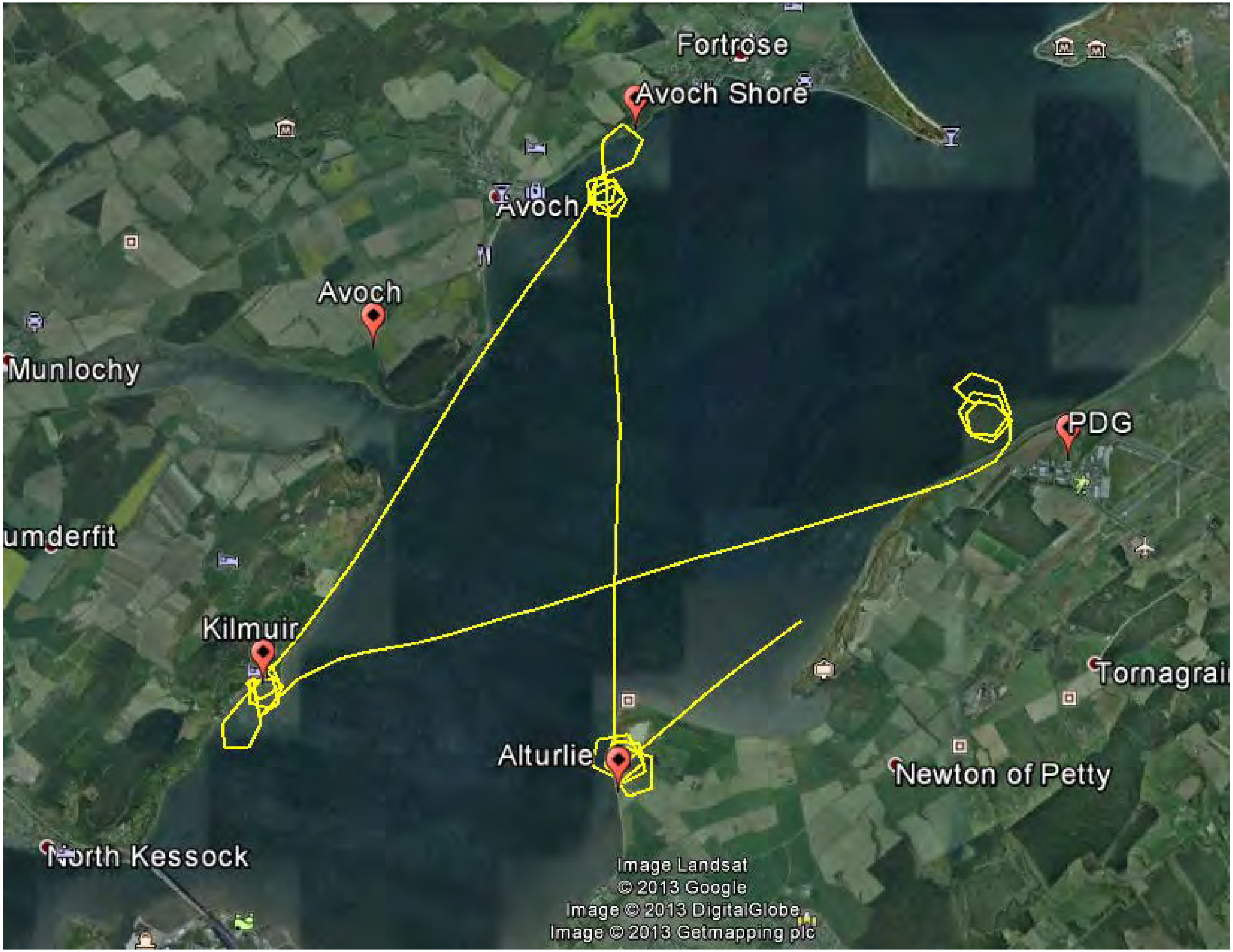
- **QC using Land IFR Measurements**
  - land IFR points in survey area are compared with nearest flight data

Helicopter IFR - Method

- **Post Processing**
  - In house software to time match data and process maps for total field, declination & dip



Compare Helicopter and Ground Shots



Compare Helicopter and Ground Shots

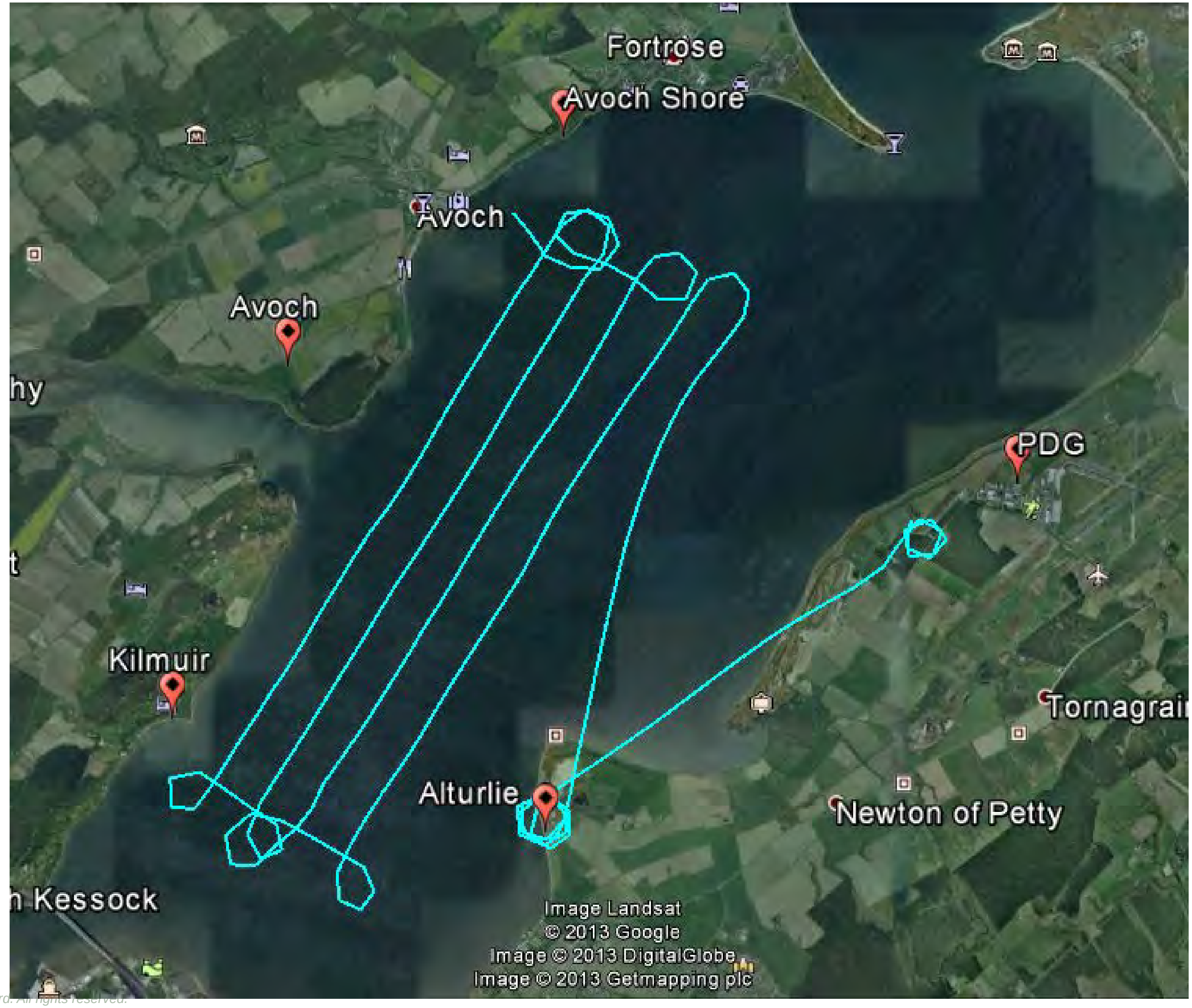
Target Specification

	Field (nT)	Dip (deg)	Dec (deg)
Error Model (1-sigma)	50	0.1	0.15
Limit for Comparing Two Surveys (1-sigma)	71	0.14	0.21

Difference at Ground Shots

	Field (nT)	Dip (deg)	Dec (deg)
PDG	55.1	0.05	0.05
Alturlie	23.6	0.05	0.01
Kilmuir	-0.4	0.01	0.06
Avoch	-	0.03	0.04

Compare Helicopter and Marine Survey



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Difference from Marine Survey (401 points)

	Field (nT)	Dip (deg)	Dec (deg)
Average	8.13	0.00	-0.02
Std Dev	10.45	0.04	0.13
Max	34.11	0.12	-0.35

Helicopter IFR

Marine system now modified for helicopter operation

- **Survey speed 50kts**
- **Magnetic data recorded at 10Hz**
- **INS data recorded at 200Hz**
- **Survey altitude ~500ft above terrain**

1^{st} Survey

Northern Alberta, March 2014

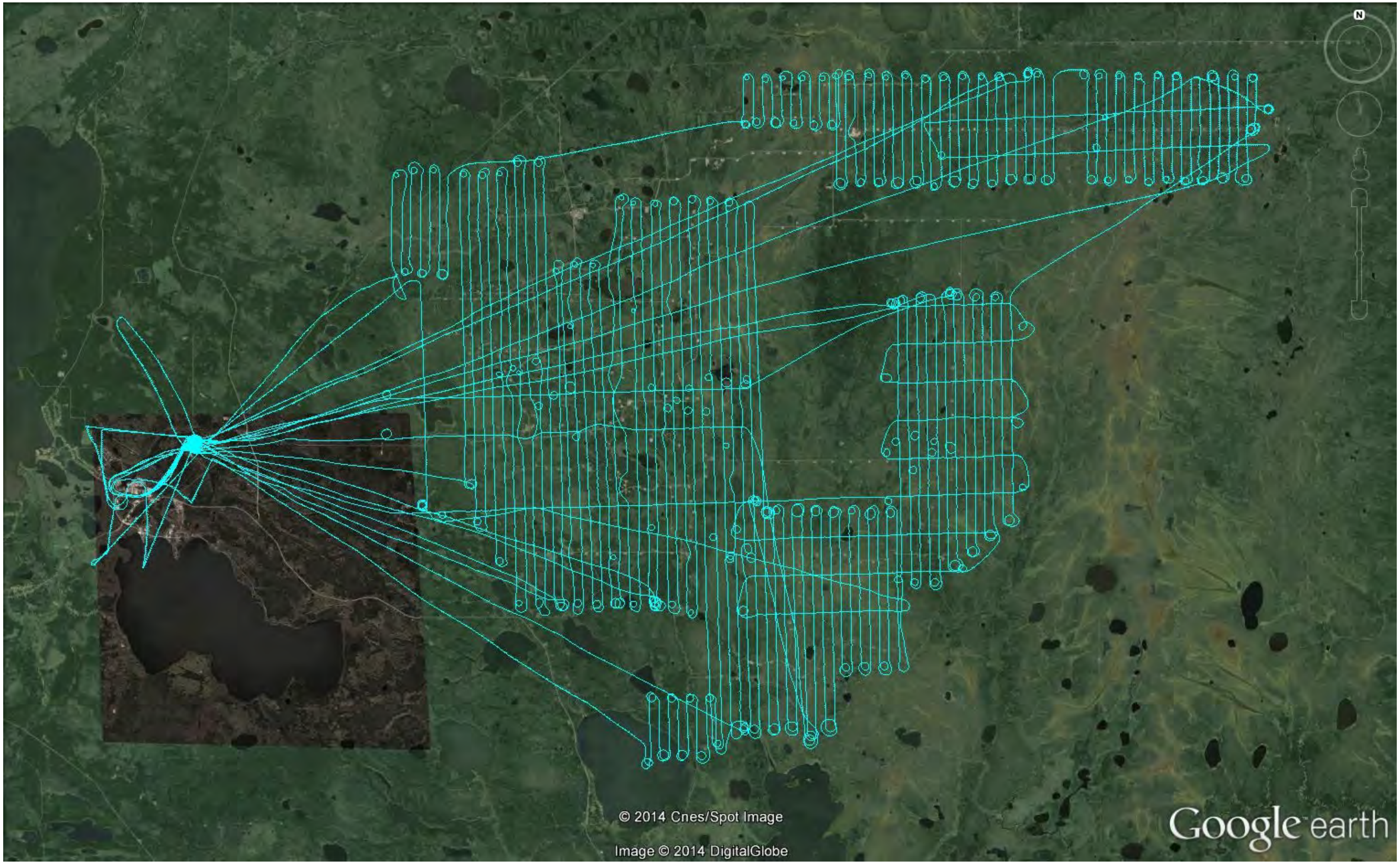
- Total area size - 25 x 36 Km - several discrete blocks
- 12 missions, 6 days.
- 10 additional ground shots required for QC

1st Survey

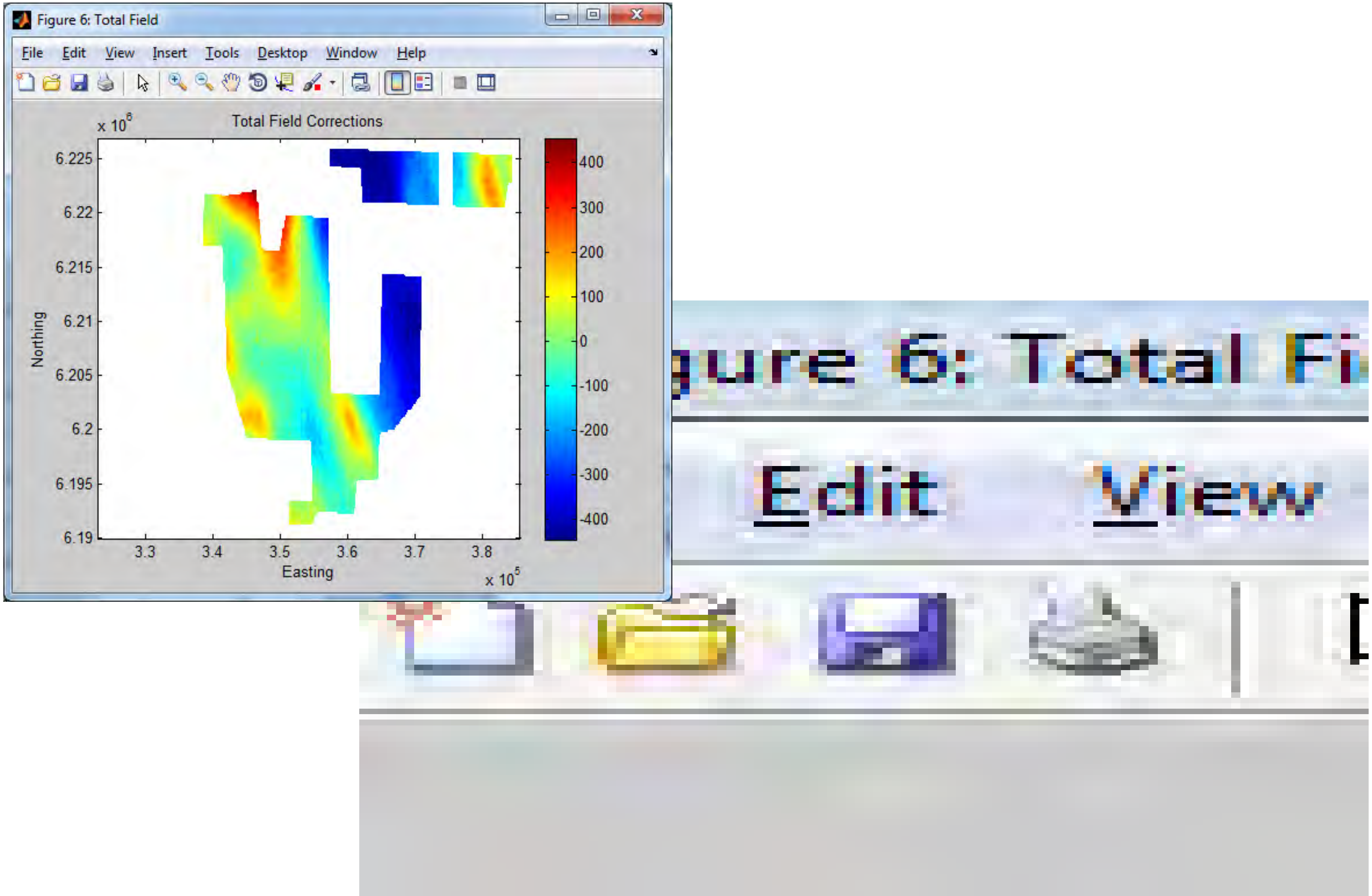
- **Full system loaded into trailer and transported to survey site**
- **Bird assembled and system installed in ½ day**
- **Test Flights performed in ½ day**

Survey Flights

Total Survey Flight Path



Helicopter IFR – Magnetic Field Map



Advantages

- High data resolution
  - At 50kts survey speed, 10Hz data acquisition, reading every 2.5m
  - Two magnetometers for QC and redundancy
- Limited Area
  - survey area specific to customer requirements
- Non aircraft specific
  - control unit is carry-on load, no official certification required
- Easily Portable
  - entire system can fit into a large trailer. All components have flight cases for air freight, including bird

Advantages

- Faster Acquisition
  - Large areas can be covered in a matter of days rather than weeks
- Area Access
  - No need for landowner permission to access. Also can fly close up to country borders
- Safer Operations
  - Autonomous acquisition requires only the pilot to be in the helicopter

Summary

- Successful development program
- New method for obtaining IFR survey data
- Commencing operational use