Short Note: Magnetic Compensation Results for an Unmanned Aerial Vehicle.

M.H. Moreton*, R. Wackerle, G. Grover*****

* Malcolm Moreton and Associates – malcolm.moreton@gmail.com.
** GeoIntrepid - wackerle@afol.com.na.
*** UAVE Limited - grahame.grover@uave.co.uk

Summary

A series of test flights have been completed validating the installation of a single magnetic sensor with associated electronics in a long range Unmanned Aerial Vehicle (UAV). A calibration flight has been carried out to permit post process compensation of the magnetic data. The results are documented herein. Industry standard techniques have been applied throughout but what is considered of interest in this document is the successful compensation of this sensor on this platform and the implication that this equipment may be considered a viable survey tool.

UAV PLATFORM - PRION MK 3

Figure 1: The Prion Mk 3

The Prion Mk3 UAV used for these flights is shown above. Specifications of interest are:

- Wingspan / Fuselage Length 3.8m / 3.0 m
- Weight 30 kg
- Survey Speed 80 kph
- Operation Range 1000 km
- Payload Optimal / Maximum 10 / 15 kg
- Deployed Internationally

The Prion is capable of operating beyond line of sight and the navigation system permits low level flight on a predetermined survey plan suitable for survey. Its large operational range facilitates high production rates of several 100 km per day/sortie.

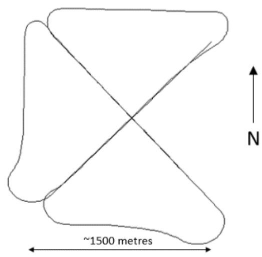
The platform, with the magnetic sensor installed, performed a compensation flight at a height of 5000ft AGL nominal.

MAGNETIC SENSOR

The magnetic sensor installed in the Prion is the MFAM MEMS device, model LCS100H, from Geometrics[1]. The device is installed in the port wing of the Prion with the twin magnetic sensors located close to the wingtip and the associated electronics located closer to the fuselage of the UAV. The MFAM employs two MEMS magnetic sensors, mounted at 180 degrees to one another. In this configuration the heading of each of the MEMS sensors can be averaged to minimise the intrinsic heading error effect. All the usual GPS, accelerometer, compass and gyroscope data is acquired in flight by the MFAM system.

CALIBRATION/COMPENSATION

During the calibration flight all magnetic and IMU data from the MFAM was recorded for later download. During the flight, roll, pitch and yaw maneuvers were executed on the four cardinal survey headings in the normal way. The magnetic data was acquired at 1kHz and during processing was decimated to 20 Hz after applying a low pass filter with a 10 Hz cutoff. This resulted in an estimated normalized 4th difference noise of 0.05nT. A magnetic compensation solution was then applied, by least squares fitting the standard Leliak's equations (Leliak 1961) [2] to the data. Additional terms to the model earths field are included in the estimate to facilitate fitting the full bandwidth of the measurements. The result is summarized below for the flight:



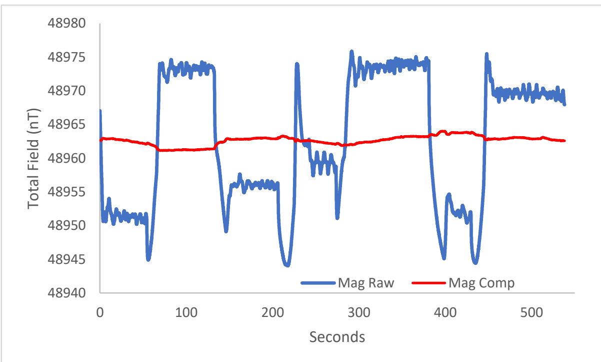


Figure 2: Pre and Post Compensation Result.

Heading: The aircraft related magnetic effect at the MFAM sensor is relatively large. The range of total field measurements across the flight, including turns, is 35nT but more typically 20nT on the cardinal headings. This is shown on Fig 2. Once this aircraft effect is removed from the data this range is reduced, across the entire flight, to approximately 3.3nT.

The table below summarises the magnetic differences at the four crossover points in the centre of the cloverleaf before and after the compensation procedure.

Intersect		Intersect Difference(nT)	
Line	Line	Before	After
2000	3000	18.10	0.11
2000	1000	5.20	0.15
4000	3000	3.60	0.26
4000	1000	19.70	0.30
	Average	11.65	0.20

Figure 3: Difference in magnetic value at the 4 intersection points in the centre of the cloverleaf before and after compensation.

The compensation has reduced the intersection mismatches from an average of 11.65nT to an average of 0.20nT.

Manoeuvre Noise: Permitting constraints, while mobilised, did not allow for a Figure of Merit (FOM) flight to be carried out. A 'pseudo' FOM determination has been attempted from the compensation flight data but this yielded an uncertain result. This is most likely due to the fact that the roll pitch and yaw manoeuvres are not distinct from one another in the flight pattern. As an alternative the before and after compensation manoeuvre noise is shown in Fig 4 below. The mean of the data in the plot area has been removed from each profile to overlay them. There is some noise introduced into the after-compensation profile by the IMU data but this will be removed in the later processing.

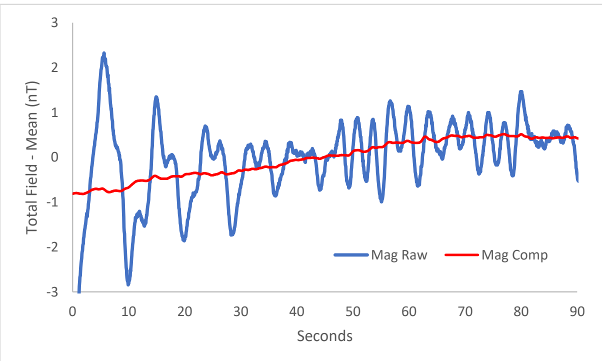


Figure 4: Manoeuvre Noise Before and After Compensation on the NE cardinal survey heading.

Levelling Statistics: A single production flight has been carried out and our client has given us permission to display the intersection statistics but not the data.
The significant improvement the compensation has on the raw magnetic data is demonstrated by the misclosures at crossovers between traverses and ties. Whereas the histogram of the misclosure of the raw magnetic data shows four broader peaks (heading effect) there is only one much narrower central peak after compensation (which can be further narrowed by applying the diurnal correction).

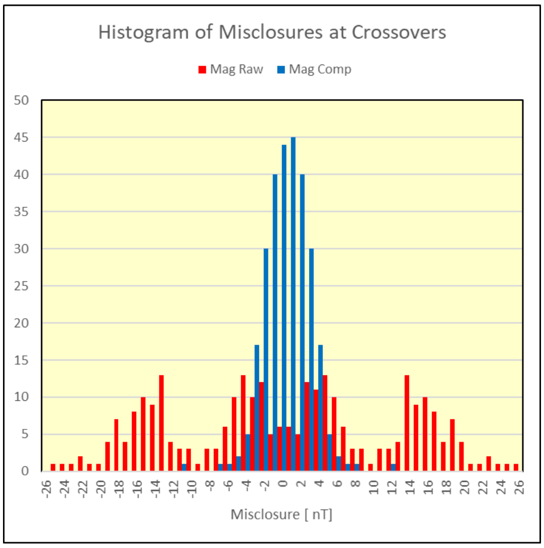


Figure 5: Histograms of Misclosures

CONCLUSION

A successful magnetic compensation flight has been conducted with the Prion airborne platform using the MFAM sensor manufactured by Geometrics. The results of this work show this to be a viable platform for airborne magnetic survey.

The payload of the Prion would also allow the addition of a good quality fluxgate magnetometer to record more accurate pitch roll and yaw angles, which will augment the compensation. In addition, operating the system with a light weight spectrometer seems feasible.

REFERENCES

1. Geometrics MFAM Sensor - http://mfam.geometrics.com/

2 P. Leliak, Identification and Evaluation of Magnetic Field Sources of Magnetic Airborne Detector MAD Equipped Aircraft, IRA Transactions on Airspace and Navigational Electronics, Volume 8, P.95-105, September 1961.