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# Evaluation of an Unmanned Aircraft for Geophysical Survey

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## SUMMARY

UAV aircraft differ significantly from manned aircraft. This paper investigates what the differences are and how that will affect decisions made by purchasers of airborne geophysical data.

Differences between manned and unmanned aircraft produce either positive or negative impact on the geophysical data due to a range of factors such as permanent, induced, eddy current, electromagnetic and microphonic noise. Flight characteristics, terrain to be surveyed, location of the survey, safety aspects and regulations are also a consideration.

Whether a purchaser of geophysical data chooses a UAV aircraft over a manned aircraft or a particular type of UAV, differs for every company. Every company will have different safety requirements, prospects, locations to survey and budget.

**Key words:** UAV Airborne Geophysics Unmanned

## INTRODUCTION

There is no doubt that in the future a large proportion of airborne geophysical surveys will be conducted with an unmanned platform. UAV use in airborne geophysics is now a reality with companies such as Shift Geophysics, Universal Wing, TGS NOPEC, and EXIGE either in advanced stages of development or offering an unmanned platform.

**Figure 1. Shift Geophysics airship UAV with single magnetometer payload.**

**Figure 2. TGS fixed wing UAV single magnetometer payload (http://www.tgs.com/geophysical/potential-field-services/uav, cited 1/3/2013).**

This paper can be used as a guide for purchasers of airborne geophysical surveys to evaluate all aspects of unmanned airborne geophysical surveys. All factors related to geophysical survey differ for manned surveys to unmanned surveys and these need to be understood by the purchaser.

Relevant criteria for evaluation include the quality of geophysical data produced, the ability of the aircraft to successfully conduct the survey, safety and regulations.

From the evaluation the purchaser can then determine if the unmanned platform offered is likely to produce the desired results for their prospect.

## DATA QUALITY

Data quality can be affected either positively or negatively depending on the type of UAV used for the type of geophysics data acquisition. Magnetic data is negatively affected by permanent, induced, eddy current fields (Geometrics, 2000), high frequency electromagnetic noise and microphonic noise generated from the airborne platform.

Permanent fields are caused by magnetic material on the aircraft or dc current in wiring producing a magnetic field. Permanent fields are generally low as all UAV manufacturers avoid using any steel products due to weight saving measures, therefore most UAV's are made of composite materials only.

The length of wiring is quite short due to the small size of the UAV. Even though cabling is short it is in close proximity to the magnetometer and may therefore be a significant source of noise if not treated properly.

Induced fields are produced by the interaction of permeable material passing through the earths magnetic field generating an induced magnetic field. This is also low as there is very little magnetically permeable material in UAV's. The main source of magnetically permeable material is in the engine. The engines used are small, generally 30-50cc when compared with a manned aircraft.

Eddy current fields are generated by conductive material in the aircraft acting as a conductive loop. When passing through the earths magnetic field eddy currents are generated in the conductive loop, when the aircraft changes attitude or orientation this induces a change in the eddy currents producing noise. This can be significant as the majority of UAV's are made of carbon fibre, which is conductive.

High frequency electromagnetic noise is produced from varying electrical currents from sources such as the electronic ignition of the engine, payload electronics, current regulators and servomotors which move the aircrafts control surfaces. These noise sources are significantly greater than the previous three noise sources mentioned and can total up to 30nT in amplitude if the aircraft is not configured correctly. Figure 3 illustrates noise of 1.5nT amplitude generated by a servomotor with the magnetometer placed 0.5m from the servomotor.

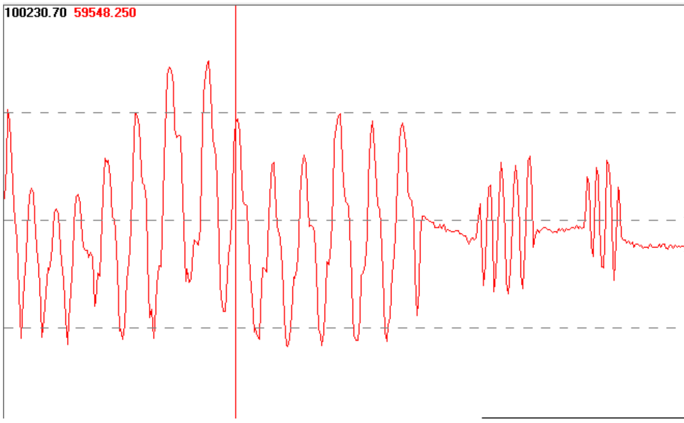


**Figure 3. Electromagnetic noise generated from a servomotor.**

Microphonics noise is produced by vibration or motion on the magnetometer. This noise source can be significant on a UAV because a combination of large wing area and lightweight materials on a fixed wing aircraft will produce very unstable flight in gusty conditions. The wings oscillate more than manned aircraft due to the lightweight materials used in the wing not offering as much dampening. UAVs are small in size, therefore a large strong and stable stinger can't be attached due to weight and centre of gravity restrictions. The UAV is also more susceptible to turbulence than a larger heavier manned plane.
Other UAVs such as an airship have very low acceleration environments due to their slower air speed.

The geophysical sensor used to collect the data will have a significant impact on the data quality. Due to payload size and weight restrictions of UAV aircraft several contractors have chosen to use a fluxgate magnetometer rather than a cesium vapour magnetometer. Fluxgate magnetometers are significantly more susceptible to attitude changes. Without any processing on either the cesium vapour or fluxgate magnetometer, on exactly the same mounting structure and therefore under the same vibration frequency, amplitude and attitude changes, Figure 4 illustrates fluxgate data noise of 40nT compared to 0.01nT from a cesium vapour magnetometer during a production flight. The fluxgate magnetometer would require significantly more filtering resulting in less high frequency information than provided by a cesium vapour magnetometer. This may be acceptable for certain prospects but unacceptable to others.

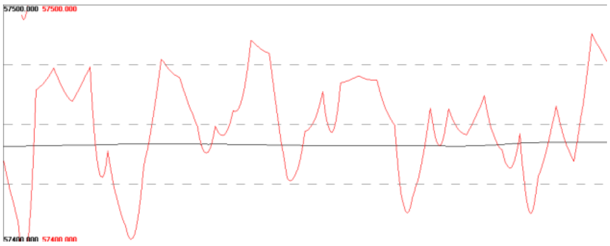

**Figure 4. Cesium Vapour magnetometer (black) microphonic noise versus Fluxgate magnetometer (red) microphonic noise. Grid lines are 25nT amplitude.**

Radiometric signal to noise also applies where the less mass means less crystal volume producing less absorption of gamma rays and a reduced signal to noise ratio. Therefore if contractors proposed a small UAV for radiometric surveys the signal to noise would be less than that produced from a manned aircraft carrying two crystal packs.

There are many different types of UAV's and they will all have different flight characteristics that will alter the geophysical response. The flying height and ability to accurately drape steep terrain will be best for heliborne UAV, then thrust vectored airships, where as flat surfaces would best be served by fixed wing UAVs which exhibit longer wavelength phugoid oscillations. In the future UAVs will be fitted with terrain avoidance technology allowing them to fly much closer to the ground.
Ability to maintain on a set heading (on line) is superior for all UAVs over manned aircraft as the autopilot reacts much quicker to crosswinds. However the contractor needs to prove the repeatability of flying on line as different autopilots have different capabilities. Older autopilots with slower processing speeds have less ability to maintain a set heading.
The stability of the platform and stability of the magnetometer mount is important when considering microphonic noise. Small fixed wing UAVs are very unstable in gusty conditions compared to other UAVs due to their large wing span and low weight.
The wind conditions at the survey area are a consideration as an airship will not be able to survey near or over the sea, where as a faster fixed wing UAV would be ideal for windy conditions.

## SAFETY

A key driver for moving to unmanned aircraft is to eliminate the potential of a pilot fatality, this is the most effective method in the hierarchy of control.
The International Airborne Geophysics Society Association (IAGSA) published statistics (Figure 5) have attributed 1.75

fatalities per 100,000 flight hours for 2011 due to airborne geophysics operations (IAGSA, 2012). With unmanned aircraft there is a real possibility this can be reduced to zero annually.

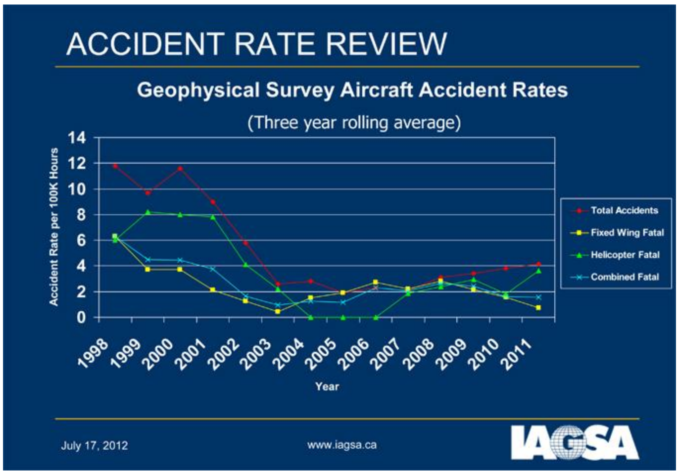


**Figure 5. Geophysical Survey Aircraft Accident Rates (IAGSA, 2012).**

The International Civil Aviation Organisation (ICAO) have considered ranking the safety of a UAV by its kinetic energy if it hits the ground, where
Kinetic energy = 1/2mass x $(\text{velocity})^2$
The greater the kinetic energy the more likely it is if an incident occurs that there will be property damage or injury to people on the ground.

Large UAV = 1,000,000J or more
Medium UAV = 10,000 to 1,000,000J
Small UAV = 10,000J or less

Two ends of the scale for airborne geophysics surveying would be TGS NORPEC fixed wing UAV being and Shift Geophysics Airship UAV.

Fixed wing kinetic energy = 0.5x30kg x $(22.22\text{m/s})^2$ = 7407J
Airship kinetic energy = 0.5x5kg x $(11\text{m/s})^2$ = 302J

All airborne geophysics operations are considered small UAVs by ICAOs standards.

To produce a risk rating the likelihood of an incident occurring also needs to be calculated. UAVs are more likely to have an incident than manned aircraft due to the complex nature of autopilots and the technology and contractors operating them are still maturing.

To reduce the likelihood of an incident it is important to ask the contractor what redundancies the aircraft has, what the maintenance schedule is, whether they keep adequate flight logs of failures and whether they use a continual improvement safety system. Small aircraft failures of items like power supply, connectors, servomotors, control surfaces, linkages, hinges, fuel supply and deteriation of the airframe occur more frequently than for manned aircraft.

Contractors should also be asked what the autopilot failure routines are when there are failures such as GPS loss, altimeter loss, communication link loss, the autopilot is not meeting waypoints and when the aircraft decreases below a certain altitude threshold.

## REGULATIONS

Every country has a different aviation authority and therefore different regulations in regards to UAV operations. Unfortunately as UAV operations for civil applications is relatively new, regulations for UAV operations are generally lagging in all countries around the world. In some areas of the world there are no regulations but the aviation authorities stance on UAV operations vary significantly. In the United States there are no regulations and the use of UAVs for commercial operations is prohibited. Western countries generally put in place policies for manned aircraft if requested to fly a UAV, third world countries often simply ask that they're notified of the location and times of operations and that relevant fees are paid. It is difficult operating in countries where there are no regulations as its difficult to get permission to operate in writing and what operations are/ are not allowed is often at the discretion of individuals within the organisation.

The Civil Aviation Safety Authority (CASA) published Part 101 (CASA, 2001) which clearly outlines what is required to operate UAVs commercially in Australia. An operating certificate is required similar to manned operations, however only UAVs over 100kg in size require a type certificate. Part 101 requires that operations in regards to maintenance, flight logs, pilot training etc are conducted similar to manned aircraft operations. Pilots are required to have a controllers certificate issued by CASA to operate the UAV type that the company operates. As of March 2013, 34 companies have operating certificates in Australia (http://www.casa.gov.au/scripts/nc.dll?WCMS:STANDARD:1001:pc=PC_100959, cited 01/03/2013).

When contacting a UAV company you will need to ensure that they are operating within the regulations set out by the country. There are many UAV operators in the United States operating illegally.

## CONCLUSIONS

Many explorers have expressed great desire for unmanned aircraft to become available for geophysical survey, however they need to examine the negatives as well as the positives before committing to any contracts.
Several noise sources are lessened over manned aircraft such as permanent, induced and eddy current noise, however noise sources such as electromagnetic noise and microphonics are greater on fixed wing and heliborne UAV's. Smaller payloads equate to lesser signal to noise when using a fluxgate magnetometer and conducting radiometric surveys.
Several terrain environments are not beneficial for certain UAV aircraft such as an airship near the ocean.
The use of a UAV does not necessarily mean that operations will be conducted in a safer manner. UAV aircraft are not as reliable as manned aircraft, therefore the operator needs to have an extremely rigorous maintenance schedule in place and have in place a best practice safety system.
Due to regulations your company may not be allowed to fly a UAV in the country you plan on surveying or the regulations

require the operator has crew with certain qualifications and the company need to have an operating licence.
UAV aircraft do differ significantly to manned aircraft and therefore the industry will need to learn what those differences are to effectively manage a UAV survey.

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