Use of unmanned air vehicles in oil, gas and mineral exploration activities

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Dyke Weatherington, author of the DoD “Unmanned Systems Roadmap 2007 – 2032” summed up the role of military Unmanned Systems as being missions that were:

- dull,
- dirty
- or dangerous.

In oil, gas and mineral exploration and production activities, there are additional potential roles for UA:

- when they can get better quality data
- where the low operating cost allows them to be used on a routine basis.
Unmanned Aircraft have already been used in Exploration & Production activities

Oil pipeline monitoring

Aeronautics Defence Systems provide pipeline monitoring services in Angola to ChevronTexaco under a $4 million contract.

More recently, Aeronautics Defence Systems have provided a similar service in Nigeria.

As well as operating several Aerosky vehicles on behalf of the IDF, ADS is currently using its short-range Aerostar UAV to provide protection and patrol services for Chevron Texaco’s operations in Angola under a two-year contract awarded last year and reportedly worth US$ 4 million. The Aerostar carries a payload of up 50 kg and has an endurance of 14 hours. According to the manufacturer, it logged more than 10,000 flight hours after being selected in 2002 to carry out routine security missions for the Israel Defence Force.

from UAV SystemsThe Global Perspective 2005 by Blyenburgh & Co
The problems with satellite imagery

- “It can take up to 14 days for the Low Earth Orbit satellite to be over the area of interest.”
- “Satellite bandwidth is both **limited** and **expensive** at the present time.”
- Clouds can obscure part, or all, of the underlying terrain of interest.
Aerial photography: the most popular civilian application of Unmanned Aircraft

Photo taken with a midsize Canon G10
Magnetic field surveys: a popular geophysical application of Unmanned Aircraft

A survey in which the Earth’s magnetic field is measured using high resolution, lightweight, Caesium beam magnetometers, mounted at the wing tips, as shown below.

MagSurvey Prion by Magsurvey Limited, from http://www.magsurvey.co.uk/
Universal Wing surveys completed in 2007 from Princeton, British Columbia

26 MAR 2007 – 10 APR 2007
1,600 line km (Alberta, Canada)

16 APR 2007 – 30 AUG 2007
>20,000 line km (Nunavut, Canada)

20 OCT 2007 – 23 NOV 2007
>6,500 line km (Northwest Territories, Canada)

**Quality magnetic field data**

Unmanned Aircraft can fly at lower elevations and at slower speeds than manned fixed wing aircraft and can deliver helicopter-like data quality at a fraction of the cost.

“We have integrated a lightweight high performance Cesium magnetometer (model G-823A), combined with an ultra-small size CM-201 Larmor counter to provide high sensitivity (0.004nT/RtHz RMS) and low heading error @ ±0.15nT over 360° equatorial and polar spins. **This facilitates high quality data acquisition.**”

Superior resolution is provided by the Cesium Larmor signal with the Earth’s field tracking rates exceeding thousands of nT over 0.1 second periods.
Magnetic field surveys using unmanned aircraft by Universal Wing of Canada.

From http://www.universalwing.com/technology/unmanned
At Carleton University we have an active project developing an integrated multi-mission UAS. The development started five years ago as one of the final-year undergraduate projects at M&AE on the 16 foot wingspan UAV with a take off weight of around 200 pounds.

In collaboration with an Ottawa geophysics company, Sander Geophysics Limited. The objective is to develop a UAS for high-resolution magnetic surveys, GeoSurv II. SGL studies have shown that a relatively small air vehicle would be highly competitive for such surveys and, consequently, the company has been providing significant in-kind support to the undergraduate project.

Four areas of critical technology were identified with SGL in 2005 and research started in 2006:
1. Autonomous Operation
2. Obstacle Detection
3. Low-Cost Composite Airframes
4. Magnetic Signature Control.

SGL funding of these projects was leveraged by obtaining matching funds from the Ontario Centres of Excellence Interact program, which provided initial short-term support.

From [http://uav.mae.carleton.ca/](http://uav.mae.carleton.ca/)
ConocoPhillips experience…

Arial Photography during Sea trials of Arctic Shuttle Tanker, Dec. 2007

From Christer Broman at ConocoPhillips
Potential UAS Applications

1. Ice Reconnaissance, Ice Measurements
2. Ice navigation Assistance for Icebreaking Ships
3. Surveys of Icebergs and Floating Ice
4. Surveys of Marine Mammals and Wildlife
5. Security information and Guard Duty
6. Geophysical Surveys for Oil and Gas

From Christer Broman at ConocoPhillips
Potential UAS Applications

7. Inspection of Land based Oil and LNG tanks
8. Inspection of Flares and Flare Nozzles
9. Aerial photography
10. Inspection of LNG carrier cargo tanks
11. Surveys and Inspection of Oil and Gas Lines
12. Metrological forecasting

From Christer Broman at ConocoPhillips
What are the compelling capabilities of Unmanned Aircraft?

UAVs can make observations beyond the reach of manned aircraft.
Unmanned Aircraft can fly all night, night after night, at low levels (such as 50 feet AGL).

From a presentation by James Macnae at SEG 2006
As exploration activities move to the more hostile regions of the Earth, such as the Arctic Ocean, and to more politically unstable areas, expect to see a growing use of Unmanned Aircraft operating in areas where it would be irresponsible to expect pilots to fly:

- low level, night flights over the Arctic Ocean;

- flights over regions in which there is low level strife, where the larger manned survey aircraft provide target practice and some excitement for the locals.
Unmanned Aircraft collect higher resolution data

Being smaller and always flying using precision navigation, the Unmanned Aircraft can fly closer to the ground (“tight drape”) and collect higher resolution data.
The advantages of using Unmanned Aircraft in E & P activities

- Unmanned Aircraft create less of a disturbance to the parameters being measured such as the magnetic, or, gravitational field, since they are physically smaller than their manned counterparts, and usually made from a larger fraction of non-metallic materials. However, the instruments are closer to sources of electrical noise on the aircraft.

- **Unmanned Aircraft cost less to operate per line km**, since:
  - an Unmanned Aircraft operator can manage several UA at the same time;
  - the Unmanned Aircraft uses less than 20% of the fuel used by a manned aircraft

- **Small Unmanned Aircraft are more environmentally friendly** since they:
  - require less materials to build and is easier to dispose of at the end of its life;
  - use less fuel and creates less pollution per km travelled;
  - make less noise in flight;

- **Unmanned Aircraft can routinely fly missions covering the same area, day after day, night after night, to perform measurements for use in change detection and data averaging:**
  - detecting a leak in an oil pipeline using differential thermal and / or SAR imaging.
However, Unmanned Aircraft have not yet seen widespread deployment...

- Unmanned Aircraft are not permitted to fly in commercial (“un-segregated”) air space.
- UA do not have a protected aeronautical frequency band.
- UA are not sufficiently reliable. Almost all present day Unmanned Aircraft are single engine experimental aircraft which do not have air worthiness certificates.
- UA have not yet clocked up sufficient flight hours to provide data for a convincing safety case, without which the National Aviation Authorities, such as the FAA, the CAA, and the like will not issue of Certificate of Authorization (“COA”) to fly even in restricted air space.
- In the absence of sufficient flight hours, and a legally sound safety case, the insurance costs are astronomical, and blow any business case out of the water. Insurance costs are inversely related to flight hours, and one typically needs $10 million of insurance cover.
- UA do not yet have a detect and avoid system to enable them to detect and avoid other airborne objects, such as the farmer flying a Cessna in the Canadian outback.
- Government security services need to be sure the Unmanned Aircraft cannot fall into the hands of, or be used by, or be taken over in flight by, criminals or terrorists.
It will take a few years before we see UA in widespread commercial applications...

- UA systems developers are getting their flight hours and experience in the military sector.
In pipeline monitoring work, we need to be able to identify objects.
Exploration and Production activities take place throughout the world...

From a climate point of view, the Arctic region has some of the most severe weather conditions one could encounter:

- Total darkness (in winter time)
- Temperatures: drop to -40°C
- Spray icing
- Snow and ice

Part of the Trans Alaska Pipeline, from http://www.usgs.gov
Exploration and Production activities take place throughout the world...

In North Africa and in the Middle East, a survey plane could encounter:

- temperatures that reach +50°C during the day;
- abrasive sand storms.

Above: pipeline in Saudi Arabia.

Right: Satellite photograph of a dust storm showing fine sand from Morocco and Western Sahara (below Morocco) being blown over to Lanzarote and Fuertaventura.
The instruments used in a geophysical survey can be divided into two groups:

- Those weighing less than 10 kg
- Those weighing more than 100 kg (best suited to manned aircraft at present)

Geometrics G822 airborne Cesium magnetometer

Gravity gradiometer: 350 kg+
Geophysical survey instruments weighing less than 10 kg

- High resolution (24.6 MPixel) digital camera
- 1.55 um InGaAs based near infrared and thermal imaging cameras
- Polarimetric (dual polarization) hyper-spectral imaging system
- Scanning LIDAR or mm RADAR unit for digital elevation mapping (DEM)
- Caesium or Potassium magnetometer for use in magnetic mapping
- Quantum cascade laser for ethane detection
- miniature SAR (such as the ImSAR NanoSAR)

Useable Payload = 4 Kg

Above: the 1 kg NanoSAR from ImSAR, http://www.imsar.net/ has flown on a Scan Eagle
High performance sensors for use in long range object identification.

The Canon EOS 5D Mk II camera body
- 5,616 x 3,744 Pixels = 21 MPixels
- computer interface and control via fast USB 2
- weight = 810 g

The Canon EF 70-300mm f/4.5 – 5.6 lens
- angle at max zoom = 6.83° x 4.58°
- uses compact diffractive optics
- weight = 720 g

- In oil and gas pipeline monitoring, a mid-size Canon G10 digital camera with a 14 MPixel resolution takes a wide-field-of-view photograph each second.

- The high resolution Canon EOS 5D Mk II with a 70 – 300 mm diffractive optics lens takes a very high resolution photograph each second at the centre of the field of view of the Canon G10 camera for use in object identification.
Number plate reading tests at 600 feet from a camera in a moving car.
Number plate reading tests at 600 feet from a camera in a moving car.

In the above photographs, using a professional “L” series image stabilised Canon lens:
- ISO setting = 800
- shutter speed = 1/2,000 second = 0.5 millisecond
Synthetic Aperture RADAR (SAR) need not be hugely expensive...

**Figure 10.** Antenna, RF stack and data storage device produced by BYU, operated by CU, flown by ACR

BYU = Brigham Young University
ACR = Advanced Ceramics Research

**Figure 17.** The MicroSAR mounted onto the electric Silver Fox UAV prior to launch in Greenland.
Geophysical survey instruments weighing more than 100 kg

- Gravity meter (absolute or gradient): 450 kg + (could be made lighter, but needs research)
- Gamma ray sensor: ~250 kg (very difficult to make lighter)
- Airborne ElectroMagnetic (AEM) probing: 1,000 amp pulses, 4 mSec long into a 24 m diameter, 6 turn, coil.

Fugro Airborne Services AEM aircraft fitted out with a large electromagnetic coil.
A 2 amp current is passed through the coil wrapped around the Advanced Ceramics Silver Fox, shown above. The current in the coil is modulated at 88 kHz. A sensing coil towed behind the aircraft detected the signals from the underground targets, enabling the Unmanned Aircraft to detect underground tunnels and buried wires. Work reported by Mark Patterson.
With reference to the above diagram, the magnetic field strength $B$ at a distance $Z$ from an $n$ turn coil is given by the following expression:

$$B = \frac{n\mu_0 IR^2}{2(R^2 + Z^2)^{1.5}}$$

One observation is that the field strength decreases with the third power of distance between the coil on the aircraft and the region where the eddy current is induced.
The suitable range for an Unmanned Aircraft engaged in geophysical survey work

- A development survey typically covers an area of $20 \times 20 = 400$ square kilometers:
  - total distance for 100m scan line separation = 4,800 km
    - 6 flights, each with 800 km range
    - 8 flights, each with 600 km range

- For a typical exploration survey covering a $100 \times 100 = 10,000$ square km region:
  - total distance for 250m scan line separation = 44,000 km
    - 73 flights, each with 600 km range
    - 55 flights, each with 800 km range
      - could use several UA

- One of the longest oil pipelines in the world is the 1,768 Km Baku-Tbilisi-Ceyhan (BTC):
  - locate UA base in each of the three countries:
    - 445 km in Azerbaijan
    - 245 km in Georgia
    - 1,078 km in Turkey

A UA with a range of **600 to 800 km** would be suitable for the above work.

**Suitable Range = 600 km to 800 km**
Estimated price for a suitable GeoSurvey UA with 4 kg payload and 700 km range.

4 kg $\times$ 700 km = 2,800 kg.km and price = 0.921 $\times$ 2,800$^{0.6}$ = $108k$ FY_02 = $131.5k$ FY_10
Caution over Unmanned Aircraft System prices: UA Systems can be expensive.

The price of an Unmanned Aircraft System can readily exceed the cost of a light manned aircraft.

**Reason:**
- UA have high Non Recurring Engineering (“NRE”) expenses.
- The NRE costs of the Cessna are in the past.
- The Cessna is produced in larger quantities on equipment that has been written off.

![Graph of Price vs R*P product for three Cessna aircraft from www.cessna.com](image)

Above: the Cessna Skylane. Yours for $390,000.
Putting the two data sets together...

Cessna aircraft: prices scaled to FY_02
The military requires Unmanned Aircraft:

- with long endurance times, to enable them to loiter over an area of interest and watch what is going on below;
- that have stealth characteristics, so that they are not easily seen as they loiter over an area of interest;
- that are agile, so they can escape any attack that might be mounted against them;
- now, with the expectation that reliability will improve with time, usage and production.

AAI Shadow 200 Unmanned Aircraft with US Forces in Iraq (photo supplied by AAI Corp).
For geosurvey and pipeline monitoring, one requires an Unmanned Aircraft:

- with a long range, to enable the Unmanned Aircraft to cover a large survey area, cost effectively, between refueling;

- with low vibration engines that have a low magnetic “signature,” so as not to perturb the sensitive measurements being made and to increase the reliability of the Unmanned Aircraft;

- that flies on a smooth and well controlled flight path, to minimize the overlap required between scan lines and maximise measurement accuracy;

- with a high reliability from the outset.
Example of a long range unmanned aircraft developed for geophysical work.
The InView unmanned aircraft takes about one hour to both assemble and test.

Forward mounted engines to get the correct centre of gravity: two engines for added safety.

Very light tail section to get the correct centre of gravity

Modular construction for ease of transportation

Big wheels for operation from rough terrain
Overview of the InView unmanned aircraft developed for geophysical work.

- for military, state and civilian missions
- many safety features, including two engines
- modular and easily transportable
- can take-off from an unprepared field
- capable of very slow flight
- high performance sensors
- manual and autopilot flight modes
- on-board computer power for use in real-time sensor data processing

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
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<tbody>
<tr>
<td>Wingspan</td>
<td>4 m</td>
</tr>
<tr>
<td>Payload</td>
<td>4 kg</td>
</tr>
<tr>
<td>MTOW</td>
<td>20 kg (with payload, no fuel)</td>
</tr>
<tr>
<td>Endurance</td>
<td>7+ hours</td>
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<tr>
<td>Loiter speed</td>
<td>25 kph (to be confirmed)</td>
</tr>
<tr>
<td>Max speed</td>
<td>100 kph (to be confirmed)</td>
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<tr>
<td>Fuel</td>
<td>AVGAS 100LL</td>
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<tr>
<td>Propulsion</td>
<td>2x SAITO FG-30 engines</td>
</tr>
<tr>
<td></td>
<td>Total Power = 3.6 kW</td>
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</tbody>
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The InView has an extensive set of safety features, together with a 700 km range. It is large enough to carry professional sensors in a massive payload bay under the wing, with powerful on-board sensor data processing, but small enough to be easily transported in a small van.

Short take-off can be from an a rough grass field, with a landing also at a convenient field.

Like the Mosquito aircraft, the InView is constructed using plywood, which is environmentally sound and will disintegrate on impact with a structure, to minimise damage to the structure.
Payloads can be carried in the InView fuselage and in under-wing pods.

- Under-wing mounted magnetometers, or cameras forming a stereo pair
- Forward looking, high resolution, camera
- Down looking, high resolution, camera
- Rear looking, high resolution, camera
- Side looking, high resolution, cameras are also supported, looking through side windows.
Example of a side looking photograph using a midsize Canon G10 digital camera.
The ability to take-off from, and landing on, a rough field is an advantage.

Flaps deployed, the InView comes in for a precision landing in a grass field.
Work on the development of detect and avoid systems is underway in the USA, Europe and in the Far East. The view is that once proven on Unmanned Aircraft, these systems will become mandatory on manned aircraft.

I have not had time to cover the important issue of the command and control link with an unmanned aircraft flying Beyond Line Of Sight. It is hoped there will be progress on an assignment of a protected UA frequency band at the next World Radio Conference WRC-12.

Many of the National Aviation Authorities have assigned staff to develop the regulations for Unmanned Aircraft flight in non-segregated air space:
- US FAA and RTCA SC-203
- EUROCONTROL and EuroCAE Working Group 73 on UAVs
- Australian, Belgian, Canadian, Dutch, Austrian, South African, Swedish and U.K. CAA

Both the FAA and EUROCONTROL are investigating solutions to the UA security aspects.

The early uses of Unmanned Aircraft will be in desolate or hostile areas where pilots do not wish to fly. Interestingly, this is one of the new frontiers for oil and mineral exploration.

Unmanned Aircraft will provide massive amounts of quality data. Developing software to interpret high resolution data is becoming a high priority activity for software developers.
In conclusion

- Lightweight Unmanned Aircraft have much to offer in the areas of oil, gas and mineral exploration and pipeline and related installation monitoring, including quality data.

- This is realized by staff in oil, gas and mineral exploration companies.

- The biggest concern expressed to us by staff in the oil, gas and mineral industries has been the **unmanned aircraft regulatory issues** in the countries in which they wish to operate.

- **Things move very, very slowly in oil, gas and mineral companies.** Often the attitude is one of let’s wait and see until someone else works on this new technology.

- Although some activities in this area have already started, there remains much work to be done before we will see widespread civilian applications.

- On the regulatory side, work is underway at EuroCAE WG-73, EUROCONTROL, the US RTCA SC-203, the FAA and the European Defence Agency, to name but a few organisations, to develop recommendations to enable Unmanned Aircraft to fly in un-segregated air space.

- A huge amount of experience is being gained in military operations.

- Please feel free to contact me at joseph.barnard@barnardmicrosystems.com
Thank you.

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