The requirements for unmanned aircraft operating in oil, gas and mineral exploration and production

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The Users need a mapping of the Earth’s magnetic field from an airborne survey.
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### Example of the UA based Geophysical Survey ("GS") Sensor Requirements

<table>
<thead>
<tr>
<th></th>
<th>Aeromagnetic</th>
<th>Photographic</th>
<th>Stereo CAM and / or scanning LIDAR for DEM</th>
<th>Hyperspectral imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost per flight hour</strong></td>
<td>$500 to $2,500</td>
<td>$ 135</td>
<td>$ 200</td>
<td>$1,000 - $2,500</td>
</tr>
<tr>
<td><strong>Payload</strong></td>
<td>&lt; 2 kg</td>
<td>2 kg</td>
<td>4 kg</td>
<td>5 kg</td>
</tr>
<tr>
<td><strong>Altitude</strong></td>
<td>80m AGL / 120m ASL</td>
<td>1,000 +/- 50 m</td>
<td>400 +/- 10 m</td>
<td>1,000 +/- 100 m</td>
</tr>
<tr>
<td><strong>Path</strong></td>
<td>Tight drape +/- 10 m</td>
<td>Fixed height AGL</td>
<td>Fixed height AGL</td>
<td>Fixed height AGL</td>
</tr>
<tr>
<td><strong>Speed (typical)</strong></td>
<td>230 kph</td>
<td>120 kph</td>
<td>120 kph</td>
<td>80 kph</td>
</tr>
<tr>
<td><strong>Line spacing (typ)</strong></td>
<td>200 m</td>
<td>100 m</td>
<td>400 m</td>
<td>350 m</td>
</tr>
<tr>
<td><strong>Data per flight hour</strong></td>
<td>&lt; 1 MB</td>
<td>~24 GB for High Res</td>
<td>~48 GB for High Res</td>
<td>~1-5 GB for Low Res</td>
</tr>
<tr>
<td><strong>Specs</strong></td>
<td>Resolution ~ 1 cm</td>
<td>Resolution ~ 1 cm</td>
<td>Resolution ~ 1 cm</td>
<td>HorzRes &lt; 5m Lo Res</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HorzRes &lt; 1m Hi Res</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>256 wavelengths</td>
</tr>
</tbody>
</table>
How are Geomagnetic Surveys performed today?
In a GS, the UA need to be able to fly from 20m to 80m Above Ground Level...

Improved spatial resolution

200m LINE SPACING, 80m HEIGHT
30m LINE SPACING, 20m HEIGHT

Images courtesy Universal Tracking Systems Pty Ltd
often flying at night, when the electrical and magnetic noise levels are low.

From a presentation by James Macnae at SEG 2006
A satellite data relay network is needed for UA operating BLOS in GS activities.

**Satellite Ground Station (SGS):**
- Interface satellite comms with Internet
  - For example, Inmarsat
  - Americas SGS located in Hawaii, USA

**UA Ground Control Station (GCS):**
- Pilot-in-Command
- Safety Co-Pilot
- Payload Operator
  - all terrain 4x4 van
  - electrical power generator
  - satellite ground comms unit
  - 5.8 GHz wireless Ethernet Bridge
  - 2.4 GHz spread spectrum unit
  - 3x computers + Ethernet switch

**Service Provider Site (SPS):**
- Survey Operations Manager
- Internet access
- 16 kbps Survey Status update
  - For example, Fugro or Sander
  - Both located in Ottawa, Canada

**The End User Site (EUS):**
- Survey Manager
- Internet access
- Survey Status update
  - For example, Shell
  - Located in Rijswijk, Netherlands

**Unmanned Aircraft with:**
- GNSS receiver
- IMU and LIDAR altimeter
- autopilot follows GNSS waypoints
- satellite communications unit
- ATC VHF communications unit
- sensors for use in geophysical survey
- 7 hrs operation BLOS of the UA GCS

**Diagram:**
- Data Relay satellite (Inmarsat, Geostationary)
- Data Relay satellite (Inmarsat, Geostationary)
- GNSS #32
- GNSS #17
- Internet
- ATC
- UA Ground Control Station (GCS)
- Service Provider Site (SPS)
- The End User Site (EUS)
The requirements for unmanned aircraft ... by Barnard Microsystems Limited

The instruments carried on the unmanned aircraft can be expensive

The crash of an unmanned aircraft carrying expensive sensors impacts the business case:

- a Headwall HyperSpec SWIR hyperspectral camera costing $80,000 to $100,000
- two Scintrex CS-3SL Cesium beam magnetometers, each costing $20,200
- one airborne broadband satellite communications terminal costing $35,000 to $50,000

- Unmanned Aircraft survivability: need reliable engines, and machine intelligence...
By way of example: the Fugro Airborne Systems “GeoRanger” unmanned aircraft.

The GeoRanger was based on the InSitu ScanEagle, and was used in geomagnetic surveys in Canada.
An oil and gas production service routinely monitors oil and gas pipelines

Below: The User needs to:

- routinely monitor several 100+ km stretches of oil pipeline;
- at least once every 2 weeks;
- and detect and identify people and objects from at least 600 feet from a moving airborne platform.

Above: timely (within 15 minutes) detection of an oil leak from a pipeline is important contributing to a societal benefit associated with reduced environmental pollution.
An oil and gas production service routinely monitors oil and gas pipelines

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Below: The User needs to:

• routinely monitor several 100+ km stretches of oil pipeline;
• at least once every 2 weeks;
• and detect and identify people and objects from at least 600 feet from a moving airborne platform.
In PM, the User needs to be notified of vehicles and people in the Right of Way

Above: the pipeline goes underground, and below: further along, we find vehicles on the buried pipeline Right Of Way (ROW).

The pipeline operators need higher resolution imagery of any personnel and vehicles on the buried pipeline ROW.
How are pipeline monitoring ("PM") services performed today?

PM in Nigeria

PM in Saudi Arabia

PM in the USA
Desirable unmanned aircraft safety features

- **Multiple**, independent, electrical power supplies

- **Separate safety autopilot**, able to land the UA in the event of failure of the main controller

- **Automatic take-off** to reduce the consequences of human error and ease the logistical demand

- **Automatic landing** to enable emergency landings, reduce the consequences of human error ease the logistical demand

- **Distributed, on-board sensor network** to provide early detection of potential failures, so measures can be taken before a more serious condition develops

- **Dual rudder** as part of a dual redundant safety system

- **Dual elevator** as part of a dual redundant safety system

- **Twin engines** are a safety requirement of some staff in mining exploration companies
The unmanned aircraft need to be able to operate in extreme climatic conditions

Severe weather conditions in the Arctic:
- total darkness (in winter time)
- temperatures: drop to -40°C
- spray icing (wing icing)
- snow and ice

In North Africa and in the Middle East, an unmanned aircraft could encounter:
- temperatures that reach +50°C
- fine dust
- abrasive sand storms.
Object detection and identification at over 600 feet from a moving aircraft.

<table>
<thead>
<tr>
<th>Camera Body: Canon EOS 5D Mk III</th>
<th>Lens: Canon EF 70-200mm f/2.8L zoom</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,760 x 3,840 Pixels = 22.1 MPixels</td>
<td>viewing angle = 10° x 7° at 200mm</td>
</tr>
<tr>
<td>computer interface and control via USB 2</td>
<td>4 stop image stabilisation</td>
</tr>
<tr>
<td>price = $3,500</td>
<td>price = $2,500</td>
</tr>
</tbody>
</table>

Side looking photo from an unmanned aircraft travelling at 30 mph, no image enhancement.
Satellite based data relay network, showing single hop link used in a PM service.

Results from the UASatCom Feasibility Study
Another aspect of unmanned aircraft survivability...
The requirements for UA operating in BOTH exploration and production activities

- Payload = 4 kg (7 kg would help with future requirements creep)
- Range = 600 to 800 km (oil pipeline typical length = 105 km)
- The take-off weight should be less than 50 kg (< 35 kg better), to minimize crash damage.
- Speed from 35 to 120 km / hour, cruising in the region of 80 kph.
- Two vibration isolated engines (typically replaced after 500 hours of operation)
- Ability to operate in the Arctic region, where temperatures can drop to -40°C
- Ability to operate in the Sahara, where temperatures can reach more than 50°C.
- Ability to fly using an onboard autopilot
  - automatic take-off
  - automatic landing
- **Support for a collision detection and avoidance “detect and avoid” system.**
- The price for each unmanned aircraft system should be less than US$ 175,000.
Modularity

- easily interchangeable payloads: easy to transport in a small van, and then assemble and test within one hour
- can be stored in a compact manner at a base, or on a ship
- easy to replace modules:
  - due to damage
  - to suit a mission: e.g. long, narrow, wings for a long range mission
  - as part of routine maintenance
The ability to operate from a rough grass field was an important requirement

Above: the InView ready to take off from a rough grass field. It will also land in this field.

- can operate near the area of interest
  - lower cost
  - more hours "on station"
  - no usage of the air space around an airport increases safety
Flaps, in this case Fowler flaps, contribute a slow flight capability.
Most UA with a satellite data communications unit have a large steerable dish.

Example of a satellite communications dish on a large unmanned aircraft: this time, a General Atomics Predator UA.

Such a high gain antenna dish is:

- too large for a small UA
- too heavy for a small UA

We have a problem:

we need some other solution...
Inmarsat were aware of a small Sat Comms unit carried on the Solar Impulse.

The Cobham SB-200 sat comms unit

Inmarsat staff were aware of the lightweight SB-200 airborne satellite communications unit from Cobham South Africa, and already had very good relations with the staff at Cobham.

Total weight = 3.8 kg
Missile Technology Control Regime ("MTCR") export controls.

- If the UAV has a range in excess of 300 km, and a payload in excess of 500 kg, then the UAV falls in Category I "Complete Delivery Systems" Item 1 Part 1.A.2 and getting export approval is that much more difficult.

- If the UAV has a range in excess of 300 km, and a payload of less than 500 kg, as many unmanned aircraft do, then the UAV falls in Category II "Other Complete Delivery Systems" Item 19 Part 19.A.2, and getting an Export License is easier.
Estimated price for a suitable UA with 4 kg payload and 700 km range.

\[4 \text{ kg} \times 700 \text{ km} = 2,800 \text{ kg.km and price} = 0.921 \times 2,800^{0.6} = \$108k \text{ FY}_02 = \$131.5k \text{ FY}_10\]
The cost of unmanned aircraft systems versus the cost of a light aircraft

Cessna aircraft: prices scaled to FY_02
Example of a suitable unmanned aircraft: the InView unmanned aircraft

- **Satellite communications unit** supporting up to 200 kbps Ethernet based Inmarsat communications
- **Two engines for safety**... with the aircraft able to fly controllably on one engine
- **Two rudders for safety**... with the ability to operate using one rudder
- **Modular construction** for ease of transportation, maintenance and upgrade
- **Robust undercarriage** for operation from rough terrain
Conclusions

• Most of the requirements for unmanned aircraft operating in oil, gas and mineral exploration and production activities can be achieved with current technology.

• One needs to exercise caution in the business case, and especially with the capital cost of unmanned aircraft in the light of the Non Recurring Engineering costs.

• **One topic that occurs almost without exception is the need for a reliable, and certified, collision detection and avoidance system.**

• The interest in the oil gas and mineral companies in the use of unmanned aircraft in their operations is both real, and growing.

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