SEG Las Vegas 2008 Thursday 13th November, 2008

The use of Unmanned Aircraft in oil, gas and mineral E&P activities

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Unmanned Aircraft come in all sizes, although most are for military applications....

From the 12,110 kg Global Hawk on the right...

to the 2.7 kg Dragon Eye shown below.

The Unmanned Aircraft System

The UA flying beyond line-of-sight has an always-on satellite (Intelsat or Iridium) link to a ground station for telemetry and VHF radio relay of Air Traffic Control voice signals.

The ground staff must reply to any Air Traffic Control VHF voice communications with the UA so the UA appears to an Air Traffic Controller to be a conventional manned aircraft.

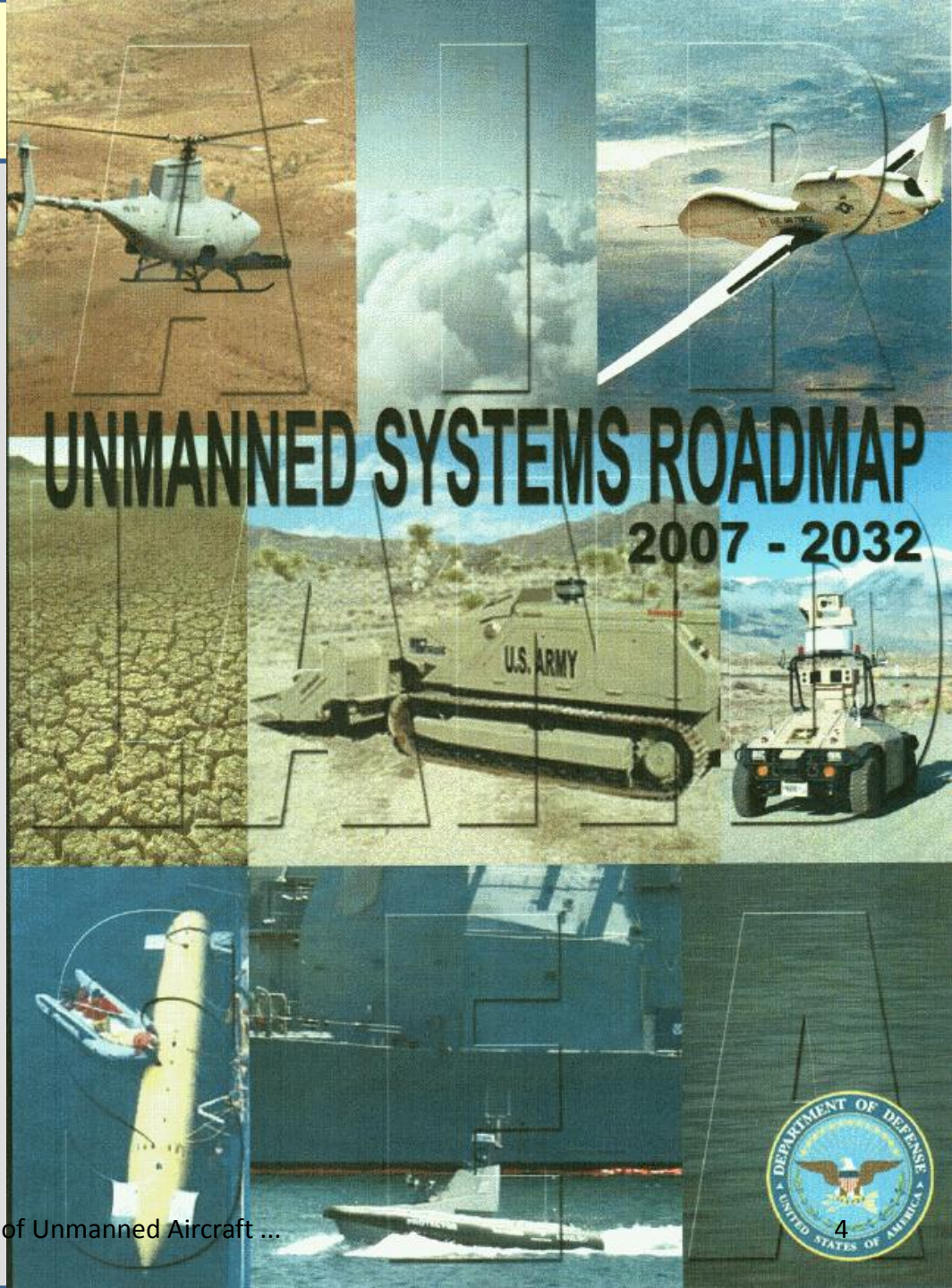
Unmanned Aircraft

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:

- **where they can generate better quality data than manned systems;**

- **where the operational cost is sufficiently low as to allow routine flights to gather data on a routine basis.**



Unmanned Aircraft have already been used in Exploration & Production activities

Oil pipeline monitoring

Aeronautics Defence Systems provide pipeline monitoring services to Chevron Texaco under a **$ 4 million** contract.

More recently, Aeronautics provided a similar service in Nigeria.

The problems with use of satellites are:

- It can take up to 14 days for the LEO satellite to be over the area of interest.
- Bandwidth is both **limited** and **expensive.**

Aerostar - Aeronautics Defence Systems, Israel

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 Systems:
The Global Perspective 2005 by Blyenburgh & Co

Aerial photography

Aerial photography using CropCam

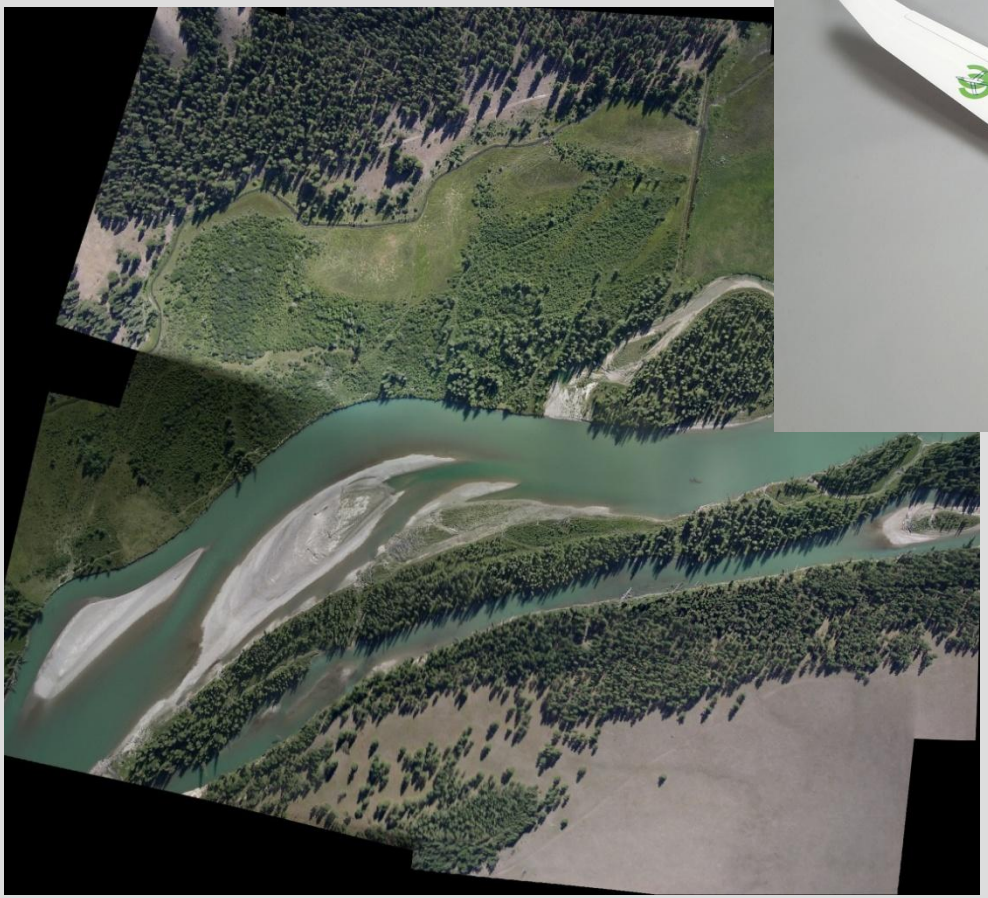


Image of 160 acres of land in British Columbia, derived from stitching together 12 separate images using the CropCam: from www.cropcam.com

Magnetic field surveys

A survey in which the Earth's magnetic field is measured using high resolution, lightweight, Caesium beam magnetometers, as shown below.

MagSurvey Prion by Magsurvey Limited, from http://www.magsurvey.co.uk/

Whale monitoring trials

ConocoPhillips tested the Scan Eagle Unmanned Aircraft, shown below, to monitor marine mammals in Puget Sound in November 2006.

Photos on this slide and the next are courtesy Christer Broman at ConocoPhillips.

ConocoPhillips experience…

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

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

ConocoPhillips
Project Development

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. Arial photography
10. Inspection of LNG carrier cargo tanks
11. Surveys and Inspection of Oil and Gas Lines
12. Metrological forecasting

ConocoPhillips
Project Development

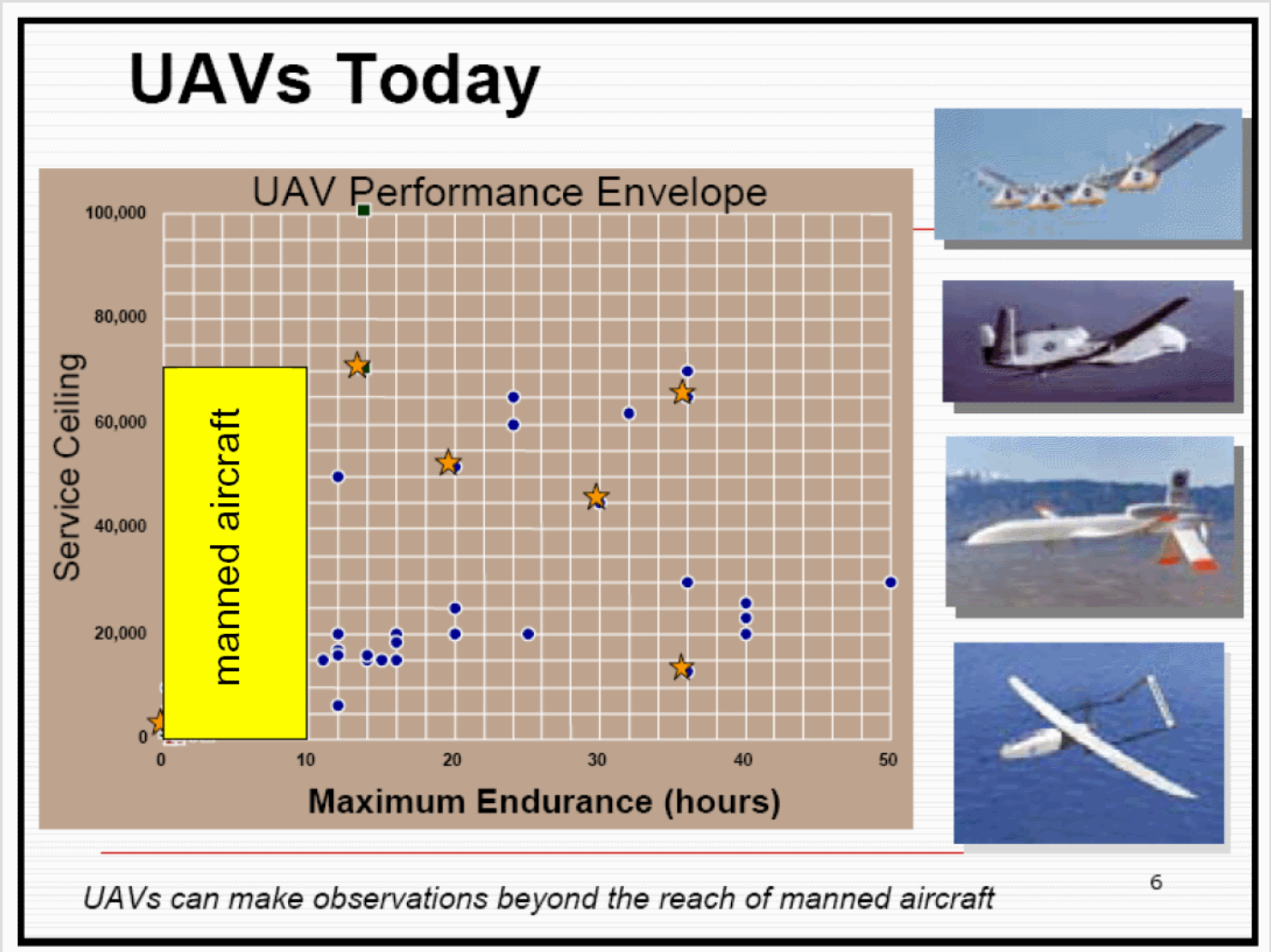
From Christer Broman at ConocoPhillips

Characteristics of Unmanned Aircraft already used in commercial applications

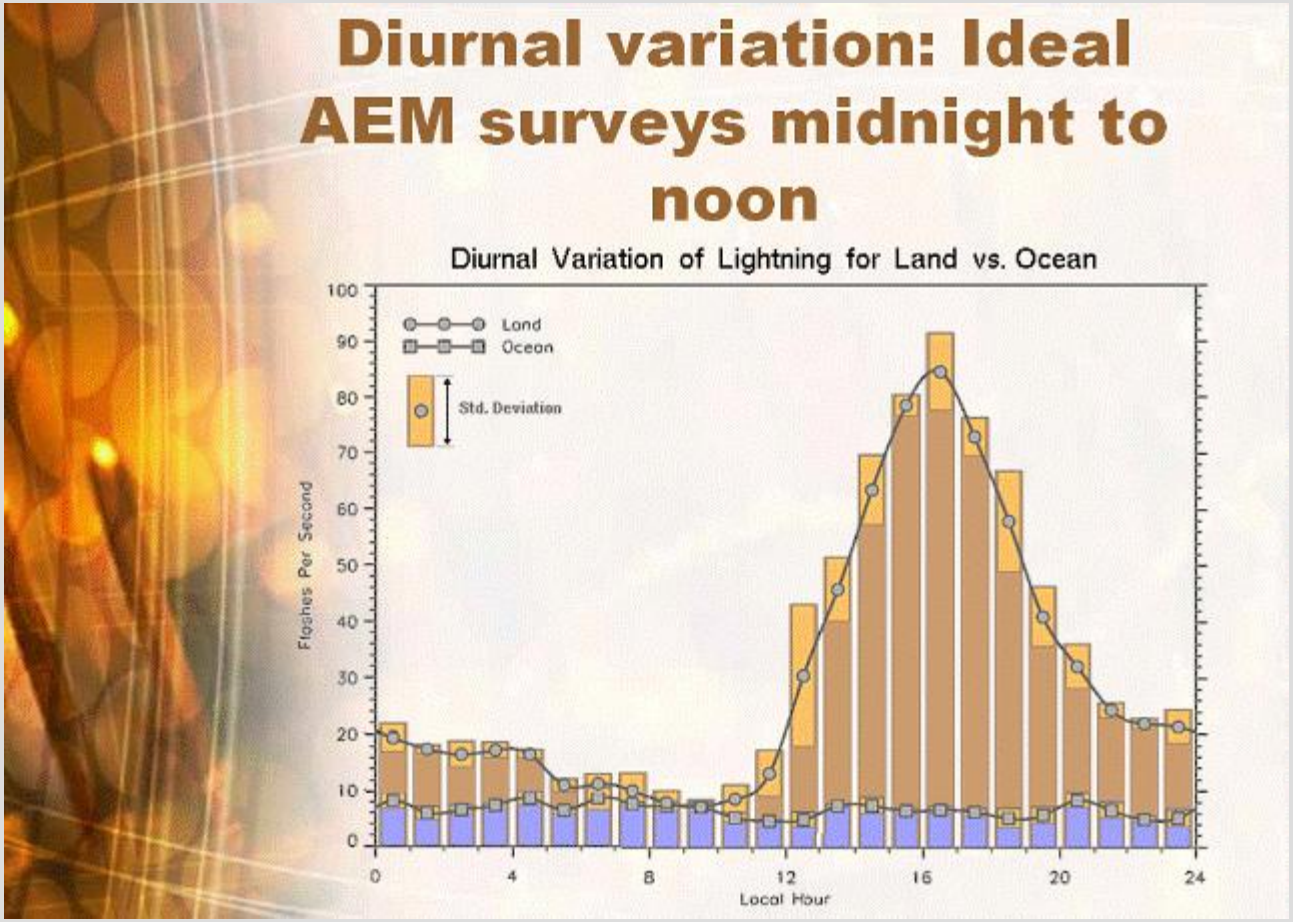
Aerostar	Max take-off weight Max payload Max range	**210 kg** 50 kg 1,550 km
MagSurvey Prion	Max take-off weight	**30 kg**
Scan Eagle	Max take-off weight Max payload Max range	**18 kg** 3 kg 1,350 km

A common theme is the use of relatively **lightweight** Unmanned Aircraft in commercial applications.

What are the compelling capabilities of Unmanned Aircraft?



Unmanned Aircraft can fly when the electrical and magnetic noise levels are low



From a presentation by James Macnae at SEG 2006

Unmanned Aircraft can fly all night, night after night, at low levels (such as 50 feet AGL)...

Unmanned Aircraft can fly where pilots prefer not to go

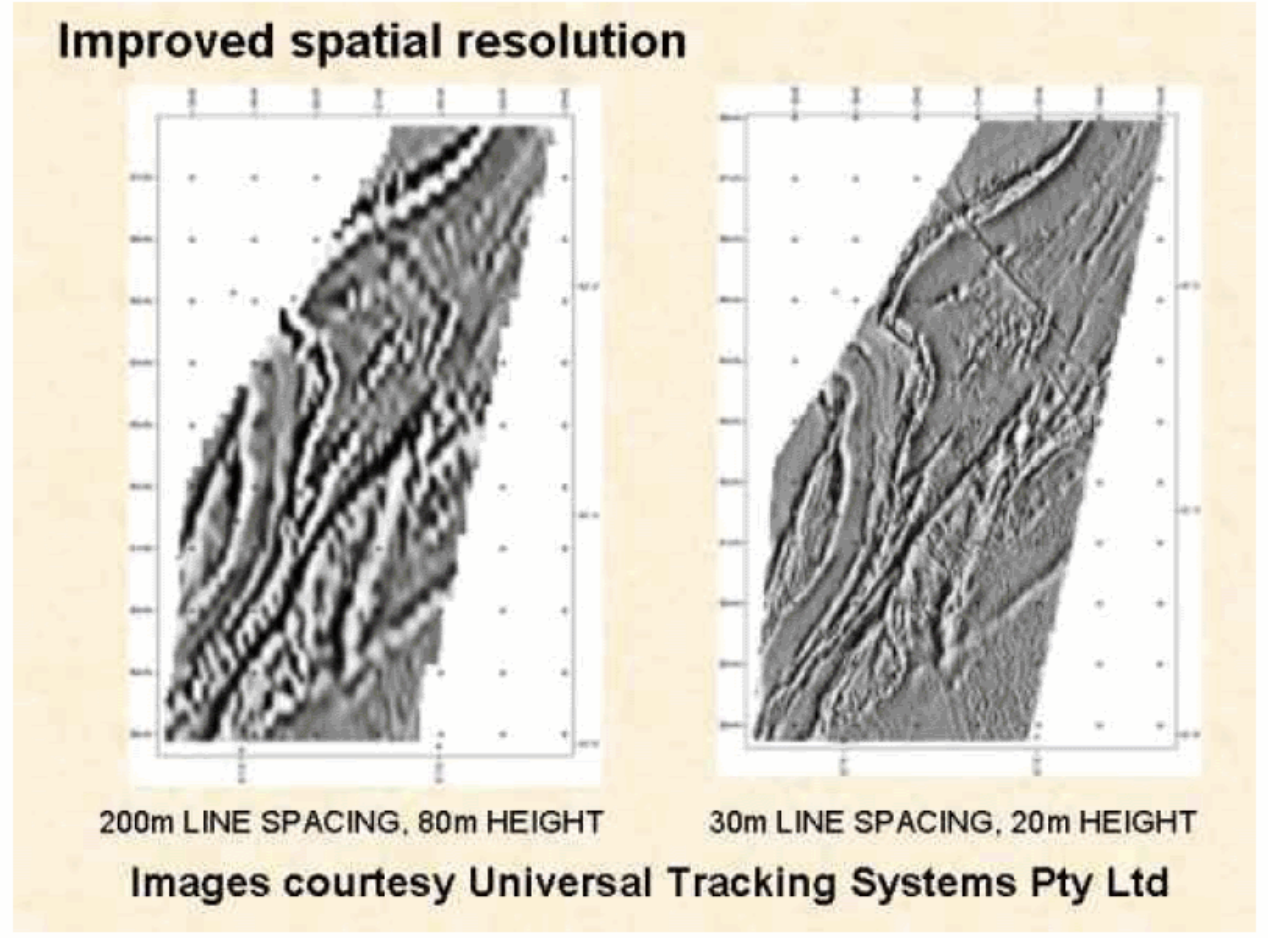
As exploration activities move to the more hostile regions of the Earth, such as the Arctic Ocean, and to more politically unstable areas, expect to see a growing use of Unmanned Aircraft operating in areas where it would be irresponsible to expect pilots to fly:

- ❑ 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 entertainment 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 ("UA") in E & P activities

❑ **The UA creates less of a disturbance to the parameters being measured** such as the magnetic, or, gravitational field, since it is physically smaller than its manned counterpart and has a lower ferrous metal content.

❑ **The UA costs 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.

❑ **The small Unmanned Aircraft is more environmentally friendly** since it:

- requires less materials to build and is easier to dispose of at the end of its life;
- uses less fuel and creates less pollution per km travelled;
- makes less noise in flight.

❑ **The UA 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 interferometric SAR imaging.

However, Unmanned Aircraft have not yet seen widespread deployment...

- ❑ UA 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 experimental aircraft with no air worthiness certificate. Potential users are rightfully concerned about "reputational damage" that follows a crash. **Being killed by a flying robot makes headlines.**
- ❑ 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 a 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.
- ❑ UA do not yet have a **sense 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

So, UA systems developers are getting their flight hours and experience in the military sector.

However, it will happen.

❑ Work on the development of sense and avoid systems is underway in North America, Europe and in the Far East. The view is that once proven on Unmanned Aircraft, these systems will become mandatory on manned aircraft.

❑ There is a concerted international effort to get an assignment of a protected aeronautical frequency band for UA use at the next World Radio Conference in 2011.

❑ 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

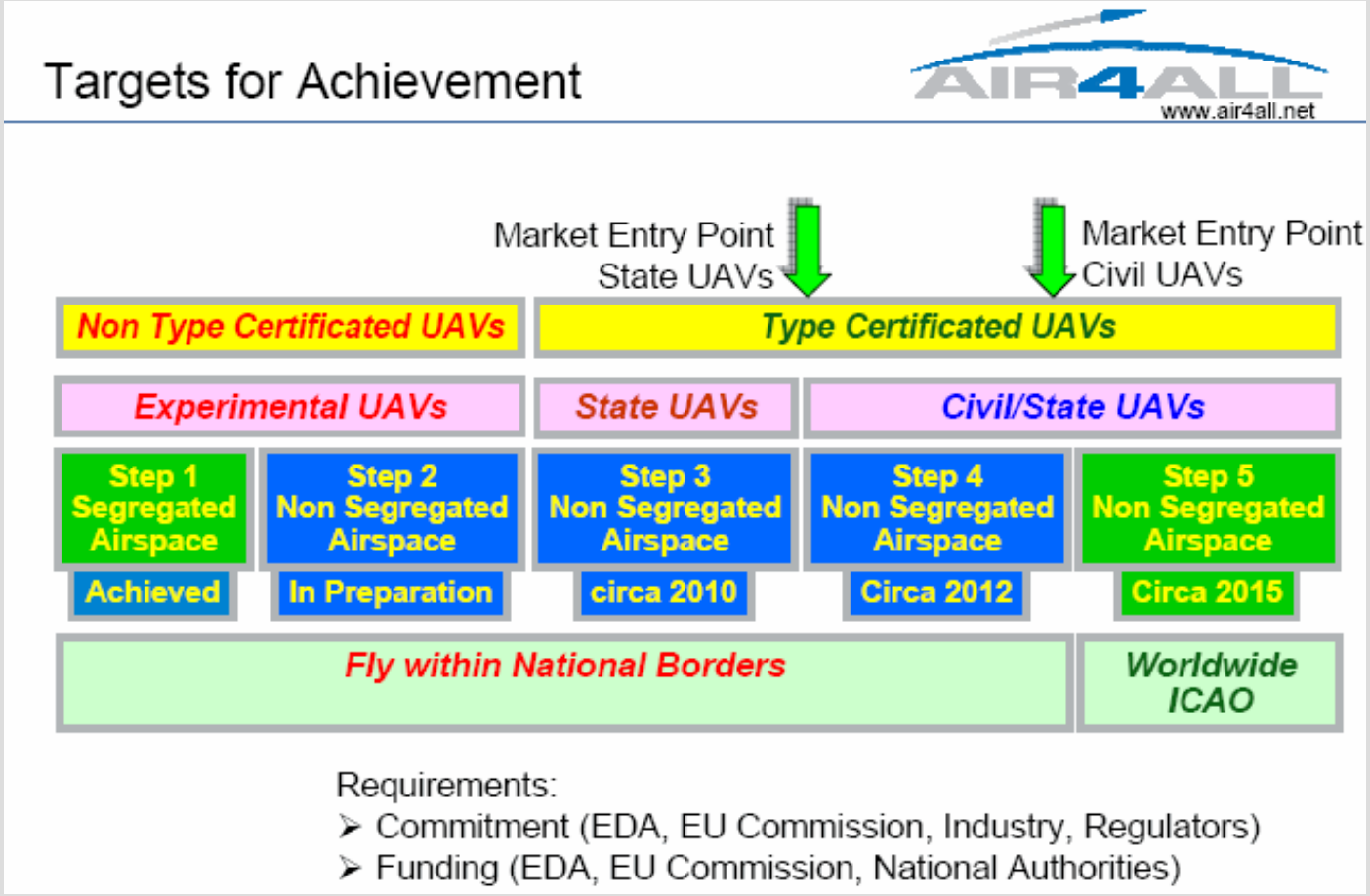
❑ Both the FAA and EUROCONTROL are investigating solutions to the UA security aspects.

❑ The early uses of Unmanned Aircraft will be in hostile areas where it would be irresponsible to send pilots. This is one of the new frontiers for oil, gas and mineral exploration.

❑ If experiences in the military area are anything to go by, Unmanned Aircraft will provide copious amounts of high quality data. Developing software to interpret high resolution data will become a high priority and a new market area for scientific and AI software developers.

Suggested attributes of the ideal UA for geophysical applications...

Now is a good time to influence the thinking of those developing Unmanned Aircraft for geophysical applications. It will take about three years to develop and test a new, high performance, Unmanned Aircraft for geophysical applications. **That will take us to 2012.**



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:

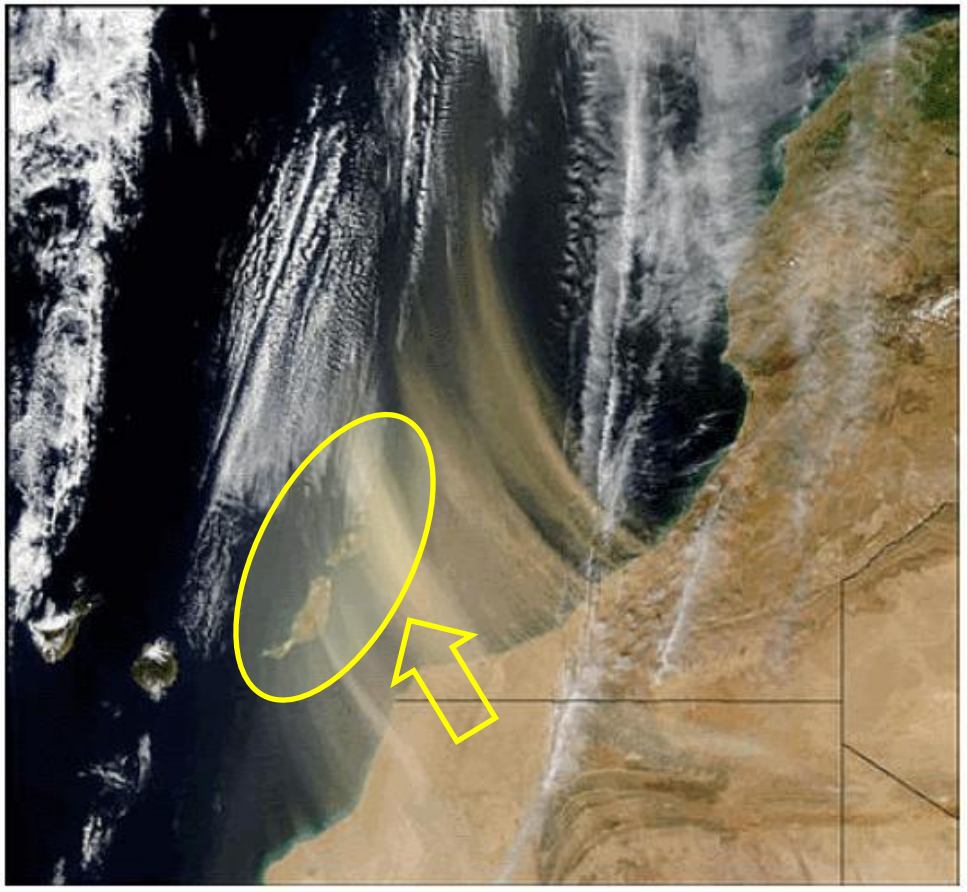
- ❑ Total darkness (in winter time)
- ❑ Temperatures: drop to -40C
- ❑ Spray icing
- ❑ Snow and ice

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 +50C during the day;
- ❑ abrasive sand storms.



Satellite photograph of a dust storm showing fine sand from Morocco and Western Sahara (below Morocco) being blown over to Lanzarote and Fuertaventura in the Canary Islands.

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)

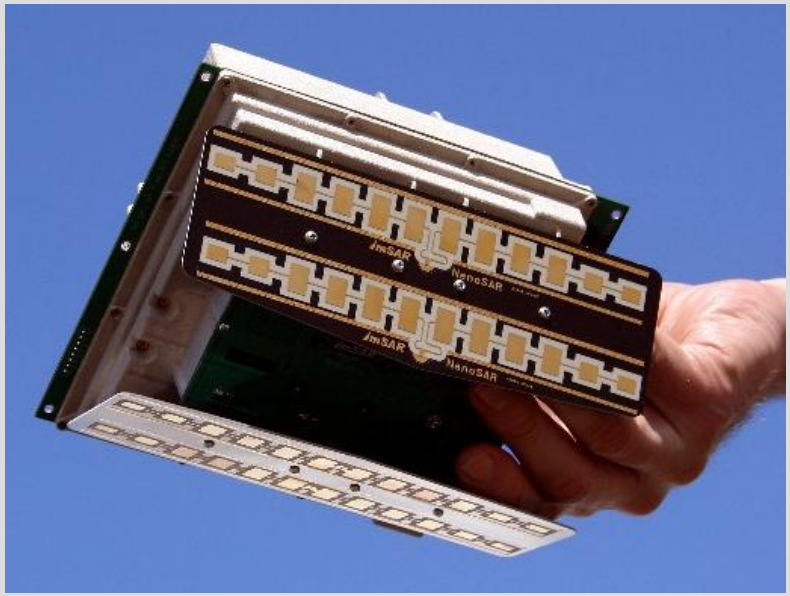
Geometrics G822 airborne Cesium magnetometer

Gravity gradiometer: 350 kg+
http://www.ga.gov.au/image_cache/GA4750.pdf

Geophysical survey instruments weighing less than 10 kg

- ❑ High resolution (24.6 MPixel) digital camera
- ❑ 0.9 – 1.6 um wavelength near infrared and 4 – 6 um wavelength 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)

Ideal Payload = 9 Kg



Above: the 1 kg NanoSAR from ImSAR, http://www.imsar.net/ has flown on a Scan Eagle

Synthetic Aperture RADAR (SAR) need not be hugely expensive...

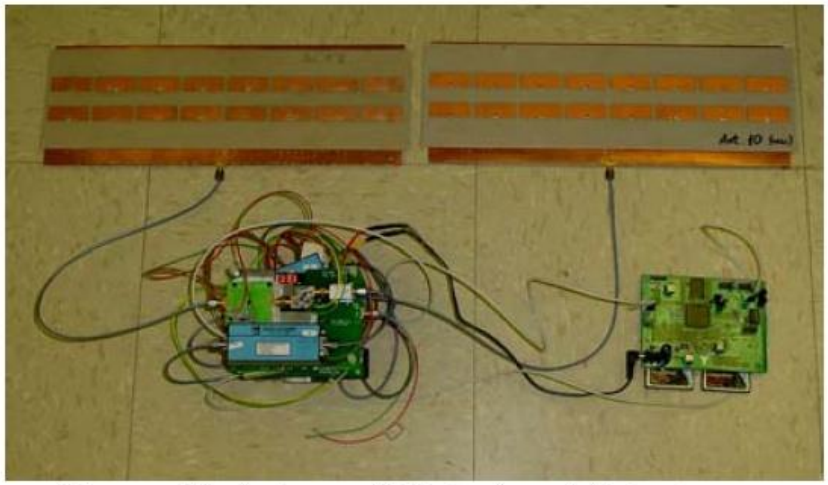


Figure 10. Antenna, RF stack and data storage device produced by BYU, operated by CU, flown by ACR

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)
- ❑ 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. Difficult to make smaller, or, lighter.

Fugro Airborne Services AEM DASH 7 aircraft fitted out with a large electromagnetic coil.

Geophysical survey instruments weighing more than 100 kg

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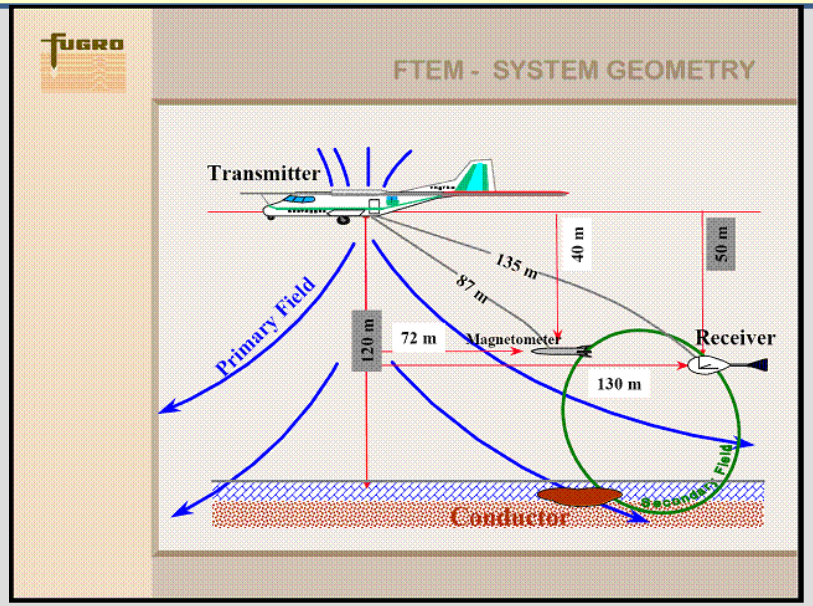
Fugro Airborne Services AEM DASH 7 aircraft fitted out with a large electromagnetic coil.

However, low level flying enables the use of Unmanned Aircraft



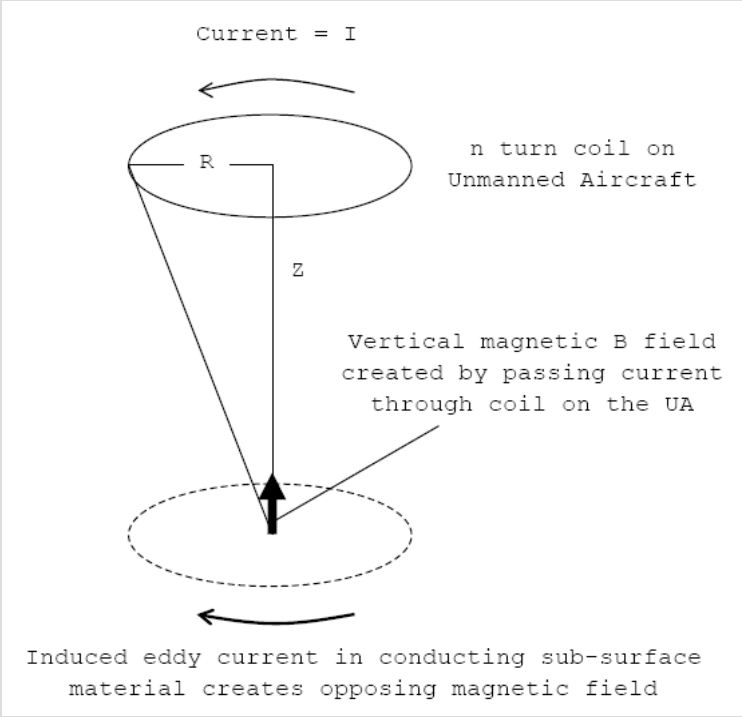
Transmitter Dipole Moment

GEOTEM					
90 Hz	2ms	540A	231m²	5T	0.62M Am²
30 Hz	4ms	500A	231m²	6T	0.69M Am²
30 Hz	6ms	500A	231m²	6T	0.69M Am²
MEGATEM					
90 Hz	2ms	595A	406m²	4T	0.97M Am²
30Hz	4ms	665A	406m²	4T	1.08M Am²
15Hz	4ms	665A	406m²	4T	1.08M Am²

A **2 amp current** is passed through the coil wrapped around the relatively small Silver Fox Unmanned Aircraft shown above. The current in the coil is modulated at around **88 kHz**.

A sensing coil is towed behind the UA and the signals detected by the towed sensor enable the **detection of underground tunnels and buried wires.** **LESS DEPTH THAN MEGATEM.**

Airborne Electromagnetic survey might suggest the use of a large aircraft...



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:

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

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 ideal range for an Unmanned Aircraft engaged in geophysical survey work

A **development survey typically covers an area of 400 square kilometers**:

2 flights x **1,569 line km** each

For a typical **exploration survey covering a 10,000 square km region:**

24 flights x **1,560 line km** each

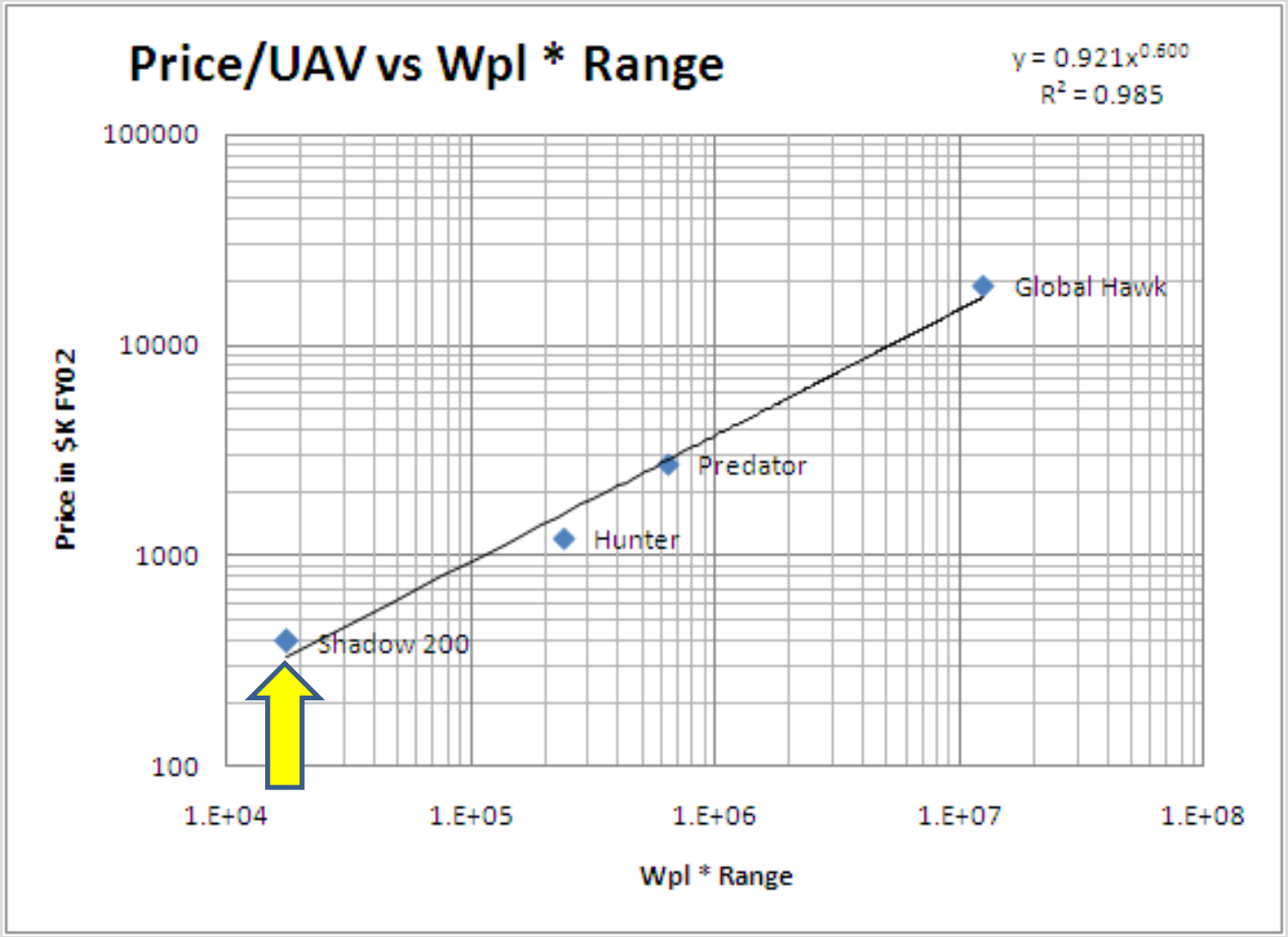
One of the longest oil pipelines in the world is the 1,768 Km long Baku-Tbilisi-Ceyhan (BTC):

locate UA base midway along the pipeline: **fly 1,768 km** to end and back

A UA with a range of **1,800 km** would be suitable for both geophysical survey and pipeline monitoring work. From a logistics point of view, having a UA flying at 100 kph for 18 hours per flight, gives sufficient time for a regular aircraft servicing period and take-off time each day.

Ideal Range = 1,800 km

Estimated price for the ideal GeoSurvey UA System = $310,000 FY [02]



9 kg x 1,800 km range *= 16,200 kg.km and price = 0.921 * 16,200^0.6 = $ 310,000.*

Caution over Unmanned Aircraft System prices... (UA Systems can be expensive)

The price of an Unmanned Aircraft System that would be needed to transport a payload in **excess** of 10 kg over a distance of 1,800 km would exceed the cost of a light aircraft.

Reason:
- UA have a 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.

Nav equipped Cessna Skylane 182-T

Max payload = 517 kg

Max range = 1,722 km

Price = $349,500

- from www.cessna.com

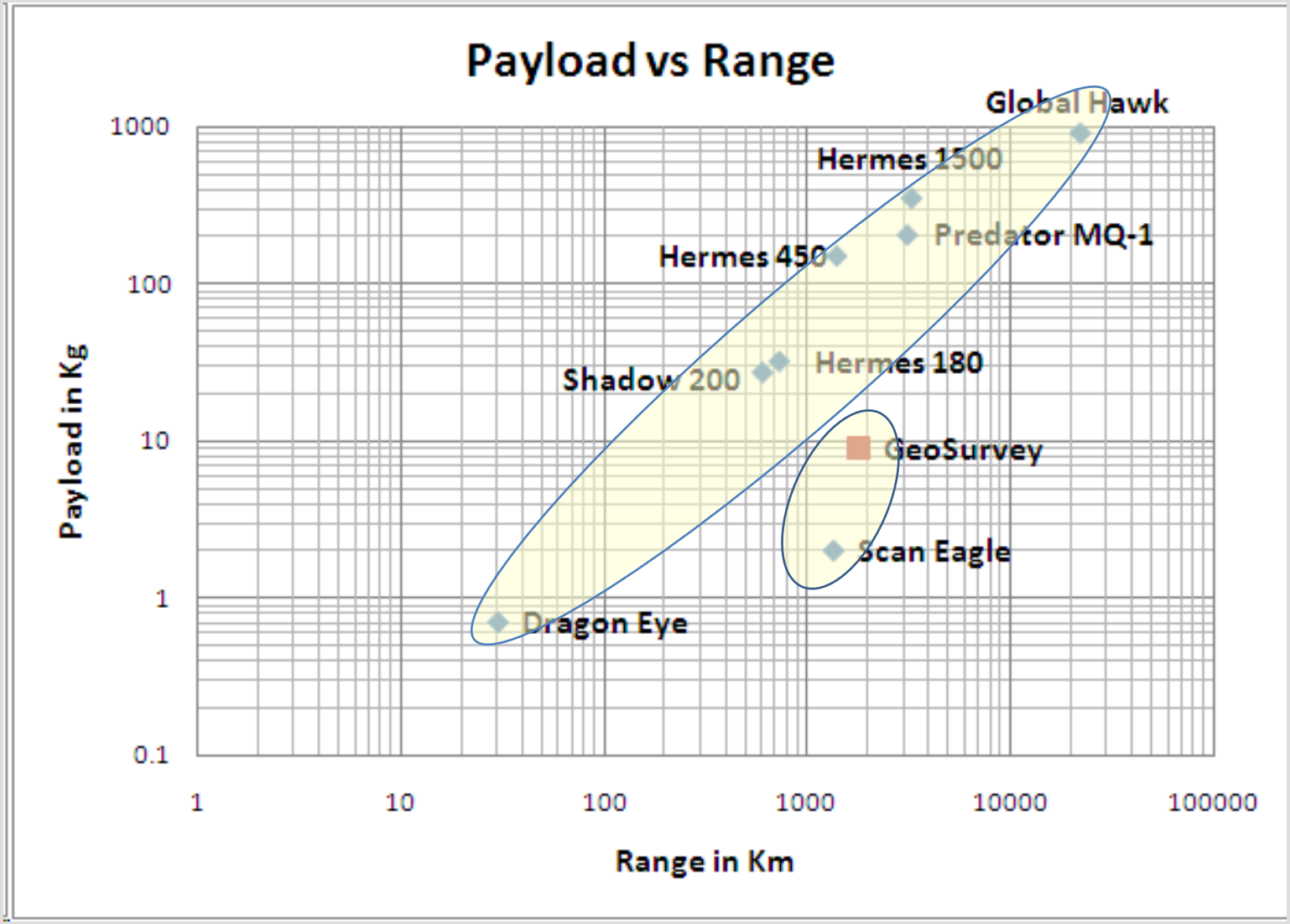
The military requires Unmanned Aircraft:

- ❑ 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 hostile action that might be mounted against them;
- ❑ **now**, with the expectation that reliability will improve with time, usage and production.

Unmanned Helicopter used to detect threats (snipers, IEDs, militia) to military personnel.

AAI Shadow 200 Unmanned Aircraft with US Forces in Iraq (photo supplied by AAI Corp).

GeoSurvey Unmanned Aircraft carry a lighter payload



For geophysical survey + 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 also 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 high reliability from the outset.

InSitu Scan Eagle Unmanned Aircraft on launcher, from uav_roadmap2005.pdf.

In conclusion

The Unmanned Aircraft has much to offer in the areas of oil, gas and mineral exploration and pipeline and facility monitoring. This is realized by staff in exploration companies.

New and exciting technologies experience unjustified exuberance, followed by despair. We are now moving towards a more realistic vision and work on the necessary issues is taking place throughout the world in a remarkable atmosphere of international cooperation.

- ❑ Increasingly, oil, gas and mineral exploration companies are considering the potential roles of Unmanned Aircraft in Exploration and Production activities.
- ❑ We conclude the maximum impact is to be gained from the development of a relatively small Unmanned Aircraft, specifically developed for Exploration and Production applications:
  - with a payload of around 9 kg,
  - a range of around 1,800 km,
  - and a take-off weight of 100 kg.
- ❑ Expect to see Unmanned Aircraft playing a greater role in oil, gas and mineral exploration and production activities in time to come. It will take time, but, in my opinion, it will happen.