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The requirements for unmanned aircraft operating in oil, gas and mineral <u>exploration</u> and <u>production</u>

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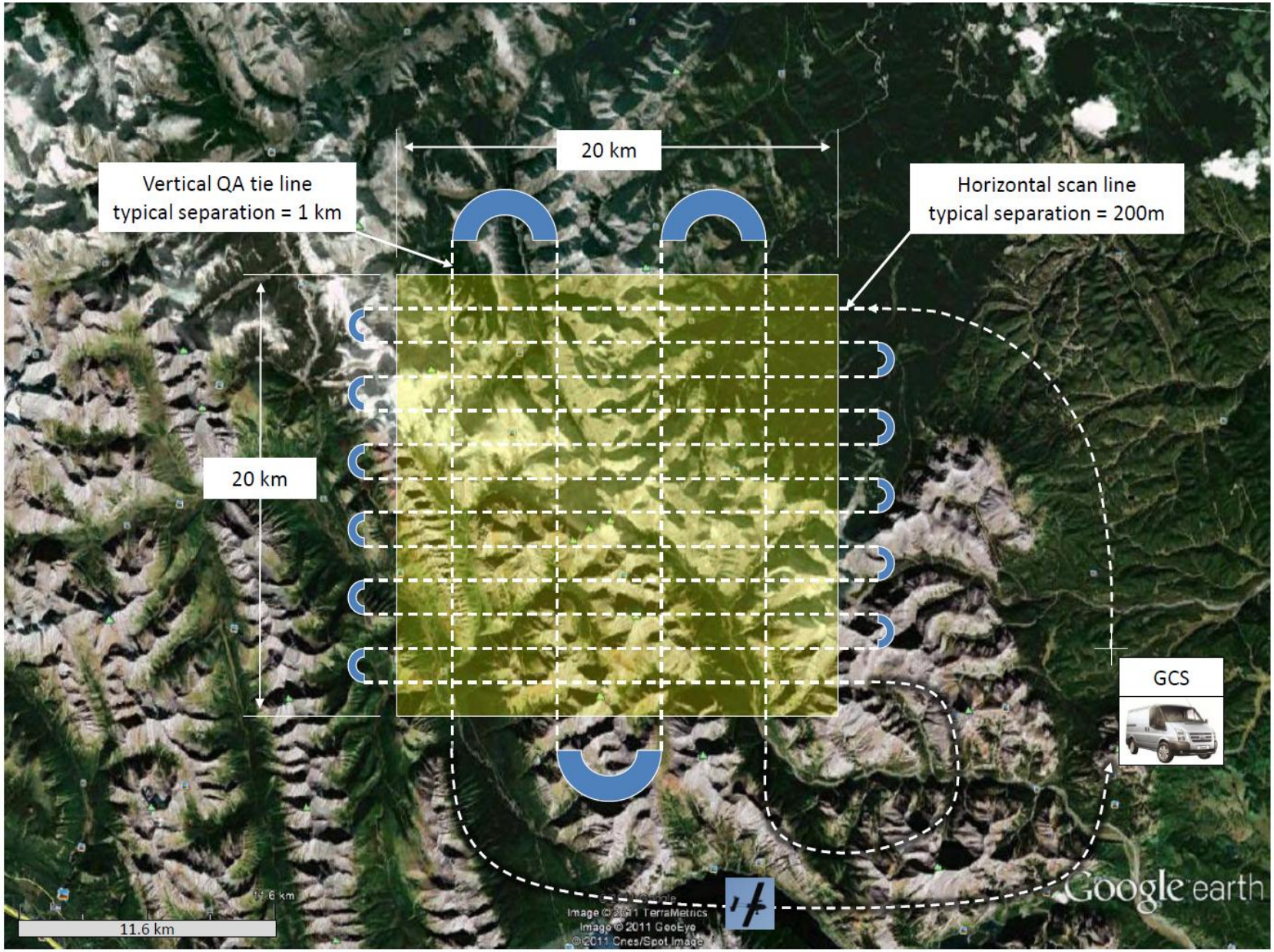
The Users need a mapping of the Earth's magnetic field from an airborne survey.



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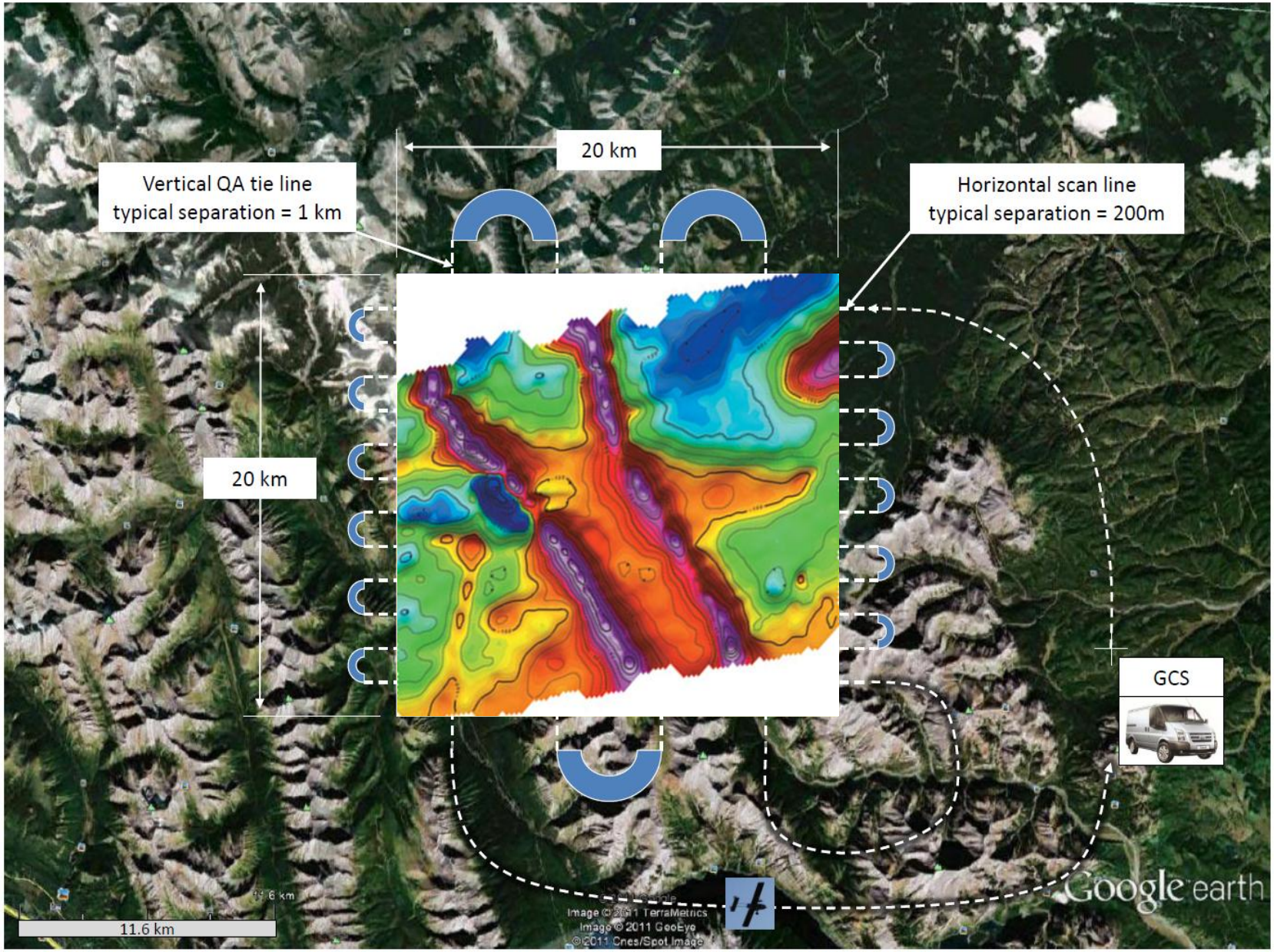
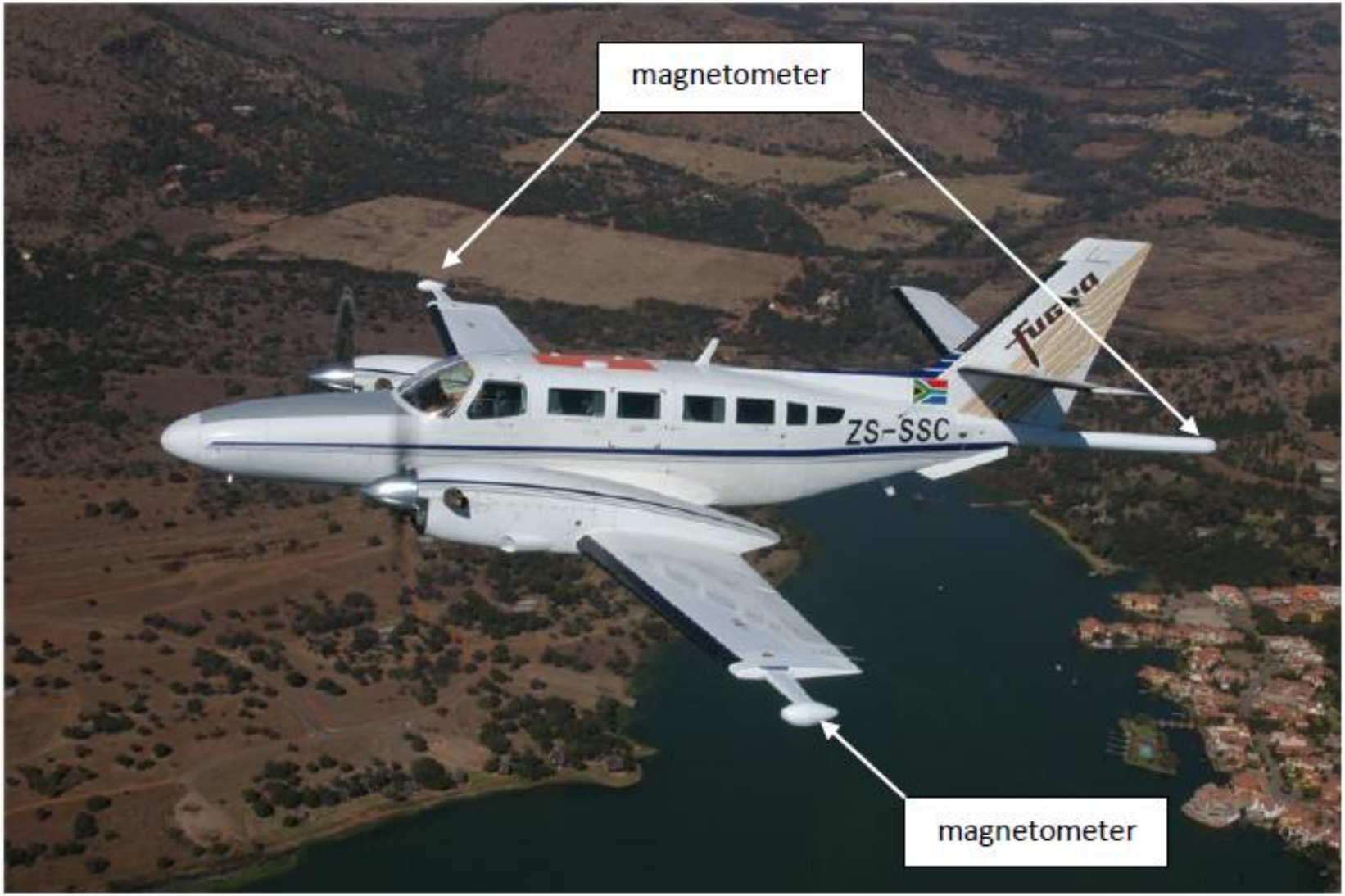


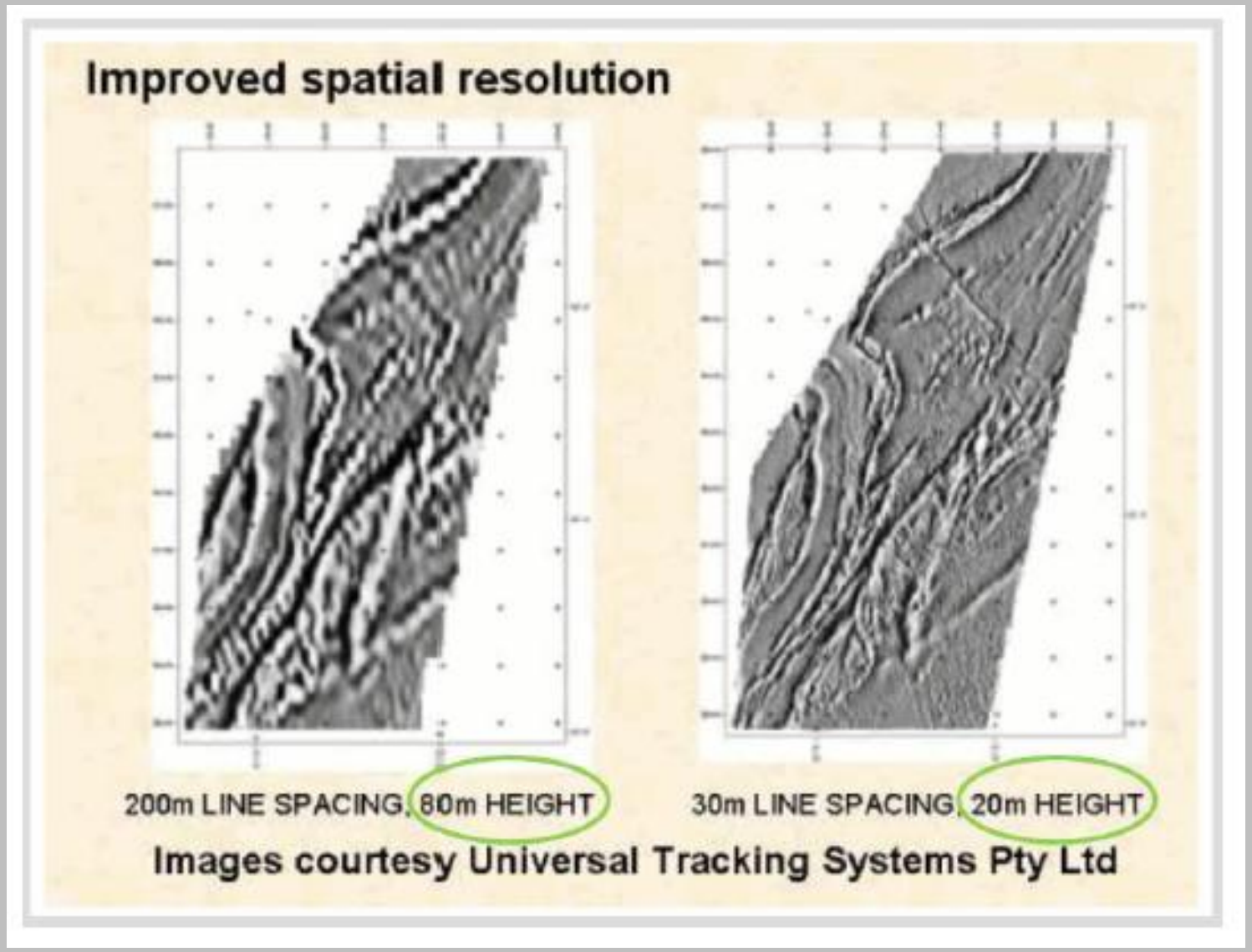
Example of the UA based Geophysical Survey ("GS") Sensor Requirements

	Aeromagnetic	Photographic	Stereo CAM and / or scanning LIDAR for DEM	Hyperspectral imaging
Cost per flight hour	$500 to $2,500	$ 135	$ 200	$1,000 - $2,500
Payload	**< 2 kg**	**2 kg**	**4 kg**	**5 kg**
Altitude	80m AGL / 120m ASL	1,000 +/- 50 m	400 +/- 10 m	1,000 +/- 100 m
Path	Tight drape +/- 10 m	Fixed height AGL	Fixed height AGL	Fixed height AGL
Speed (typical)	230 kph	120 kph	120 kph	80 kph
Line spacing (typ)	200 m	100 m	400 m	350 m
Data per flight hour	< 1 MB	~24 GB for High Res	~48 GB for High Res	~1-5 GB for Low Res
Specs		Resolution ~ 1 cm	Resolution ~ 1 cm	HorzRes < 5m Lo Res HorzRes < 1m Hi Res 256 wavelengths

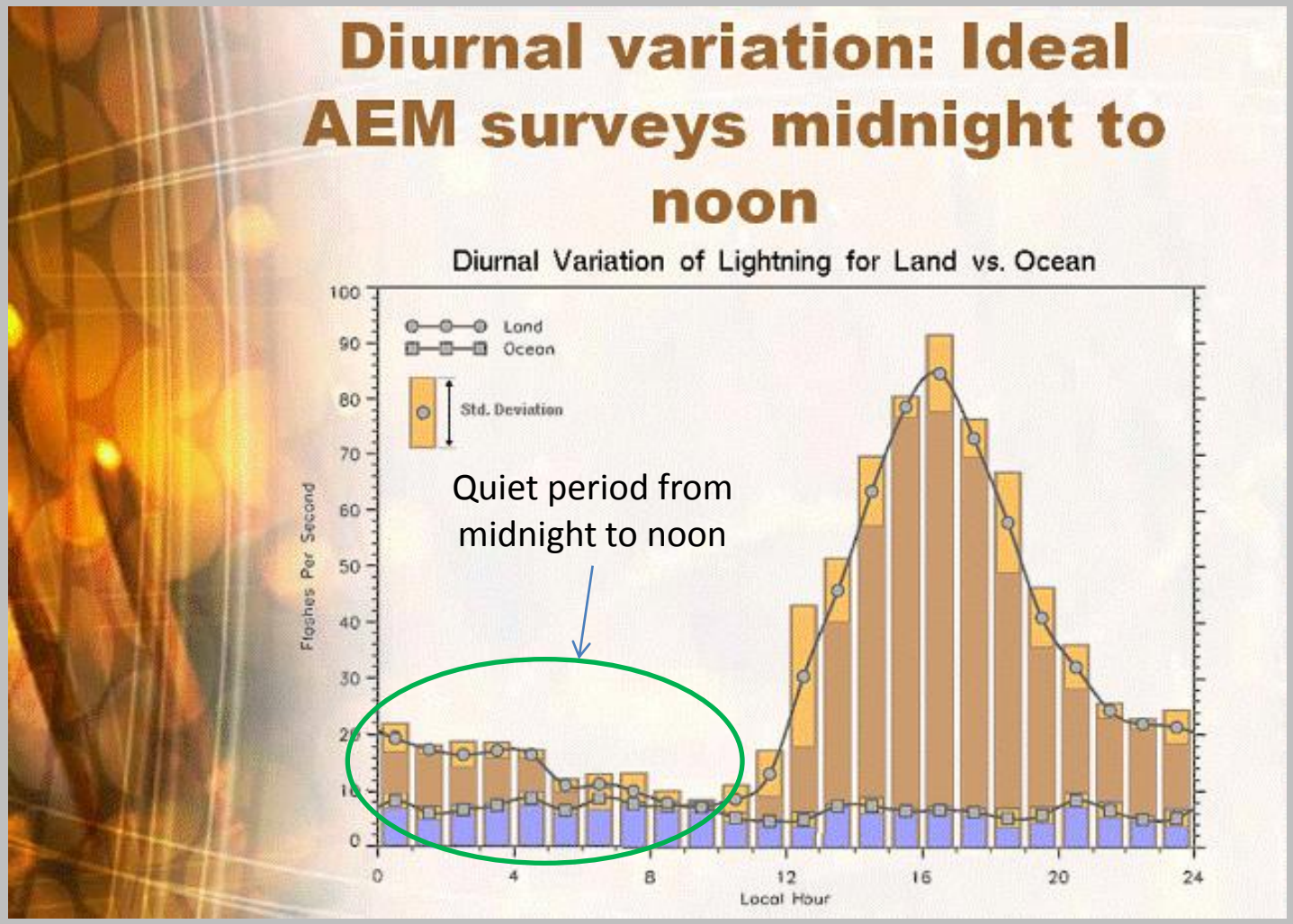
How are Geomagnetic Surveys performed today?



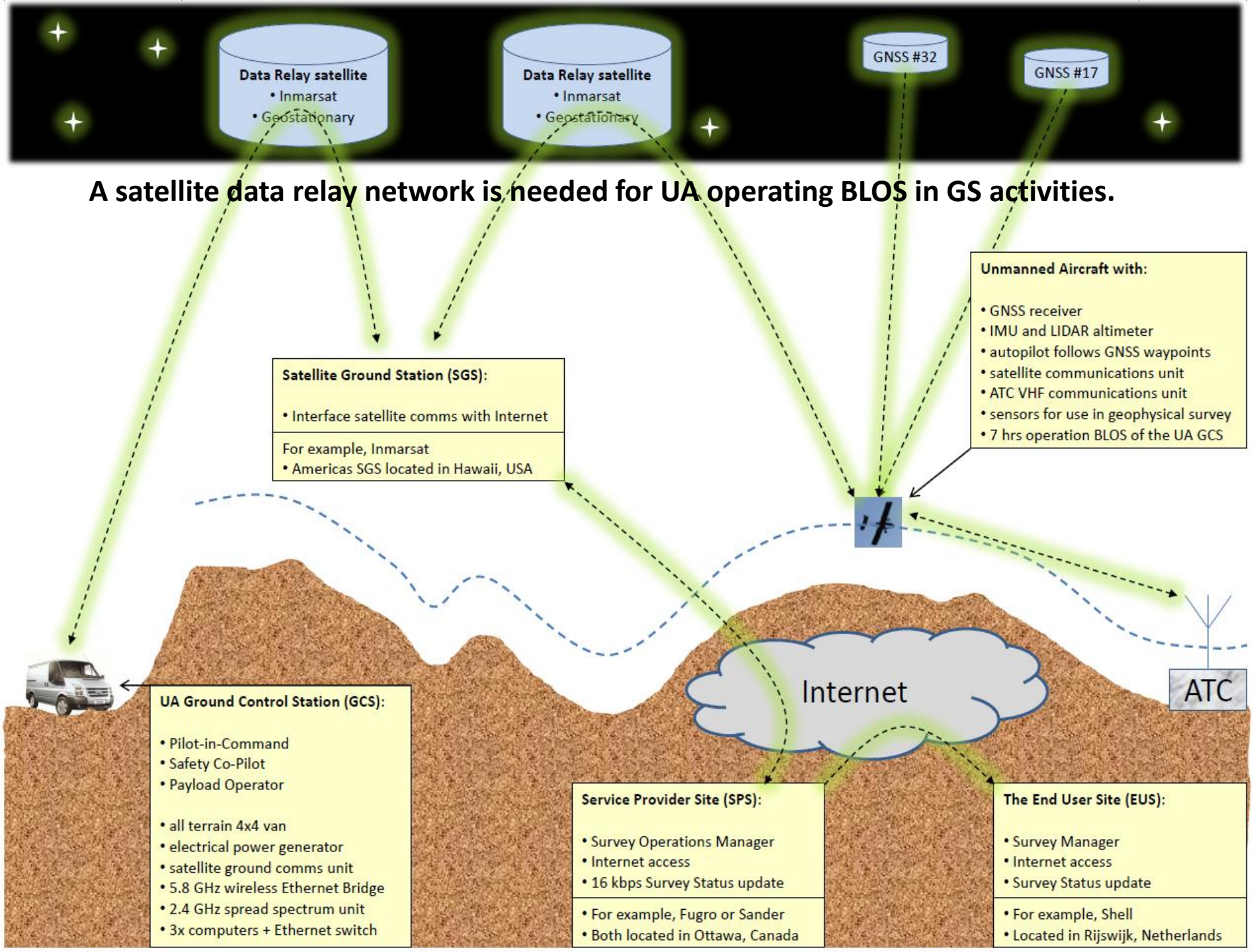
In a GS, the UA need to be able to fly from 20m to 80m Above Ground Level...



often flying at night, when the electrical and magnetic noise levels are low.



From a presentation by James Macnae at SEG 2006


Data Relay satellite
• Inmarsat
• Geostationary
Data Relay satellite
• Inmarsat
• Geostationary
GNSS #32
GNSS #17
A satellite data relay network is needed for UA operating BLOS in GS activities.
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
Satellite Ground Station (SGS):
• Interface satellite comms with Internet
For example, Inmarsat
• Americas SGS located in Hawaii, USA
Internet
ATC
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

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.

Fugro’s ground control station for the GEORANGER UAVs.

The GeoRanger was based on the InSitu ScanEagle, and was used in geomagnetic surveys in Canada.


Fugro’s GEORANGER UAV was used in several surveys in Quebec’s Gaspé area.

National Governments
are the ultimate End Users

The End Users for the purposes of this UASatCom Feasibility Study

Oil and gas Exploration and Production
e.g. BP, Exxon, **Shell**, Saudi Aramco, Statoil

- Geophysical survey
- Pipeline monitoring

Mineral Exploration
Anglo American, BHP Billiton, Xstrata

- Geophysical survey

Local public opinion
e.g. public opinion in Alberta re UA

- Television
- Newspapers
- Local Radio
- YouTube

Local facilitators
e.g. **CCUVS** (Canada), GS&TS (Nigeria)

- Interface with Nat Aviation Authority
- Interface with Govt bodies (Security)
- Make local arrangements
- Understand / manage public opinion

Legal and Insurance service providers
e.g. Catlin, **Griffiths & Armour**

- UAV operator liability insurance
- Insurance for UAV and payload loss
- Legal advice on operating practices
- Legal support in case of an accident

Exploration and production service providers
e.g. **Fugro Airborne Surveys, Sander Geophysics**

- UA operators
- Geophysical survey planning
- Get regulatory approvals for the survey
- Survey data processing
- Survey data Quality Assurance
- Safety aspects of an airborne survey
- Advice on survey sensor technology

National Aviation Authorities
e.g. **Transport Canada**, UK CAA

- < 150 kg UA flight regulations
- < 150 kg UA certification
- Permission to fly (e.g. SFOC)
- Provision of segregated air space

Satellite service providers
e.g. Astrium, **Inmarsat**, Iridium, US DoD

- Provide satellite data relay service
- Precision global location service
- Planning of data relay service

UA certification and pilot training
e.g. **EuroUSC**

- UA certification
- UA Pilot-in-Command training
- Maintain UA
- Provide training in UA operations

Systems and software providers
e.g. **AnsuR**, Thrane & Thrane, Micropilot

- Comms systems and software
- Avionics units and software
- Mission management software
- Systems and software for GCS

Systems integrators
e.g. Aerovironment, **BML**, Boeing Insitu

- UA development
- GCS development
- UAS testing and validation
- Payload testing and validation

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.

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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?

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.

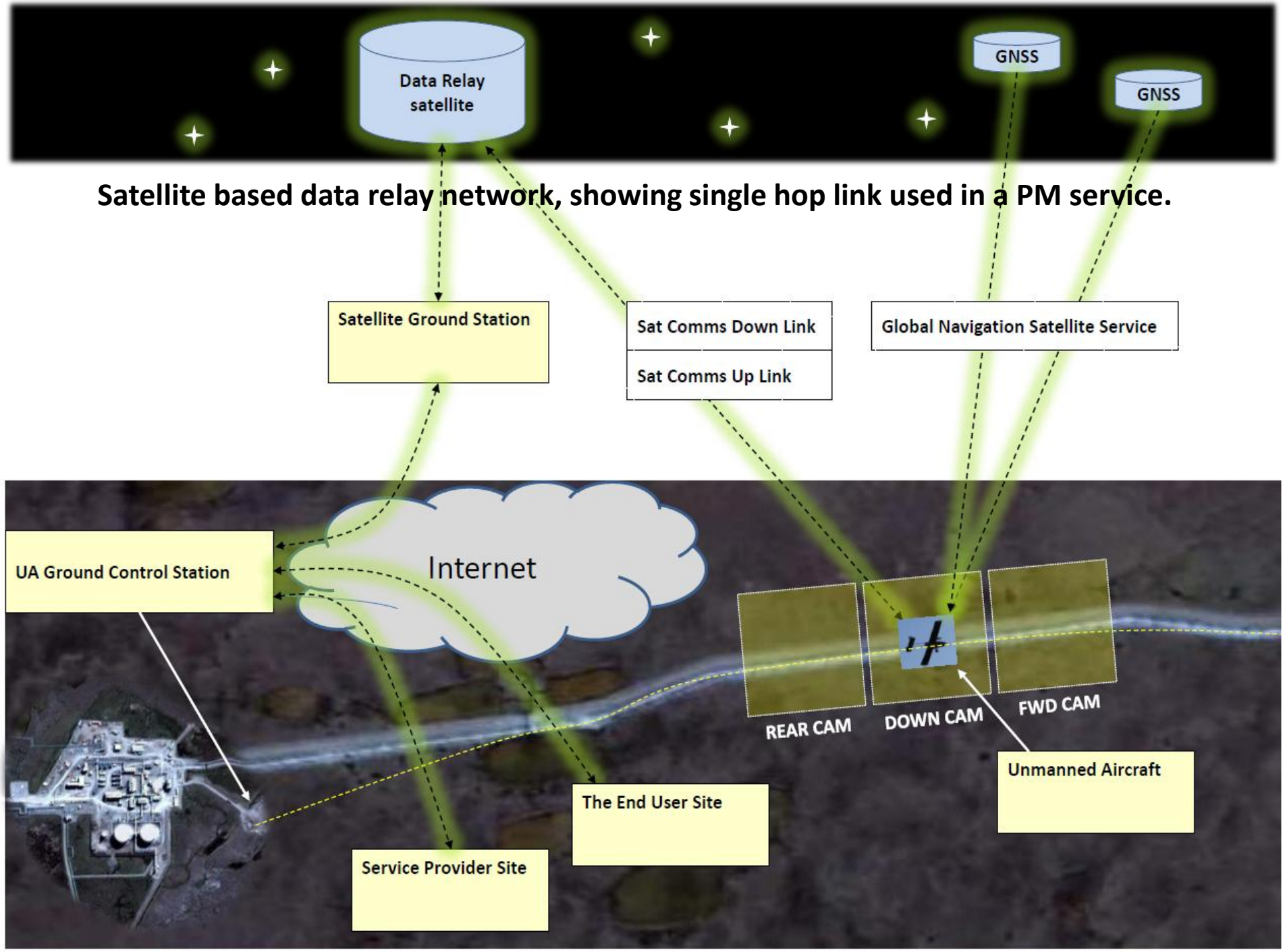

Part of the Trans Alaska Pipeline


Pipeline in Saudi Arabia

Object detection and identification at over 600 feet from a moving aircraft.

	
Canon EOS 5D Mk III camera body ▪ 5,760 x 3,840 Pixels = 22.1 MPixels ▪ computer interface and control via USB 2 ▪ price = $ 3,500	Canon EF 70 - 200mm f/2.8L zoom lens ▪ viewing angle = 10° x 7° at 200mm ▪ 4 stop image stabilisation ▪ price = $ 2,500

Side looking photo from an unmanned aircraft travelling at 30 mph, **no image enhancement.**


Data Relay satellite
GNSS
GNSS
Satellite based data relay network, showing single hop link used in a PM service.
Satellite Ground Station
Sat Comms Down Link
Sat Comms Up Link
Global Navigation Satellite Service
UA Ground Control Station
Internet
REAR CAM
DOWN CAM
FWD CAM
Unmanned Aircraft
The End User Site
Service Provider Site

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.

<u>The Cobham SB-200 sat comms unit</u>

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.

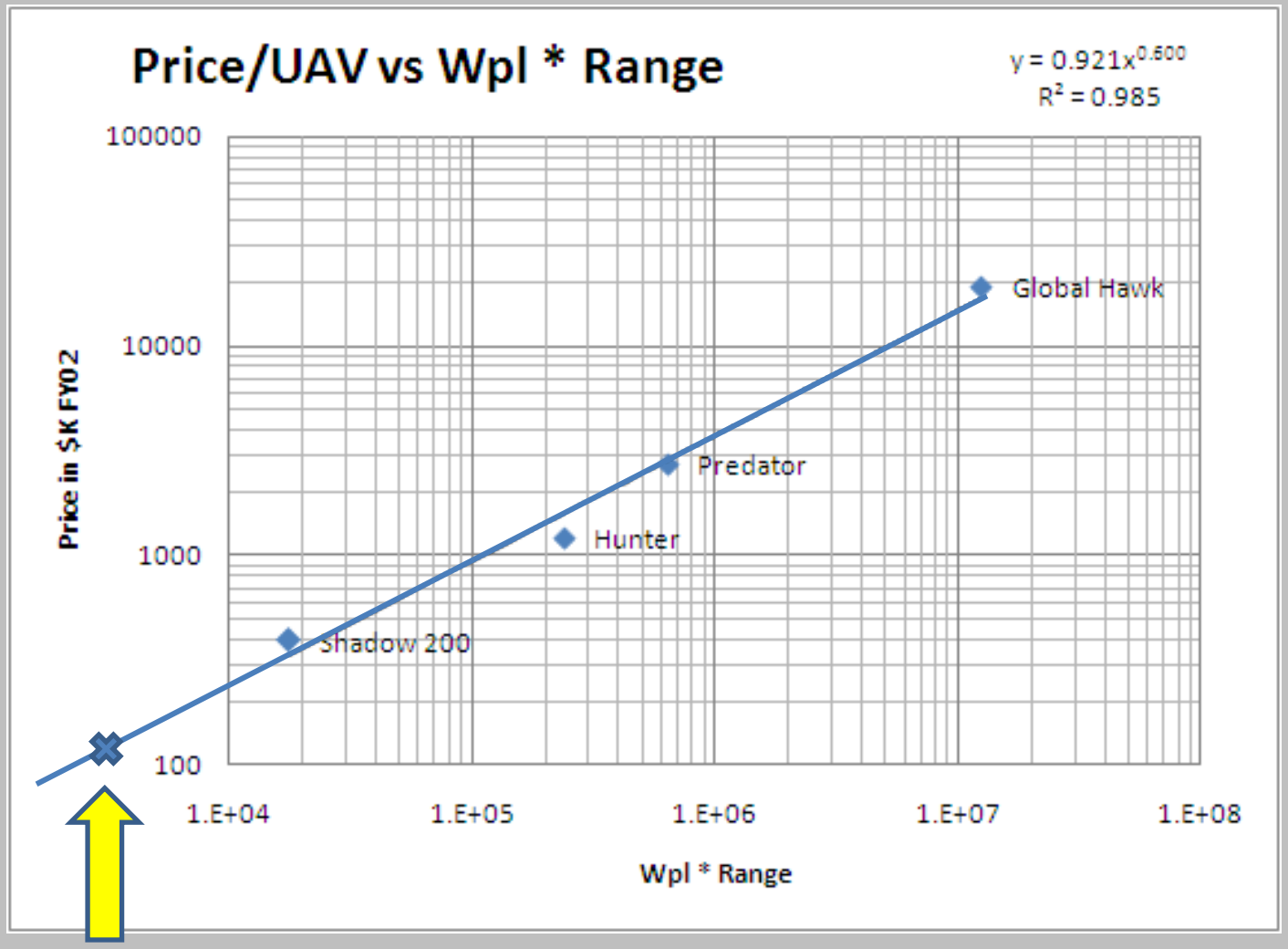
Total weight = 3.8 kg

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.

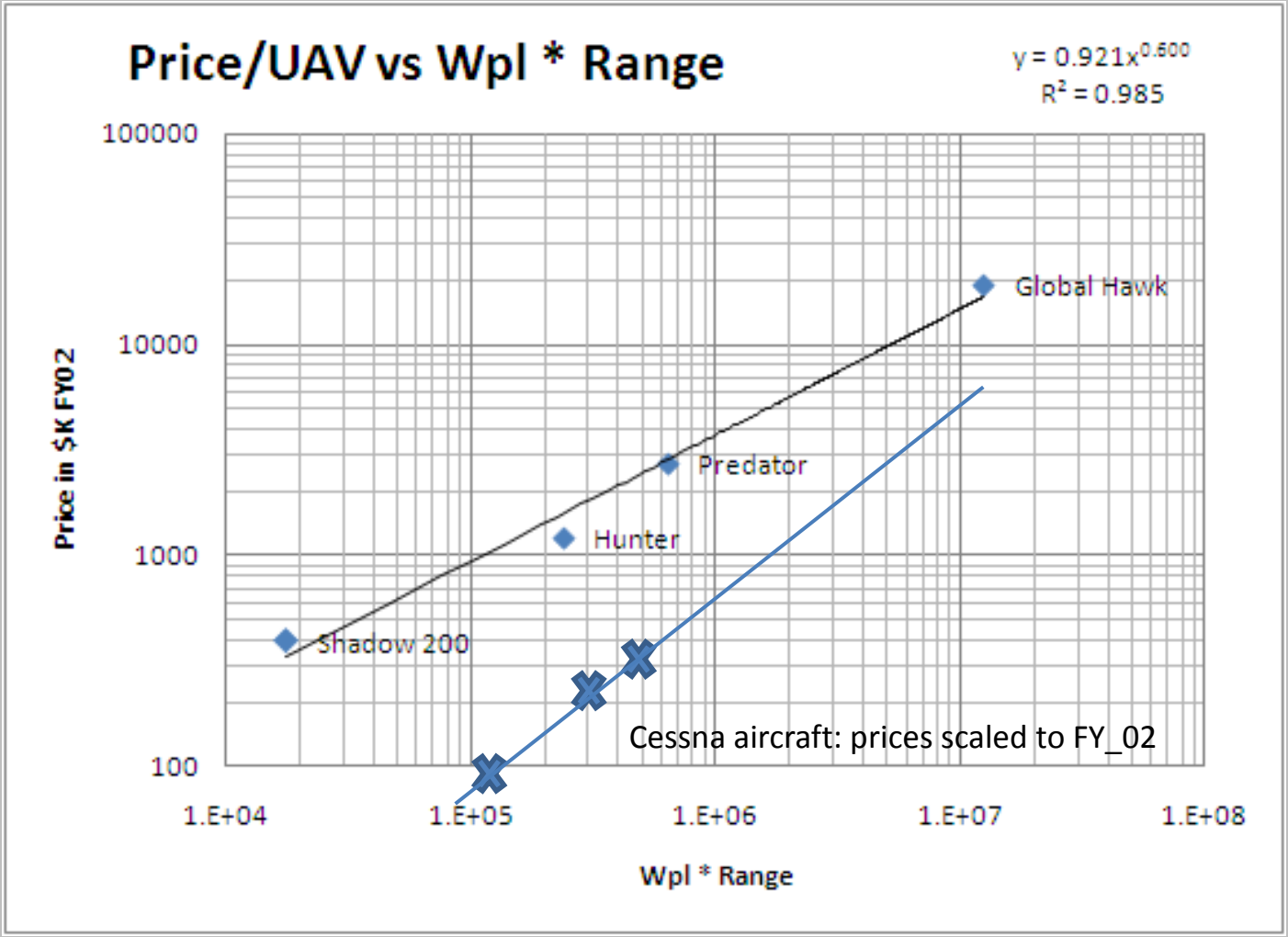
- If the UAV has a range in excess of 300 km, and a payload of less than 500 kg, as many unmanned aircraft do, then the UAV falls in Category II "Other Complete Delivery Systems" Item 19 Part 19.A.2 , and getting an Export License is easier.

Estimated price for a suitable UA with 4 kg payload and 700 km range.

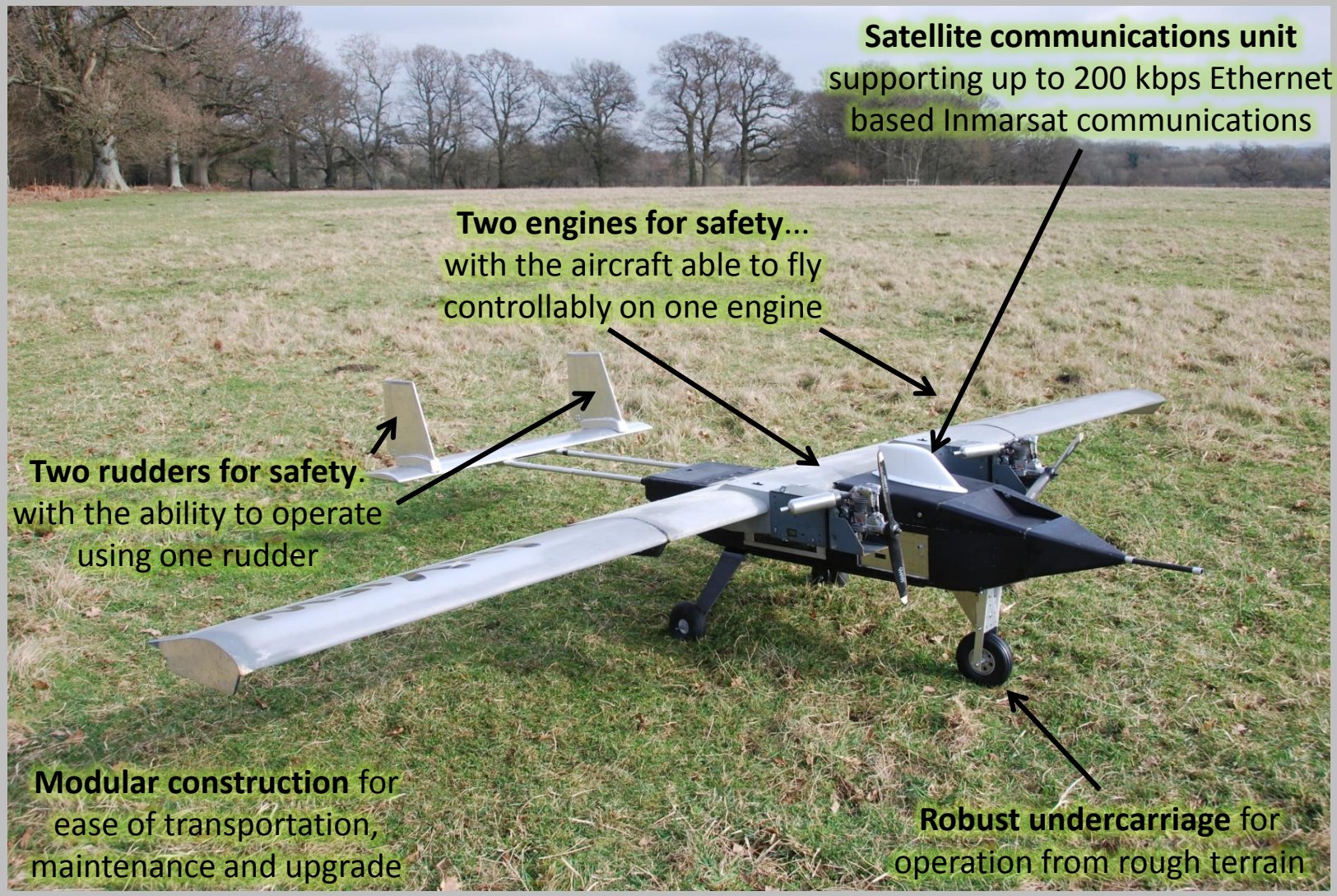


<u>4 kg x 700 km</u> *= 2,800 kg.km and price = 0.921 * 2,800^0.6 = $ 108k FY_02 =* ***$ 131.5k FY_10***

The cost of unmanned aircraft systems versus the cost of a light aircraft



Example of a suitable unmanned aircraft: the InView unmanned aircraft



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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Acknowledgements

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