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Unmanned Aircraft in Border Patrol Activities

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Nature of border patrol work.

- Monitor shipping, e.g. ships loading oil at oil rigs
- Monitor fishing activities in exclusive economic zones
- Detect small pirate boats
- Detect Self Propelled Semi-Submergible (SPSS) vessels
- Detect the movement of people on foot and in vehicles
- Detect people, drug and weapon trafficking activities

- Day and night time surveillance
- Real time, high definition, still image and video feed
- Ability to read number plates and names on ships and identify small arms and RPG
- Aircraft range in excess of 300 km; payload from 4 to 10 kg

SPSS

The digital camera is the most typical sensor used in border patrol work.

	
Canon EOS 5D Mk II camera body ▪ 5,616 x 3,744 Pixels = 21 MPixels ▪ computer interface and control via USB 2 ▪ weight = 810 g	Canon EF 70 - 200mm f/2.8L zoom lens ▪ viewing angle = 10° x 7° at 200mm ▪ 4 stop image stabilisation ▪ weight = 1,490 g

Above: side looking photograph using a 100mm MACRO lens and camera travelling at 30 mph.

In the above photographs, using a professional “L” series image stabilised Canon lens:

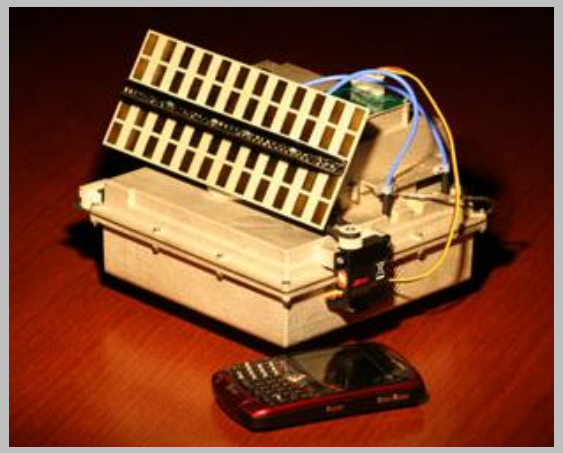
ISO setting = 800

shutter speed = 1/2,000 second

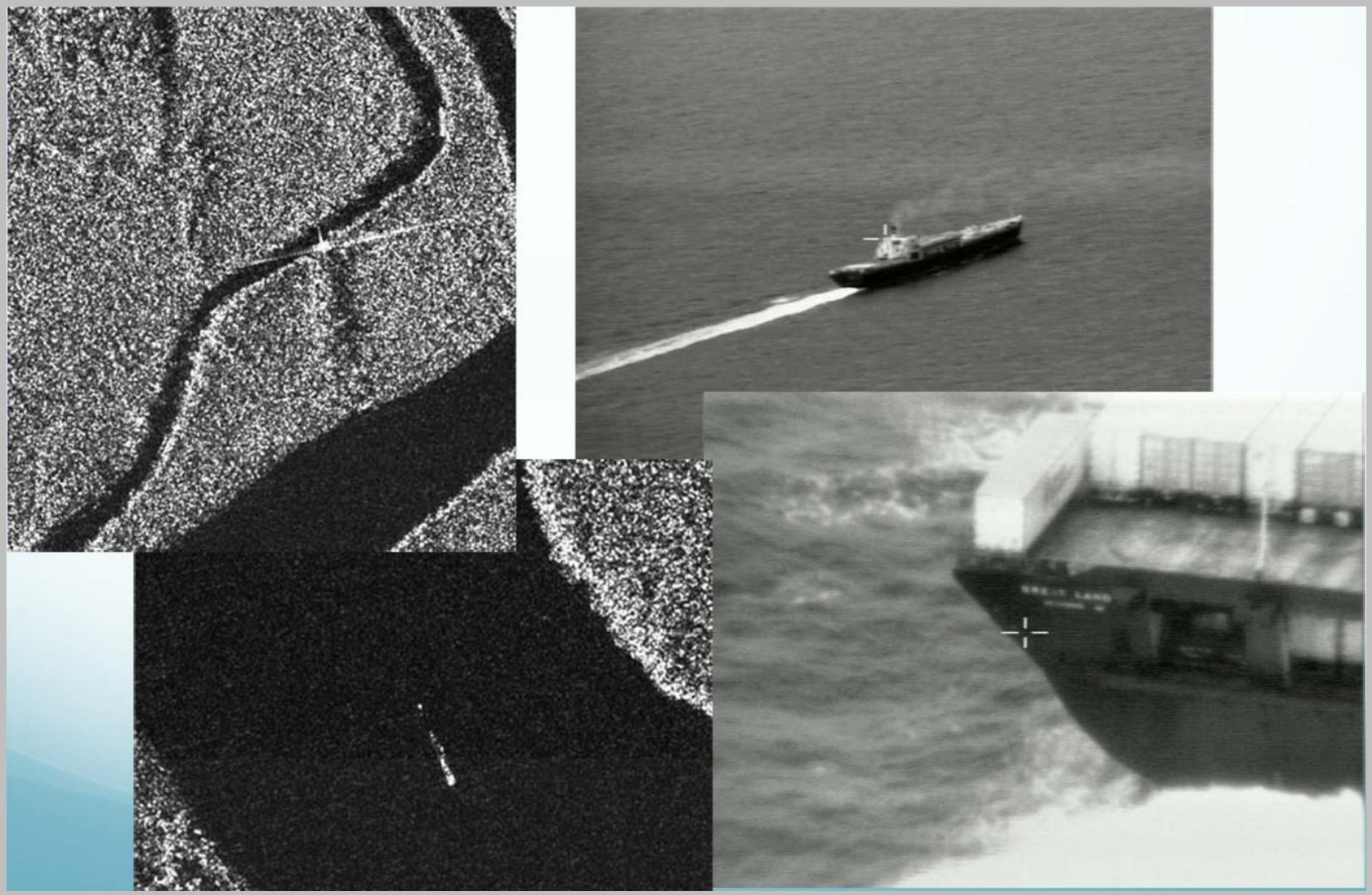
1.6 kg ImSar NanoSAR B using less than 30 Watts of electrical power.

Key Specifications	
Transmitted Power	1W
Range Resolution	0.3, 0.5, 1, 2, 5 m
Standoff Range	1-4 km
Slant Swath	4000 Resolution Cells
Frequency	X-Band

Features	
Operating Mode	Stripmap, Spotlight, Circular SAR
Command and Control	Lisa Dashboard™
Communication	RS-232, Ethernet
Sensor Cueing	Cursor On Target
Image Products	Google Earth complex image NITFS JPEG/PNG/BMP



Detection of ships in all weather conditions using Synthetic Aperture RADAR.



Example of manned aircraft currently used in border patrol work.

Dash 8 Maritime Patrol Aircraft (MPA) for the U.S. Department of Homeland Security - Customs and Border Patrol (CBP).

Could unmanned aircraft be used in border patrol work?

The SINUE Project looked into the use of unmanned aircraft in border patrol work

indra SINUE

Ref.: SINUE_EID_00035_FINAL REPORT
Iss./Rev.: 1.3
Date: 11/02/2011

Type/ Denomination	Material	Size			Radar Cross Section (RCS) (m^2)	Speed (knot)
		Long (m)	Wide (m)	Height ASL (m)		
Rubber boat	Rubber/fibre	5 – 8	~ 2	~ 0.5	1 – 5	1 – 60

Table 4-14: Typical characteristics of vessels for illegal immigration (and smuggling/trafficking)

Patera Cayuco Rubber boat

Figure 4-10: Typical vessels for illegal immigration (and smuggling/trafficking)

SINUE was an ESA funded Project, in which Indra considered the case of maritime border patrol off the Canary Islands.

SINUE: Satellites for the Integration in Non-segregated airspace of UAS in Europe

ESTEC Contract Nº: 23018/10/NL/CLP

Predator B unmanned aircraft patrolling the U.S. Southwest border.

"Thanks to the addition of two more Predator B unmanned aircraft to the existing fleet, the U.S. Customs and Border Patrol is now conducting aerial patrols of virtually the entire U.S. Southwest border from California to the Gulf of Mexico in Texas, according to the Department of Homeland Security (DHS).

The expanded Predator B flights, originating from Corpus Christy, Texas, are being flown courtesy of $600 million in new funding included in the recently passed Southwest border security bill.

From http://usgovinfo.about.com/b/2010/09/02/predators-now-patrol-entire-southwest-border.htm

Advantages of using smaller unmanned aircraft in border patrol work.

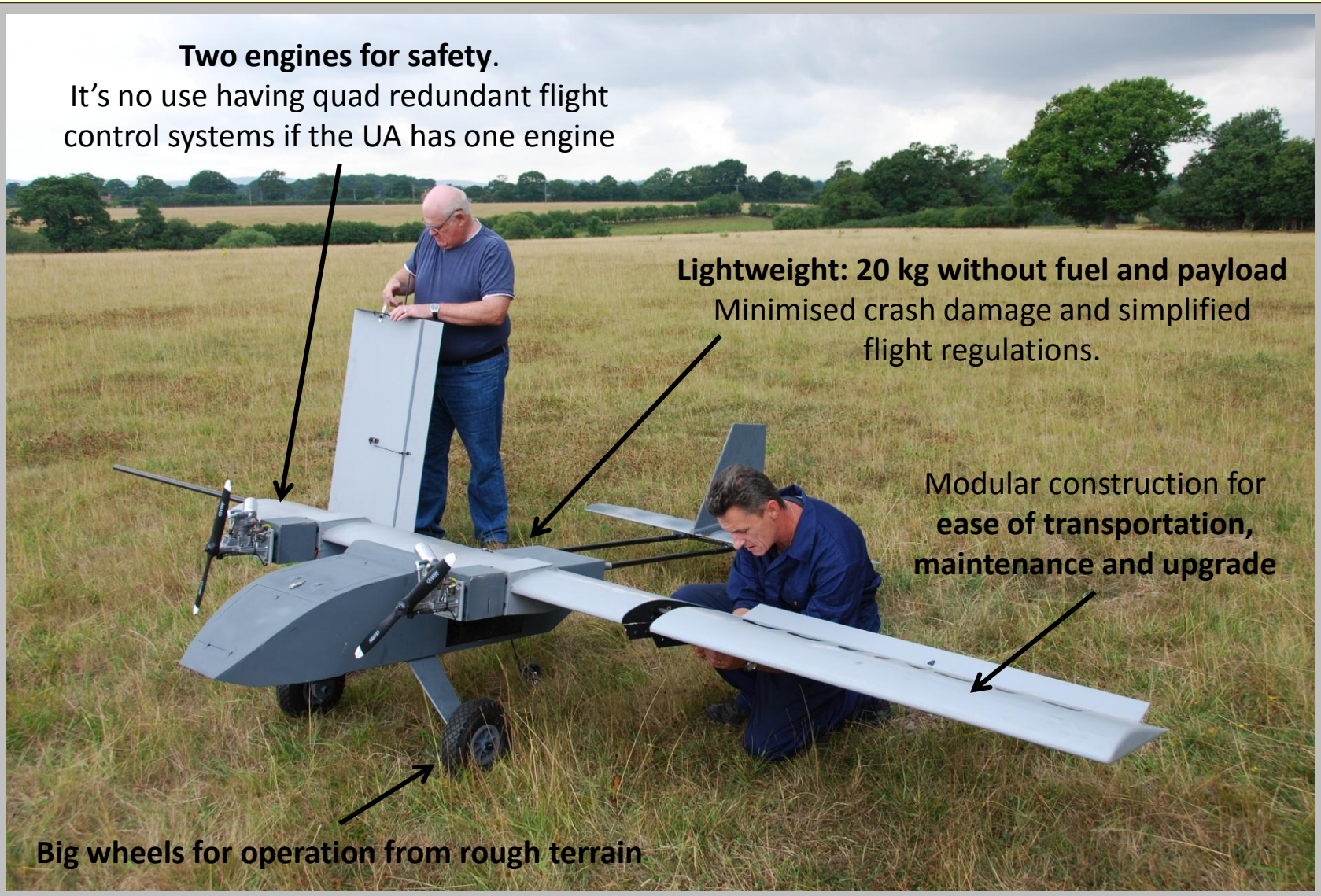
Unmanned aircraft with two, or more, engines, a Maximum Take-Off Weight of 35 kg, or less, and a range in excess of 300 km have the following advantages in border patrol work:

- they will cause less damage in the event of a crash
- they are generally less complex to operate and / or maintain (smaller logistical footprint)
- they are less expensive to acquire, or lease, and are less expensive to operate
- they are more reliable (if they can fly on 1 engine) than an aircraft with 1 piston engine
- it is easier to get approval to export the unmanned aircraft for use throughout the world

We are developing the InView unmanned aircraft for use in the following applications:

- **scientific** volcanic ash cloud density monitoring
- **commercial** oil and mineral exploration work and pipeline monitoring
- **state** land and maritime border patrol work

Introduction to the InView unmanned aircraft.



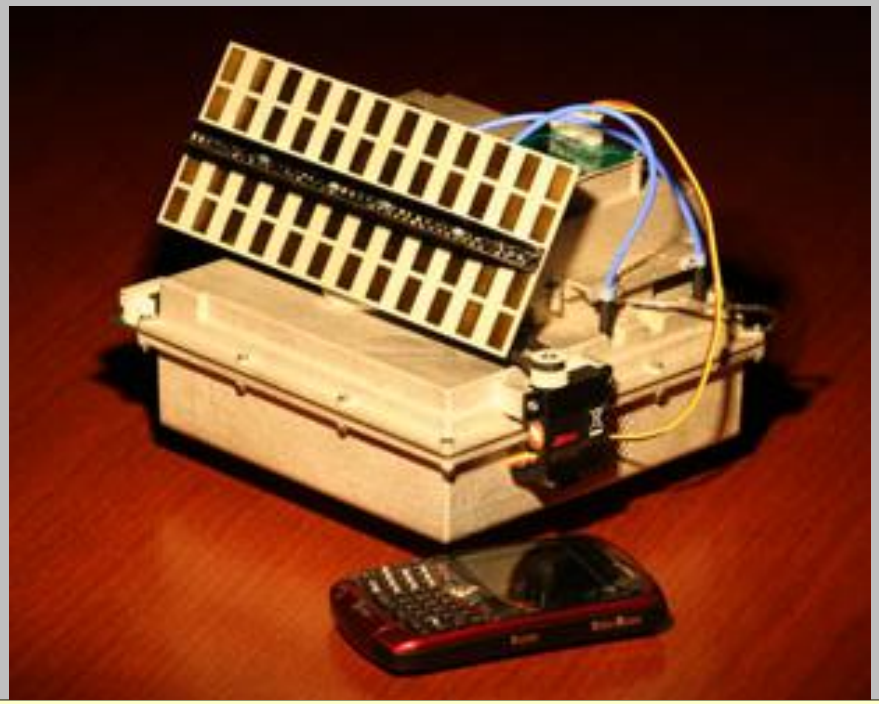
InView unmanned aircraft features at a glance.

▪ for scientific, commercial and state missions	**Payload**	4 kg
▪ comprehensive safety features	**Endurance**	7+ hours
▪ modular and easily transportable	**Max speed**	112 kph
▪ assembled and tested within an hour	**Loiter speed**	24 kph
▪ can operate from a grass field	**Weight**	19.5 kg without fuel
▪ capable of very slow flight	**Wingspan**	4 m
▪ user definable payloads can be carried	**Fuel**	Gasoline + synthetic oil 20:1
▪ operates in manual, Microprocessor based autopilot and PC autopilot flight modes: **moving towards more automation to reduce the errors introduced by human involvement.**	**Propulsion**	2x SAITO FG-30 engines Total Power = 3.6 kW

The instruments carried on the unmanned aircraft can be expensive.

To detect difficult targets in all weather conditions, the unmanned aircraft might carry:

- An ImSAR NanoSAR B unit **costing $ 95,000** (budgetary price)
- two Scintrex CS-3SL Cesium beam magnetometers, **total cost $ 40,400**
- an airborne broadband satellite communications terminal **costing $ 35,000** (budgetary)



Safety and reliability features.

- use of **dual flight control units**:
  - manual flight control for flight training and emergency control
  - microprocessor based flight control for safe, but not very versatile, flight control
  - PC based flight control for flexibility and experimentation, but less safe flight control

- **automatic take-off** using the Sky Circuits SC2 autopilot (shown below) to reduce the consequences of human error and ease the logistical footprint

- **automatic landing** using the Sky Circuits SC2 autopilot to enable emergency landings and reduce the consequences of human error

- **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**, the aircraft can fly on one engine alone

- **parachute deployment** to reduce the kinetic energy

Accidents and safety.

Event	Comment	Ascribed to
IV-01 sheared off undercarriage	pre-flight check error	human error
IV-02 crash after failure of one engine	lack of situational awareness pre-flight check deficiency	design error human error
IV-03 crash due to little rudder authority	design deficiency	design error
IV-05 manually landed on top of tall trees	pilot perception error	human error
IV-06 sheared off undercarriage	hard manual landing	human error
IV-07 sheared off undercarriage	hard manual landing design deficiency	human error design error

Most accidents occurred during take-off and landing. So, as far as we are concerned, unmanned aircraft testing in the U.K. under CAA CAP 722 regulations is fine.

Our test flight experience has convinced us that **the human is the weak link**, and that more pre-flight test automation and flight control machine intelligence will lead to increased safety.

The key barriers to the use of unmanned aircraft in civil and state applications.

The frequently mentioned barriers are suggested to be:

- **Regulations**
- **Sense and avoid system**
- Safety
- Air worthiness
- Type certification
- ATM Integration
- Availability of radio spectrum
- Air crew training
- Human factors and autonomy
- Public perception

An important barrier that is rarely mentioned is:

- **Long term reliability of small engines**

Small engines have a really tough time:

- increased wear due to higher RPM operation
- particulates in the fuel clog small fuel tubes
- Carbon build-up due to the fuel : oil mixture

The twin cylinder SAITO FG-57T four stroke engine is an example of an engine used on long range unmanned aircraft.

Example of advanced small engine technology from Currawong Engineering.

Currawong Engineering, located in Australia, have developed an Electronic Fuel Injection unit for use on small gasoline and heavy fuel engines, operating up to 20,000 feet to give them:

- increased power output
- increased torque output
- increased fuel efficiency
- ease of starting in cold weather

Ray Cooper, Monash University's UA pilot, gets a briefing from Gavin Brett, Lead Development Engineer for Aerosonde Ltd. The stunning long range capability of the Aerosonde, the first Unmanned Aircraft to cross the Atlantic, is very much a tribute to the skills of Gavin Brett. Gavin is now the CEO and Director of Currawong Engineering in Tasmania.

U.K. Military and Strategic Export Control List.

Schedule 3 U.K. controlled dual-use Goods, Software and Technology	
Category 9	**Aerospace and Propulsion**
9A	Systems, Equipment and Components
9A012	"Unmanned Aerial Vehicles", associated systems, equipment and components, as follows:
9A012.a.	UAVs having any of the following:
9A012.a1.	An autonomous flight control and navigation capability (e.g. an autopilot with an Inertial Navigation System); or
9A012.a2.	Capability of controlled flight out of the direct vision range involving a human operator (e.g. televisual remote control);
9A012.b.	Associated systems, equipment and components, as follows:
9A012.b1.	Equipment specially designed for remotely controlling the "UAVs" specified in 9A012.a
9A012.b2.	Systems for navigation, attitude, guidance or control other than those specified in 7A and specially designed to provide autonomous flight control or navigation capability to "UAVs" specified in 9A012.a;
9A012.b4.	Air breathing reciprocating or rotary internal combustion type engines, specially designed to propel "UAVs" at altitudes above 50,000 feet (15,240 metres).

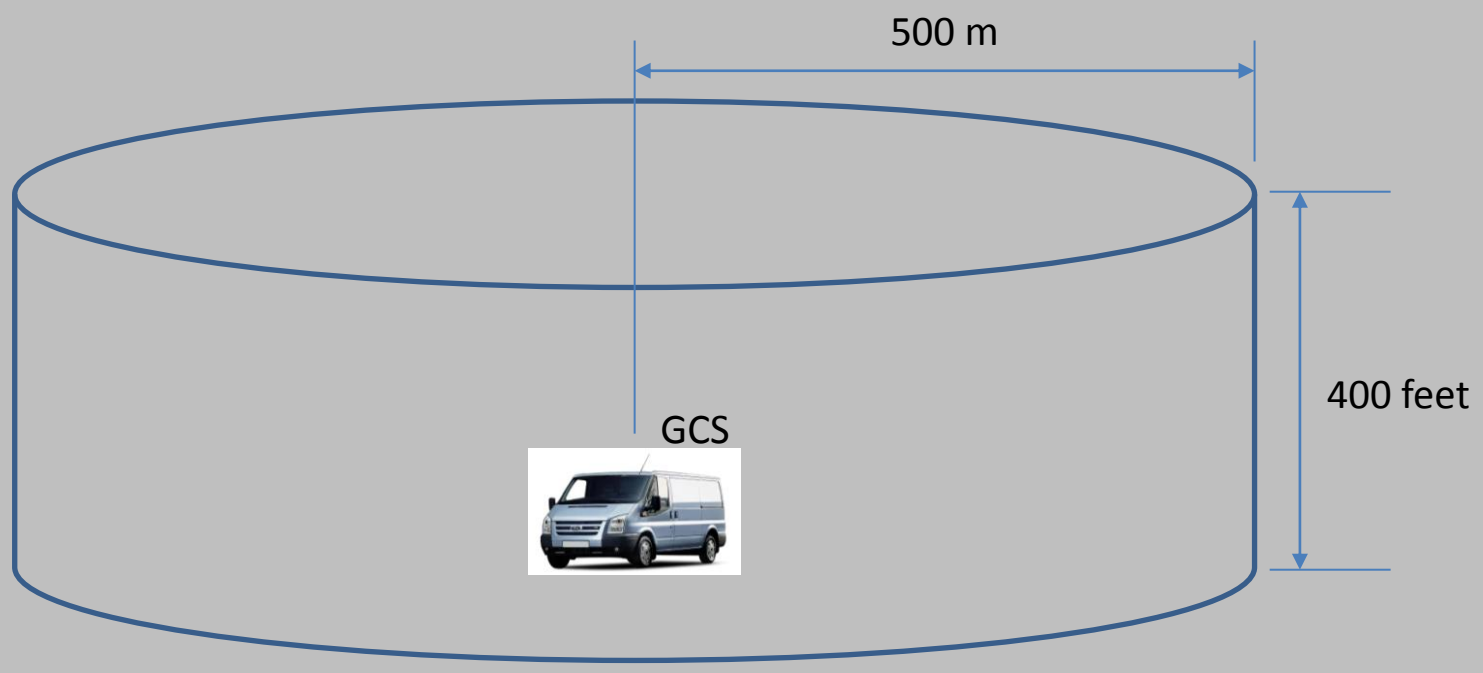
Missile Technology Control Regime ("MTCR") export controls.

- 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 a Standard Individual Export License is easier.

Phase 1: Line Of Sight ("LOS") operation during take-off and landing.

Rx / Tx	Frequency GHz	Description
Rx	1.22760	precision GPS PRBS L2 signal, upper and lower 10 MHz side bands
Rx	1.57542	precision GPS PRBS L1 signal, upper and lower 10 MHz side bands
Rx	2.400 to 2.483	spread spectrum uplink for manual flight control at 819.2 kbit/sec

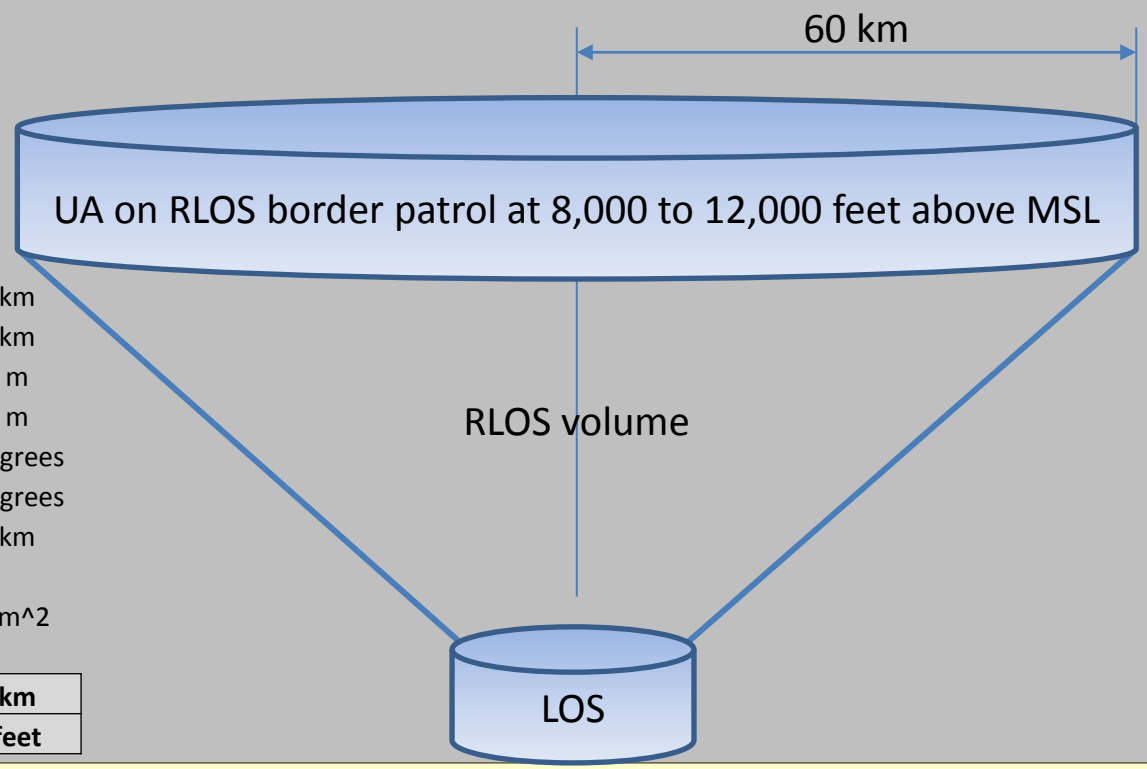


Phase 2: Radio Line Of Sight ("RLOS") operation during border patrol mission.

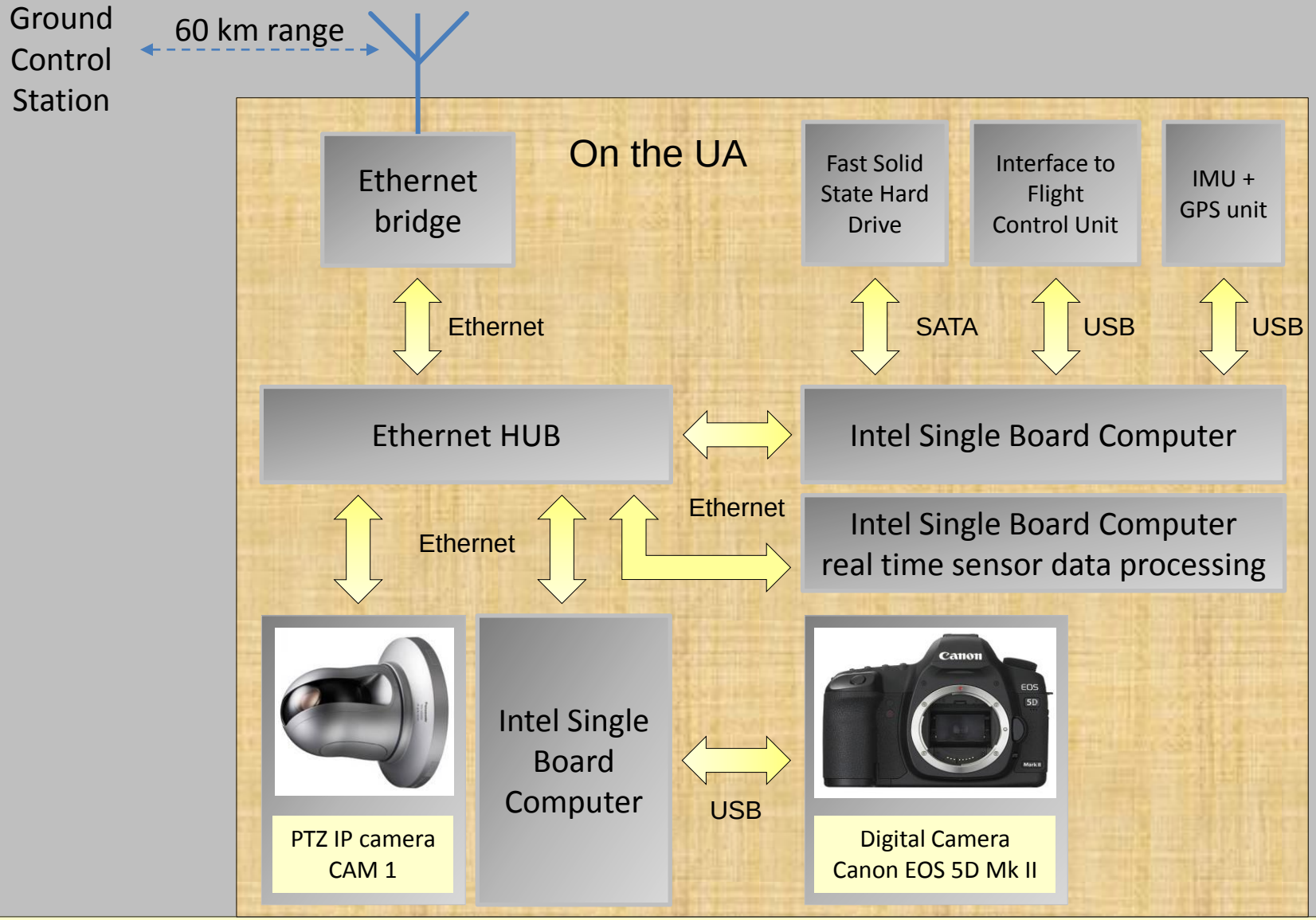
Rx / Tx	Frequency GHz	Description
Rx	1.5250 to 1.6605	Inmarsat satellite broadband downlink at 64 kbps
Tx	1.6252 to 1.6605	Inmarsat satellite broadband uplink at 64 kbps
Rx & Tx	5.725 to 5.850	Wireless Ethernet bridge IEEE 802.11a OFDM link at 6 Mbps Rx sensitivity is -74 dBm at 54 Mbps and -94 dBm at 6 Mbps

PI	3.141592654	
Circum Earth (Polar)	40008	km
Radius Earth	6367.470963	km
Height tree	10	m
Distance to tree	300	m
Angle to horizontal	1.909152433	degrees
Angle total	91.90915243	degrees
RLOS range	60	km
RHS	40573742.21	km^2

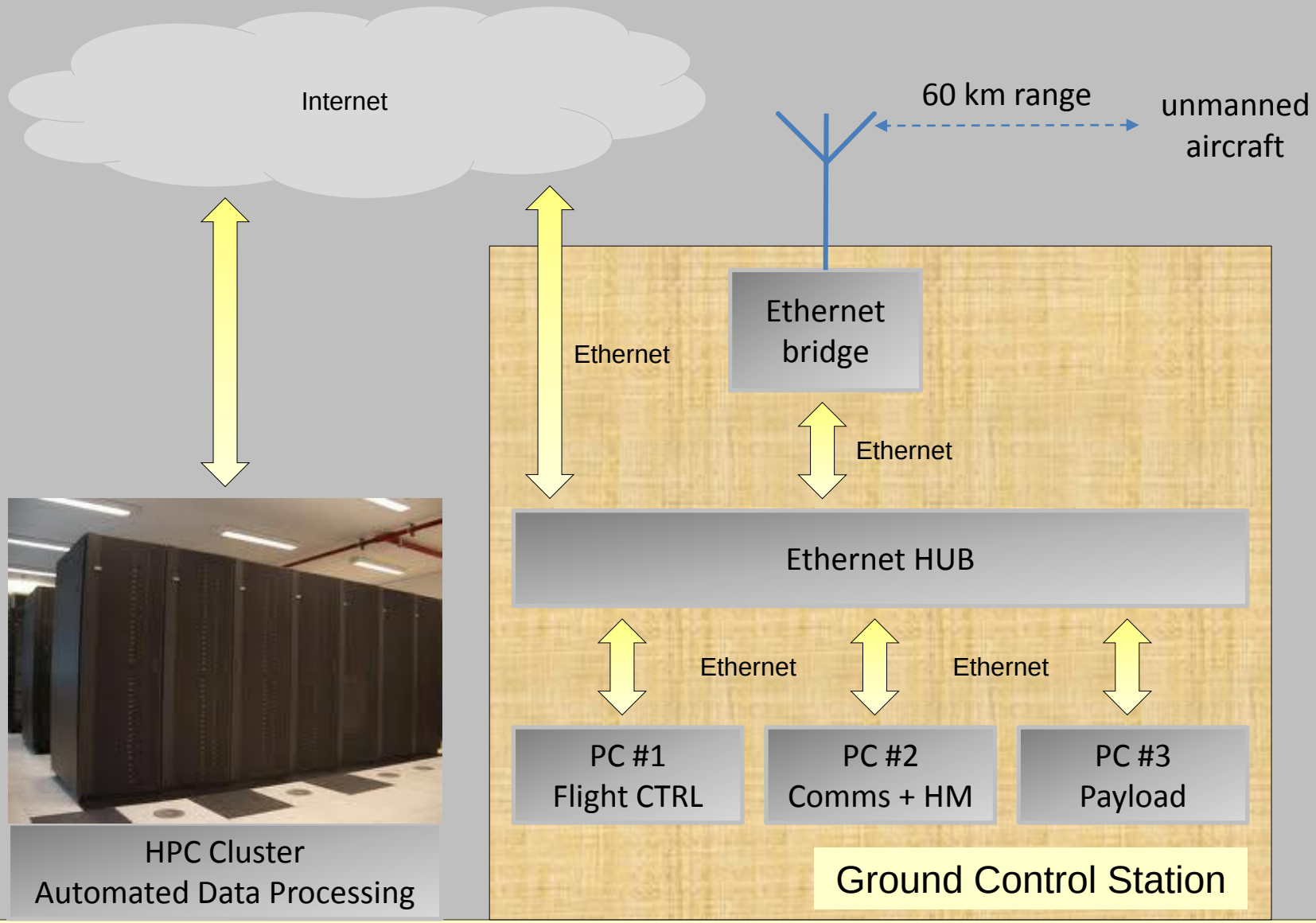
H minimum	**2.281**	**km**
	7484	**feet**



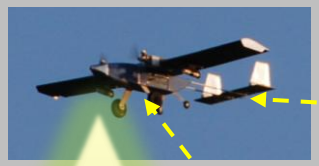
The InView avionics architecture uses an Ethernet based connectivity.



The InView Ground Control Station and Data Processing Centre.



Two unmanned aircraft on patrol can provide improved identification capability.



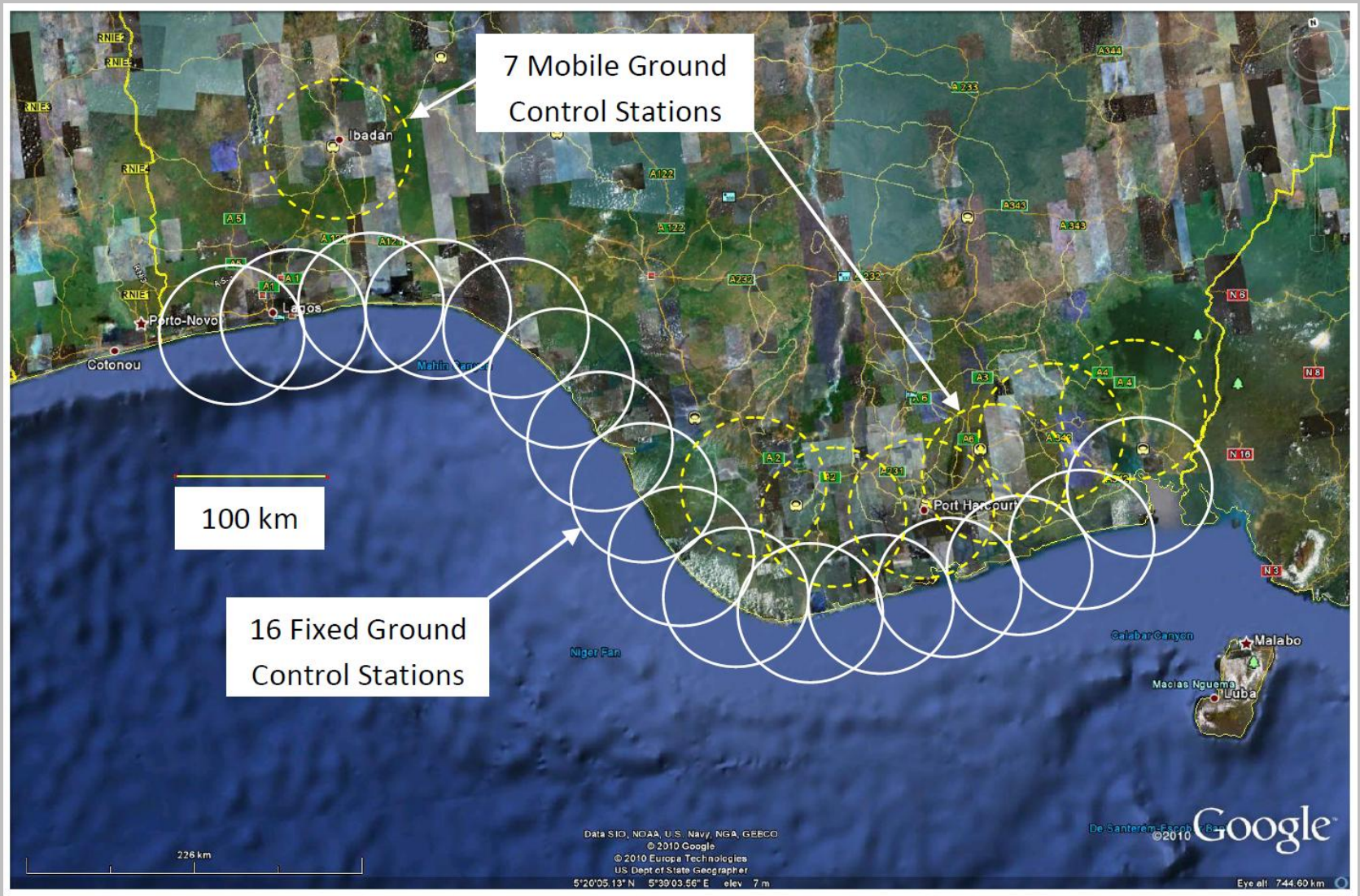
UA at 8,000 feet AGL provides wide area coverage

5.8 GHz IEEE 802.11a Ethernet link
RLOS between UA and the GCS

2.4 GHz IEEE 802.11N WLAN link

UA flying at 400 feet AGL provides high resolution side looking image for ID

Ground Control Station handover is advantageous in the patrol of long borders.



Conclusions

Border Patrol using unmanned aircraft has already started with Predator B unmanned aircraft being used to monitor the US Southwest border with Mexico.

Smaller unmanned aircraft with a Maximum Take-Off Weight of less than 35 kg have advantages over the use of heavier, and usually larger, unmanned aircraft, especially in lower leasing and operational costs and reduced impact of a crash.

In order to relay the high bandwidth video stream from the unmanned aircraft to the Ground Control Station, the UA needs to remain within Radio Line Of Sight (60 to 250 km) of the GCS.

GCS handover capability is useful in the patrolling of a border outside of the RLOS range.

Acknowledgements

1. The Technology Strategy Board ("TSB") in the STUAC Project to incorporate sensors to monitor the health of an Unmanned Aircraft.
2. The TSB in the INMARA Intelligent Machine Reasoning and Action Feasibility Study
3. The European Space Agency in the form of the UASatCom IAP Feasibility Study

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Thank you.

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