Unmanned Aerial Vehicles:
Their uses for ecological surveying

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• The advantages and disadvantages of using them.

• Regulatory requirements.

• The range of sensors and their potential applications.

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• Current research work into invasive species surveying.
What is a UAV?

• A UAV is an Unmanned Aerial Vehicle (often called a drone in the media).

• They usually take the form of a plane (fixed wing), a helicopter or multi-rotor.

(Examples of UAVs: a) Powered glider; b) powered parachute; c) helicopter; d) fixed wing aircraft; e) Draganflyer X8 quadrocopter; f) Aeryon Scout quadrocopter, Zhang & Kovacs 2012)
Military origins

• UAVs in one form or another have been around since the first world war, when Archibald Low created the Ruston Proctor Aerial Target.

• Initial development and use in the military, with new high tech solutions being developed:
  – The UK’s Taranis stealthy UCAV (unmanned combat aerial vehicle) prototype.
  – The Black Hornet battlefield observation nano UAV.
General airframe differences

• Multi-rotors:
  – Very stable in flight and able to hover to get good imagery.
  – Vertical take-off and land (VTOL) ability, so can operate from small areas easily.
  – Fairly easy to control, especially with GPS assisted flight modes.
  – Poor endurance, so multiple flights may be required depending on the area being surveyed.

• Fixed Wing:
  – Very good endurance, allowing large areas to be surveyed.
  – Depending on size/weight can be difficult to launch by hand so may require a catapult launcher or small airstrip (likewise landing can be more problematic/require more space depending on size/weight of aircraft).

• Helicopter:
  – Similar to multi-rotor but mechanically more complex and more difficult to control.
  – Can carry heavy payloads more efficiently and can be petrol powered, giving greater endurance but more vibrations (which could hinder image capture).
How the autopilot works

- The autopilot uses on-board sensors to identify where it is in the world.
  - A GPS is used for positional information.
  - A magnetometer (compass) is used for directional (heading) information.
  - A barometer senses air pressure for identifying altitude.
  - Gyroscopes and Accelerometers sense the attitude of the aircraft.

(Example of an autopilots components)
How are they controlled?

- They can be controlled manually using a radio transmitter, or fly autonomously using a given a set of waypoints to follow:
  - Extra waypoints or specific positional commands can also be transmitted to the UAV via the use of wireless telemetry from a ground control station (specific software running on a computer).

(An example survey flight over grass trial plots near Edinburgh, the blue line denotes the path the UAV took during the survey)
Advantages of UAVs

- They can collect higher resolution imagery at a lower cost than manned aircraft or satellites:
  - UAV resolution typically less than 5 cm per pixel.
  - Manned aircraft resolution typically 25-12.5 cm per pixel.
  - Satellite resolution at best around 50 cm per pixel.

- They can also operate below cloud cover, increasing availability as satellites and manned aircraft will not be able to see the ground.

(A UAV flying on a typical Scottish day!)
Advantages of UAVs

- As they can be accessed and flown directly by researchers, they have a high temporal availability.

- You can re-run the same mission multiple times in a day, or every other day/week etc.

(Example of repeated data collection of grass trial plots at SRUC’s Boghall farm, Edinburgh).
Disadvantages of UAVs

- More limited in the sensor load (and therefore complexity) that they can carry.

- Although this is due to a combination of cost, ease of use and regulations.

- More susceptible to high winds and adverse weather compared to manned aircraft.

- Typically wind speeds above 15 knots (17 mph) lead to poor image capture from a UAV.

(Edinburgh University, School of Geosciences ECO-Dimona research aircraft; This can carry multiple sensors at the same time, including an ortho-photography system, hyperspectral imaging system and gas analysers).
Disadvantages of UAVs

- Individual flights cover much smaller areas compared to manned aircraft and satellites.

- Therefore more flights are required to cover larger areas and more time is required to process imagery produced.

- Larger areas (multiple km$^2$) could be captured per flight for fixed wing UAVs, however regulations limit this due to visual flight rule requirements.

(The difference between the extent of coverage and level of detail from different aerial platforms).
Regulations

- As UAVs share airspace with other aircraft (including paragliders etc.), there are regulations surrounding their use and their maximum weight.

- The general safety guidelines are:
  - Cannot exceed 400 feet (~122 m) above ground level.
  - Must be within line of site or 500 m distance of the operator (whichever is closest).
  - Must stay 50 m away from structures, vehicles and people.
  - Must stay 150 m away from built up urban areas or large concentrations of people.

- Airworthiness certificates are not required for UAV’s with an all up weight of < 20 kg, and air traffic control clearance is not required when operating a UAV < 7 kg (or if outside of class A, C, D or E airspace).

- The key message is that a UAV must be observable at all times along with the airspace directly surrounding it, as the operator is responsible for getting it out of the way of other low flying airspace users.
CAA Permission to operate

• For commercial work, the pilot must hold a valid certificate of competence (typically BNUC-S or RPQ-s) and the company must have permission to operate from the Civil Aviation Authority (CAA).

• The CAA’s view on what is commercial work is a little grey, but essentially if the flight is for financial gain then you must have permission.

• The general consensus is that research related flights conducted in house will not fall into this category and so approval is not required, however if the research is being externally financed this could be a problem (new guidance from the CAA should help to clarify this soon).

• To gain CAA permission, one or more pilots must complete a ground theory test and flight test, and once completed the company’s operations manual is assessed and used to obtain CAA permission.
What can they be used for?

- **Scientific Research**
  - Atmospheric research
  - Geological research
  - **Ecological research**
  - Studying hurricanes
  - Volcano observation
  - Transportation science
  - **Agriculture and forestry**

- **Disaster Management**
  - Disaster effects management
  - Rescue and clear up effort supervision
  - Disaster damage estimation
  - **Forest fire monitoring and prevention**
  - Monitoring flooding

- **Security**
  - Security and Control
  - Aerial Reconnaissance
  - Aerial Policeman and Crowd Monitoring
  - Aerial Traffic and Security Watch

- **Crop Management**
  - **Countryside and Agriculture**
  - Agricultural Activities
  - Crop Dusting

- **Communications**
  - Telecommunications
  - Telecom relay and signal coverage survey

- **Survey**
  - Oil and Gas Exploration and Production
  - Mineral exploration
  - Geophysical surveys

- **Search and Rescue**
  - Maritime and Mountain Search and Rescue
  - Liferaft Deployment
  - Rescue point marking

- **Monitoring**
  - Civil engineering sites
  - Waterways and shipping
  - Oil and gas pipeline
  - **Forestry**
  - Fishery Protection
  - The countryside
  - Pollution Control and Air Sampling
  - Crop Performance
  - Observing traffic flows

(Elements in red are being considered for investigation by SRUC)
Typical aerial-based sensors

• Imaging systems
  – Colour cameras
  – Multi-spectral cameras
  – Hyper-spectral cameras
  – Thermal cameras

• Other sensors
  – Spectrometers
  – LiDAR
  – SAR (Synthetic Aperture RADAR)
  – Spore traps
  – Gas analysers

• Physical interactions
  – Spray booms
  – Robotic arms
How images are processed

- (Images collected)
- (Processed into a 3D point cloud to enable orthorectification)
- (Stitched into a orthomosaic)
- (The point cloud can be analysed as a 3D model to identify height)
- (The orthomosaic then can be analysed in conjunction with other data)
Agisoft Photoscan example

There are several different software packages that can effectively process UAV derived imagery, some are open source.

Note the ground control points being used due to the limitations of the UAV’s on-board GPS.

(An example of a mosaic image processed within Agisoft Photoscan)
3D Processing example

(A 3D model of a wooded area processed through Agisoft Photoscan)
SRUC’s UAVs

- SRUC currently has two multi-rotor UAVs with a third in development. All of the UAVs are using 3DR auto pilots with Arducopter firmware.

- Typical flight times on a set of batteries is between 10-15 minutes.

- The size of area covered per battery set could be up to 15 ha, however it’s typically less than 5 ha as larger image overlaps are used.

- In contrast a fixed wing UAV would typically be able to cover ~1 km² per battery (this is limited due to keeping the UAV within line of site).

(Left: Quadcopter; Middle: Octocopter; Right: Coaxial tricopter)
Current sensors

- Currently only simple consumer level digital cameras are being used.
- These use customised firmware (CHDK).
  - This allows the camera to record RAW images and run pre defined scripts or to take a picture on command from a USB pulse.
- One of the cameras has had its hot mirror filter removed and a 585 nm long pass filter added, allowing it to capture near infra-red light.

(The electromagnetic spectrum showing the range of an unmodified (420-670 nm), and a modified or full spectrum (400-900 nm) Canon A2200 digital camera.)
Current research work

As part of my research I am attempting to use a UAV to quantify the ground cover extent of *Rhododendron ponticum* in deciduous and mixed woodland.

I will also be surveying for other invasive non-native species (e.g. *Heracleum mantegazzianum*), automatically classifying the vegetation using both pixel and object based image analysis.

(Methods of vegetation classification of the Rhododendron infestation at Penicuik Estate, Midlothian, Scotland)
Experiences and expectations

• The imagery and videos produced can be of excellent quality and there appears to be almost no end to how they could be applied, although setting up an area often takes longer than the actual survey flight.
  – UAVs are however not always the easiest tools to work with and if things go wrong, you end up quite literally picking up the pieces!

• Advances in UAV technology mean:
  – UAVs will become cheaper, more robust, more autonomous (e.g. improved GPS accuracy, terrain following, more active sensors), with improved battery life performance and therefore endurance.

• In the future personal UAVs could be of great value, as they can be set to follow a GPS signal (i.e. a mobile phone) with little input from the operator.

(An example of swans being unconcerned by the UAV once it had exceeded ~30 m above ground level)
Any questions?

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Some useful references: