Plymouth Marine Laboratory

PORTWIMS Workshop

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Introduction to RPAS (Remotely Piloted Aircraft Systems)

Aser Mata, William Jay

PML Plymouth Marine Laboratory

Aser Mata

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At work:

-Physicist, joined PML in 2015

-Airborne data processing and calibration

-Drone pilot with CAA accreditation (since 2018)

-Experience in the RS of marine plastic debris

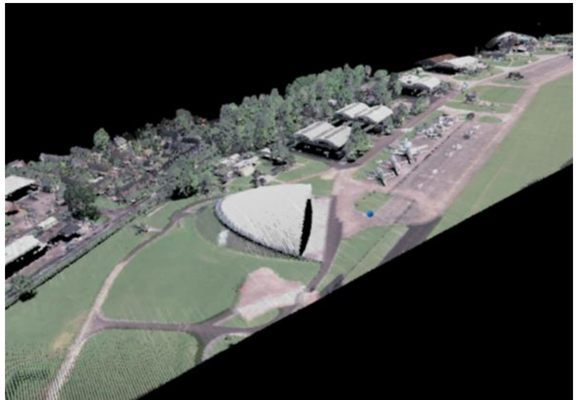
Today, on PORTWIMS:

-Overview about different drone types and sensor types

-Creating orthomosaics using Structure from Motion and other tools

-Planning a drone operation, legal regulations and tools

-If weather allows, drone practice flights



Introduction

The Drone Sector in Europe (2018, De-Miguel-Molina & Segarra-Oña)

Accepted uses

Source	Use
Amukele et al. (2017)	Blood transportation
Hardy et al. (2017)	Mapping malaria vector habitats
Pulver et al. (2016)	Transporting automated external defibrillators
Chabot and Francis (2016)	Bird detection
Hodgson et al. (2017)	Surveying marine fauna
Sankey et al. (2017)	Forest monitoring
Casella et al. (2017)	Mapping coral reefs
Szantol et al. (2017)	Mapping orangutan habitat
Chowdhury et al. (2017)	Disaster response and relief
Restas (2015)	Supporting disaster management (earthquakes, floods, fires)

Water Quality Monitoring
BETA project, St John's lake (Plymouth)

*Remotely Piloted Aircraft Systems are able to collect **extremely high resolution data** by flying at low altitudes. Drones have become a key tool for Earth Observation as they can **monitor and quantify** different physical properties by using different sensors attached: optical reflectance or/and thermal properties, aerosol composition...*

Plastic Waste Detection
HyperDrone ESA Project, Headwall sensor (380-2500 nm)

Most common drone types

Fixed Wing

SkyWalker X8 (Image Source: Heliguy)

+Long endurance (large flight times)
+Large coverage area
+Faster speeds (for larger areas)

-Take off/Landing needs a lot of space
-No hover
-More difficult to operate
-Expensive

Multirotor

DJI Phantom 4 (Image Source: DJI Phantom 4 website)

+Ease to use and manoeuvre
+Vertical take off/landing and hover flight
+Cheaper
+Can operate in a confined area

-Short flight times (batteries ~30 min top)
-Small range (lower speeds)
-Smaller payload capacity

Drones are specially suited to provide solutions to key challenges on the Remote Sensing of the Enviroment

Very high resolution monitoring
For local fisheries, human health... or quantify human impact (sea and society)

Ground Validation
For new satellite products or models
Upscaling/Downscaling

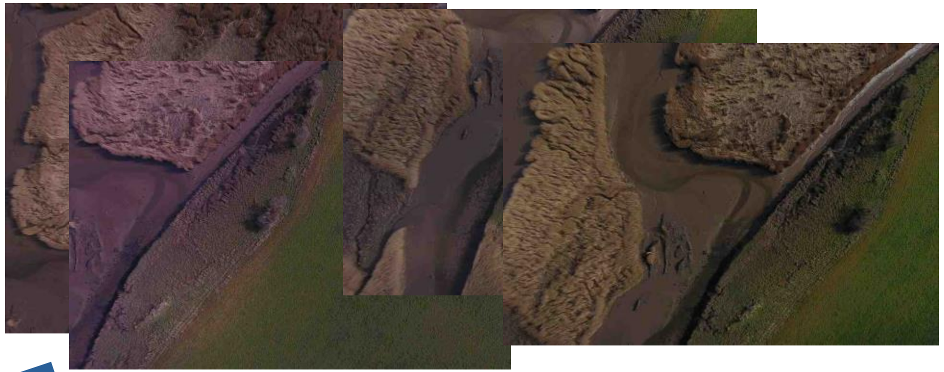
Communications
Improve research impact

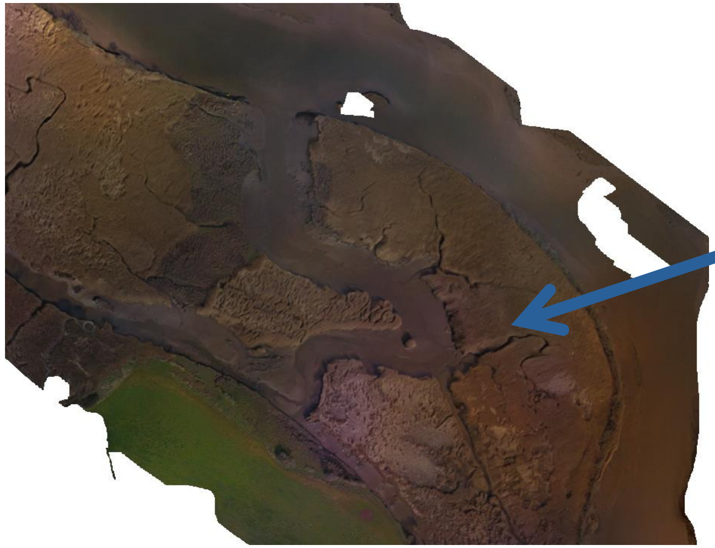
Examples: litter detection, macro-algae mapping (BETA), surveying of invasive pacific oysters…

Very High Resolution Mapping (and 3D)

Example: Quantifying erosion on Sharpham Marsh (collaboration with the South Devon estuary officer)

Structure from Motion



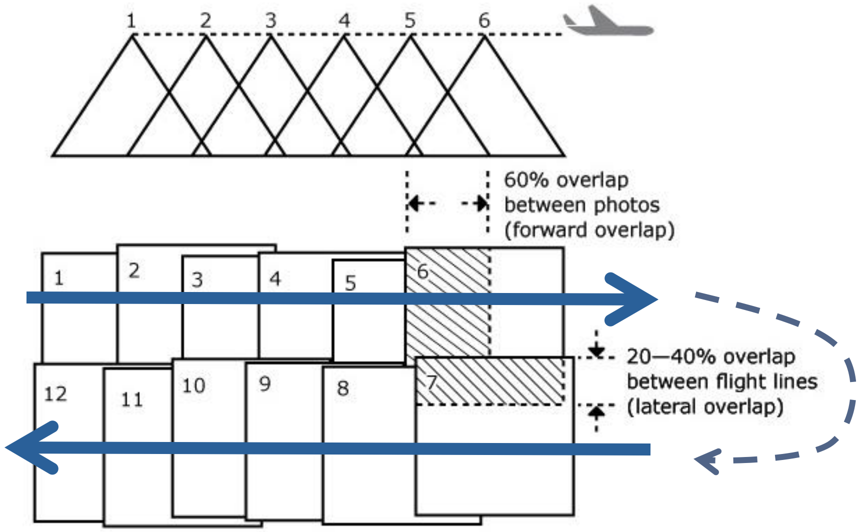


Orthomosaic of Sharpham

Doesn’t work well over water!

Digital Elevation Model.

Structure from Motion (SfM)



Agisoft (2018)

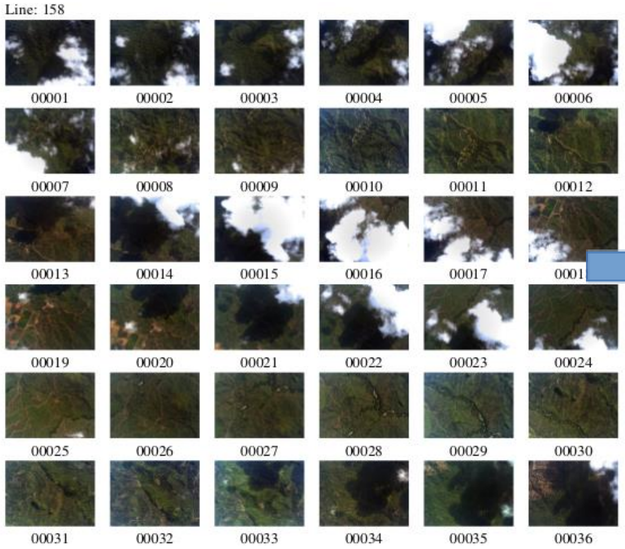
Processing using Structure From Motion techniques:

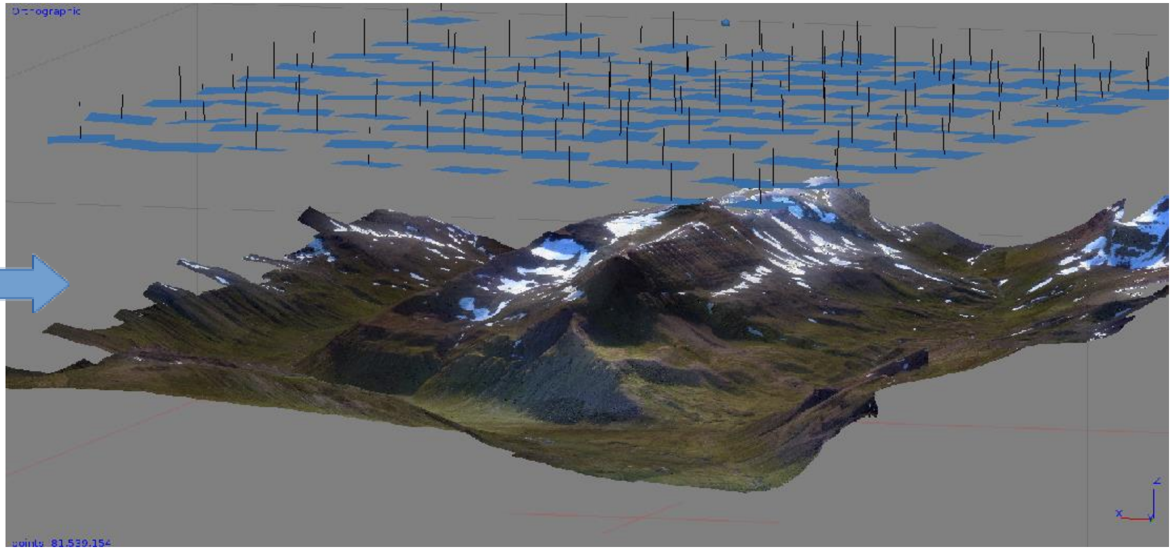
-Photogrammetry tool that uses **overlapping photos** of the target

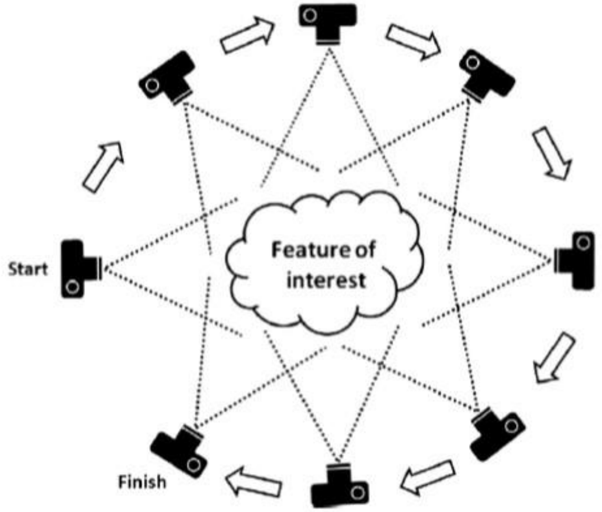
-Software identifies common features in overlapping regions

-Stitch images together and creates an orthomosaic

-Computes 3D shape by computing angle of the camera, altitude, location, shadows…







SfM is also used to capture 3D models of buildings, pieces of art for preservation…

A. Dirt ground
B. Leaves and twigs
C. Clover ground
D. Clover leaves
E. Fern large
F. Fern medium
G. Fern small
H. Log large
I. Log medium
J. Log small
K. Tree large
L. Tree medium
M. Tree small
N. Tree stump
O. Vegetation

Endor

Endor

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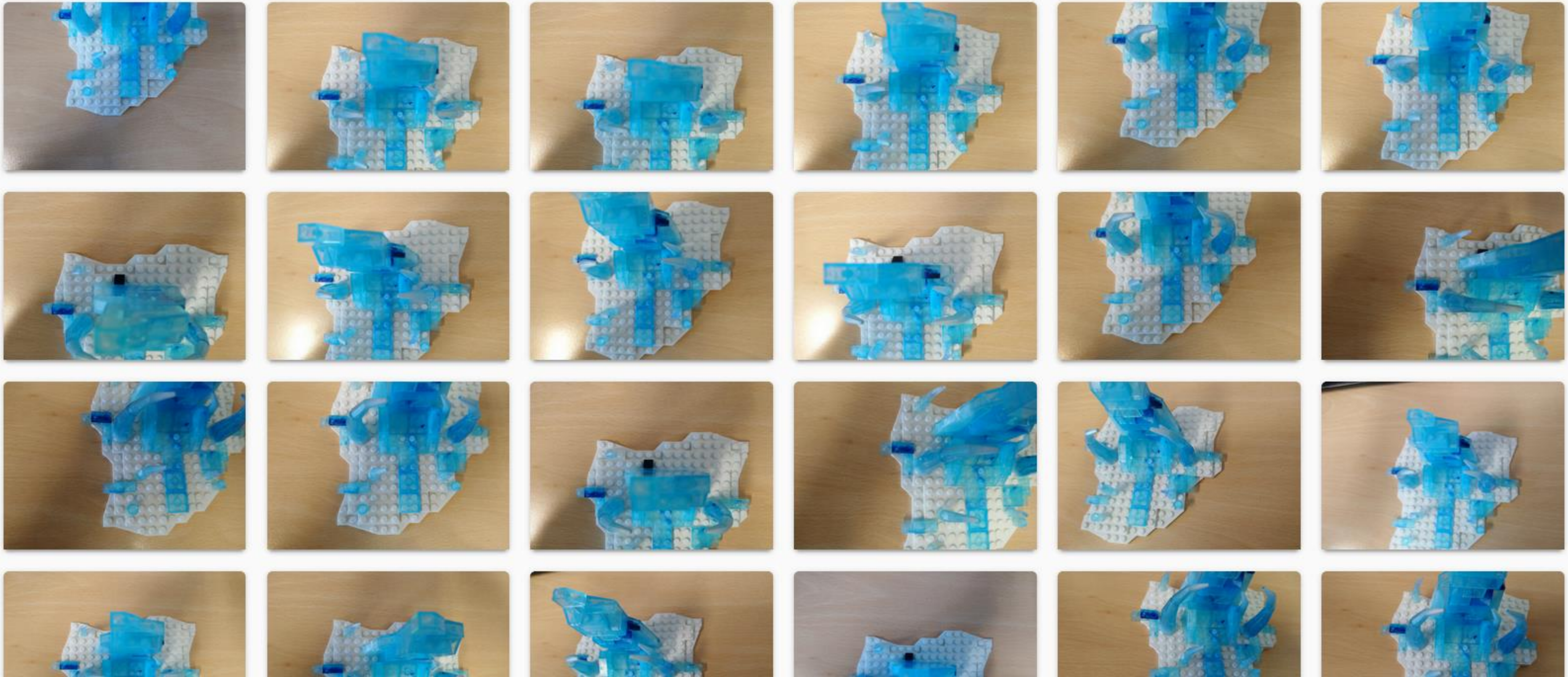
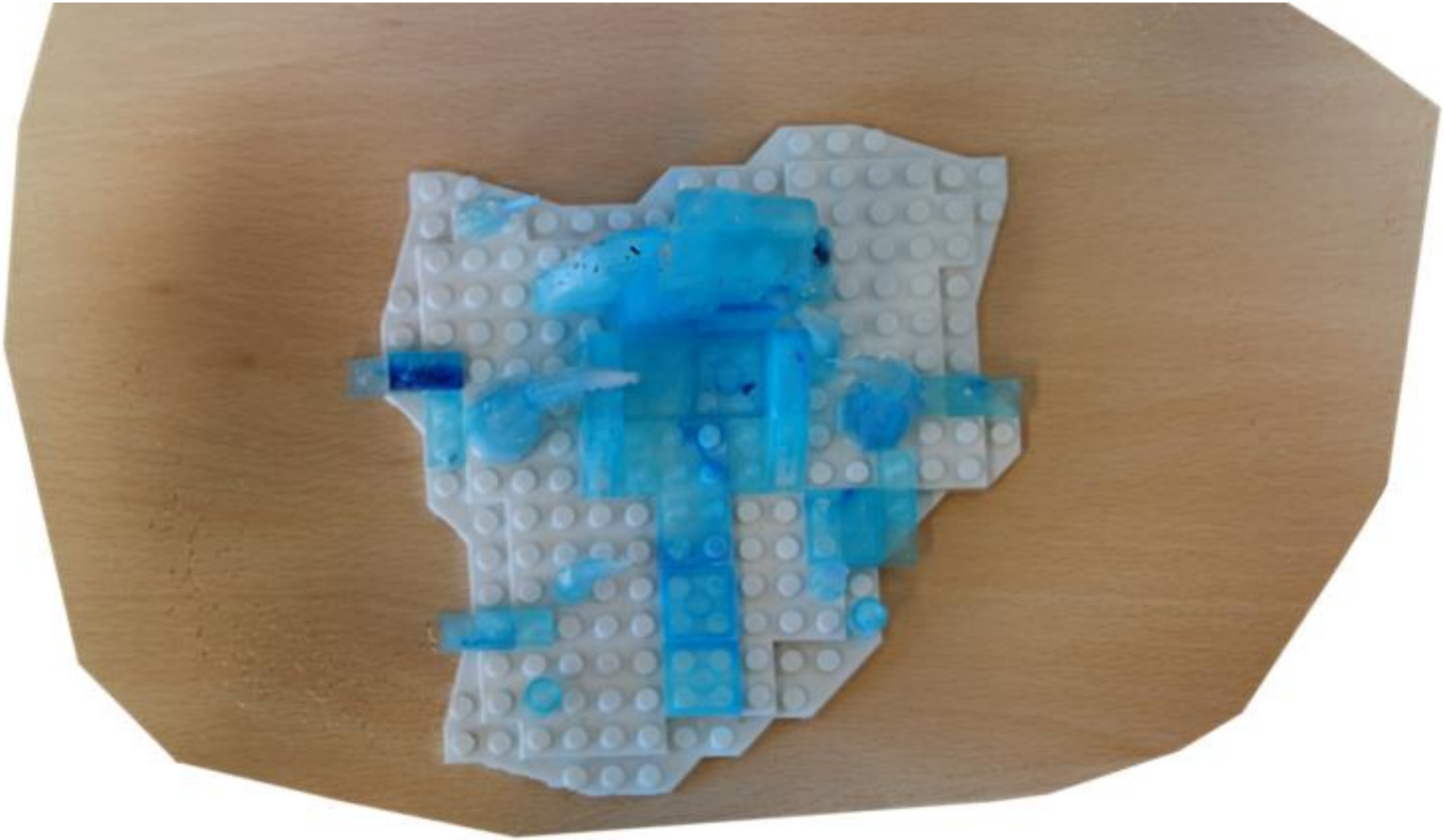
IMAGES RESULTS

68 images



Orthomosaic

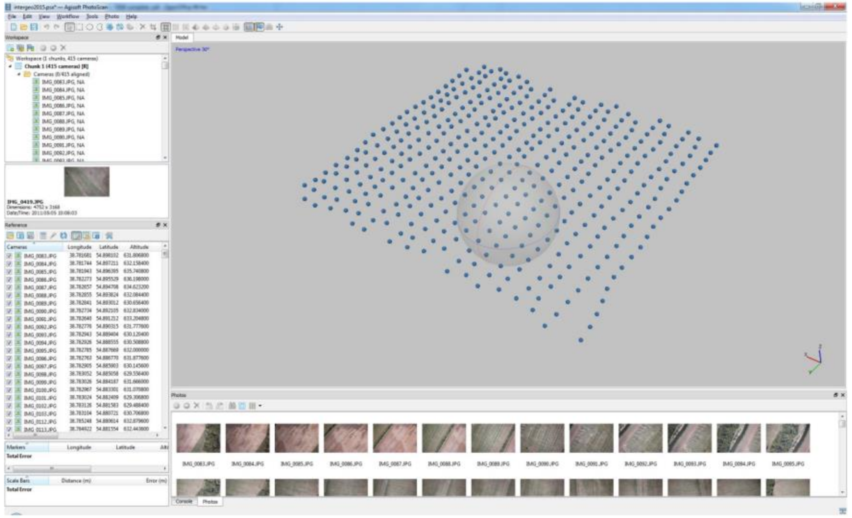


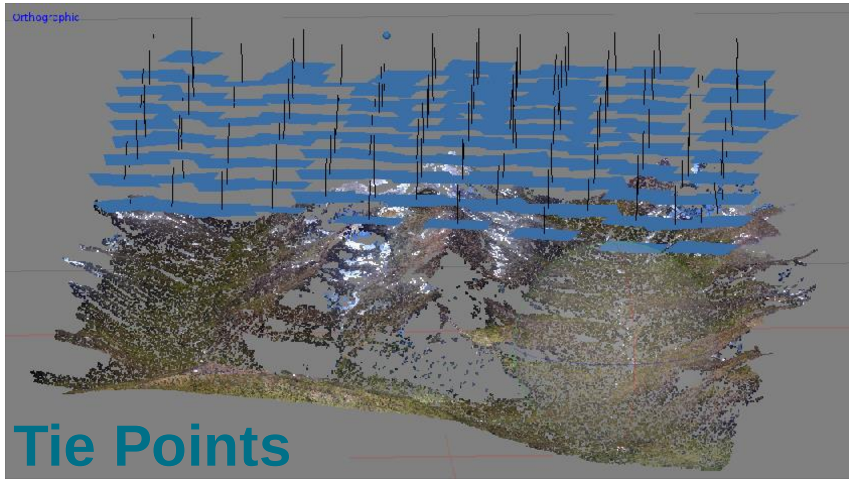
SfM

Metashape PIX4D DroneDeploy OpenDroneMap

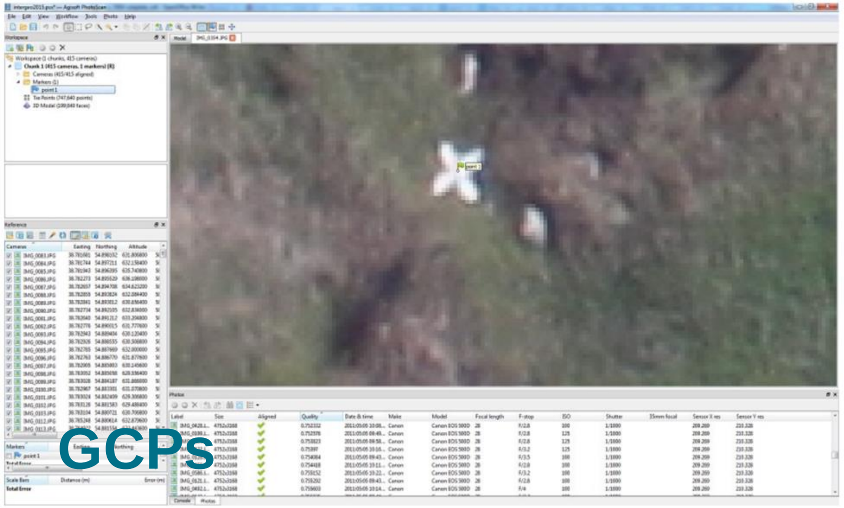
Workflow

PML currently uses **Agisoft Metashape** within a semi-automated script in Python which uses. Only manual step is the placement of GCPs.

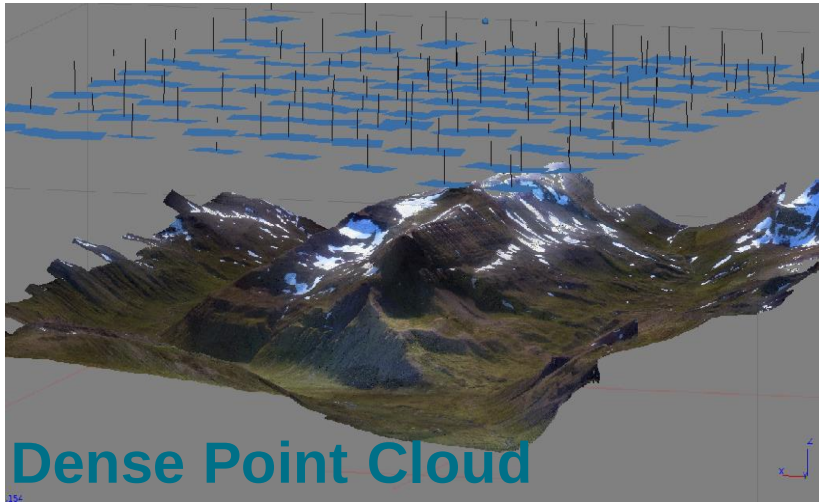




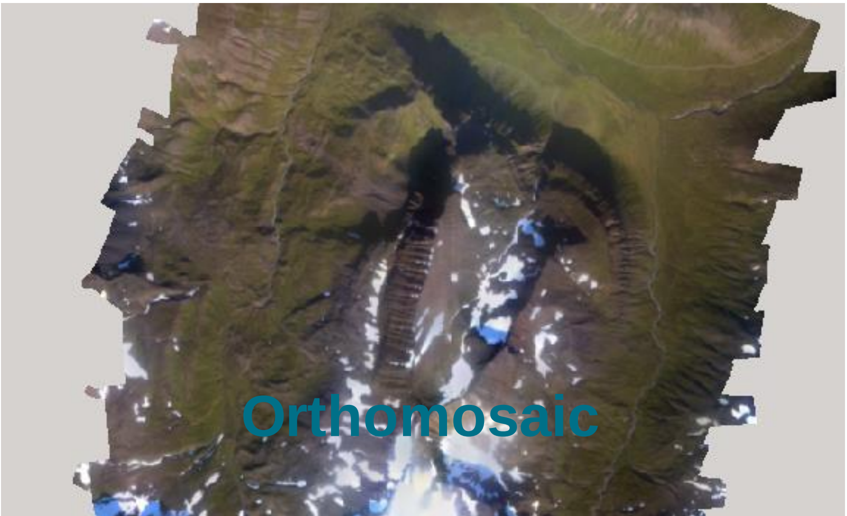
Tie Points



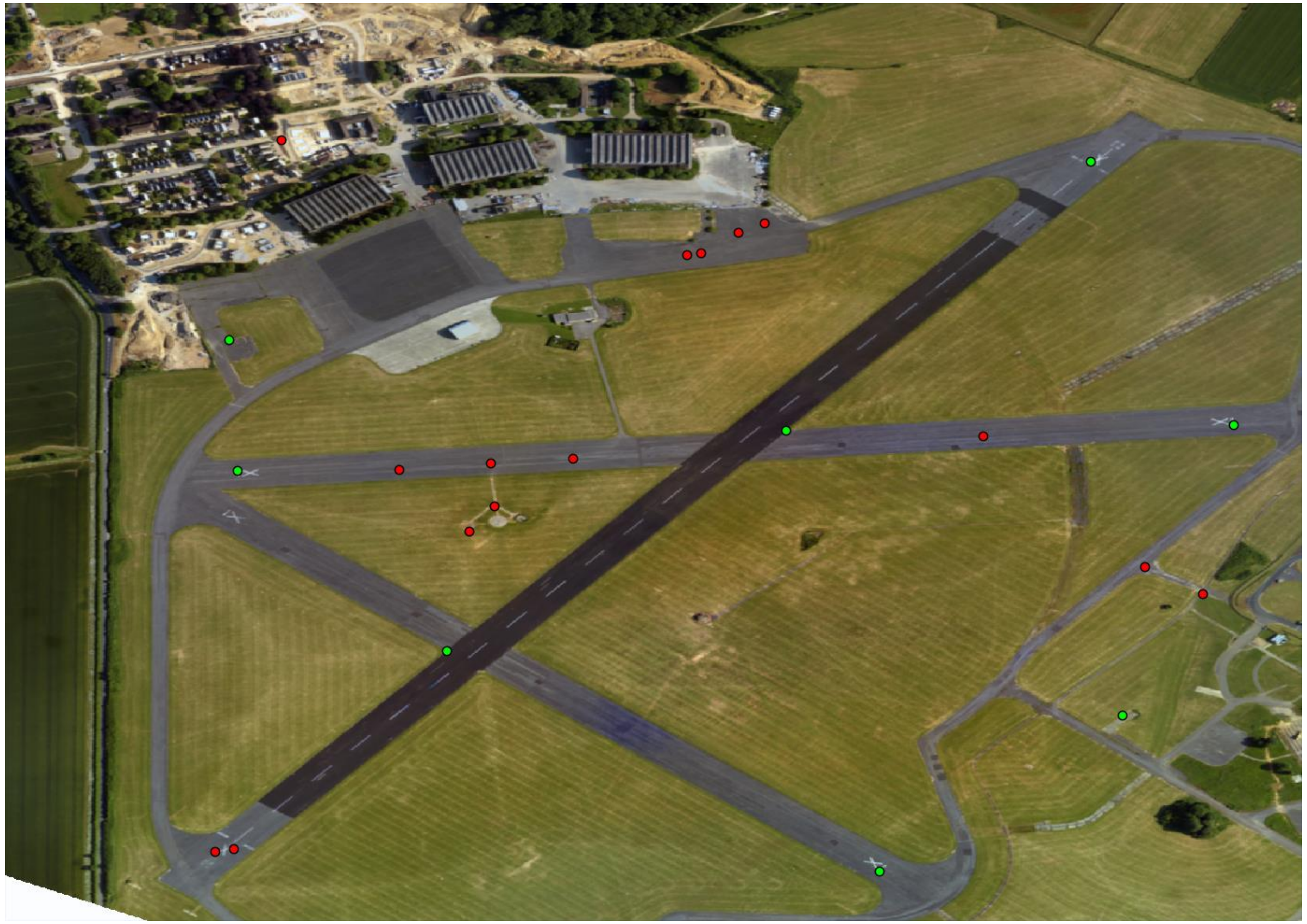
GCPs

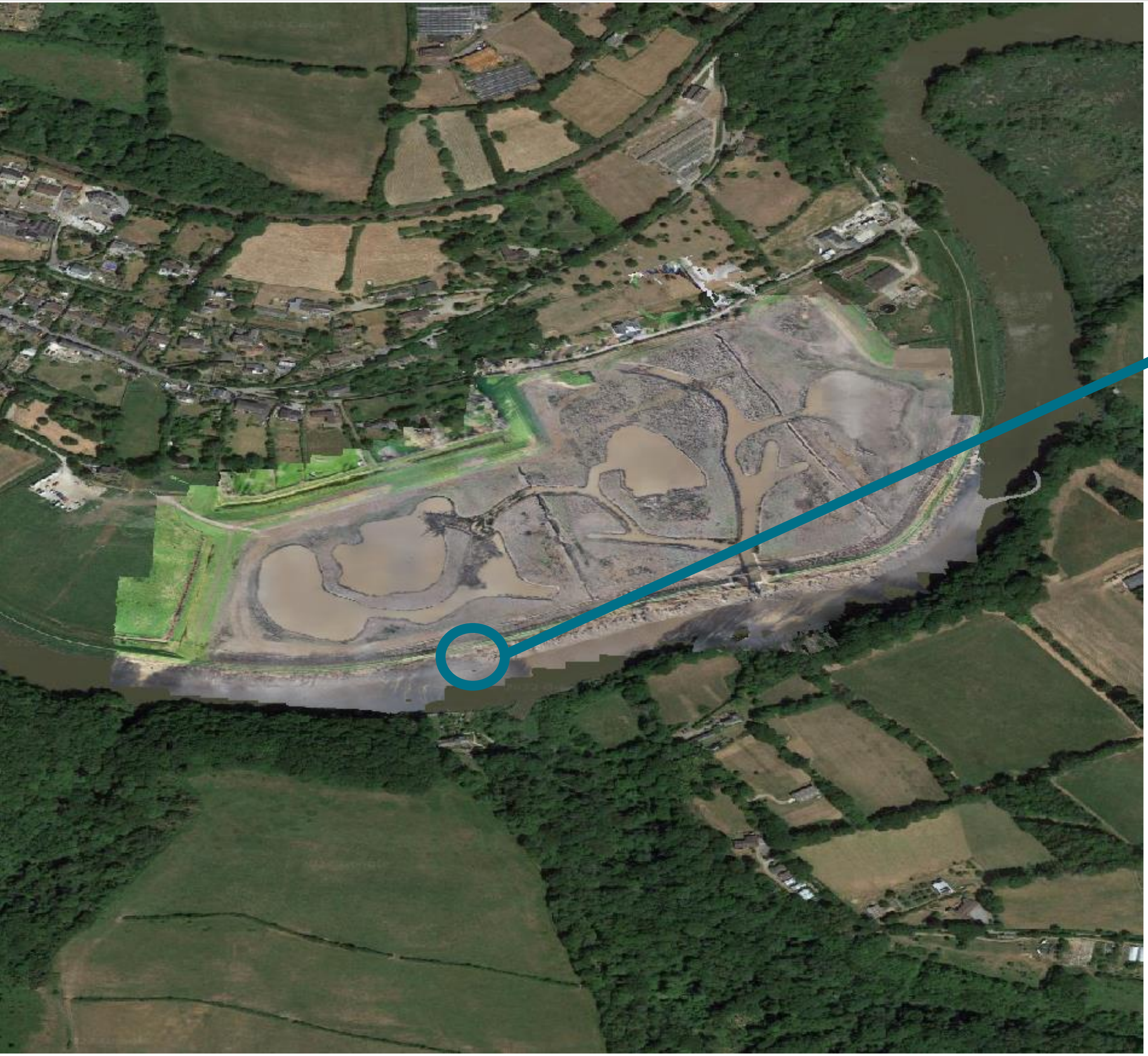


Dense Point Cloud



Orthomosaic





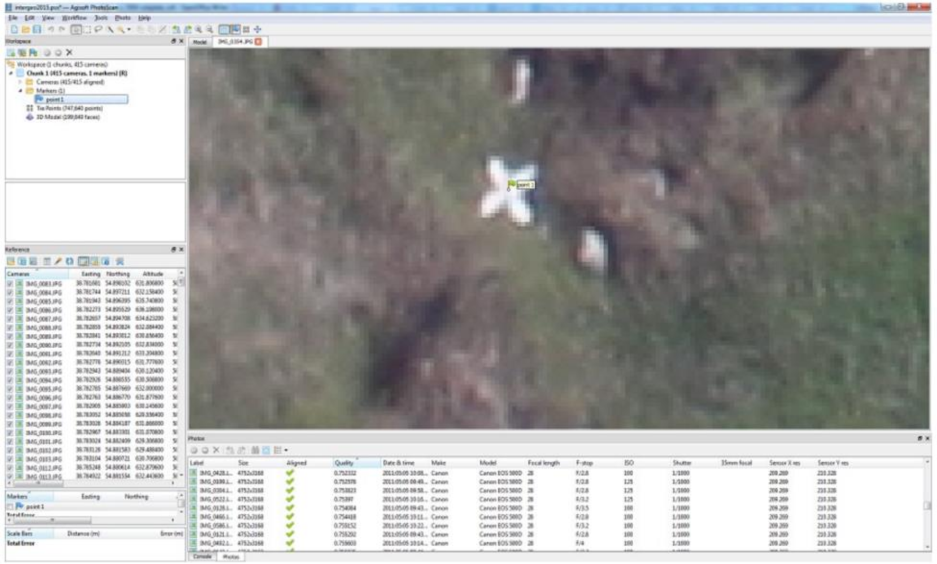


Image Analysis And Classification Maps

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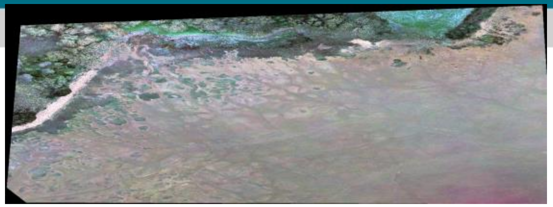
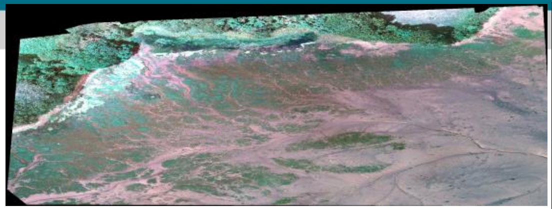
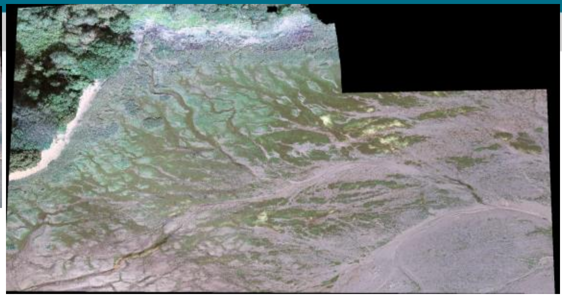
Project BETA: St John's lake



13th September 2021



19th March 2021

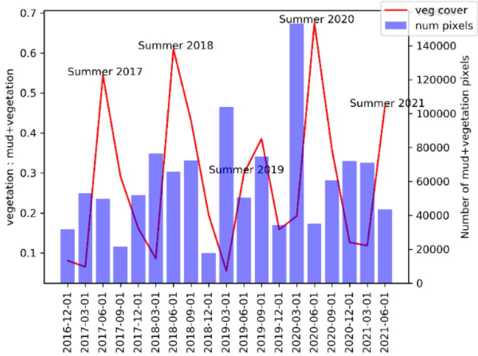


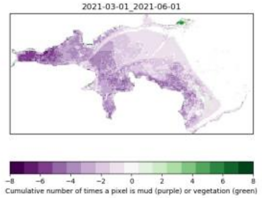
9th September 2020

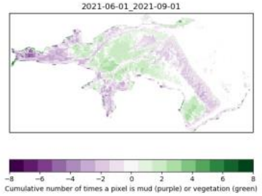
Stakeholders: South West Water and Natural England.

Seasonal drone surveys and water samplings were collected to create high resolution orthomosaics and develop classification maps to identify algae growth. These datasets are also used to assess the feasibility of using satellite algorithms to detect algae in this area

Sentinel-2: June 23 2021







Regions of presumed macroalgae were manually delineated in a GIS (also separating classes such as water, mud, reeds, grass and trees). Pixels within macroalgae vectors were counted based on RGB colour and contrast to derive macroalgae areal coverage (MA).

*Image analysis using high resolution data can be exploited to monitor water quality, detect plastic debris…Drone data is an **ideal candidate for AI***

RGB drone imagery for litter detection

Marine Pollution Bulletin 155 (2020) 111158

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Mapping marine litter with Unmanned Aerial Systems: A showcase comparison among manual image screening and machine learning techniques

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[b] INESC Coimbra, Department of Electrical and Computer Engineering, Coimbra, Portugal
[c] University of Coimbra, CMUC, Department of Mathematics, Faculty of Sciences and Technology, Coimbra, Portugal

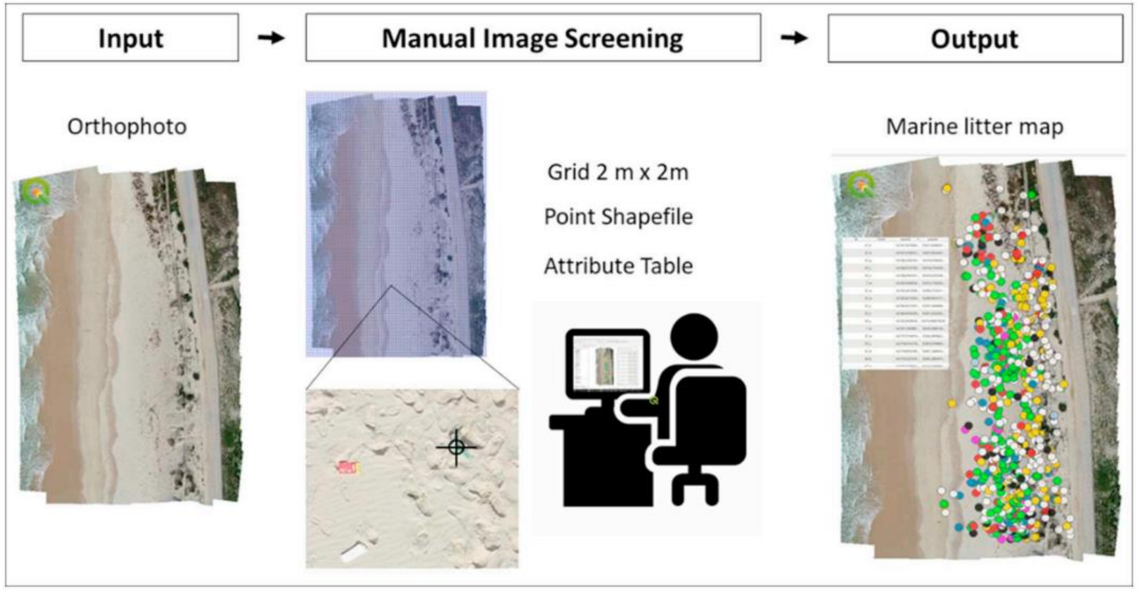


Fig. 2. Manual image screening workflow.

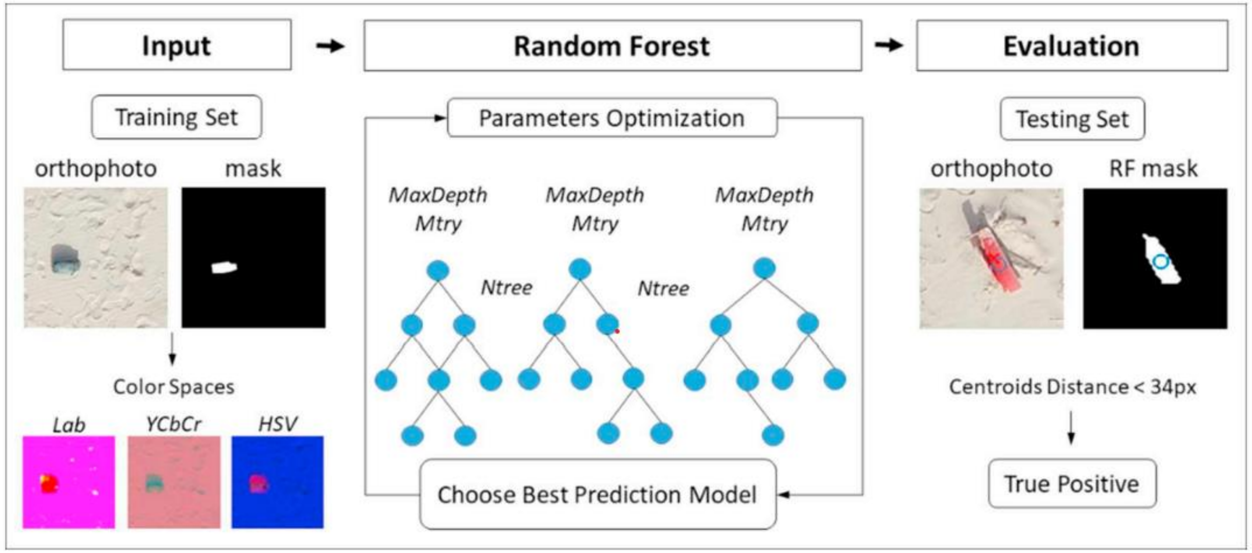


Fig. 3. Random forest workflow.

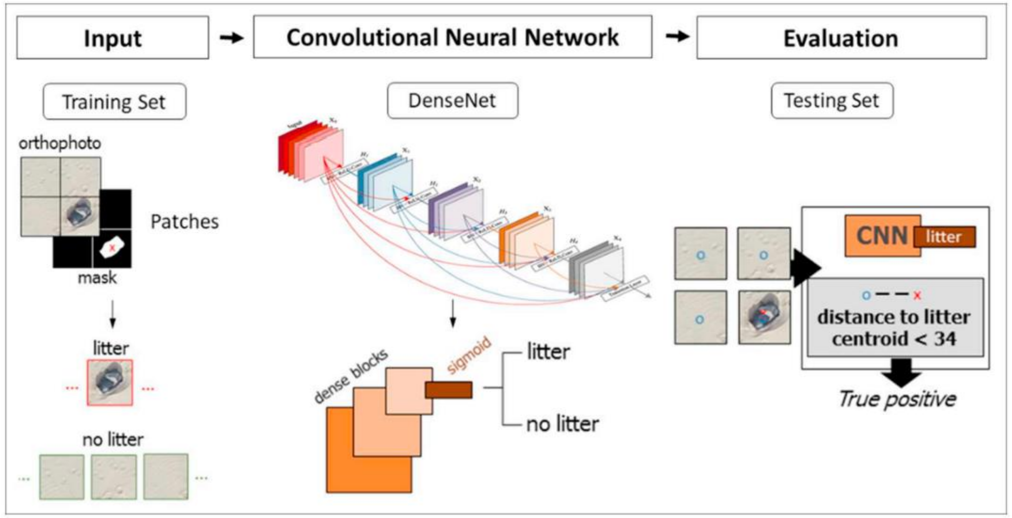
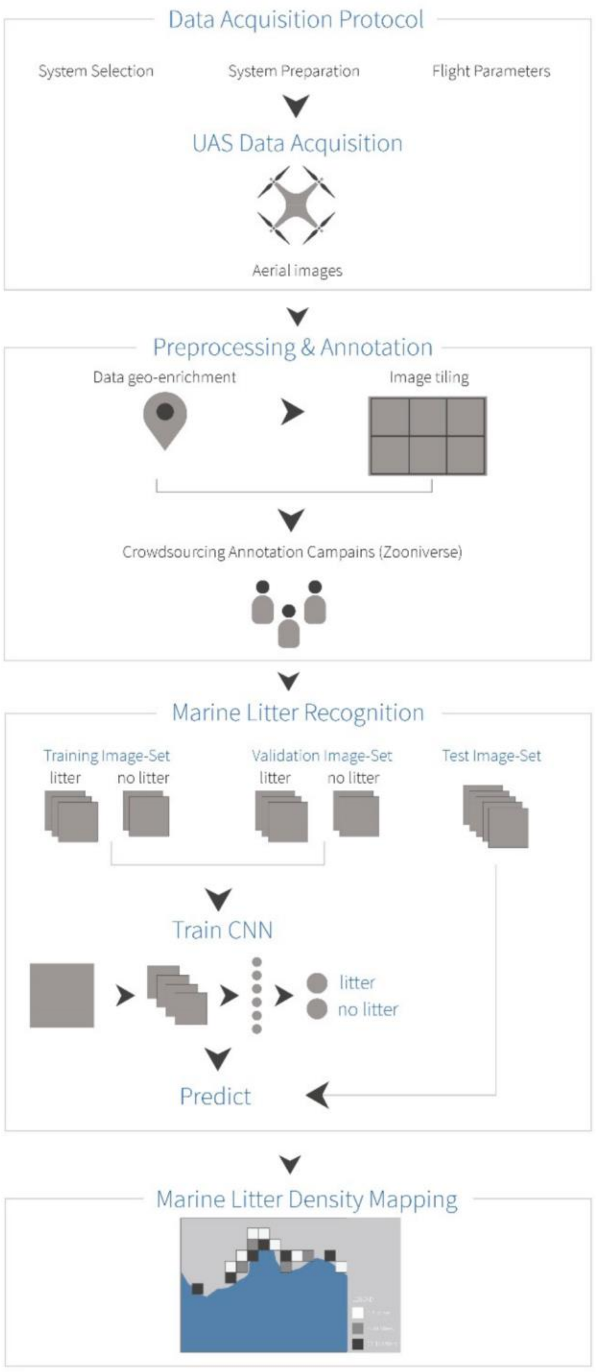


Fig. 4. Convolutional neural network workflow. DenseNet structure figure is from Huang et al. (2017).



drones

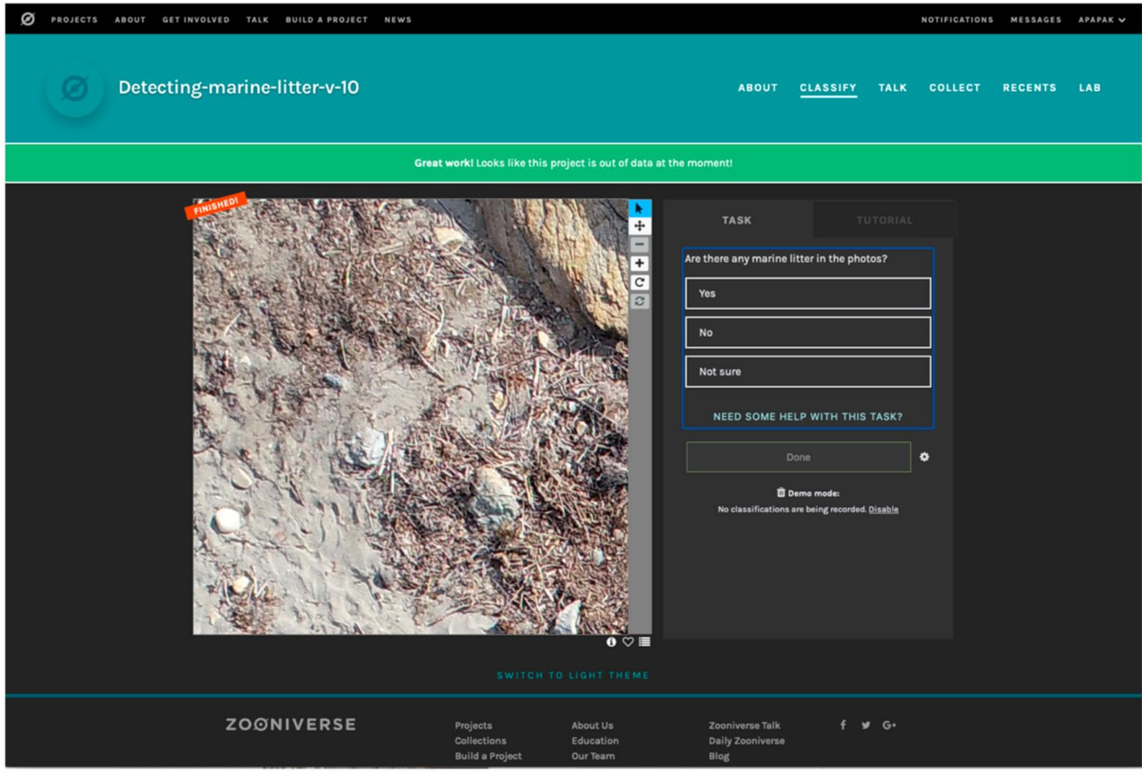
MDPI

Article

A Citizen Science Unmanned Aerial System Data Acquisition Protocol and Deep Learning Techniques for the Automatic Detection and Mapping of Marine Litter Concentrations in the Coastal Zone

Apostolos Papakonstantinou [1,*], Marios Batsaris [2], Spyros Spondylidis [1] and Konstantinos Topouzelis [1]

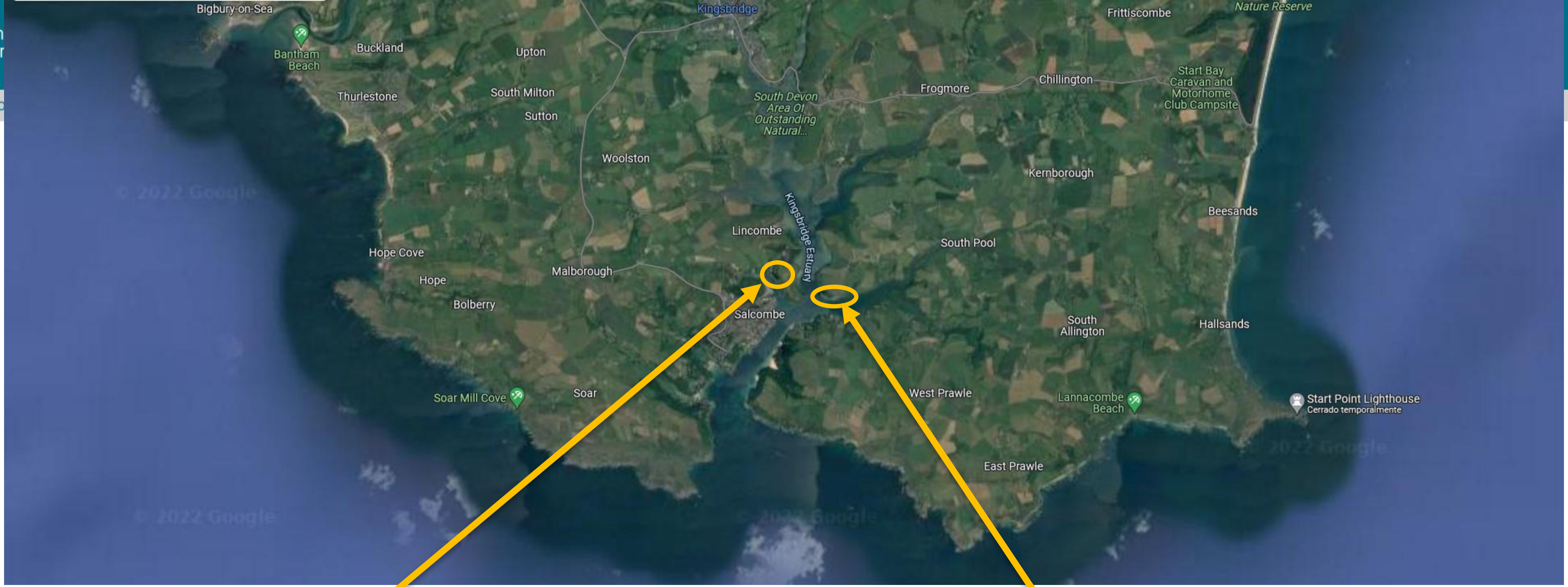
Citizen science annotation protocol combined with deep learning techniques for the automatic detection and mapping of ML concentrations in the coastal zone. Five convolutional neural networks (CNNs) were trained to classify UAS image tiles into two classes: (a) litter and (b) no litter.



Oyster Detection

Several sites have been reported in unfavourable condition, due to the alteration of the biotopes, and therefore the loss of original species and biotopes which make up the protected habitat features.

If populations are left unmanaged the expansion of dense Pacific oyster populations will most likely reduce the extent of the sites and could reduce species richness and change community composition, as well as their diversity.


Bigbury-on-Sea
Kingsbridge
Frittiscombe
Nature Reserve
Bantham Beach
Buckland
Upton
Thurlestone
South Milton
Sutton
South Devon Area Of Outstanding Natural...
Frogmore
Chillington
Start Bay Caravan and Motorhome Club Campsite
Woolston
Kernborough
Beesands
Kingsbridge Estuary
Lincombe
South Pool
Hope Cove
Malborough
Hope
Bolberry
Salcombe
South Allington
Hallsands
West Prawle
Soar Mill Cove
Soar
Lannacombe Beach
Start Point Lighthouse
Cerrado temporalmente
East Prawle
© 2022 Google

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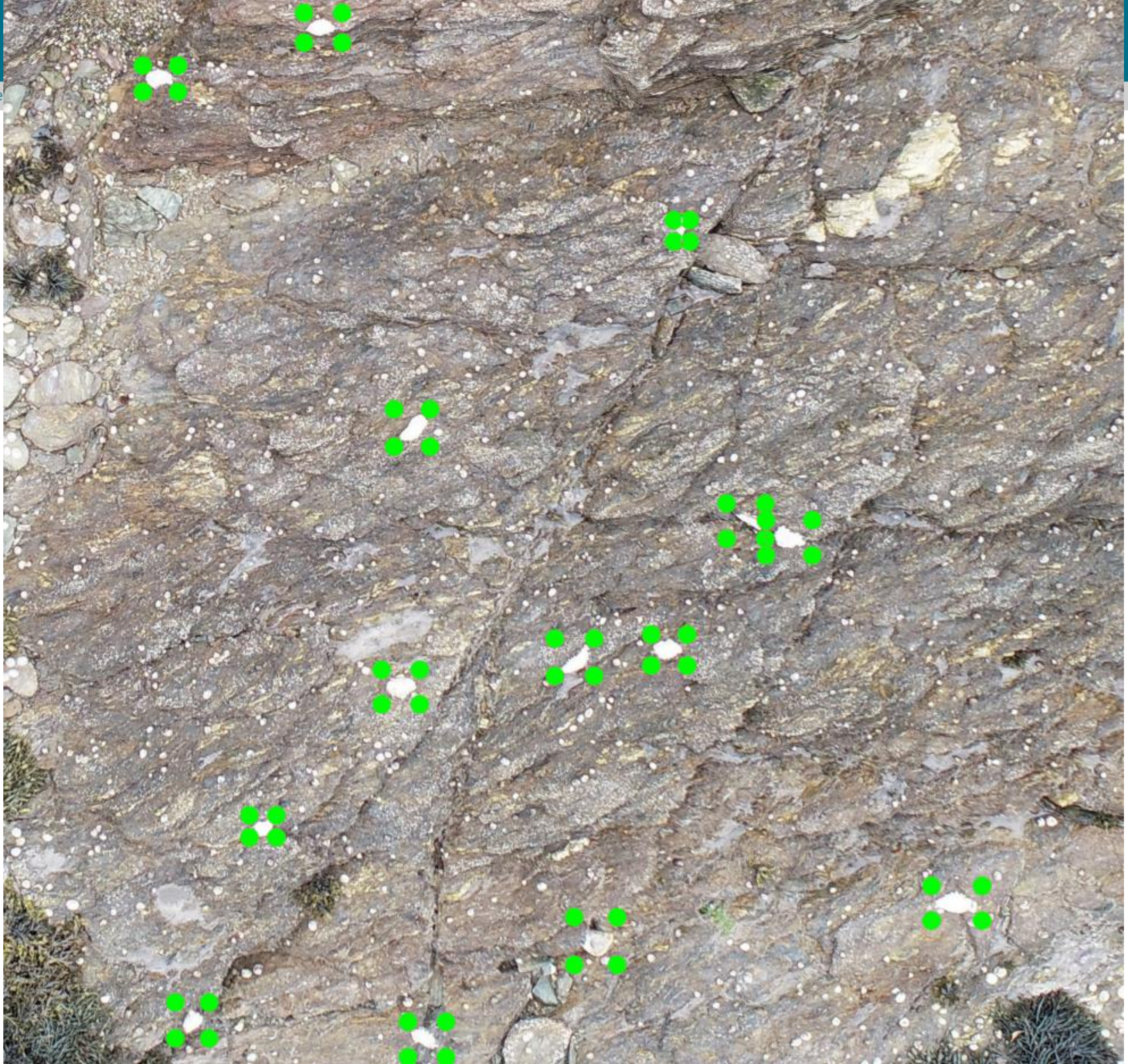
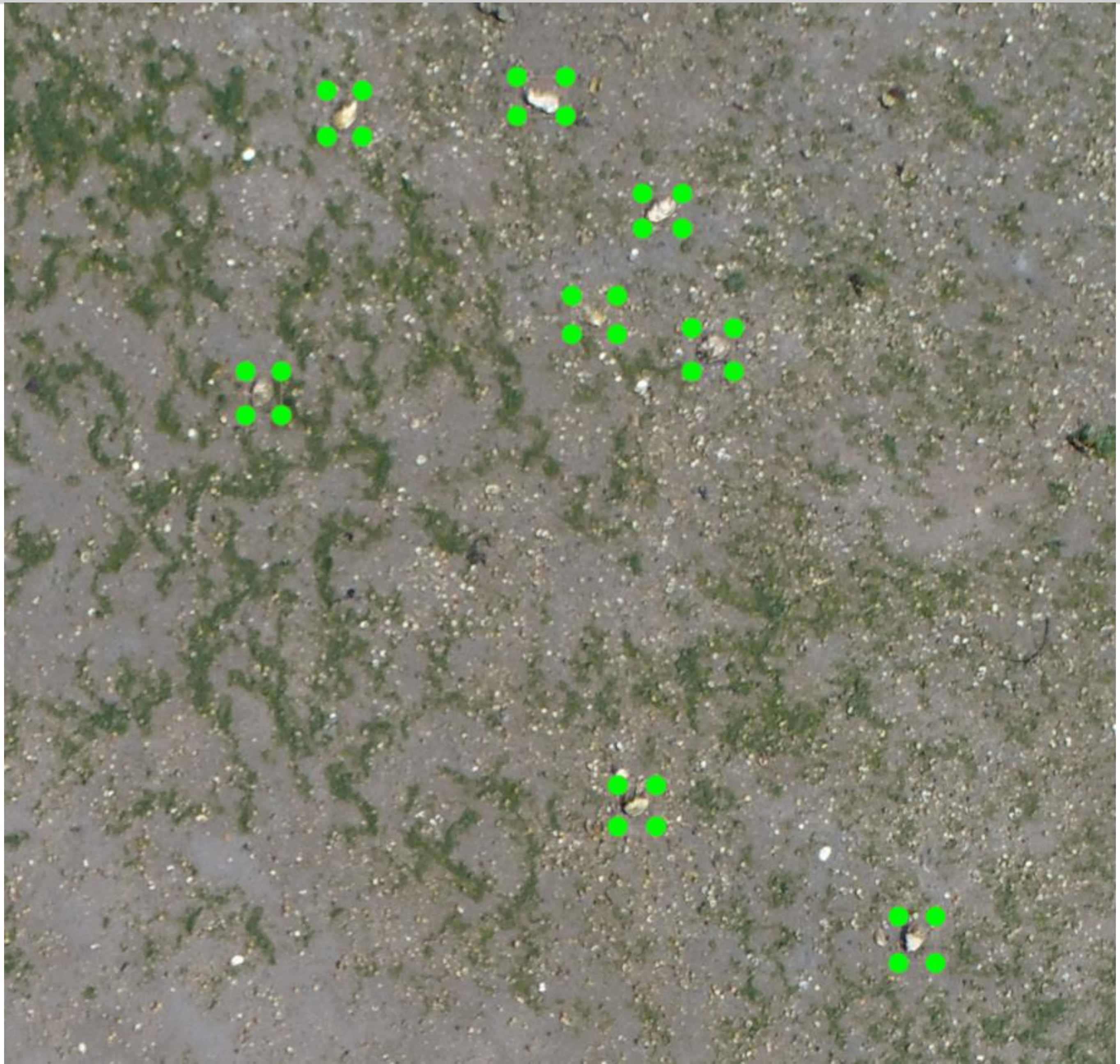
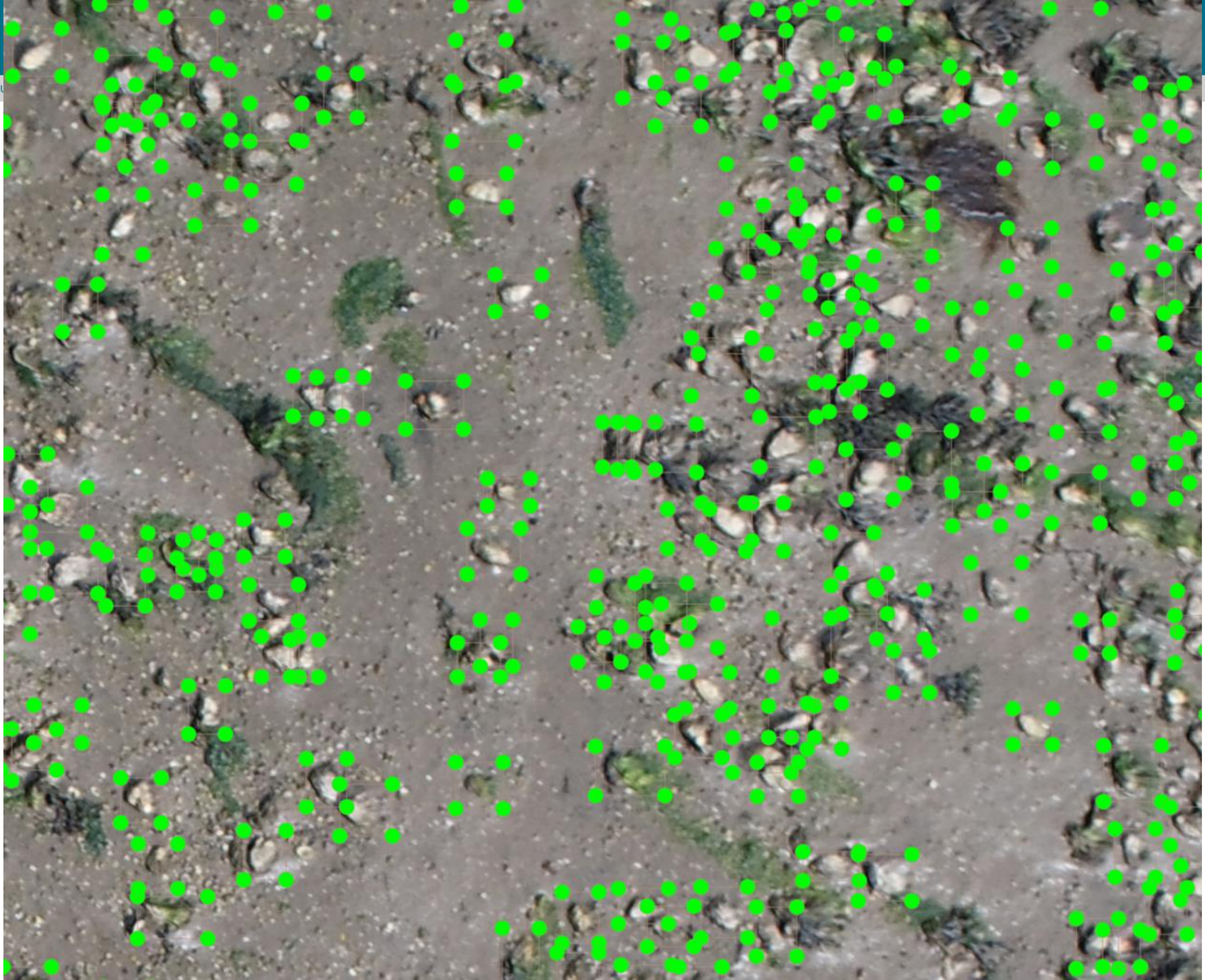


Oysters





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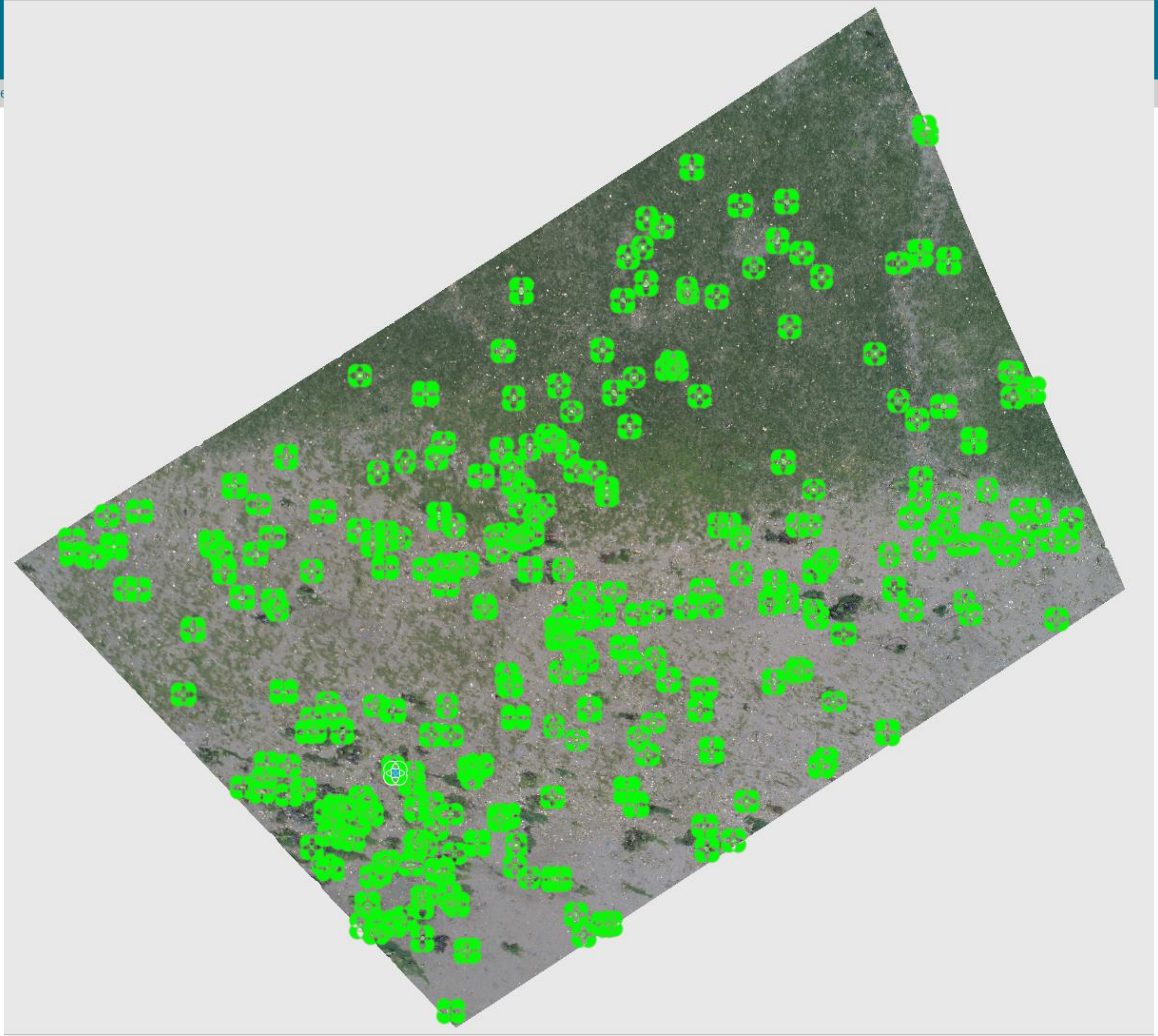


Most common multispectral sensors

Parrot Sequoia

Lens	Bandwidth *	Central Wavelength *	Resolution
GREEN	40 nm	550 nm	1.2 Mpx
RED	40 nm	660 nm	1.2 Mpx
RED-EDGE	10 nm	735 nm	1.2 Mpx
NIR	40 nm	790 nm	1.2 Mpx
RGB			16 Mpx

~£3 600

MicaSense RedEdge

Band number	Band color	Center wavelength (nm)	Band width (nm)
1	Blue (B)	475	20
2	Green (G)	560	20
3	Red (R)	668	10
4	Near infrared (NIR)	840	40
5	Rededge (RE)	717	10

[1] *https://support.micasense.com/hc/en-us/article_attachments/204648307/RedEdge_User_Manual_06.pdf accessed 18.10.2018.*

~£5 000

DJI Multispectral

~£5 750

Available at PML

STS-VIS spectrometer

-Hyperspectral spectrometer (no image)
-Range 350-800 nm, mounted on P4
-Measures radiance, needs reflectance panel to convert to reflectance.
-Currently available

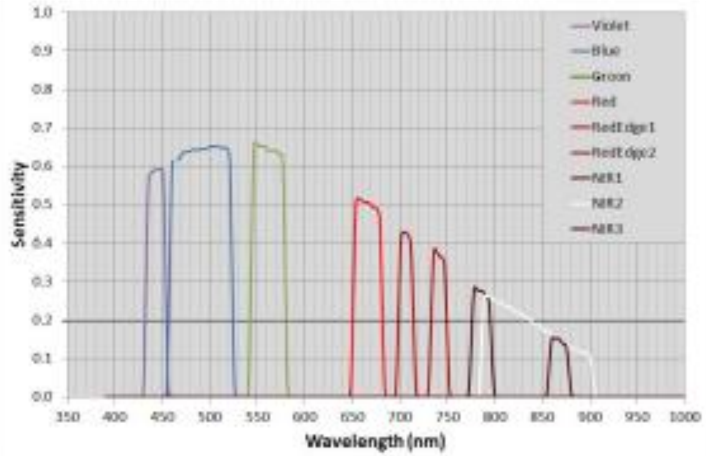
"Perfect for measuring full VNIR water leaving reflectance that can be used for water quality purposes."

~£1 200 x 2

MAIA multispectral camera

-Multispectral Imager
-9 bands on range 390-950 nm matching bands and response of Sentinel-2
-Mounted on larger DJI M100
-Downwelling sensor, allows conversion to reflectance
-Expected early June 2020 (NEODAAS and NERC-FSF partnership)

"Ideal for high-res spatial mapping and validation of satellite data, especially for Sentinel-2".



~£15 000

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HyperDrone

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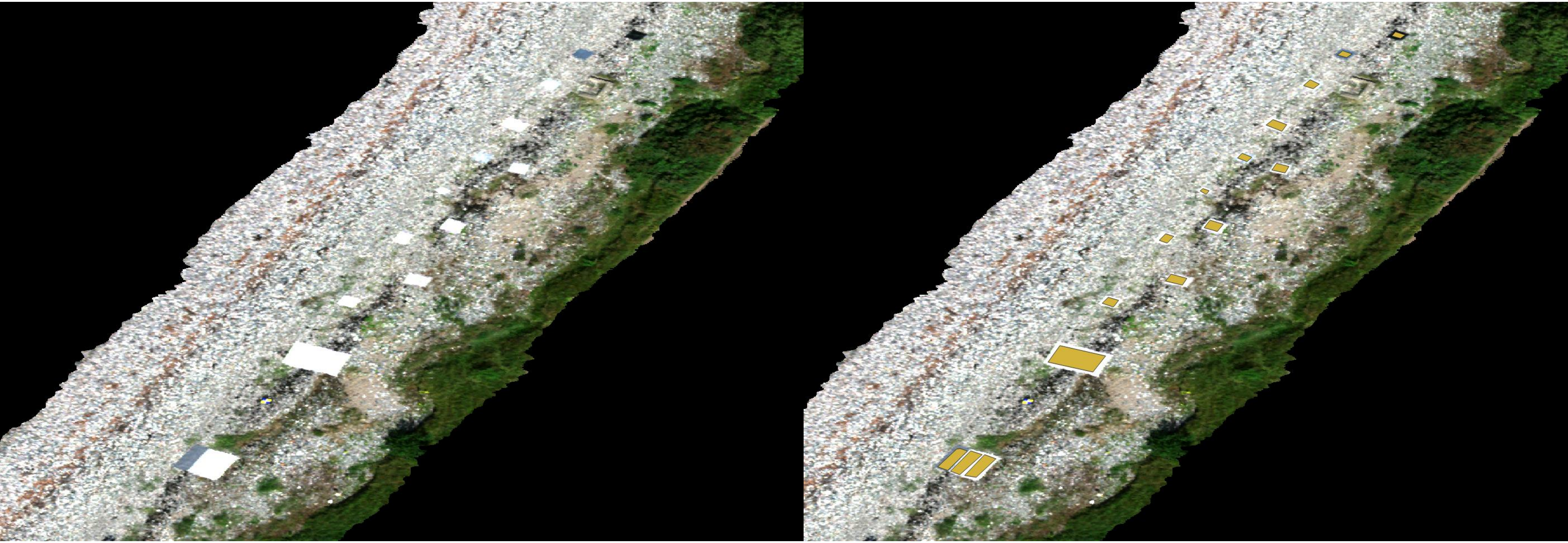
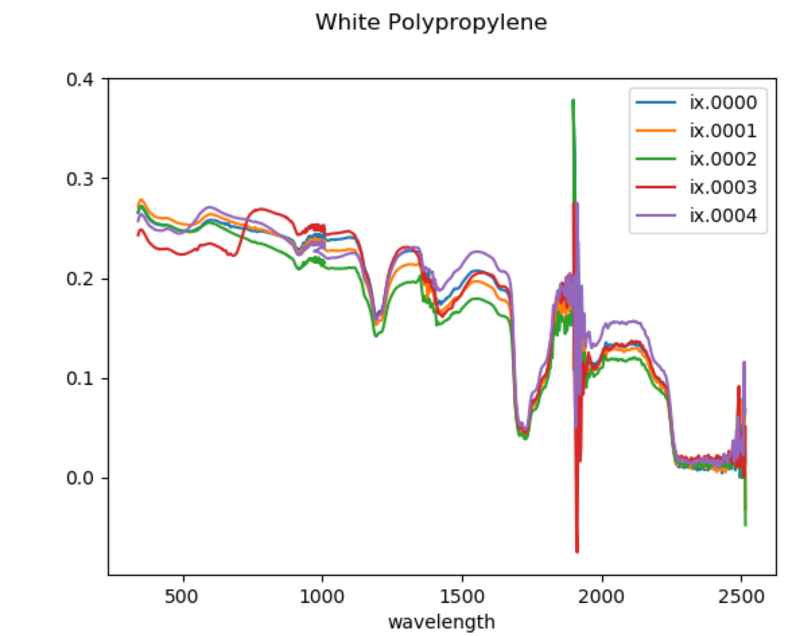


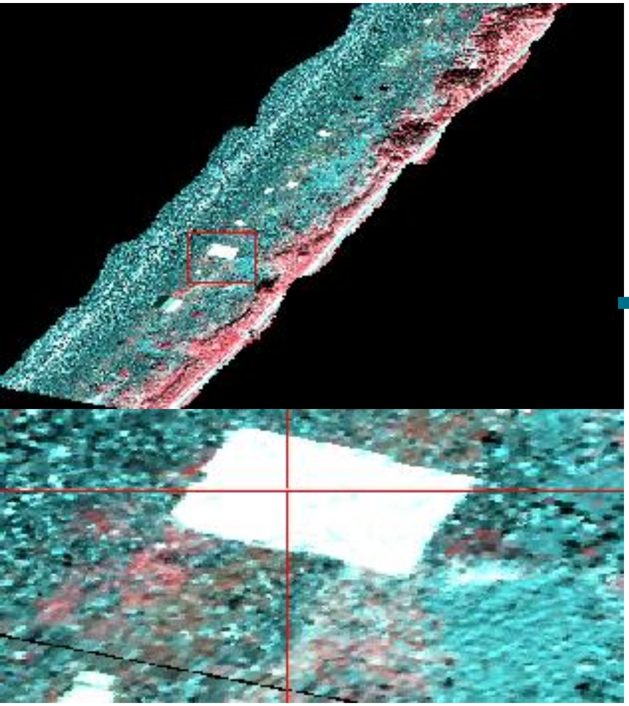
-Targets deployed on zig zag pattern to avoid pixel bleeding (specially if it saturates)
-Targets should be at least 8-10 times bigger than the pixel size.
-Avoid using pixels in the edge for your analysis

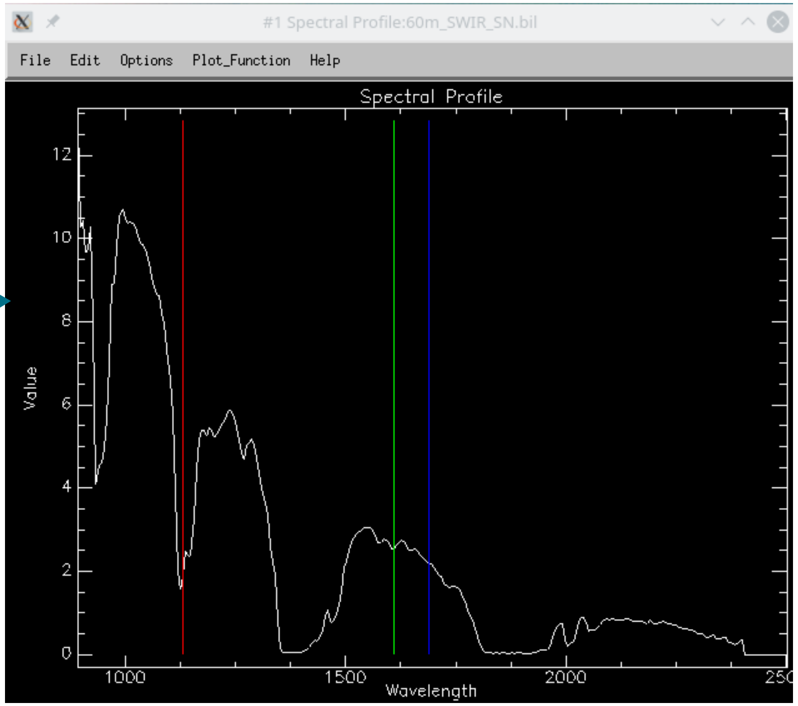
-Assuming light conditions are constant, can convert from radiance to reflectance by using an empirical calibration method.

-In situ data needs to be filtered and account for sections where the internal sensor change (bands are removed).

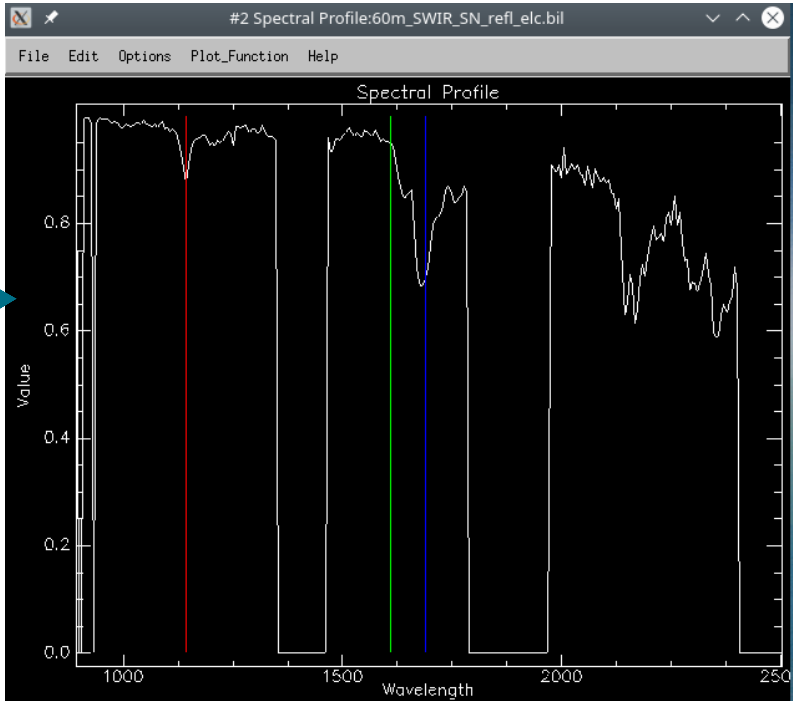
-Atmospheric water absorption bands masked





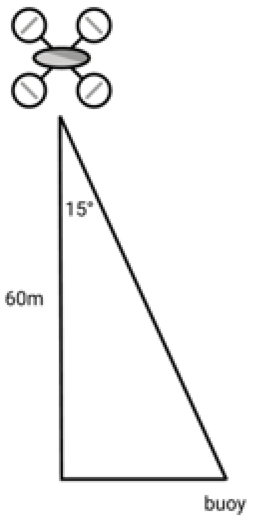


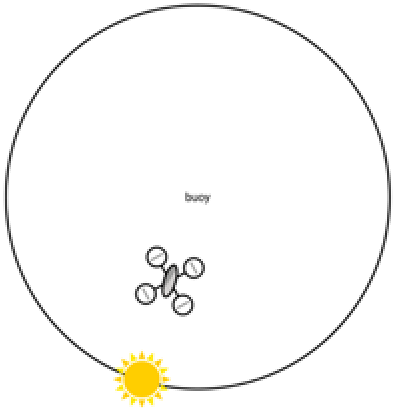
Radiance

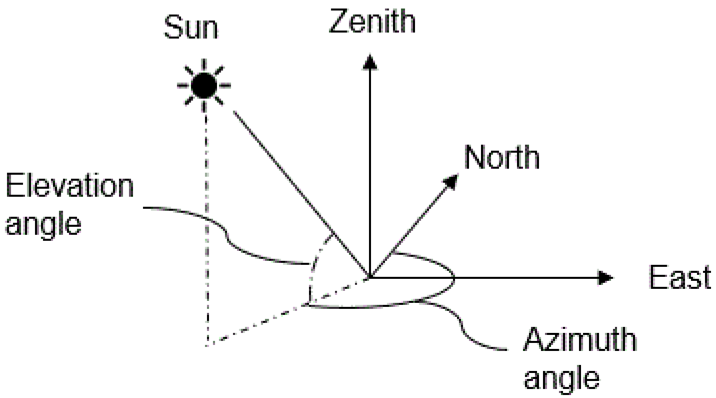


Reflectance

Avoiding water sunglint







hh:mm	Elevation angle	Azimuth angle
11:30	59.58	155.42
11:45	60.44	162.16
12:00	61.03	169.19
12:15	61.33	176.38
12:30	61.33	183.64
12:45	61.02	190.84
13:00	60.43	197.86
13:15	59.56	204.60
13:30	58.45	211.01
13:45	57.11	217.04
14:00	55.58	222.68
14:15	53.88	227.95
14:30	52.04	232.85
14:45	50.08	237.43
15:00	48.02	241.71
15:15	45.87	245.73
15:30	43.66	249.53
15:45	41.40	253.12

- **Position the camera under an angle of 15° from nadir (to avoid sun glint)**
- During the flight, the camera should point away from the sun (under an angle at or near 135° from the solar azimuth)
- Check maximum flying altitude, range, … allowed by the local drone legislation
- Hover at the beginning and end of each flight over the spectral reference targets and take at least 3 pictures.

MONOCLE
Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries

Best Practices

-Ensure to have good overlap in images to create **orthomosaic** using SfM (minimum 60% forward, 40% sideways, ideally more)
-Use Ground Control Points to get the best geocorrection possible
-Avoid moving features (people in the image, vessels…)
-Avoid saturation, direct reflection and sunglint from water bodies
-Consider different camera angles for complex terrain

<u>When collecting radiometric data:</u>
-Set integration times depending on illumination and scene
-Ensure the instrument is well calibrated
-Collect calibration data during flight (or at least before and after)
-Use downwelling sensors if possible (and microtops)
-Deploy well known reflectance panels in zig-zag
-Collect simultaneous in-situ data from target (area of interest), background and calibration targets.

Drone regulations

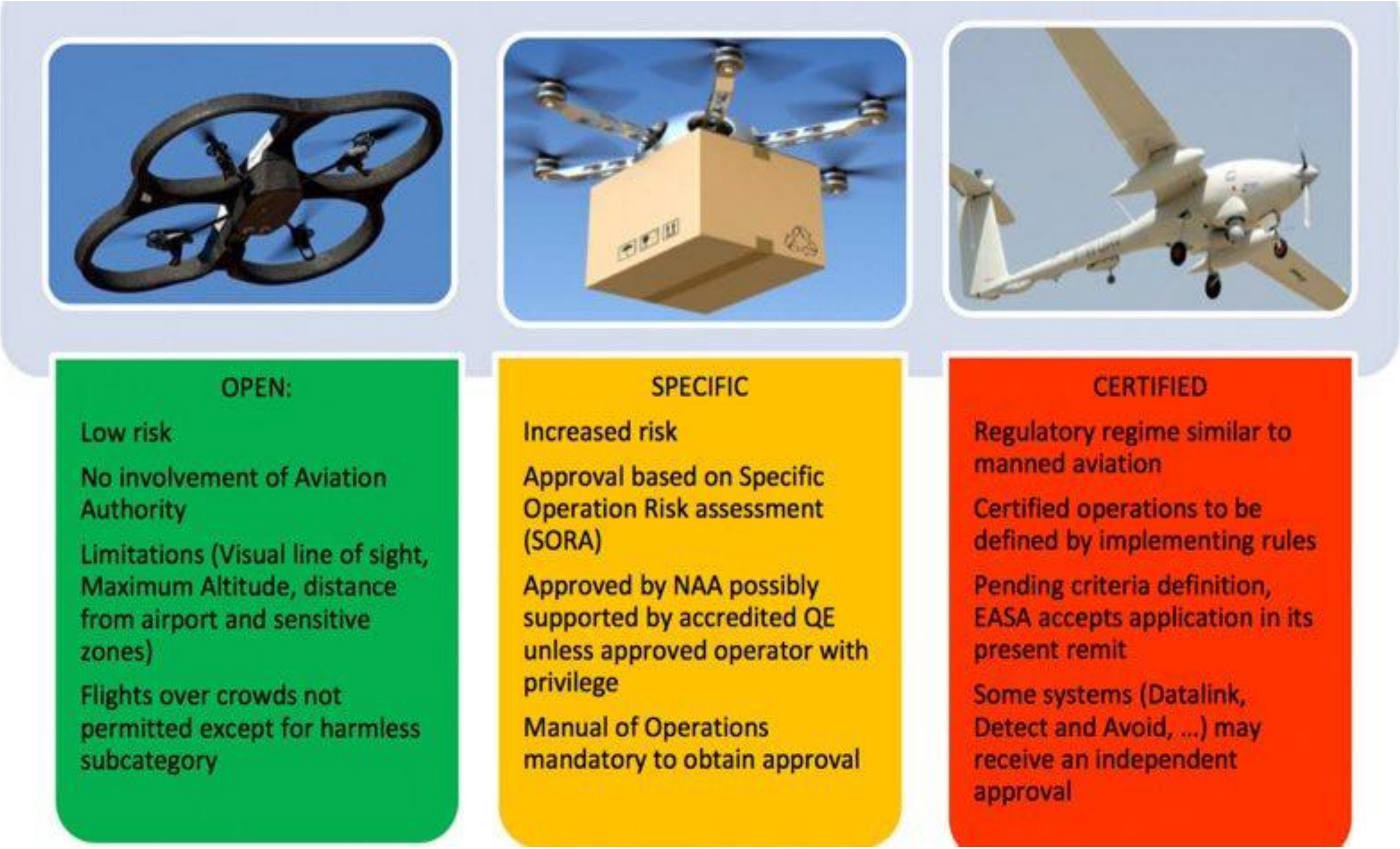
- Regulations are different in different countries
- International Civil Aviation Organization establish minimum safety criteria
- The Civil Aviation Authority (CAA) creates drone regulations in **UK**
- Each country can make regulations stricter
- Generally speaking, European regulations are similar to those in UK

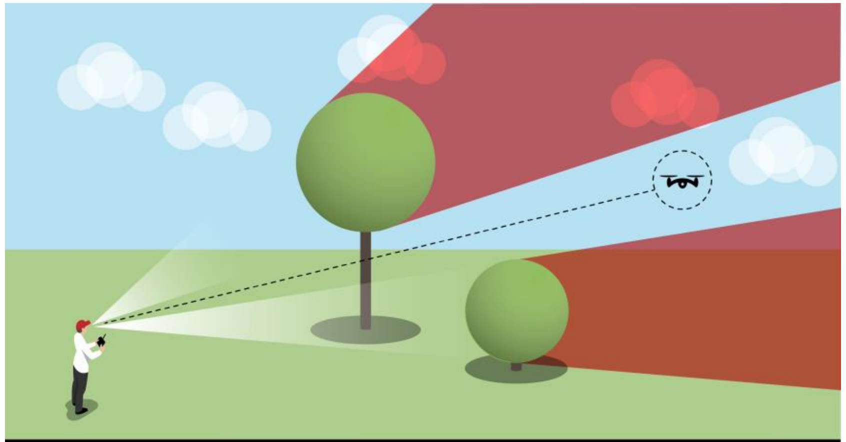
If you want to fly, you need to start considering looking at different regulations at an early stage.
For example:
- Special requirements in your area: Is it a national park, is it nearby Danger Area, do you need landowner permission...
- **India:** Drones can't be imported, they are confiscated at airport
- **Vietnam:** All flight missions must be submitted and approved before entering the country or drones will be confiscated at airport

The General VLOS Certificate (GVC) is a remote pilot competency certificate which has been introduced as a simple, 'one stop' qualification that satisfies the remote pilot competency requirements for VLOS operations within the Specific category. Practical flight test + theoretical test

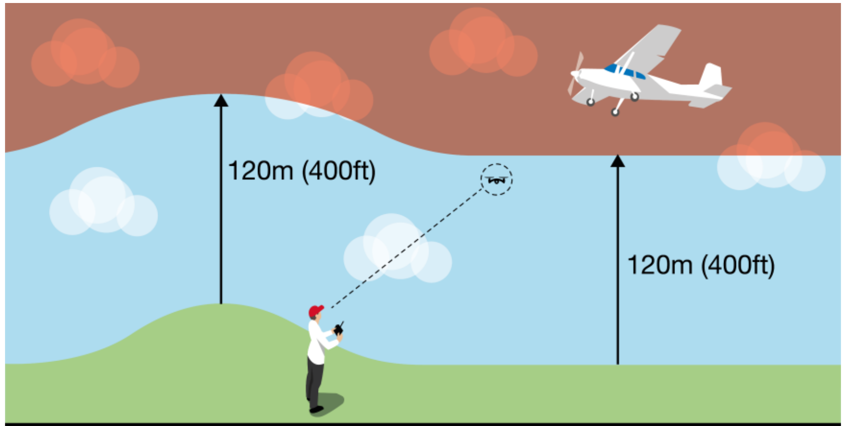
It's worth noting that the main goal of an operational license **addresses the safety aspects of the flight**.
- Pilot is trained to operate the drone, understand aviation rules and how to mitigate risks
- A valid liability insurance
- Each flight needs: Pre-deployment and deployment risk assessments and flight logs (yearly submitted to CAA)

Current Drone Categories

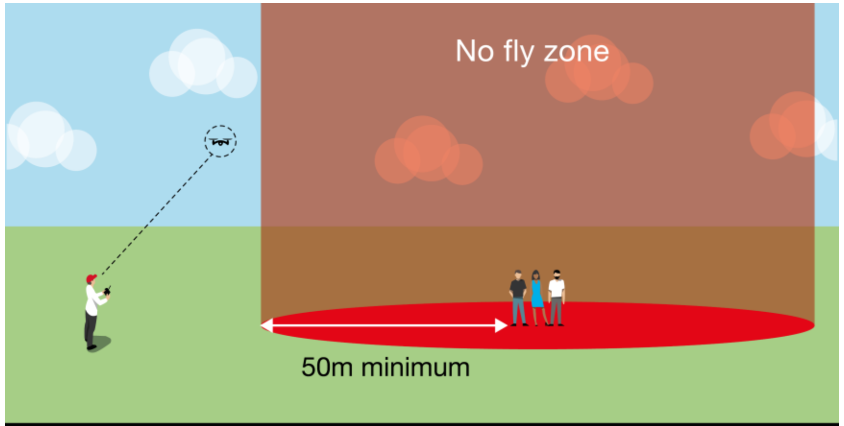




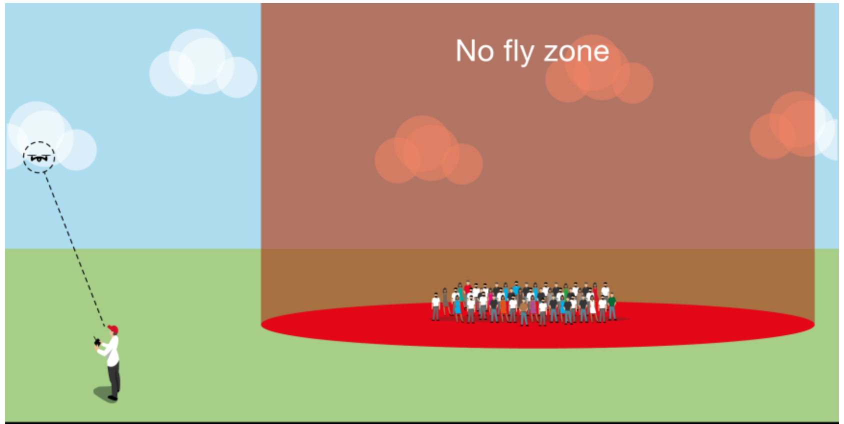
Always keep your drone or model aircraft in direct sight.



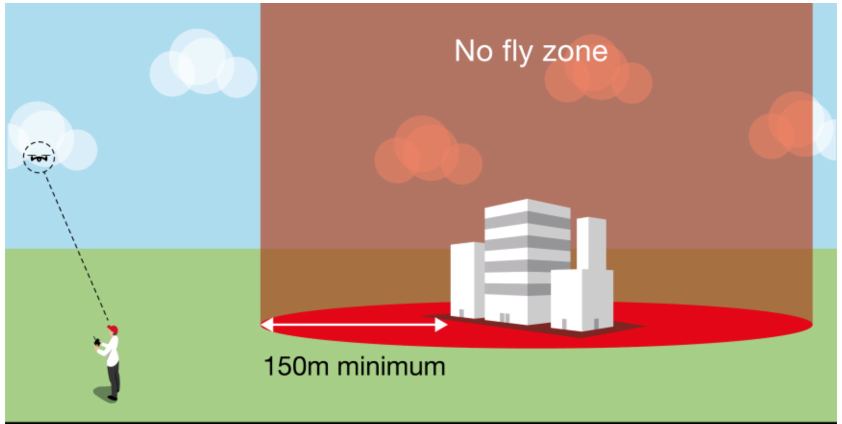
Never fly more than 120m (400ft) above the earth's surface.



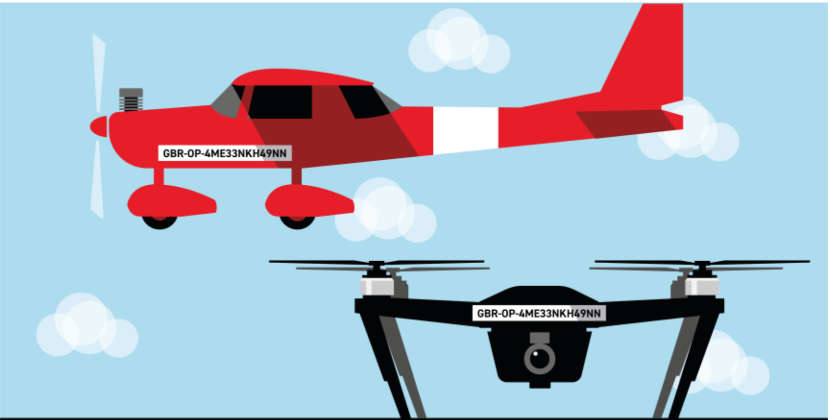
Do not fly closer to people than 50m.



Never fly where people have gathered in crowds or groups.

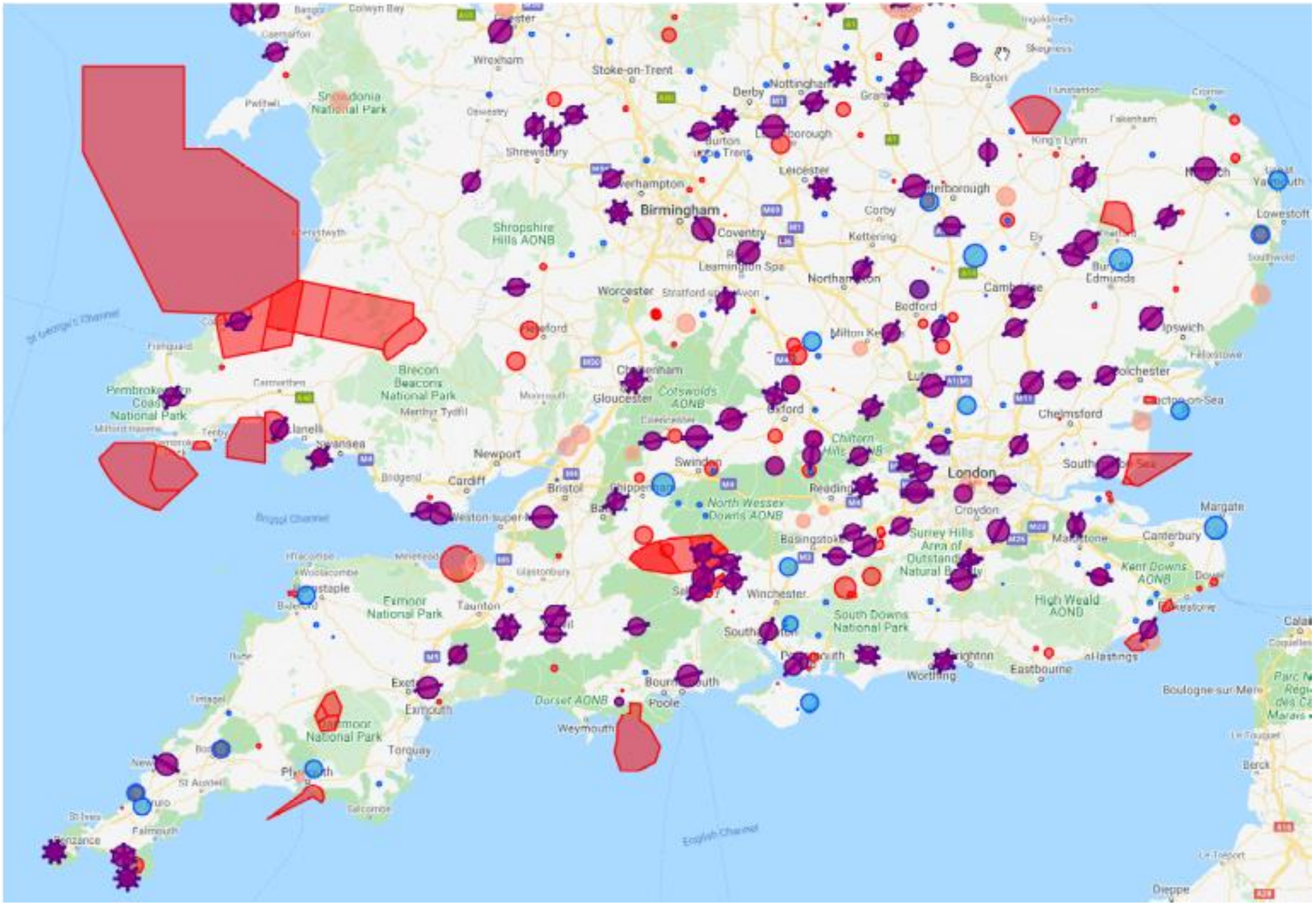


Keep at least 150m away from residential, recreational, commercial and industrial areas.



You must label your operator ID on every drone or model aircraft you're responsible for. You can use the same operator ID for every aircraft.

Stay away from restricted airspaces

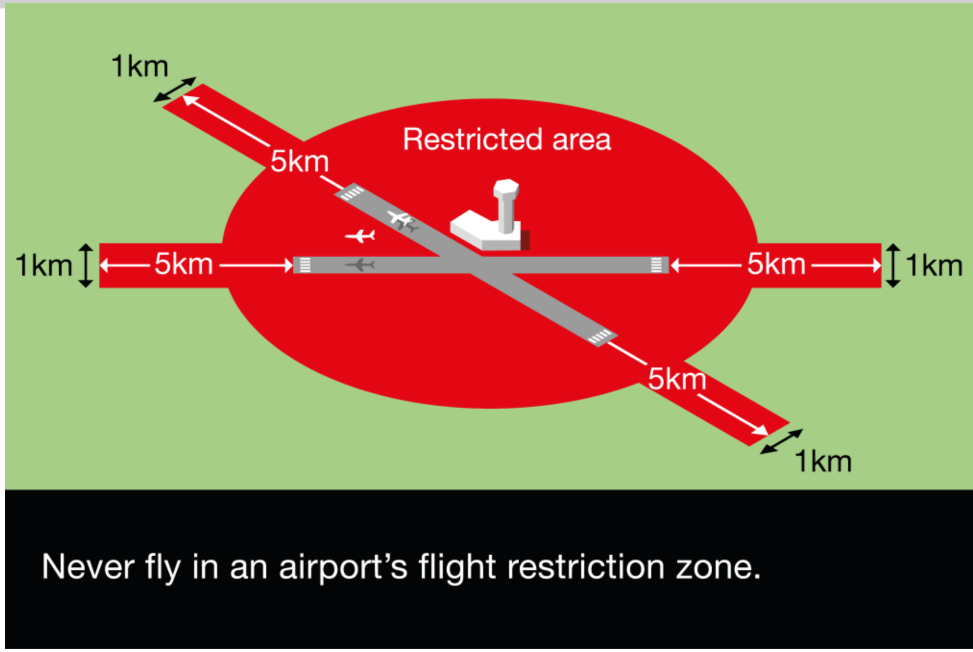


-Most manufacturers include software that prevents drones flying at airports (Aircraft will not take off or land if it enters the area)

-NOTAMs (Notice to Airmen such as air shows, fireworks…) and Danger Areas might be active in your area. Those are not on display in the drone software and must be accounted for.

-Local restrictions also apply. (For example no drone can fly over Dartmoor without permission)

-Pilot must be trained to know how to find those hazards and comply



UAS	Operation		Drone operator/pilot		
Max weight	**Subcategory**	**Operational restrictions**	**Drone operator registration**	**Remote pilot competence**	**Remote pilot minimum age**
< 250 g	A1 (can also fly in subcategory A3)	— No flight expected over uninvolved people (if it happens, overflight should be minimised) — No flight over assemblies of people	No, unless camera / sensor on board and the drone is not a toy	— No training required	No minimum age
< 500 g			Yes	— Read carefully the user manual — Complete the training and pass the exam defined by your national competent authority or have a 'Proof of completion for online training' for A1/A3 'open' subcategory	16*
< 2 kg	A2 (can also fly in subcategory A3)	— No flying over uninvolved people — Keep a horizontal distance of 50 m from uninvolved people	Yes	— Read carefully the user manual — Complete the training and pass the exam defined by your national competent authority or have a 'Remote pilot certificate of competency' for A2 'open' subcategory	16*
< 25 kg	A3	— Do not fly near or over people — Fly at least 150 m away from residential, commercial or industrial areas	Yes	— Read carefully the user manual — Complete the training and pass the exam defined by your national competent authority or have a 'Proof of completion for online training' for A1/A3 'open' subcategory	16*

DO

- Make sure you are adequately insured
- Check for no-fly zones and any limitations in the area where you want to fly
- Keep the drone in sight at all times
- Maintain a safe distance be-tween the drone and people, animals and other aircraft and of at least a distance of 150m from residential, commercial, industrial and recreational areas
- Inform your national aviation authority immediately if your drone is involved in an accident that results in a serious or fatal injury to a person, or that affects a manned aircraft
- Operate your drone within the limits defined in the manufacturer's instructions

DO NOT

- Do not fly higher than 120m from the ground
- Do not fly near aircraft & in the proximity of airports, helipads or where an emergency response effort is ongoing
- Do not infringe other people's privacy.
- Do not record intentionally or publish photographs, videos or audio recordings of people without their permission
- Do not use the drone to carry dangerous goods or to drop material
- Do not modify your drone. Only software uploads recommended by the drone manufacturer are allowed

-Mission Planning
-Drone flies autonomously collecting images with the given overlap percentage in a pre-set altitude

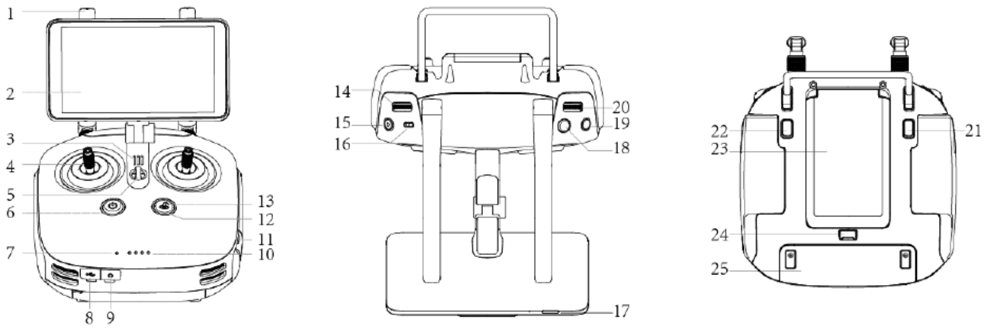
Orthomosaic map from South West part of St John's Lake (Cornwall)

Planning the mission

-Google Maps
-Notam maps
-DJI Geo Zone Map
-Altitude Angel Map

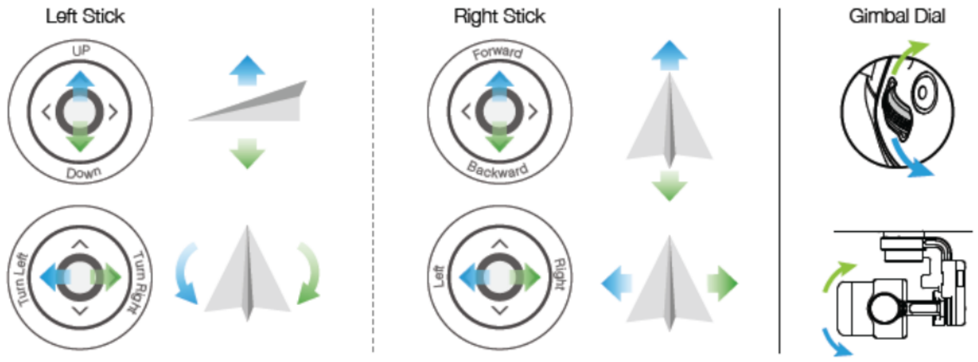
-DJI GS Pro
-Pix4D capture
-Litchi

Risk Assessment



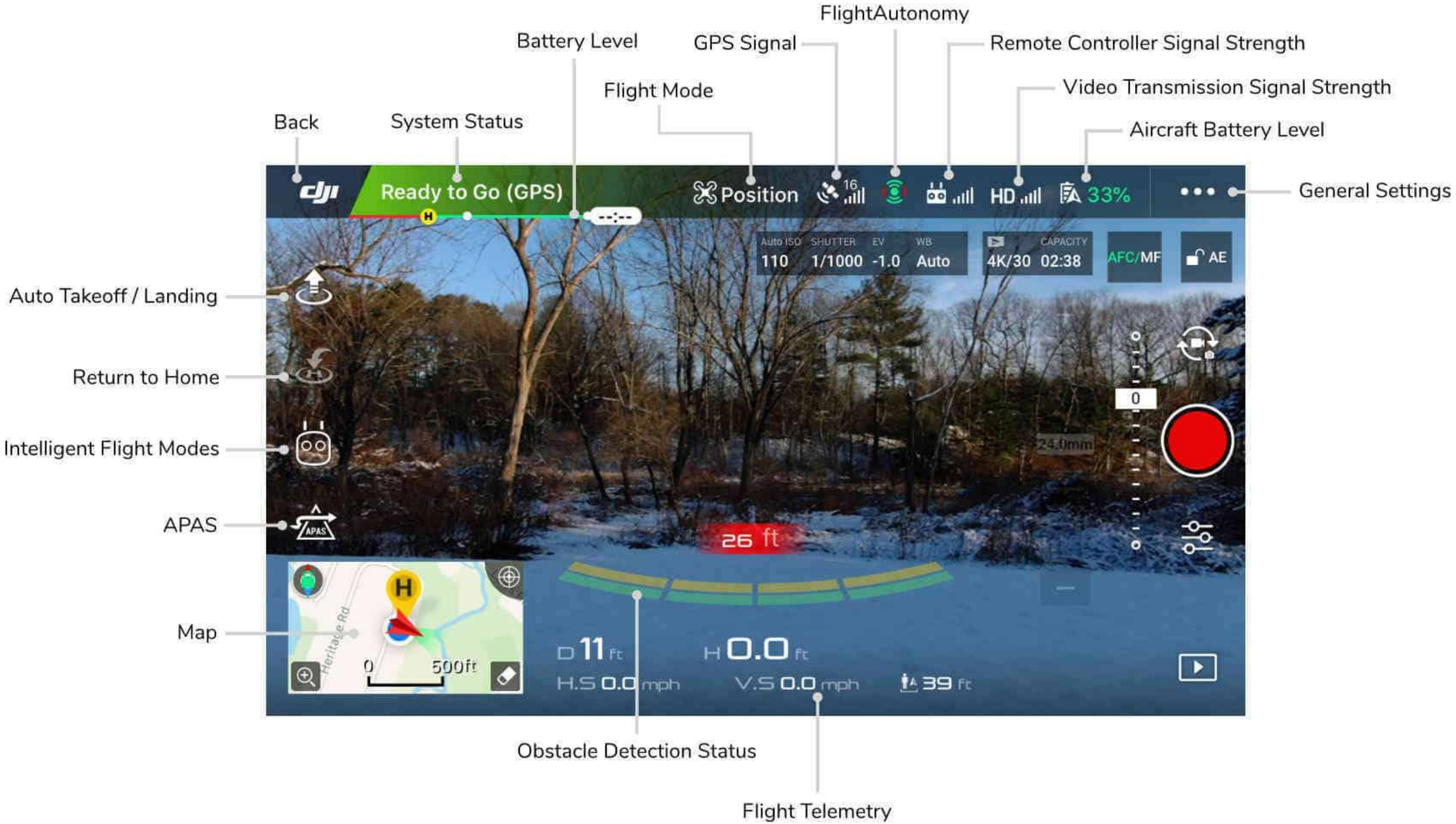
1 Antennas	10 Battery Level LEDs	19Pause Button
2Display Device	11 Micro SD Card Slot	20 Camera Settings Dial
3 Speaker	12 RTH Status LED	21 C1Button (customizable)
4 Control Sticks	13 RTH Button	22 C2Button (customizable)
5 Lanyard Attachment	14 Gimbal Dial	23 Battery Compartment Cover
6Power Button	15 Record Button	24Battery Compartment Cover Lock
7 Status LED	16 Flight Mode Switch	25Remote Controller Back Cover
8 USB-CPort	17 Sleep/Wake Button	
9 3.5 mmAudio Port	18 Shutter Button	

The default flight control is known as Mode 2. The left stick controls the aircraft's altitude and heading, while the rightstick controls its forward, backward, left and right movements. The gimbal dial controls the camera's tilt.



*The remote controller is able to reach its maximum transmission distance (FCC) in a wide openarea with no Electro-Magnetic Interference, and at an altitude of about 400 feet (120 meters).

Drone app overview



Thank you