UAS (Drones) for forest health and inventory

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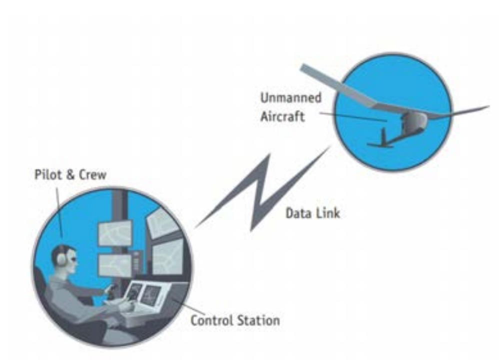
What is an UAS?

Unmanned (or Uncrewed) - without a person onboard(operated by automatic or remote control)

Aerial/Aircraft – able to fly

System - associated elements related to safe operations (may include control stations, control links, support equipment, payloads, flight termination systems, and launch recovery equipment)



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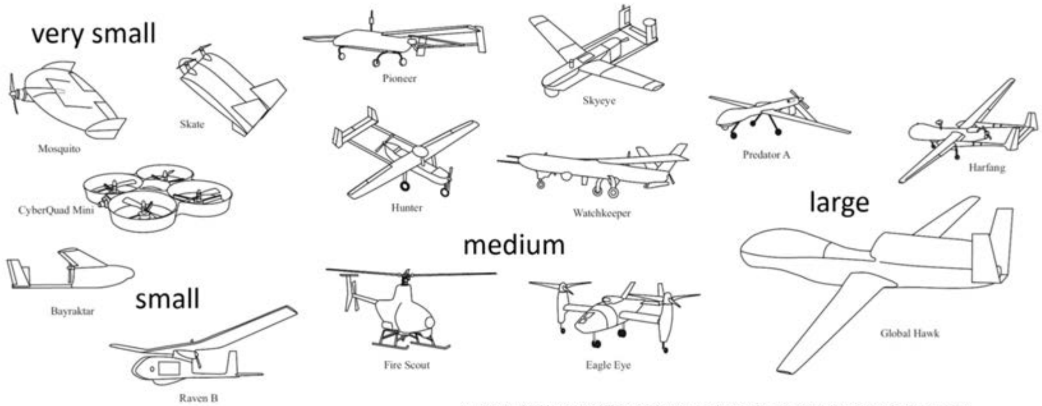
How does an UAS look like?



Source: Paul Fahlstrom and Thomas Gleason, 2012, Introduction to UAV Systems, 4th edition, Wiley

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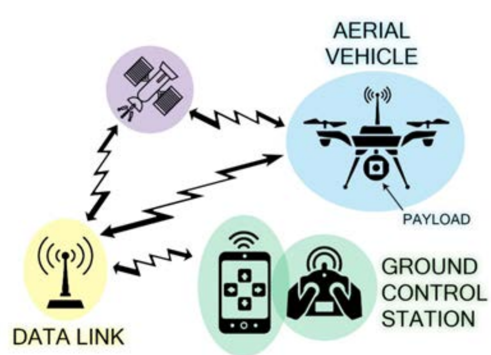
Generic Unmanned Aircraft System

- Air vehicle
- Mission planning element
- Command and control element
- Communication link
- Launch and recovery element (for some of them)
- Payload



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UAS sensors

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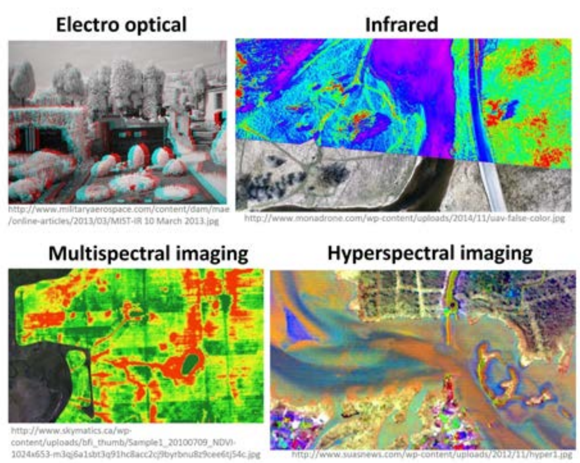
UAS sensors for mapping

- RGB cameras
- Infrared sensors
- Multispectral and hyperspectral sensors
- Laser scanners
- Thermal sensors



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RGB (natural color) cameras

Most common payload for consumer grade UAS

Photo or video mode

Mapping (orthophoto and DSM generation) possible even with non-photogrammetric cameras

Variety of cameras, lenses and mounting systems - some suitable for 3D modeling

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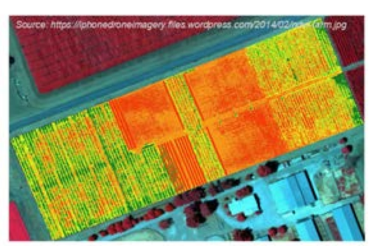
Multispectral and hyperspectral cameras

Miniaturization is challenging in terms of optics and sensor calibration

Weight, cost, data quality has improved; spectral bands, resolution need improvements

Cameras with NIR band: agriculture and vegetation mapping (for NDVI)

The more bands the more information, but also higher price of the sensor (multispectral - couple thousands, hyperspectral - tens of thousands $)



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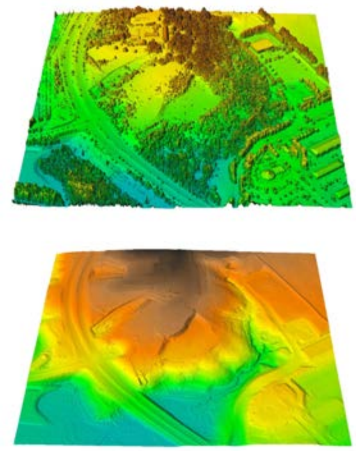
Active sensors - LiDAR and SAR

Active sensors can reach bellow-canopy ground surface

Large trade-offs between performance and size or cost of LiDAR

LiDAR now common on UAS thanks to miniaturization

SAR (Synthetic Aperture Radar) used experimentally, still faces challenges in adaptation to UAS



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Thermal imaging

Used in forest fire monitoring, search and rescue missions

For mapping purposes coupled with visible band sensors (see example FLIR Vue Pro R)

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Drone design

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Sensor and platform integration

The optimal combination of carrier (Unmanned Vehicle) and sensing payload needs to be determined based on:

Volume, size and weight specifications

Specific application requirements

Mounting: integrated by manufacturer or custom solutions

The sensors must be adapted to the carrier and vice versa

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It's not only about a drone

HARDWARE	SOFTWARE
UAS; sensor (camera)	flight planning (and management)
GCP equipment (panels & GPS)	data processing (photogrammetry)
workstation (computer)	data analysis (GIS & 3D modelling)

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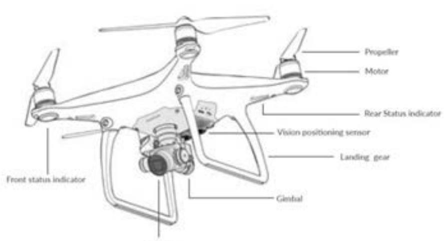
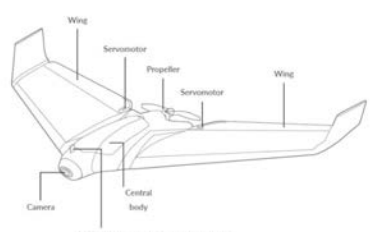
Two main types of UAS

Multi-rotor (rotary)



Fixed wing



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Fixed wing vs. Multi-rotor

Multi-rotor/Fixed-wing UAS Comparison

Maneuverability	✓	✗
Price	✓	✗
Size / Portability	✓	✗
Ease-of-use	✓	✗
Range	✗	✓
Stability	✗	✓
Payload Capacity	✓	✗
Safer Recovery from Motor Power Loss	✗	✓
Takeoff / Landing Area Required	✓	✗
Efficiency for Area Mapping	✓	✗

Source: DroneDeploy's 2017 Drone Buyer's Guide

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UAS rules and regulations

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Types of UAS operations

FAA (Federal Aviation Adminiostration) distinguishes 3 main types of operations

Different rules apply for legal operations of UAS depending on the type of UAS operations

Additional type - educational use can be considered as recreational or commercial

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Commercial use - Remote Pilot requirements

Must be at least 16 years of age

Must hold a remote pilot airman certificate with a small UAS rating or be under the direct supervision of someone holding a remote pilot airman certificate

Must pass the applicable Transportation Security Administration (TSA) vetting

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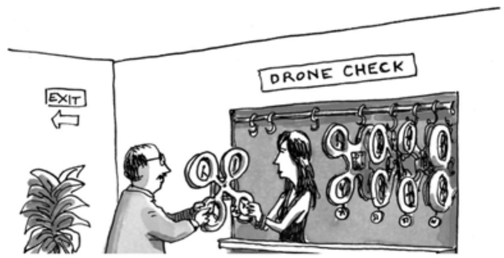
Commercial use- UAS requirements

Must weight less than 55 lbs.

Must undergo pre-flight check by remote pilot in command (or the person supervising the operation)

Must be registered and the registration number must be displayed on the aircraft



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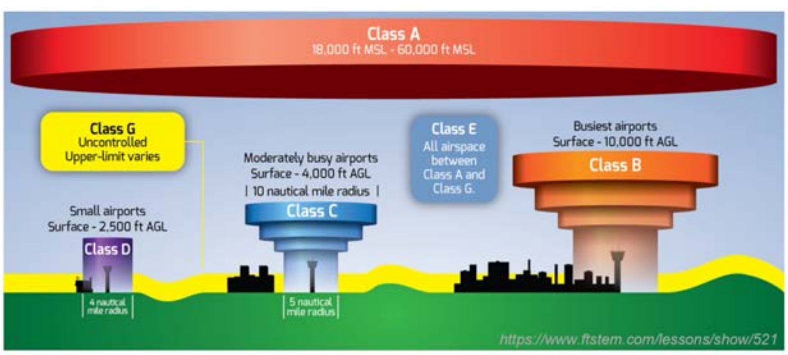
Commercial use- location requirements



Class B/C/D May operate with permission from local Air Traffic Control
CLASS E/G – May operate while following all other regulations

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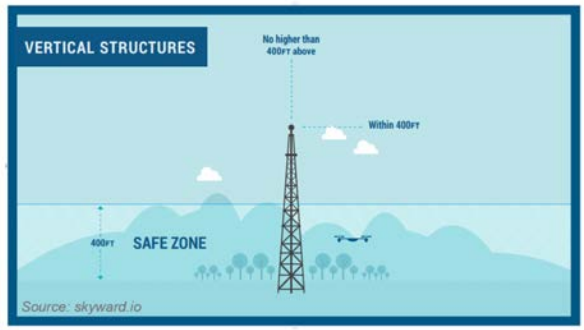
Commercial use - operating rules

Must fly under 400 feet above ground level (AGL) or, if flying at an altitude higher than 400 feet AGL, stay within 400 feet of a structure.

Must not fly from a moving vehicle unless you are in a sparsely populated area

Must fly at or below 100 mph



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Commercial use - operating rules

Must fly during daylight hours or civil twilight hours (30 minutes before official sunrise to 30 minutes after official sunset, local time) with appropriate anti-collision lighting

Must yield right of way to manned aircraft

Source: https://pbblogassets.s3.amazonaws.com/uploads/2016/09/UAS_Drone_Commercial_Use_Waiver_Registration.jpg

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Commercial use - operating rules

Must keep the UAS in sight (i.e. visual line of sight), either by the remote pilot in command or a visual observer

Must not fly over people

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Flight planning

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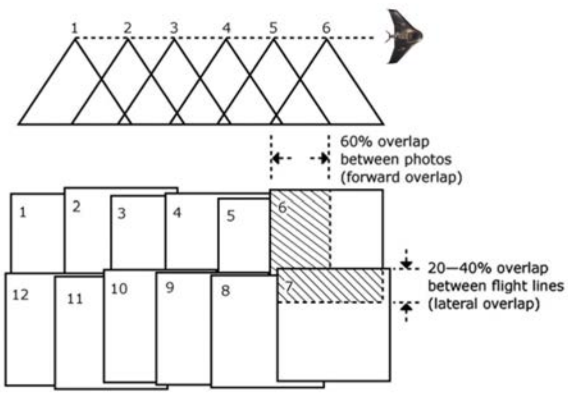
How to plan a mapping flight?



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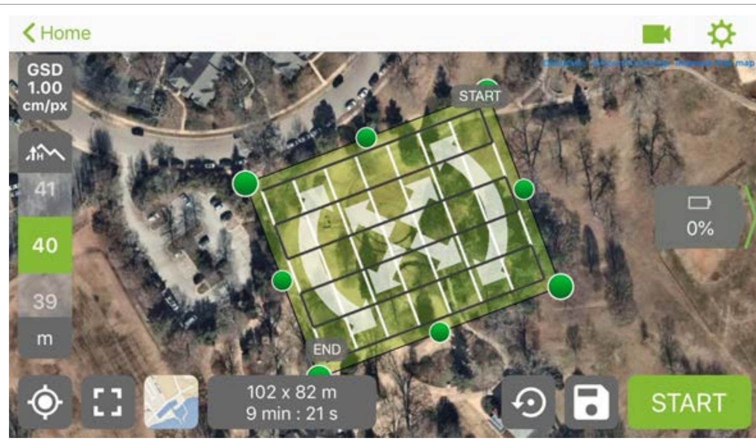

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How to plan a mapping flight?

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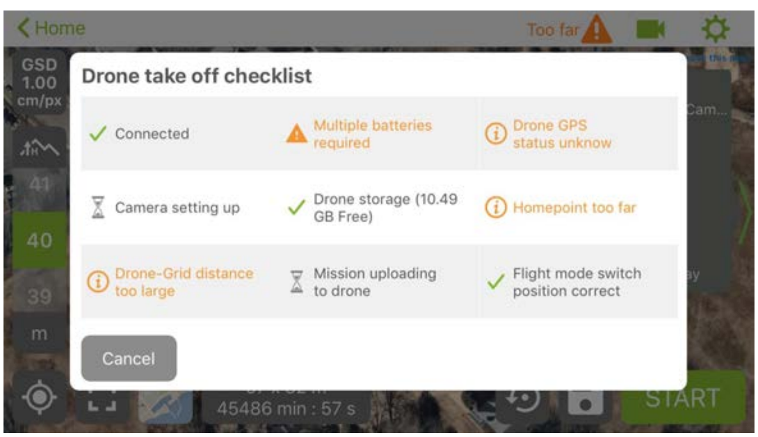
How to plan a mapping flight?



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Data processing

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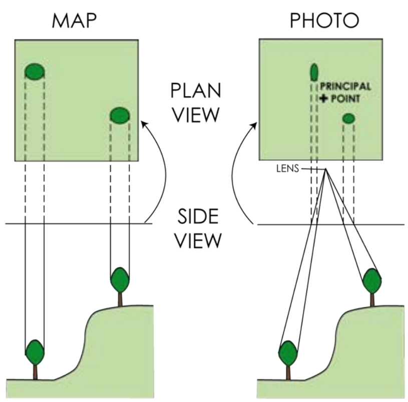
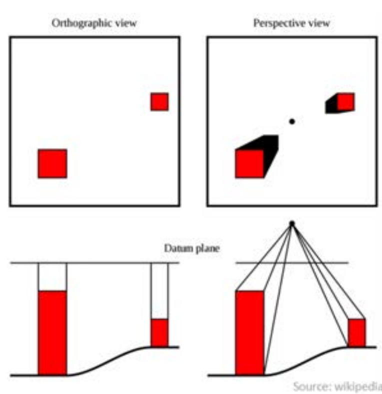
Why do we need to process the images?





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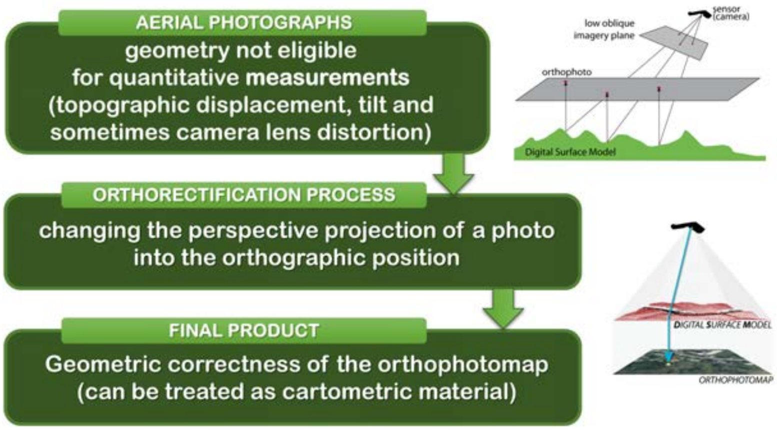
Orthorectification



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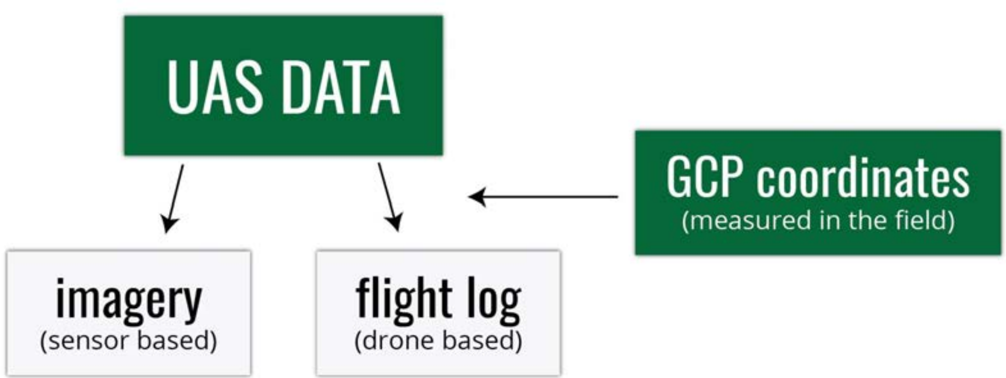
UAS data



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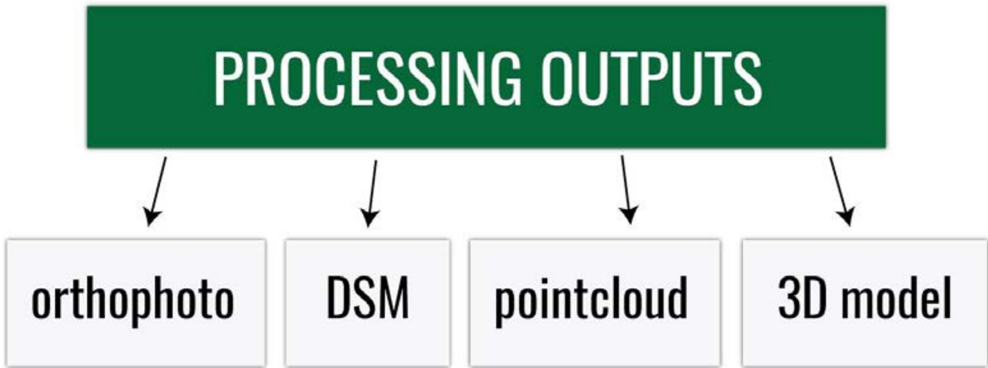
UAS data processing outputs



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Orthophoto

aerial imagery geometrically corrected ("orthorectified") such that the scale is uniform

Photo that is geometrically corrected and has a uniform scale;

Can be used to measure true horizontal distances

raster: consists of red, green and blue bands

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Digital Surface Model

DEM/DTM - Digital Elevation Model / Digital Terrain Model
representation of a terrain's elevation
bare-earth raster grid
DSM - Digital Surface Model
representation of a visible surface
captures the natural and built features on the Earth’s surface

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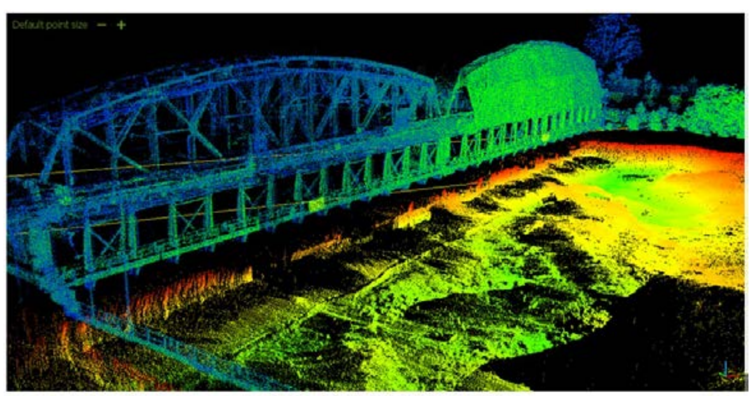
Pointcloud

representation of the external surface of an object

set of vertices in a three-dimensional coordinate system



http://h2hassociates.com/wp-content/uploads/2015/01/point-cloud-processing-CaptureMD11DS1.png

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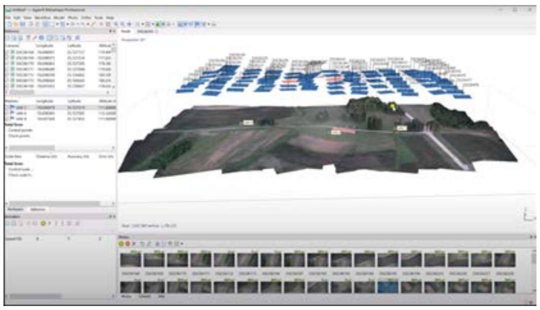
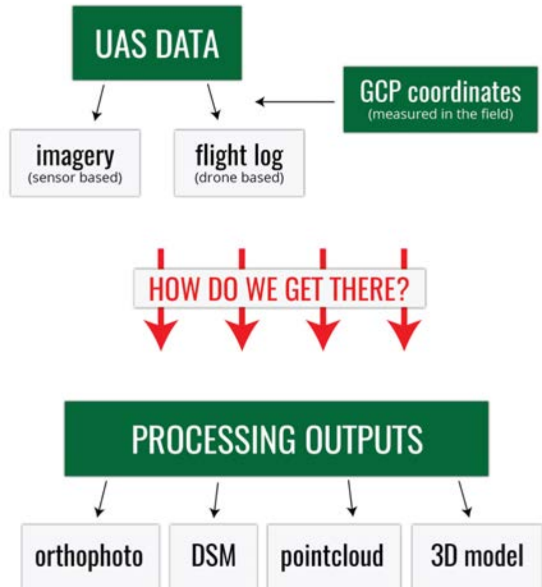
UAS data processing:





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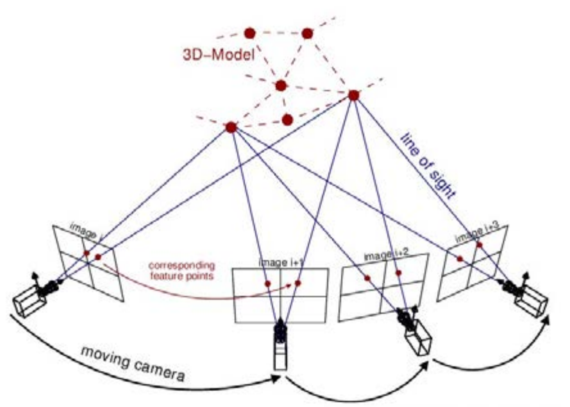
Structure from Motion (SfM)

range imaging technique,

process of estimating 3D structures from 2D image sequences



Source: http://www.theia-sfm.org/sfm.html

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Processing options

Everything boils down to... money (and time)

What is my starting budget and equipment?;

How frequently will I fly?;

Do I have the experience/ training necessary for processing (or am I able to hire people who do)?

Do I have time to process the data by myself?

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Processing options - software

Agisoft Metashape

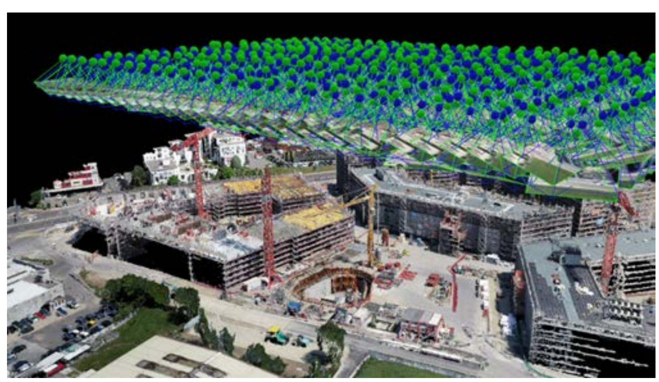
Pix4D

Trimble Business Center - Aerial Photogrammetry Module

Drone2Map (ESRI)

DroneMapper

opendronemap



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UAS Forestry applications

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UAS Forestry applications

Estimation of dendrometric parameters

Tree species classification

Quantification of spatial gaps in forests

Post-fire recovery monitoring and forest fire measuring

Forest health monitoring and forest diseases mapping

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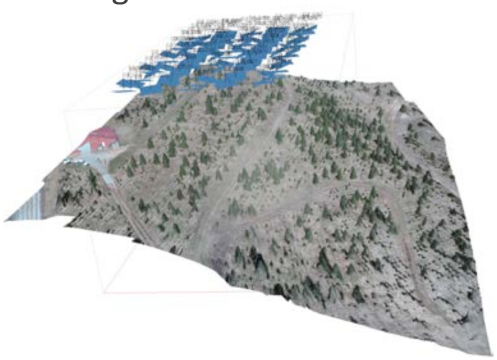
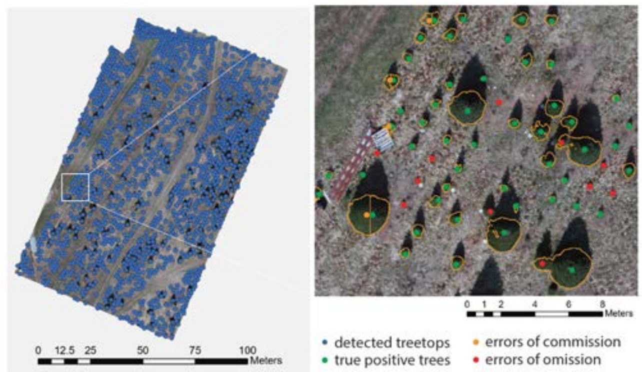
Estimation of dendrometric parameters

Automatic treetop detection

Height measurement





Individual tree detection from UAS-derived Canopy Height Model. Test site P1.

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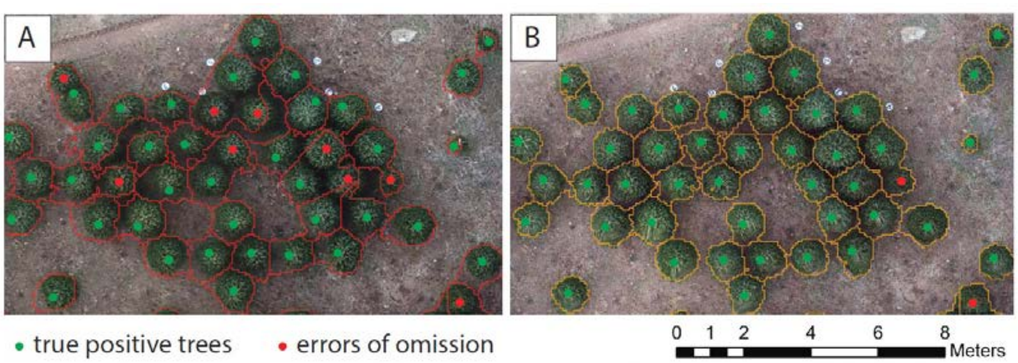
Estimation of dendrometric parameters

Height measurement

Tree crown delineation



Individual tree detection from UAS-derived Canopy Height Model. Comparison of 64 m altitude flight (A) and 27 m altitude flight (B). Test site P6.

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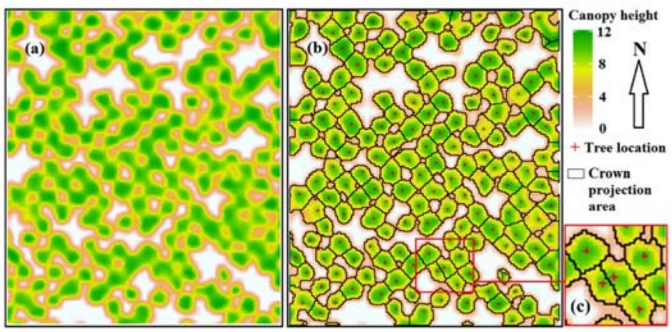
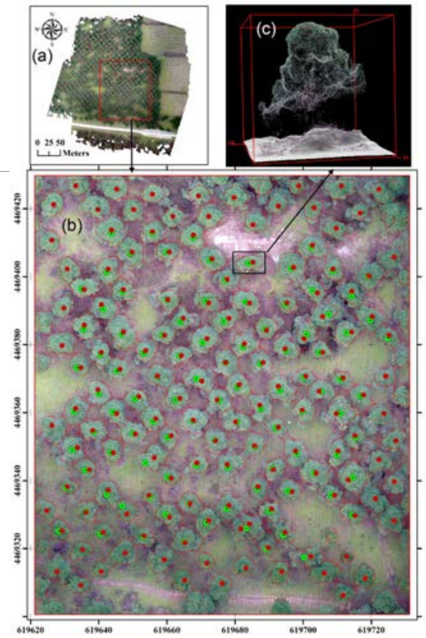
Estimation of dendrometric parameters

Timber volume estimation





Gülci, S., Akay, A. E., Gülci, N., & Taş, İ. (2021). An assessment of conventional and drone-based measurements for tree attributes in timber volume estimation: A case study on stone pine plantation. In Ecological Informatics (Vol. 63, p. 101303). Elsevier BV. https://doi.org/10.1016/j.ecoinf.2021.101303

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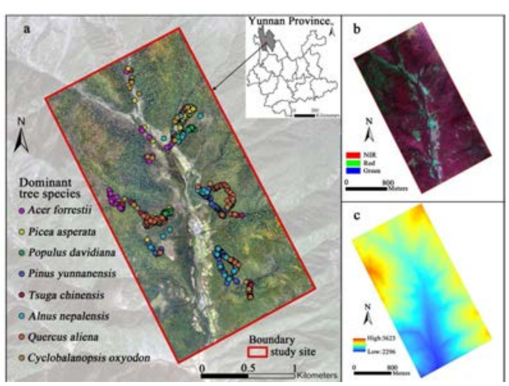
Tree species classification



Xu, Z., Shen, X., Cao, L., Coops, N. C., Goodbody, T. R. H., Zhong, T., Zhao, W., Sun, Q., Ba, S., Zhang, Z., & Wu, X. (2020). Tree species classification using UAS-based digital aerial photogrammetry point clouds and multispectral imageries in subtropical natural forests. In International Journal of Applied Earth Observation and Geoinformation (Vol. 92, p. 102173). Elsevier BV. https://doi.org/10.1016/j.jag.2020.102173

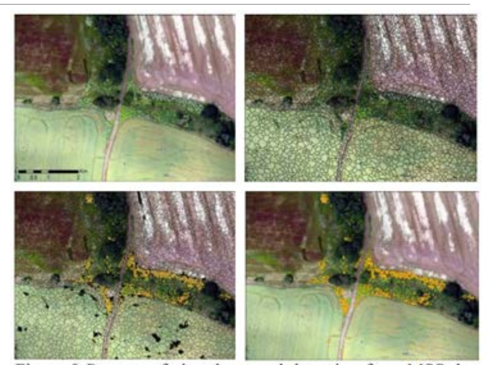


Figure 9 Process of giant hogweed detection from MSS data of UAV origin, OBIA approach

Dvořák, P., Müllerová, J., Bartaloš, T., & Brůna, J. (2015). UNMANNED AERIAL VEHICLES FOR ALIEN PLANT SPECIES DETECTION AND MONITORING. In The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences: Vol. XL-1/W4 (pp. 83–90). Copernicus GmbH. https://doi.org/10.5194/isprsarchives-xl-1-w4-83-2015

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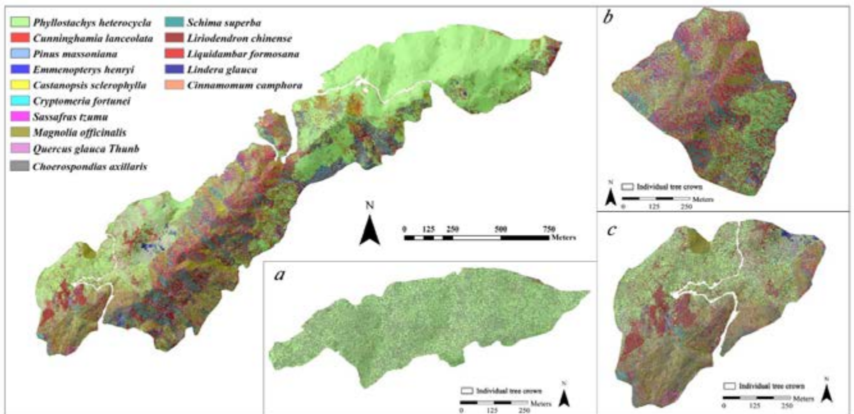
Tree species classification



Liu, K., Wang, A., Zhang, S., Zhu, Z., Bi, Y., Wang, Y., & Du, X. (2021). Tree species diversity mapping using UAS-based digital aerial photogrammetry point clouds and multispectral imageries in a subtropical forest invaded by moso bamboo (Phyllostachys edulis). In International Journal of Applied Earth Observation and Geoinformation (Vol. 104, p. 102587). Elsevier BV. https://doi.org/10.1016/j.jag.2021.102587

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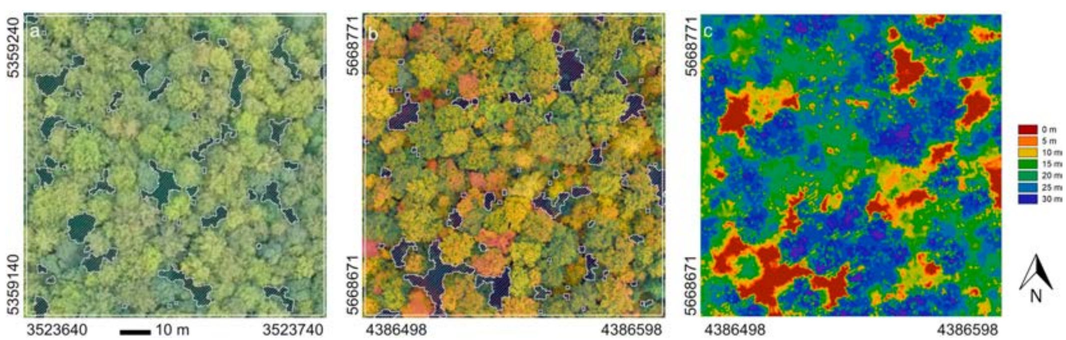
Quantification of spatial gaps in forests



Getzin, S., Nuske, R., & Wiegand, K. (2014). Using Unmanned Aerial Vehicles (UAV) to Quantify Spatial Gap Patterns in Forests. In Remote Sensing (Vol. 6, Issue 8, pp. 6988–7004). MDPI AG. https://doi.org/10.3390/rs6086988

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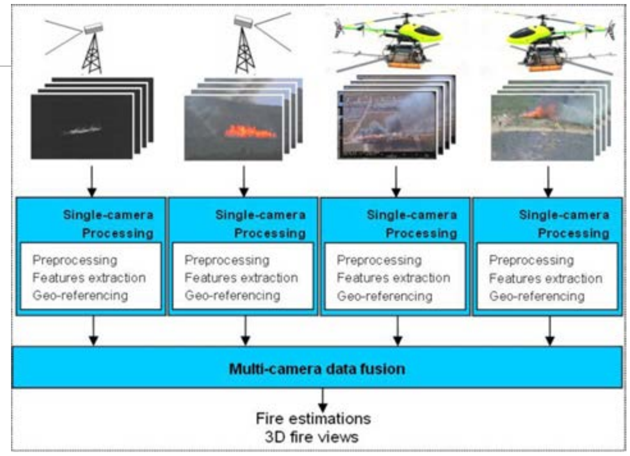
Post-fire recovery monitoring and forest fire measuring

Fig. 1. UAV in forest fire monitoring mission [1].

E. Cheng, Drones podrían detectar incendios forestales automáticamente,visited on 20/06/2017, http://www.emol.com/noticias/Tecnologia/2016/10/26/828436/Drones, 2016.



Martínez-de Dios, J., Merino, L., Caballero, F., & Ollero, A. (2011). Automatic Forest-Fire Measuring Using Ground Stations and Unmanned Aerial Systems. In Sensors (Vol. 11, Issue 6, pp. 6328–6353). MDPI AG. https://doi.org/10.3390/s110606328

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Post-fire recovery monitoring and forest fire measuring

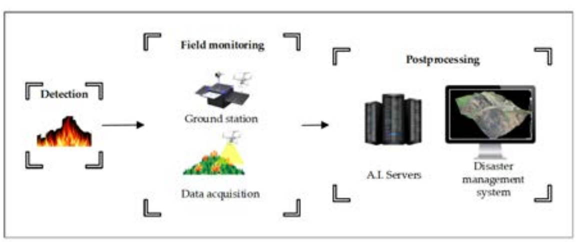

Figure 1. Conceptual framework of an unmanned aerial vehicle (UAV)-based forest-fire monitoring system.

Tran, D. Q., Park, M., Jung, D., & Park, S. (2020). Damage-Map Estimation Using UAV Images and Deep Learning Algorithms for Disaster Management System. In Remote Sensing (Vol. 12, Issue 24, p. 4169). MDPI AG. https://doi.org/10.3390/rs12244169

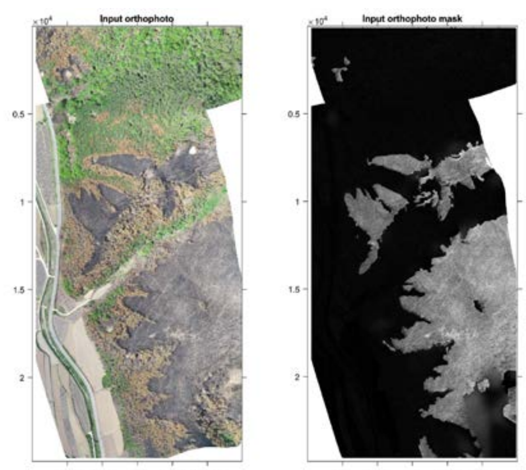

Figure 13. Original orthophoto from location 1 and its mask. The orthophoto of size 24,142 × 11,662 × 3.

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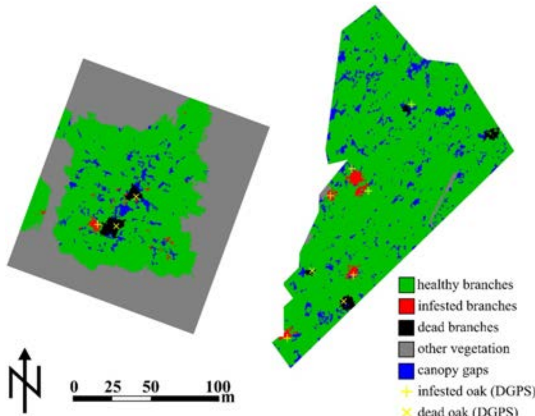
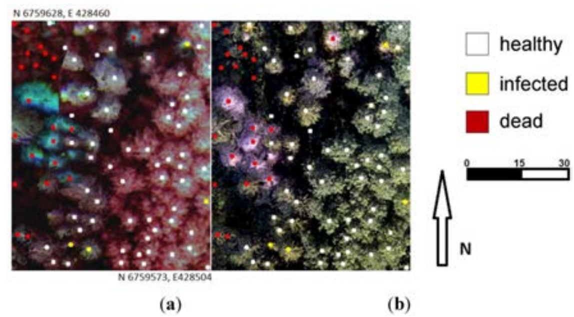
Forest health monitoring and forest diseases mapping



Lehmann, J., Nieberding, F., Prinz, T., & Knoth, C. (2015). Analysis of Unmanned Aerial System-Based CIR Images in Forestry—A New Perspective to Monitor Pest Infestation Levels. In Forests (Vol. 6, Issue 12, pp. 594–612). MDPI AG. https://doi.org/10.3390/f6030594



Näsi, R., Honkavaara, E., Lyytikäinen-Saarenmaa, P., Blomqvist, M., Litkey, P., Hakala, T., Viljanen, N., Kantola, T., Tanhuanpää, T., & Holopainen, M. (2015). Using UAV-Based Photogrammetry and Hyperspectral Imaging for Mapping Bark Beetle Damage at Tree-Level. In Remote Sensing (Vol. 7, Issue 11, pp. 15467–15493). MDPI AG. https://doi.org/10.3390/rs71115467

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Forest health monitoring and forest diseases mapping

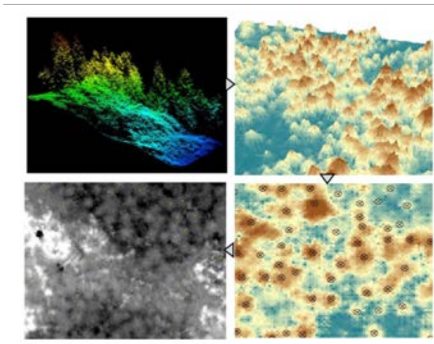

Figure 11. *Georeferencing process of UAV-borne imagery: 1) canopy height model derivation, 2) tree tops identification, 3) registration to CHM on "tree to tree" basis.*

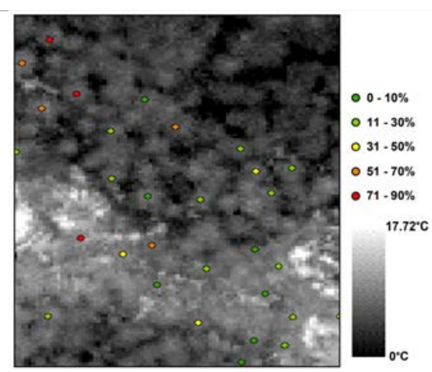

Figure 12. *Survey trees distribution with their estimated disease levels, on georeferenced thermal UAV-borne imagery.*

Smigaj, M., Gaulton, R., Barr, S. L., & Suárez, J. C. (2015). UAV-BORNE THERMAL IMAGING FOR FOREST HEALTH MONITORING: DETECTION OF DISEASE-INDUCED CANOPY TEMPERATURE INCREASE. In The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences: Vol. XL-3/W3 (pp. 349–354). Copernicus GmbH. https://doi.org/10.5194/isprsarchives-xl-3-w3-349-2015

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References:

Getzin, S., Nuske, R., & Wiegand, K. (2014). Using Unmanned Aerial Vehicles (UAV) to Quantify Spatial Gap Patterns in Forests. In Remote Sensing (Vol. 6, Issue 8, pp. 6988–7004). MDPI AG. https://doi.org/10.3390/rs6086988

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Thank you!

Questions?

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