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Drones in Agriculture

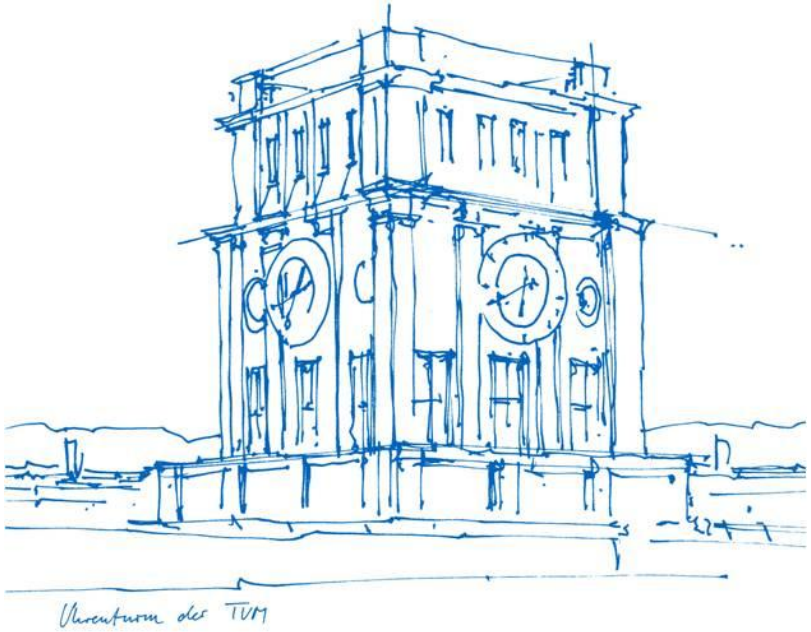
Maximilian Treiber

Technical University of Munich

TUM School of Life Sciences Weihenstephan

Agricultural Systems Engineering

SFIoT, November 2022




YAMAHA
Revs Your Heart
RMAX
N546WY

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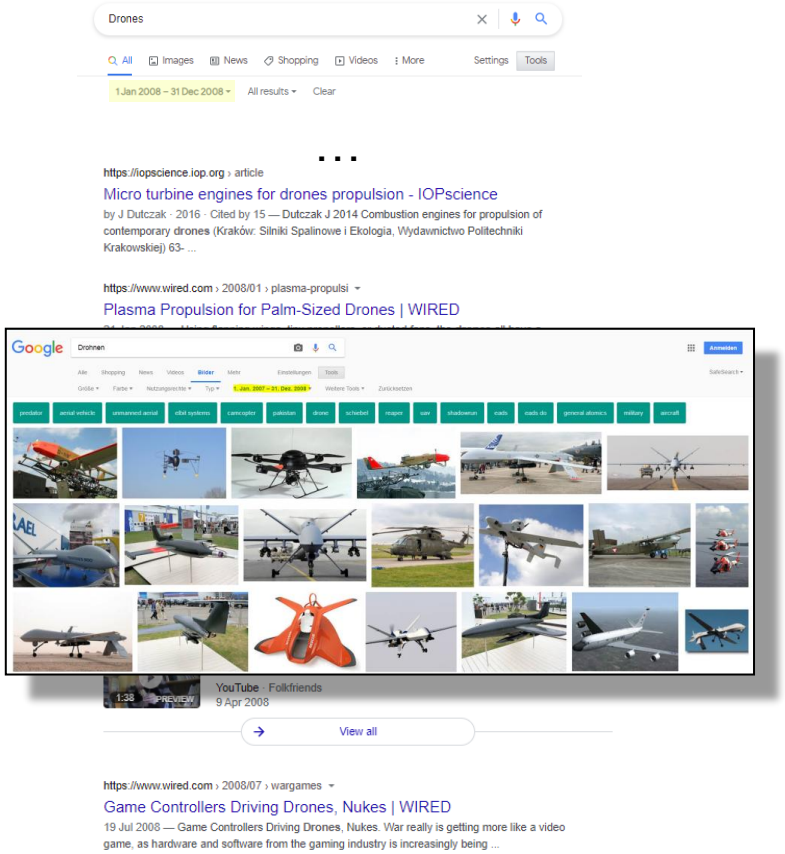
Introduction


Drones
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Images
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1 Jan 2008 – 31 Dec 2008
All results
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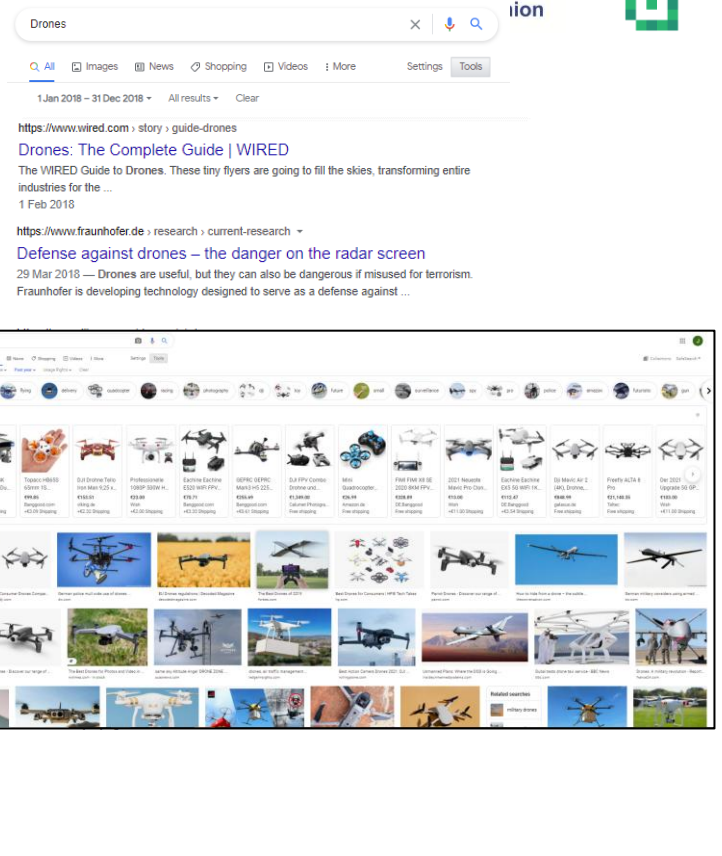
...
https://iopscience.iop.org › article
Micro turbine engines for drones propulsion - IOPscience
by J Dutczak · 2016 · Cited by 15 — Dutczak J 2014 Combustion engines for propulsion of contemporary drones (Kraków: Silniki Spalinowe i Ekologia, Wydawnictwo Politechniki Krakowskiej) 63- ...
https://www.wired.com › 2008/01 › plasma-propulsi
Plasma Propulsion for Palm-Sized Drones | WIRED
Google
Drohnen
YouTube · Folkfriends
9 Apr 2008
View all
https://www.wired.com › 2008/07 › wargames
Game Controllers Driving Drones, Nukes | WIRED
19 Jul 2008 — Game Controllers Driving Drones, Nukes. War really is getting more like a video game, as hardware and software from the gaming industry is increasingly being ...

2008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1 Jan 2018 – 31 Dec 2018
All results
Clear
https://www.wired.com › story › guide-drones
Drones: The Complete Guide | WIRED
The WIRED Guide to Drones. These tiny flyers are going to fill the skies, transforming entire industries for the ...
1 Feb 2018
https://www.fraunhofer.de › research › current-research
Defense against drones – the danger on the radar screen
29 Mar 2018 — Drones are useful, but they can also be dangerous if misused for terrorism. Fraunhofer is developing technology designed to serve as a defense against ...

2018

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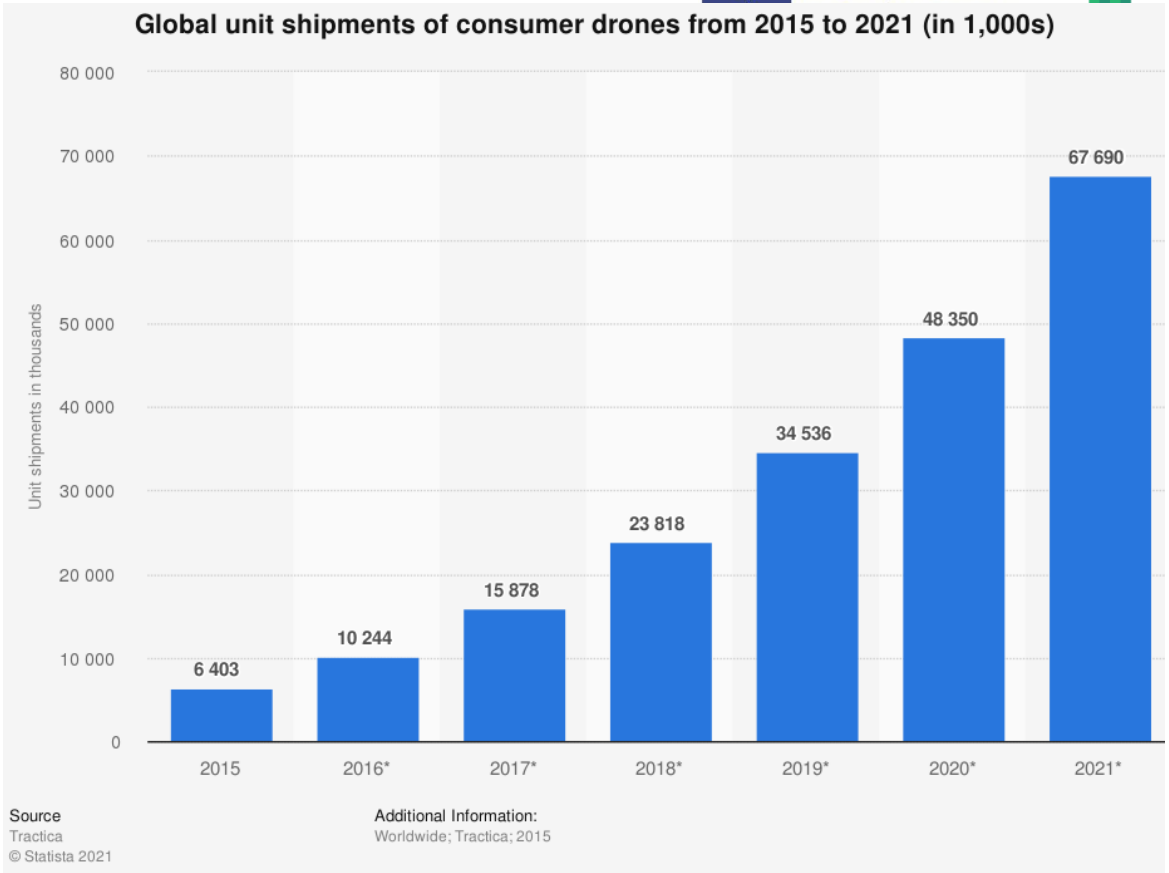
Drone Market



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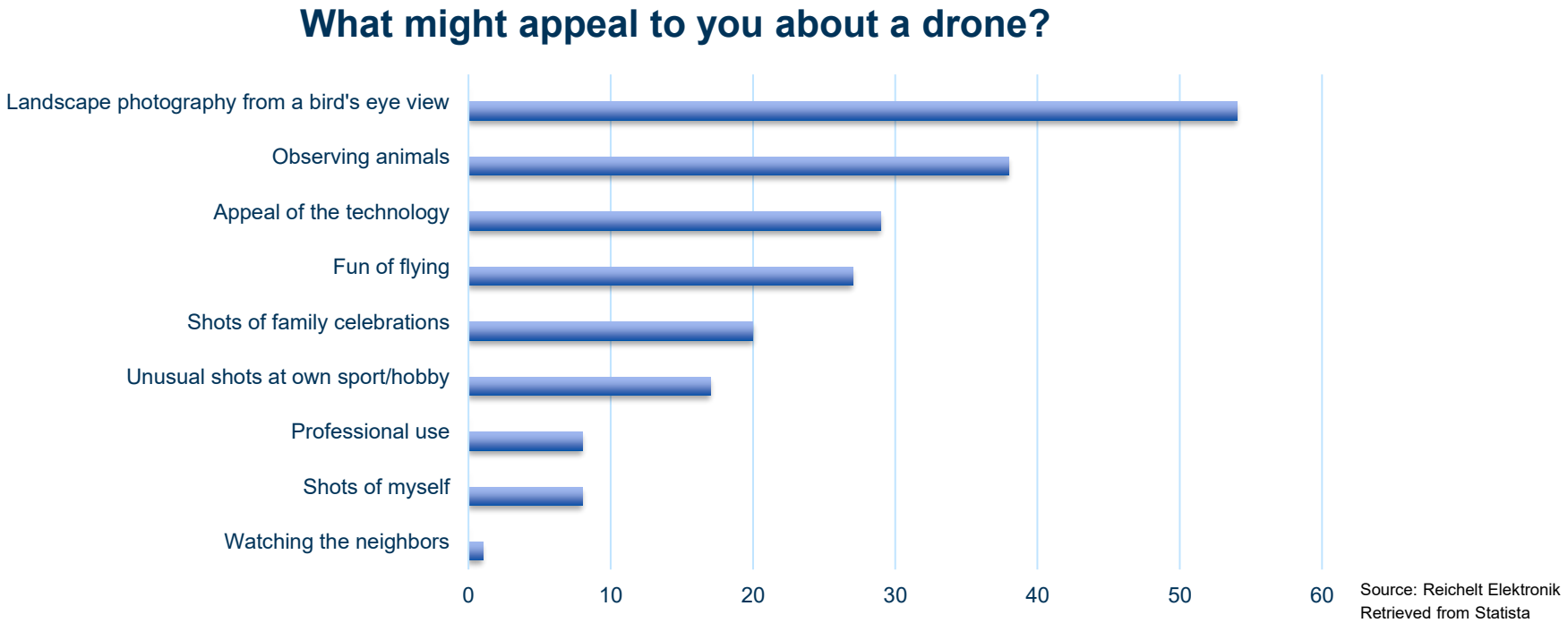
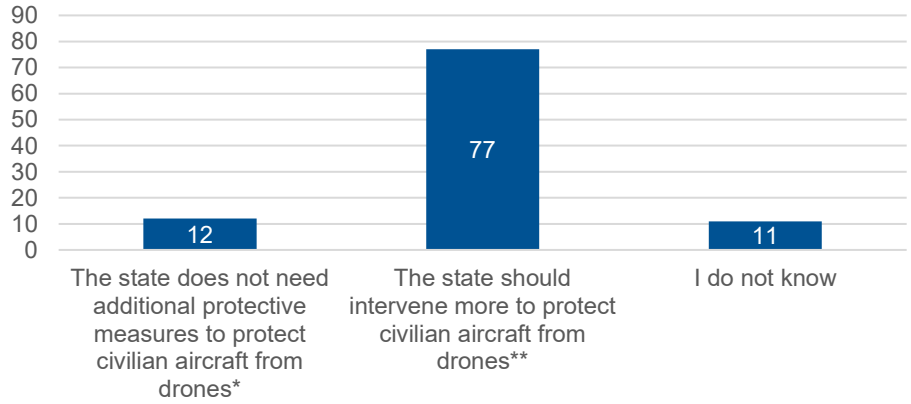
Drones in Germany



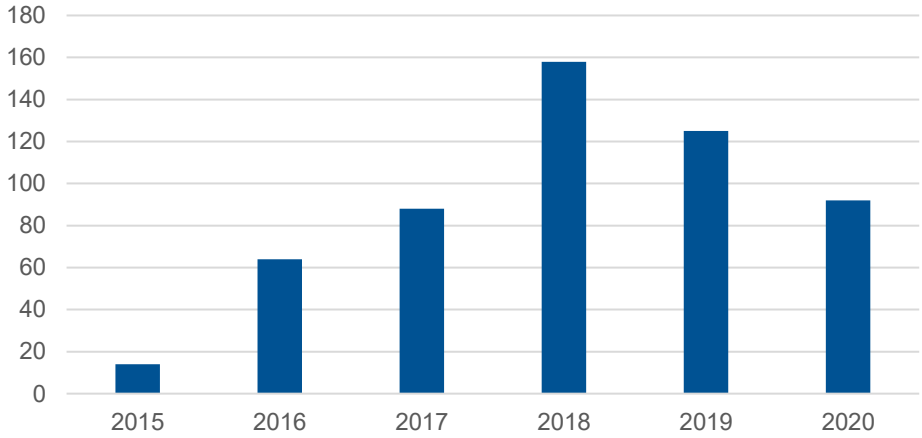
Hazards

Need for increased protective measures due to the use of civil drones in Germany in 2016.



Source: BDL 2016
Retrieved from Statista

Reported obstructions to air traffic caused by civil drones in Germany from 2015 to 2020



Source: Deutsche Flugsicherung 2021
Retrieved from Statista

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Principles

Copter
vs
Fixed Wing

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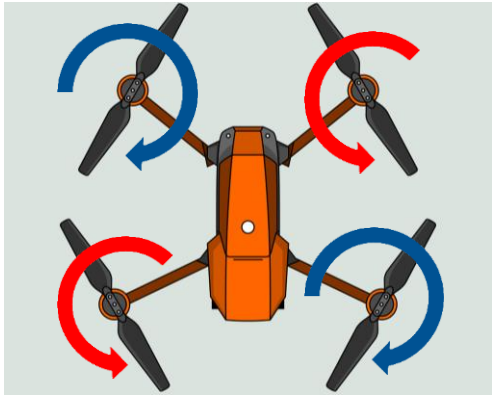
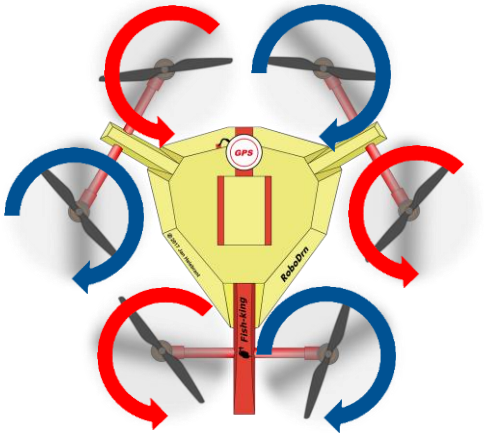
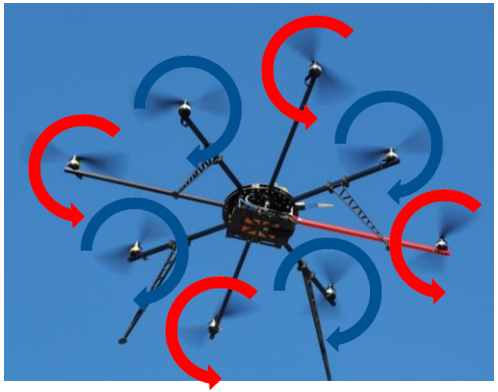
Drones - Copter







RPAS	Remotly Piloted Aircraft System
UAV	Unmanned Aerial Vehicel
UAS	Unmanned Aircraft System
UA	Unmanned Aircraft

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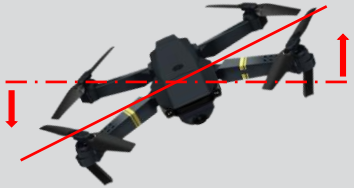
Flight commands

Steigen (ascend)	Sinken (decend)	Rollen (roll)	Nicken (pitch)	Gieren (yaw)
• Increase flight altitude • Increase rotor speed	• Decrease flight altitude • Decrease rotor speed	• Flight to left or right • Inclination longitudinal • Orientation constant • Rotor speed between rotors left and right different	• Flight forward, resp. backward • Inclination crosswise • Orientation constant • Rotor speed between front and rear motors different	• Rotation around vertical axis • Orientation changes • RPM between rotor pairs different • Example: RPM left-hand > RPM right-hand = rotation to the right



Source of pictures: Rodri Paz on Pixabay

Drone – Fixed-Wing

Source: Image credit BLM Oregon & Washington on Wunderstock

RPAS	Remotly Piloted Aircraft System
UAV	Unmanned Aerial Vehicel
UAS	Unmanned Aircraft System
UA	Unmanned Aircraft

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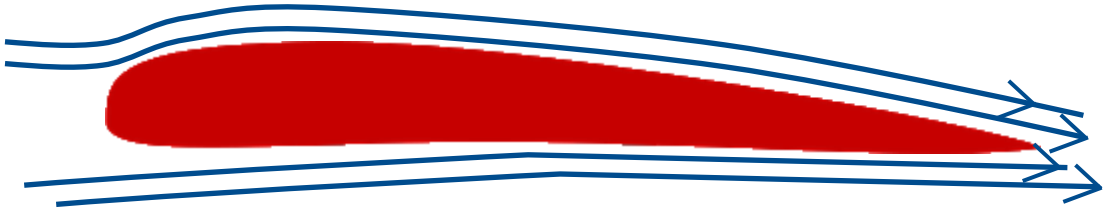
How wings can turn to fly

Bernoulli-Effect

Path over upper side of wing longer than path over lower side of wing = air at top faster = negative pressure at top



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The magic behind

A drone needs several sensors to fly perfectly

- RPM sensor
- Acceleration sensor
- Position sensor
- Gyro sensor
- Ultrasonic senors

- Positioning System (GPS/GLONASS/GALILEO/BEIDU)
- Stereo camera

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Differences in Drone Types

Fixed-Wing	Multicopter
High acquisition costs	Low acquisition costs
Long flight times	Low flight times
High flight distances	Low flight distances
High Speeds	(Lower) Speeds
Low load capacity	Higher load cpacity
No Hovering	Hovering possible
Needs kind of Runway	VTOL (Vertical Take-Off and Landing)
Low agility	High agility

Source: DELAIR – Aerial Intelligence

Agricultural Drone Examples

© HoneyComb AgDrone

© PrecisionHawk Lancaster 5

© Trimble UX5

© Sentera PHX 2

© Parrot Bluegrass

© Sentera NDVI Upgrade for DJI Phantom

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Regulation

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Regulation

- Till 2021: no uniform rules given in Europe
- Since 2021: European Regulation (2019/947 & 2019/945)
  - Risk-based assessment methodology (SORA – Specific Operations Risk Assessment)

Regulation

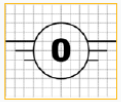
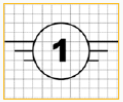
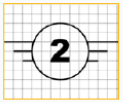
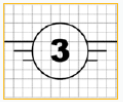
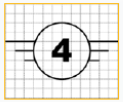
The EU directives define uniform basic rules for all EU countries. In addition, however, there are still country-specific requirements of the EU member states (MSs = Member States) that must be met in addition.

The application scenarios are divided into three categories after a risk assessment:

Open
Specific
Certified

Furthermore, drones are divided into 5 risk classes (according to technical characteristics of the drone):

Regulation – drone classes

					
Max. take-off weight	< 250 g	< 900 g	< 4 kg	< 25 kg	< 25 kg
Max speed	19 m/s	19 m/s	-	-	-
Max Flight altitude	120 m	120 m / Setting	120 m / Setting	120 m / Setting	-
Altimeter	No	Yes	Yes	Yes	No
Remote identification	No	Yes	Yes	Yes	No
Geo-sensibilisation	No	Yes	Yes	Yes	No

Source: LBA

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Category „Open“

Will be most common for drones used in private sector: Leisure drones activity + low risk commercial activity

Divided in three sub-categories:

- A1: „fly over people but not over assemblies of people“
- A2: „fly close to people“
- A3: „fly far from people“

Source: EASA

Category „Open“

Regulations till January 1, 2023

For drones without class

UAS		Operation		Drone Operator/pilot		
Class	MTOM	Subcategory	Operational restrictions	Drone Operator registration	Remote pilot competence	Remote pilot minimum age
Privately built	< 250 g	A1 (can also fly in subcategory A3)	- No flying expected over uninvolved people (if it happens, should be minimised) - no flying over assemblies of people	No, unless camera / sensor on board **and** a drone is not a toy	- no training needed	No minimum age
Drones without class identification label	< 500 g			Yes	- read user manual - complete the training and pass the exam defined by your national competent authority	16*
Drones without class identification label	< 2 kg	A2 (can also fly in subcategory A3)	- no flying over uninvolved people - keep horizontal distance of 50 m from uninvolved people (this can be reduced to	Yes	- read user manual - complete the training and pass the exam defined by your national competent authority	16*
Drones without class identification label or privately built	< 25 kg	A3	- do not fly near people - fly outside of urban areas (150 m distance)	Yes	- read user manual - complete the training and pass the exam defined by your national competent authority	16*

Source: EASA

Figure 1 - Limited open category valid until January 1, 2023, using drones without class identification label

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Category „Open“

Regulations for drones with Class

→ Inventory drones, without a class from 2023:

- Up to 250g: A1
- Up to 25kg: A3

UAS		Operation		Drone Operator/pilot		
Class	MTOM	Subcategory	Operational restrictions	Drone Operator registration	Remote pilot competence	Remote pilot minimum age
Privately built	< 250 g	A1 (can also fly in subcategory A3)	- may fly over uninvolved people (should be avoided when possible) - no flying over assemblies of people	No, unless camera / sensor on board **and** a drone is not a toy	- no training needed	No minimum age
C0					- read user manual	16*, no minimum age if drone is a toy
C1	< 900 g		- No flying expected over uninvolved people (if it happens, should be minimised) - no flying over assemblies of people	Yes	- read user manual - complete online training - pass online theoretical exam	16*
C2	< 4 kg	A2 (can also fly in subcategory A3)	- no flying over uninvolved people - keep horizontal distance of 30 m from uninvolved people (this can be reduced to 5 m if low speed function is activated)	Yes	- read user manual - complete online training - pass online theoretical exam - conduct and declare a self-practical training - pass a written exam at the NAA (or at recognized entity)	16*
C3	< 25 kg	A3	- do not fly near people - fly outside of urban areas (150 m distance)	Yes	- read user manual - complete online training - pass online theoretical exam	16*
C4						
Privately built						

Figure 2 - Open category after January 1, 2023

Source: EASA

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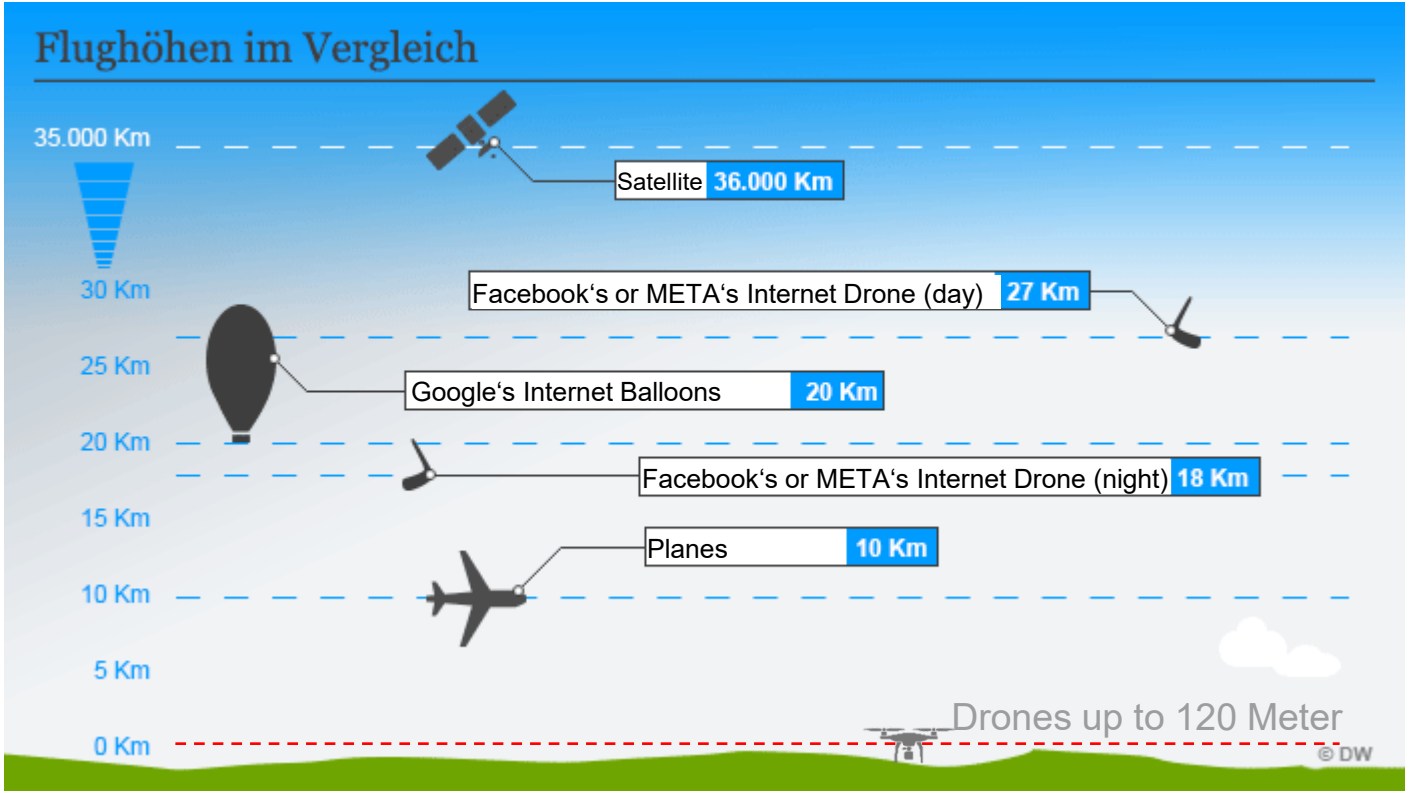
Category „Specific“ & „Certified“

For special use, and flights which are not covered by Open Category
eg:

- Increased risk for persons
- Increased risk for air traffic

- Risk assessment necessary
- Specific authorisation necessary (National Aviation Authority, NAA)

Less expensive than satellite images	Single plant specific Treatment/observation	Fast and targeted application of biological or chemical PPPs



Advantages

- Action and observation level
- Highly accurate images in the cm range
- Non-invasive observations
- Bird's eye view for new perspective
- Multisensor solutions reveal invisible statuses
- Whole area observations

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Basics of drone flights

Regulation basics - EASA

Source: EASA

Regulation basics - EASA

Source: EASA

Regulation basics - EASA

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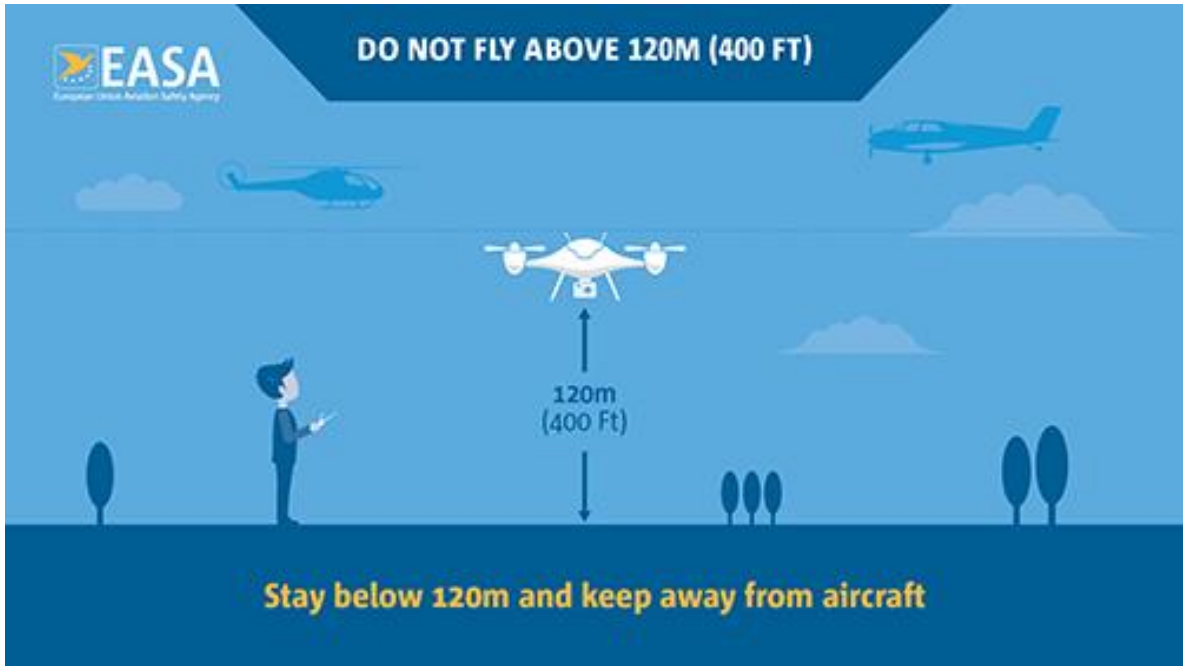
Regulation basics - EASA

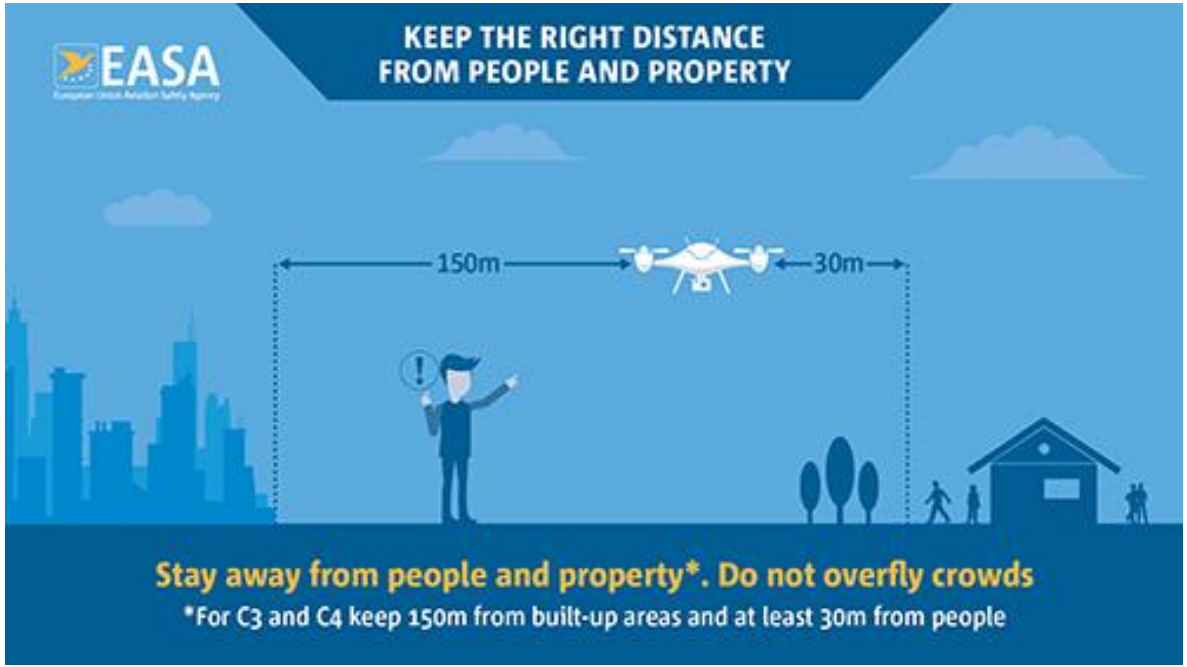
Source: EASA

Regulation basics - EASA



Source: EASA

Regulation basics - EASA



Source: EASA

Regulation basics - EASA

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Source: EASA

Regulation basics - EASA

Source: EASA

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Flight planning

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Flight planning an Mapping

Basically 4 Questions:

What do I have to take into consideration?
- WHAT do I want to do?
- WHERE will I fly?
- WHICH regulations have to be followed there?
- ANY obstacles?

Usage of specific Apps for flight planning:
- Litchi
- Pix4D
- DJI Flight Planner

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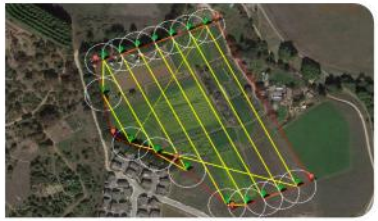
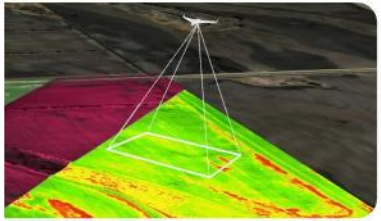
Flight planning an Mapping

Plan Flight



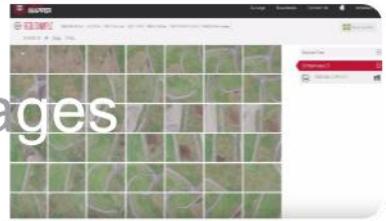
- Set field boarders (Software e.g. Pix4D)
- Define the wanted image resolution, altitude and speed
- Upload data to drone

Fly & Shoot



- Check, assemble and calibrate equipment
- Start and Land manually or automatically
- Start and End routine manually or automatically

Process Images



- Use image processing software to get results from your gathered data (Pix4D, DataMapper, AgEagle´s RAPID,…)
- Or upload the data to a cloud-based image processing service

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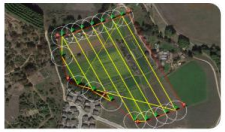
Flight planning an Mapping

Plan Flight



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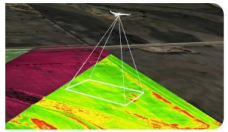

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Process Images

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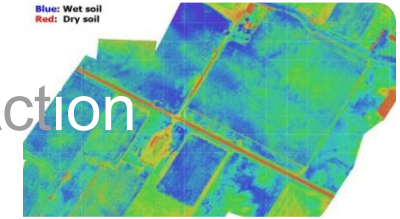
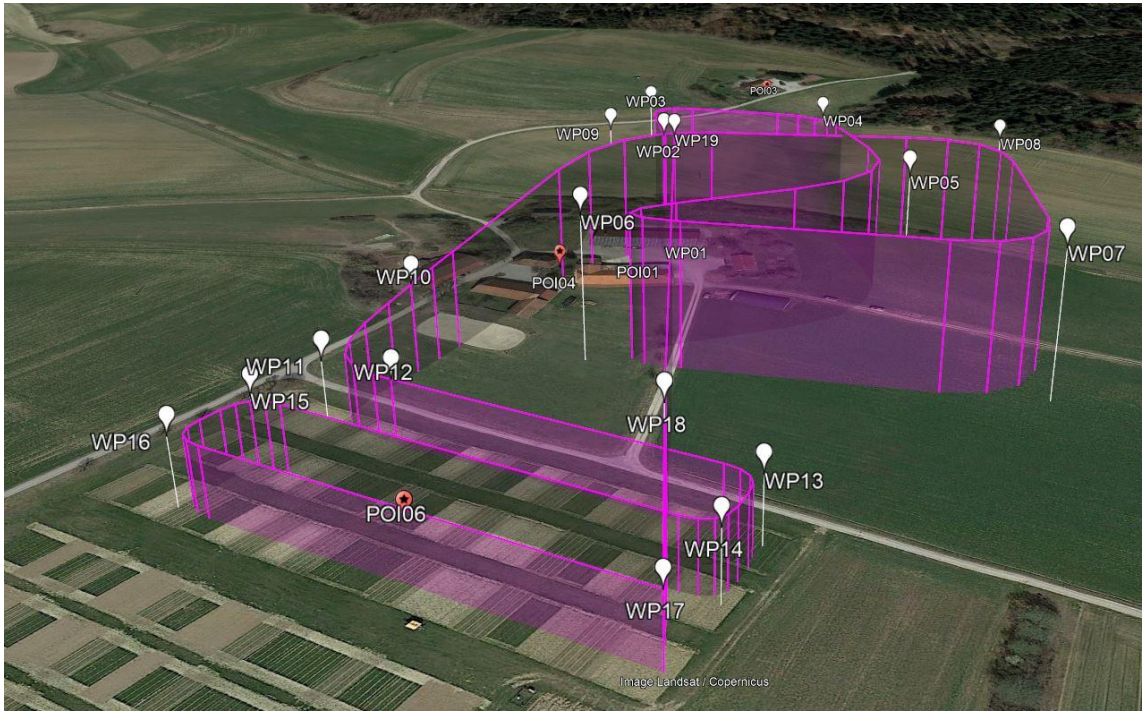
- Or upload the data to a cloud-based image processing service

Review & Action



- Review the results, analyze and take action if necessary
- Transfer data into your farm management system or your machines (drone-to-tractor)

Flight planning and simulation



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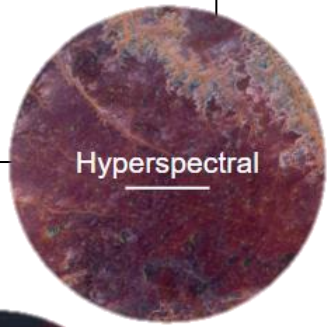
GIS Layer

Electromagnetic spectrum in narrow steps (5 - 10 nm)
- mineral and chemical surface properties
- plant supply
- plant diseases
- water supply
- determination of leaf chemistry

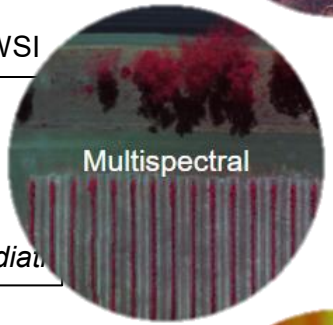


LiDAR = Light Detection and Ranging
Distance measurement using time of flight
Creates elevation profiles and Topological maps

NDVI, CCCI, NDRE, MCARI, CWSI

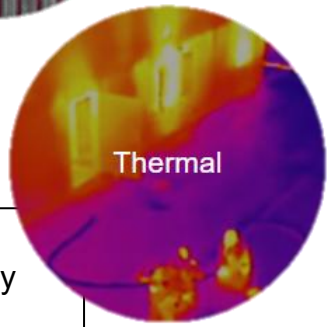
$$NDVI = \frac{R_{NIR} - R_{Red}}{R_{NIR} + R_{Red}}$$

R_{NIR} reflectance of NIR radiation
R_{Red} reflectance of visible red radiati



- Surveying and land use
- 3D reconstruction
- Volume measurement
- Photogrammetry
- Plant census
- Monitoring

Resolution a decisive factor

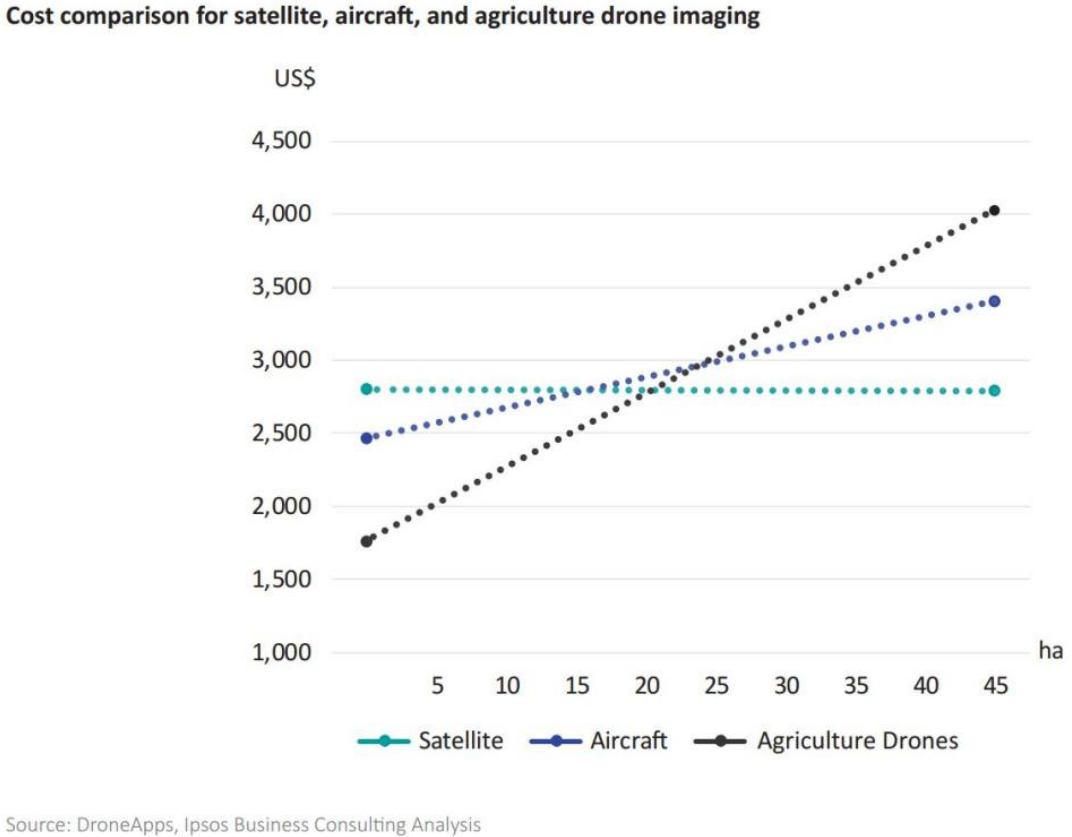


Microbolometer (therm. sensor)
- Infrared radiation meets thermally variable resistance
- Relative measurements only

- Mapping
- Monitoring
- Plant census
- Photogrammetry
- Volume measurement
- 3D reconstruction
- Surveying and land use

Source: PrecisionHawk

Cost comparison



Source: DroneApps, Ipsos Business Consulting Analysis

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Use Cases in Agriculture

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Other use cases in agriculture - Pesticides

- Used in USA / Japan (also with plane or helicopter)
- Prohibited in the EU! (2009/128/EG)
  - Exemptions (e.g. Vine) possible

Source: DJI-Agras, Pixabay

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Other use cases in agriculture – corn borer

- Trichogramma brassicae -> parasitic wasp (Schlupfwespe)
- 3-5 min per hectare, 100 pills each (10x10 m)
- Provider available

Source: Heiko Schattauer

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Other use cases in agriculture – animal protection

- With usage of thermal cameras
  - Heat signature stands out clearly from the ground
  - Only usable at night or early in the morning (sun radiation)

Source: celle-von-oben.de

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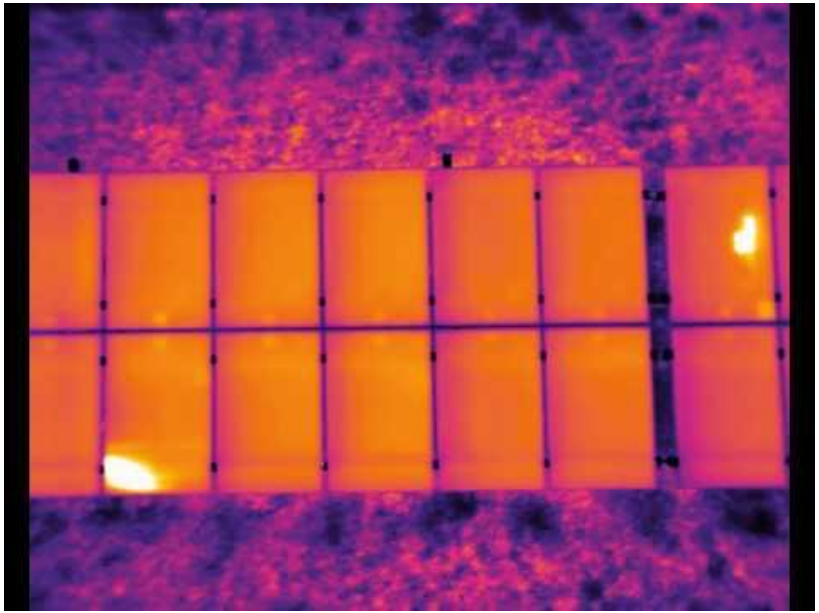
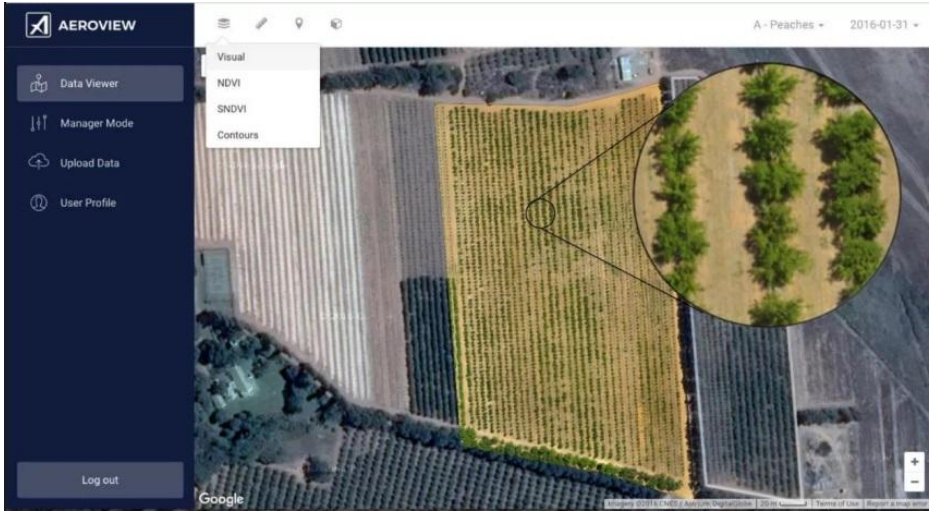
Other use cases in agriculture – inspection of solar panels

- With usage of thermal cameras



Source: Branding Energy GmbH, Iliotec GmbH

Other use cases in agriculture – Orcharding



- Numbers and health status of trees

Source: DroneAG

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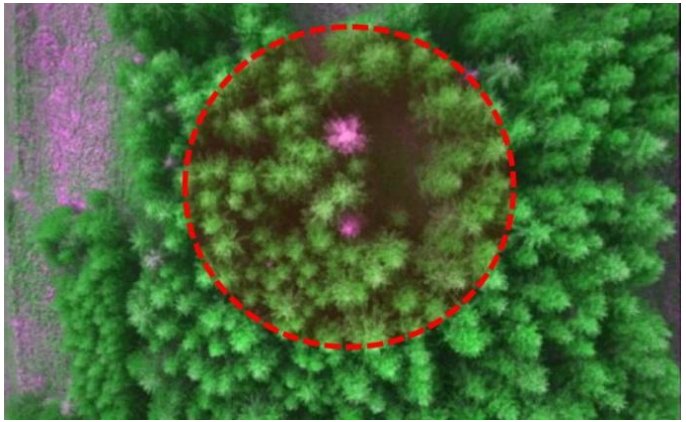
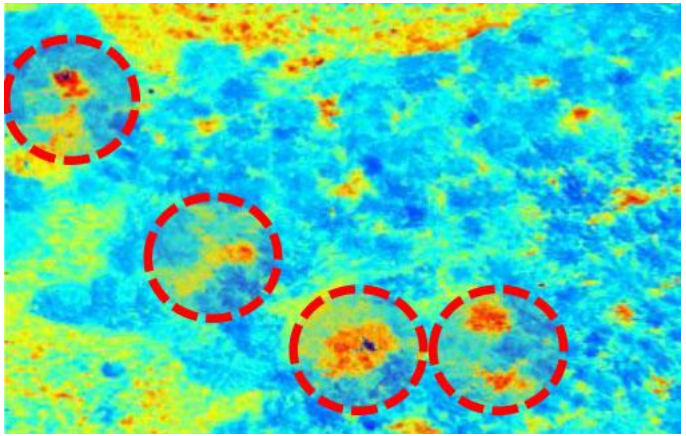
Other use cases in forestry





- Health status of trees
  - Green index
  - Temperature differences

Source: DroneAG

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Drones at AST