Multicopters

A practical View on Unmanned Aerial Vehicles

Hamburg HAW,
05/06/2014

Jon Verbeke

Overview

- UAS/RPAS
  - Introduction UAS/RPAS
  - Civil Applications
  - Legislation
  - Systems & operational aspects
- Multicopters
  - Introduction
  - Design
  - Control
  - Example
  - Live presentation

UAS/RPAS

UAS = RPAS

- UAS = Unmanned Aerial System
  RPAS = Remotely Piloted Aircraft System

"A set of configurable elements consisting of a remotely-piloted aircraft, its associated remote pilot station(s), the required command and control links and any other system elements as may be required, at any point during flight operation"

- UAV = Unmanned Aerial Vehicle
  RPA = Remotely Piloted Aircraft

- GCS= Ground Control Station
  RPS = Remote Pilot Station

Command & Control

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RPAS

RPAS vs. RC model aircraft

	RC planes	RPAS
What?	Toy	Perform useful task (payload)
Purpose?	Recreational	Aerial work
Where?	Specific terrains	"Everywhere" Only after approval CAA
Legislation?	Existing model aircraft legislation	New legislation
Insurance	Model aircraft club	Operator

Parrot AR.Drone

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History

- Started in the late 1800's with unmanned gliders
- First "successful" RPA's during WW2 as aerial targets or missile
- During Vietnam (1960's) first used in reconnaissance role



History

- From the 1980's: more military applications

Drones = BAD

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Why use RPAS?

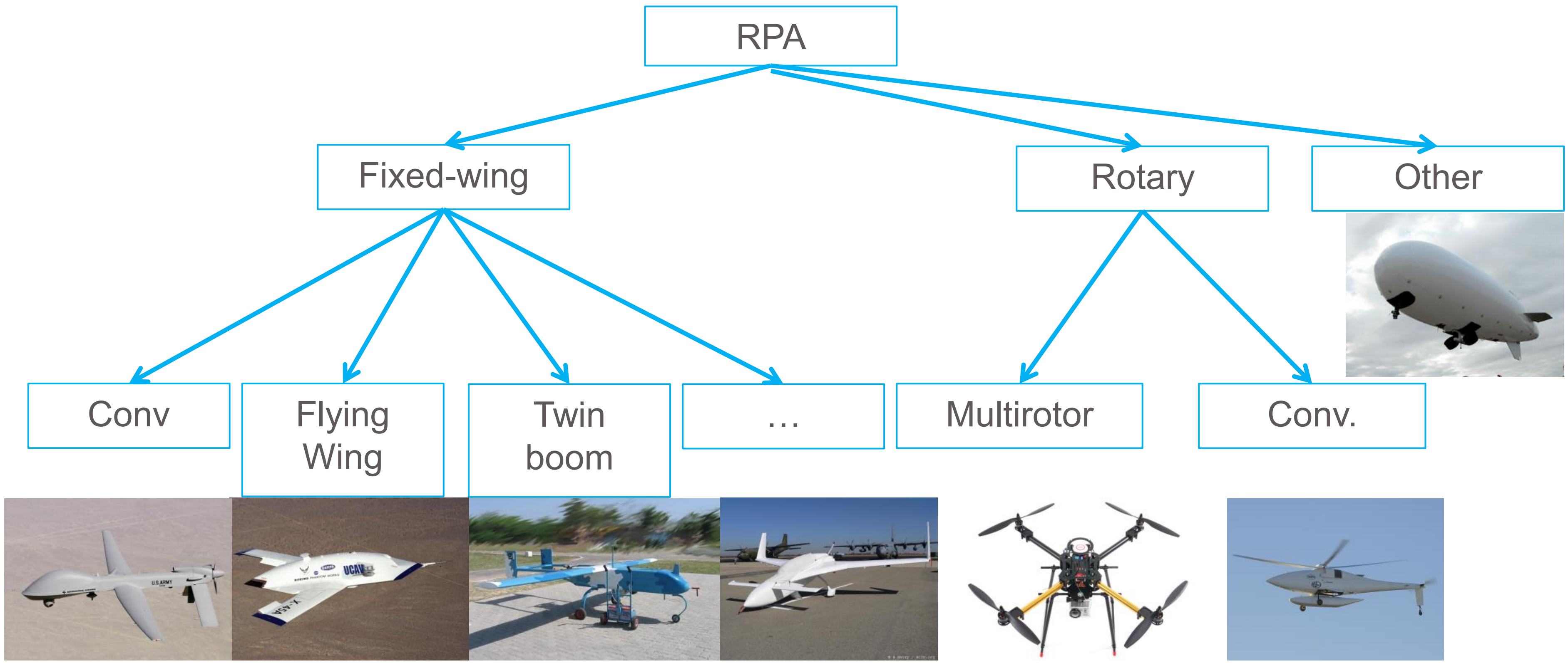
- Dangerous applications (close-up inspection)
- Tedious applications (area monitoring)
- “Stealth” applications (surveillance)
- Research (test platform, R&D,…)
- RPAS generally cheaper than manned aircraft
- Versatility

Cost comparison

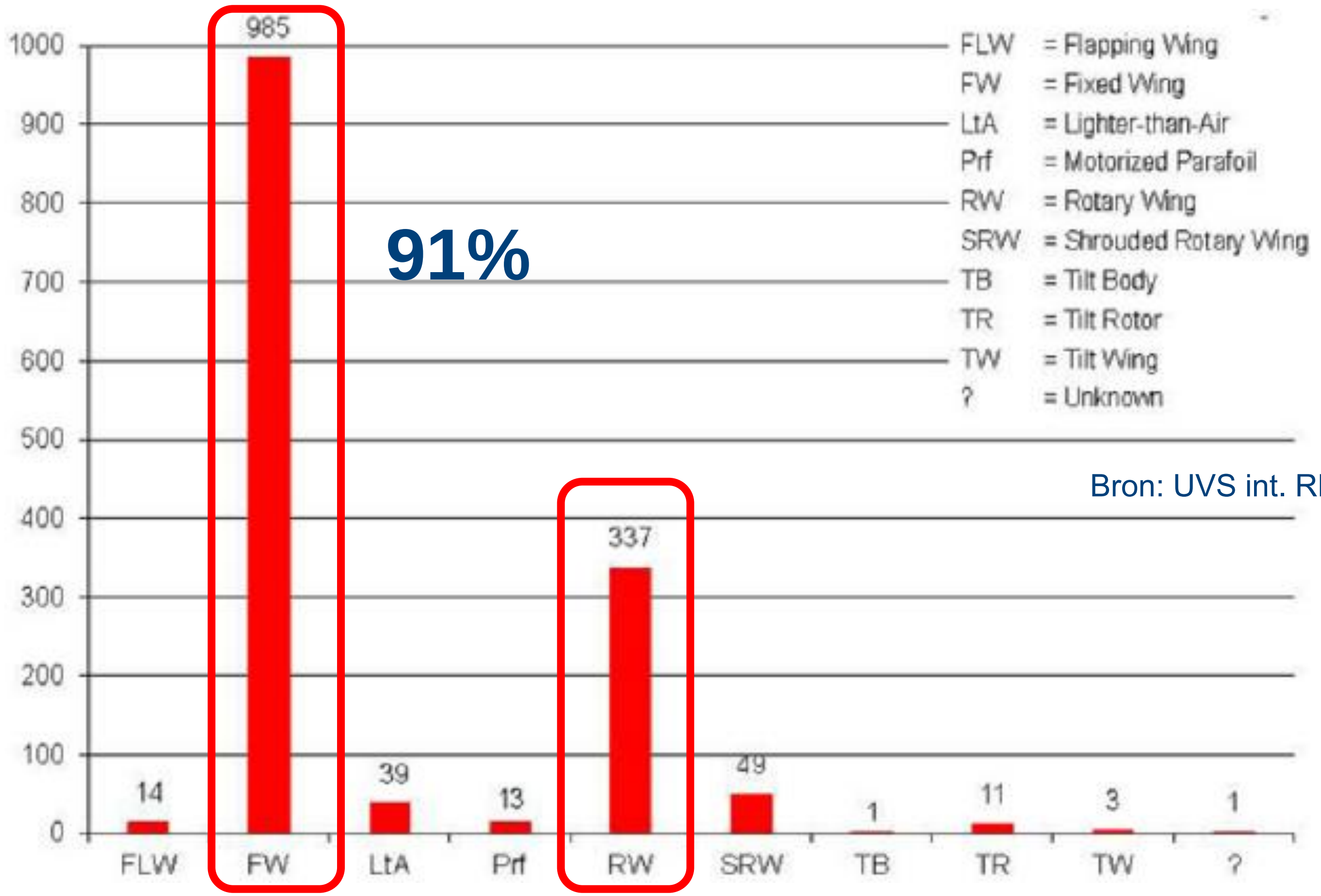
- RPAS overall cheaper
  - RPA is cheaper than manned version
    (No systems needed for pilot: ECS, ejection seat,…)
  - RPS and ground handling is more expensive
  - Pilot training is cheaper

- Difficult to precisely quantify the cost
  - 1 manned aircraft = ? Unmanned aircraft?
  - Small or large RPA? Certification? Safety systems?

Configurations

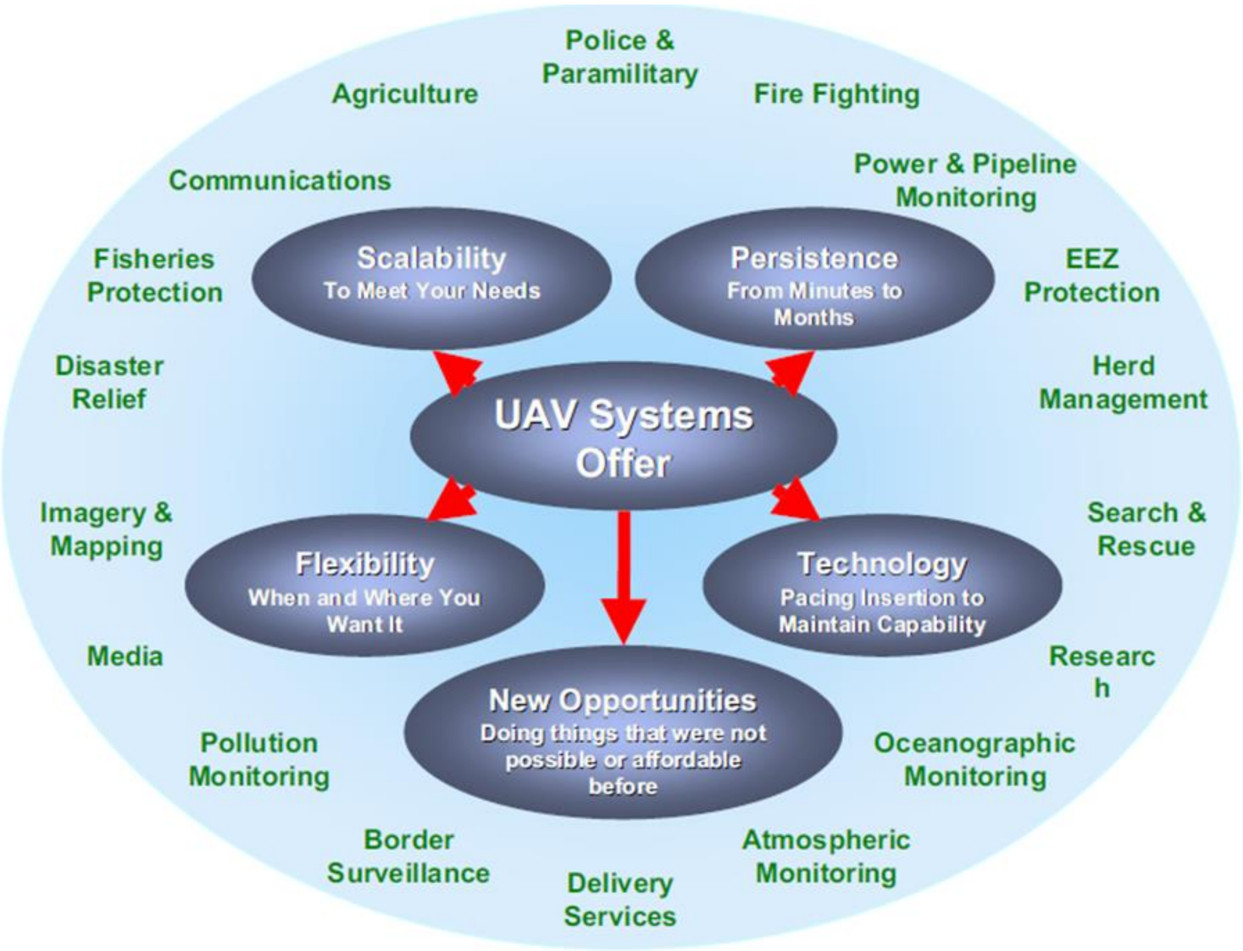


Configurations/classifications



Bron: UVS int. RPAS yearbook 2013

Civil applications



Your imagination is the limit…

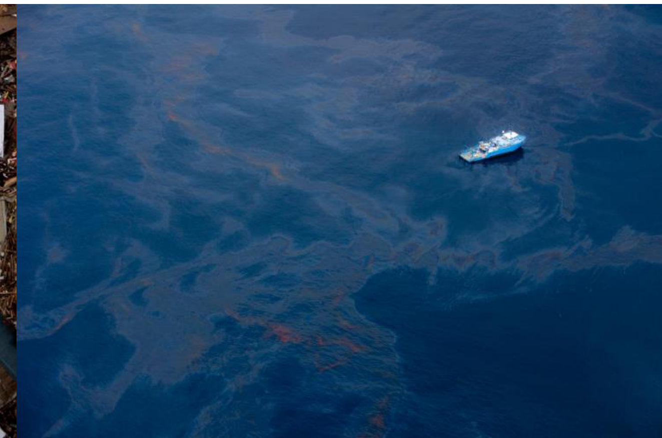
Applications

- Inspection

Applications

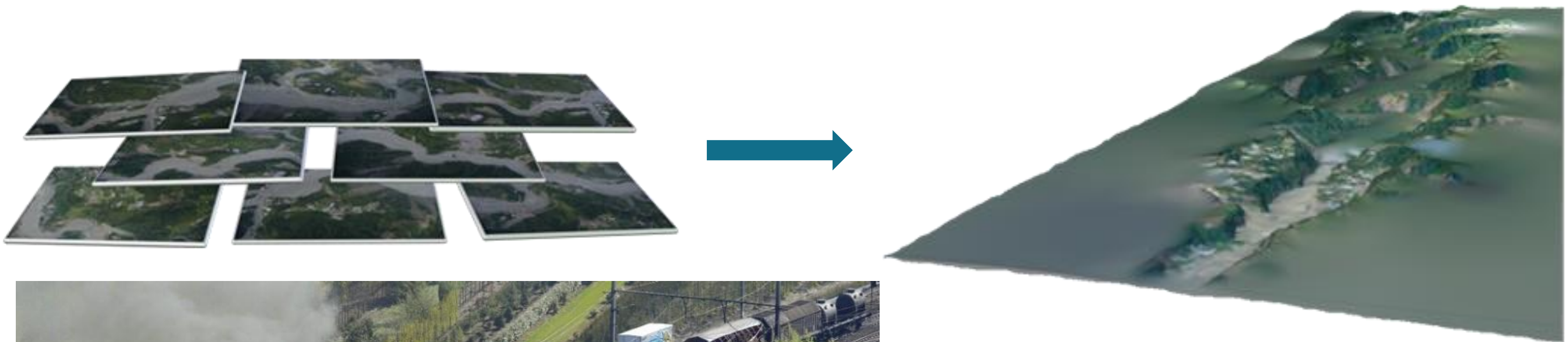
- Surveillance

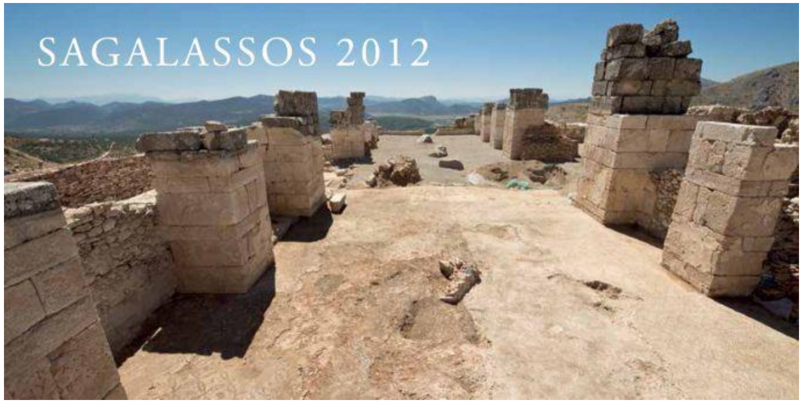




Applications

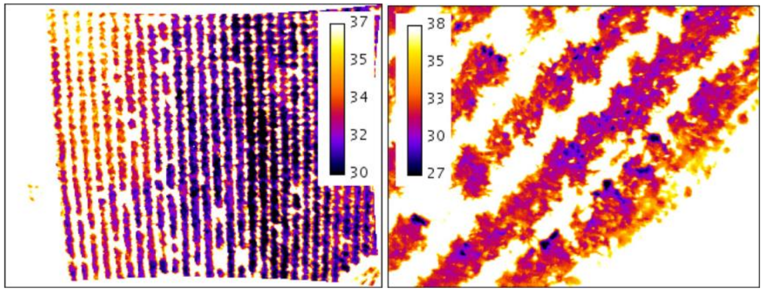
- Mapping (GIS = Geographic information system)

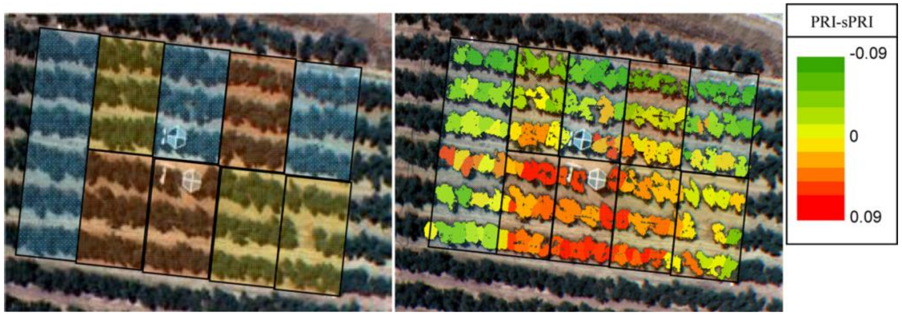




Applications

- Precision agriculture





Applications

- Delivery Services

“Beer-delivery drone grounded by FAA”

Applications

- Media (Filming + photography)

Flying-cam Sarah 3.0

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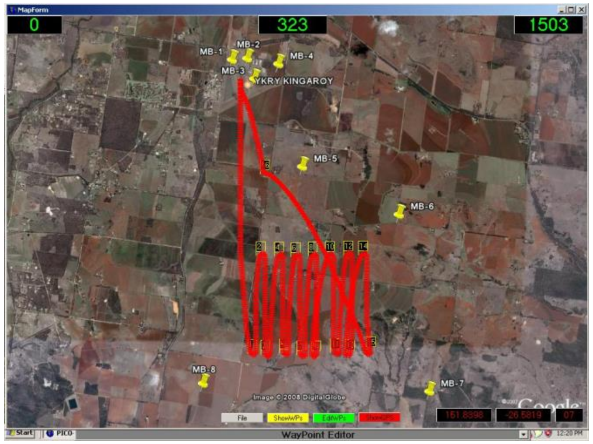
Applications

- Herding

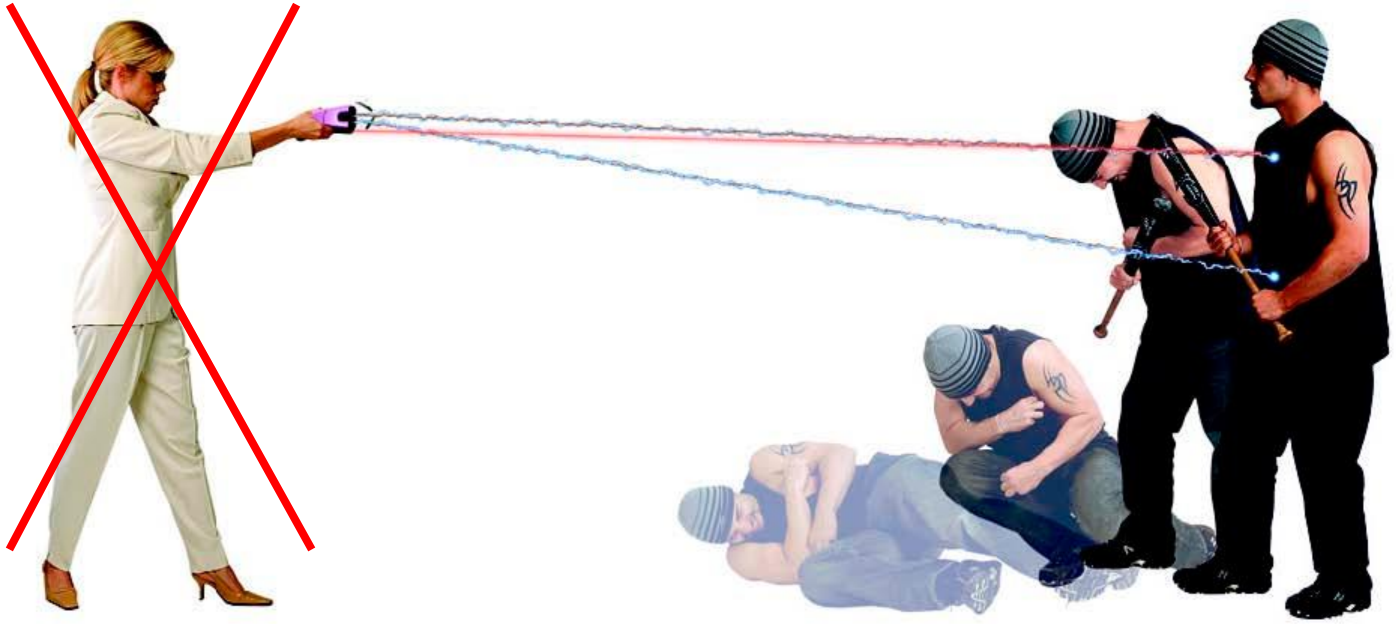

Applications

- Search (and Rescue)



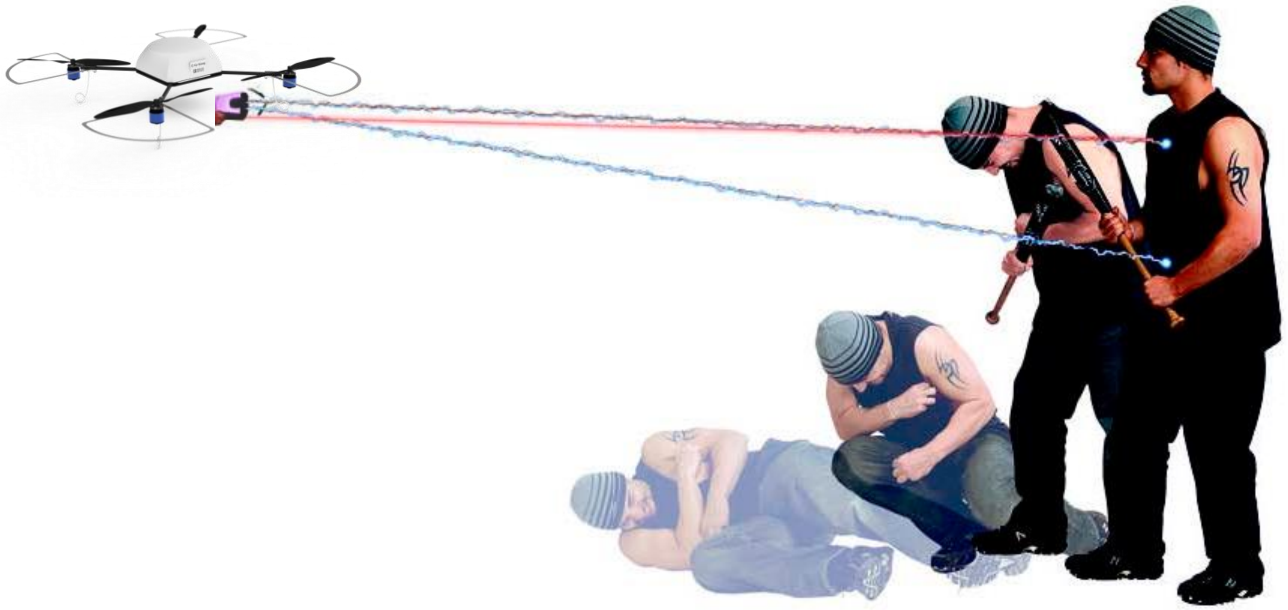
Applications

- Search (and Rescue)



Applications

- Search (and Rescue)



Flying RPAS legally

1. Am I allowed to fly (Permit)?
   ⇒ Aviation Authorities (State < 150kg, EASA >150kg)
2. Where may I fly?
   ⇒ Airspace, airports CTR, military areas,…
3. What operational measures should I take?
   ⇒ Location, Mission, Command & Control,…
4. Privacy?
   ⇒ Photo and video capturing

Safety!!

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Permit

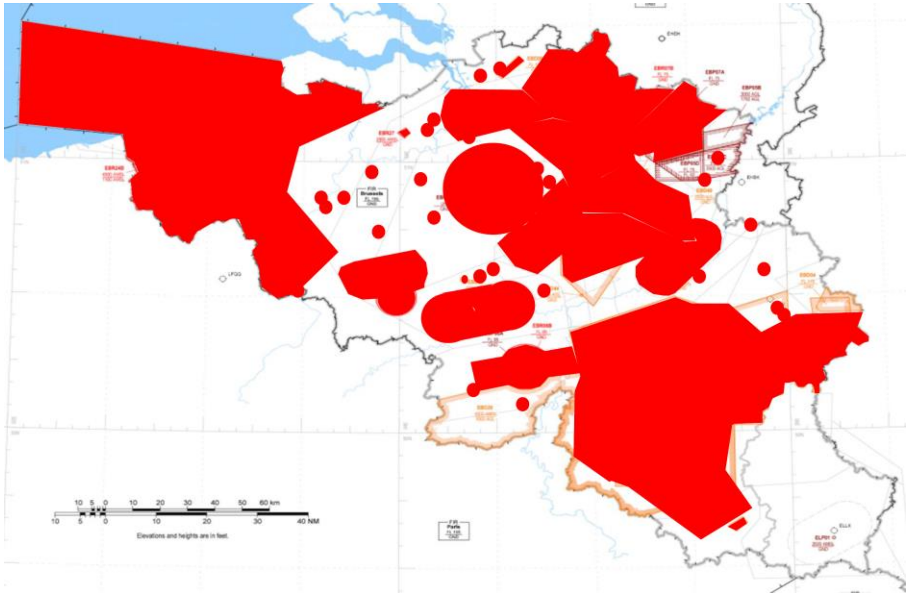
- Aircraft airworthiness and registration
- Pilot license
- Operator permit (operational manual, maintenance log,..)
- Insurance

- Launch and recovery location owner's permission
- Local authority permission

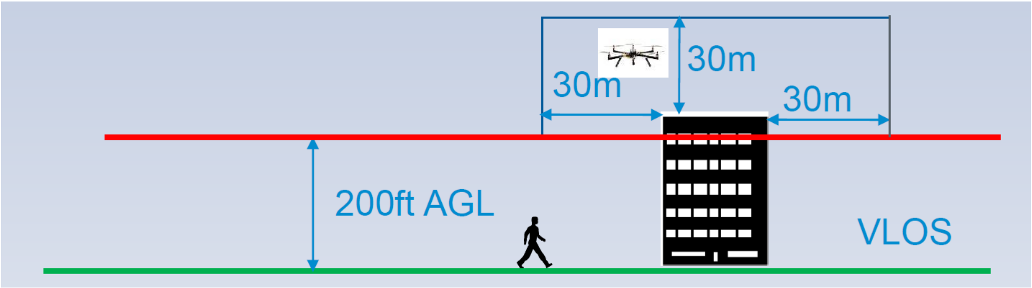
- Depends on (national) legislation!
  - http://uvs-international.org/ (European society)
  - http://www.uavdach.org/ (German society)

German society

Where?



- Airspace:
  - A,B,C,D,G?
  - P,R,D regions
  - Cities?
- Airports CTR
- Low level operations
  - Military low flying areas (LFA, down to 75m)
  - Helicopter training area (HTA, GND up to 75m)
- VLOS, BLOS
  - Visual Line of sight
  - Beyond line of sight



Operational measures

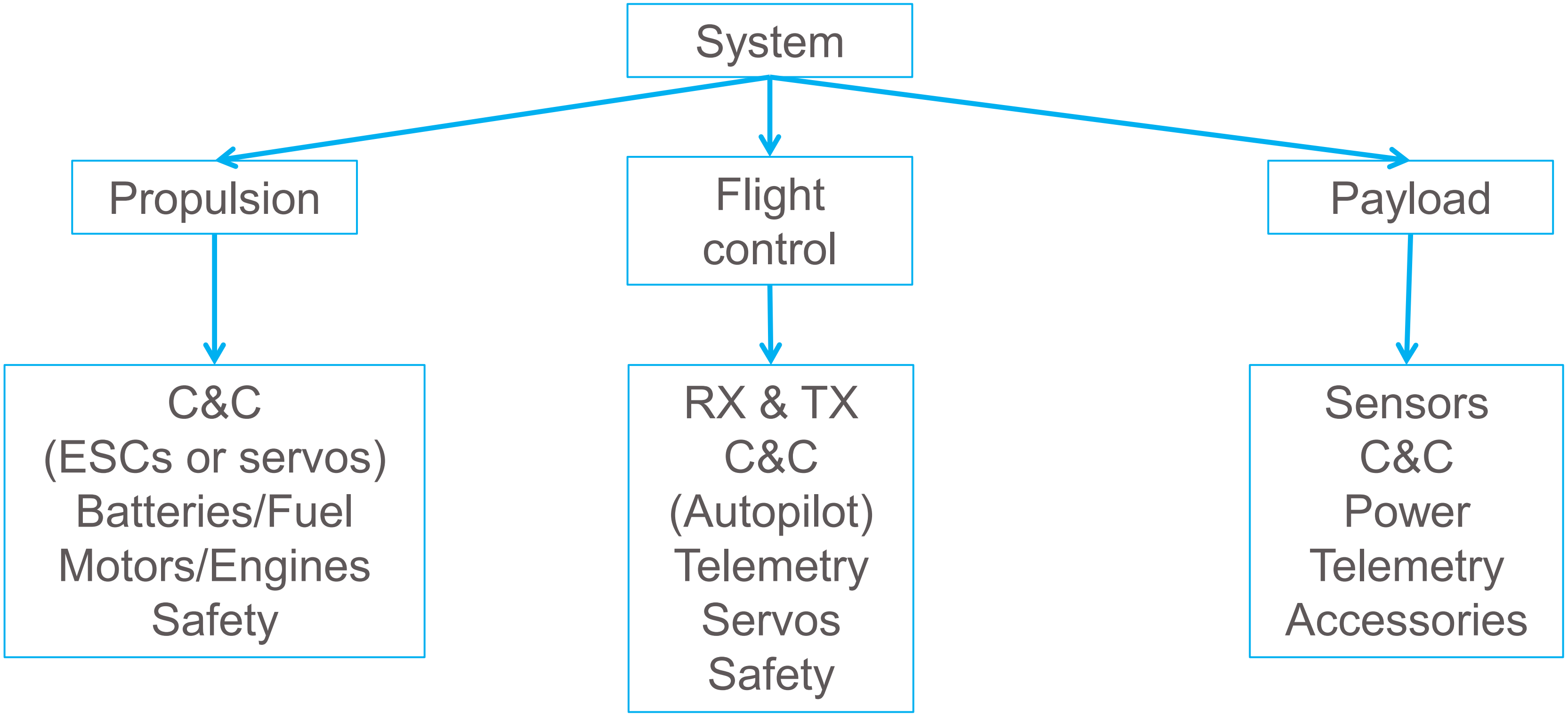
- Launch and recovery area
  - Obstacles
  - Safety region
- Mission
  - Close-up inspection industrial site vs. monitoring fields
- Line of sight, Command and Control
  - Control and telemetry data protection, frequencies
- Right of way
  - RPAS at the bottom
- Meteo
  - Required minima depend on RPA and mission

Privacy

- No separate RPAS-privacy laws. Normal laws apply.

- It is forbidden to take images AND distribute them IF people can be identified WITHOUT permission UNLESS there is a justified reason

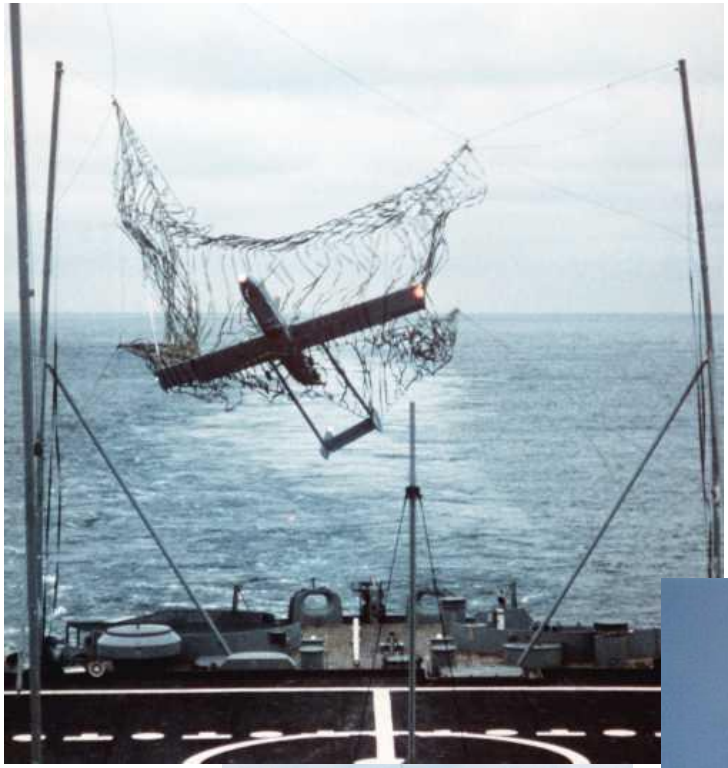
System overview

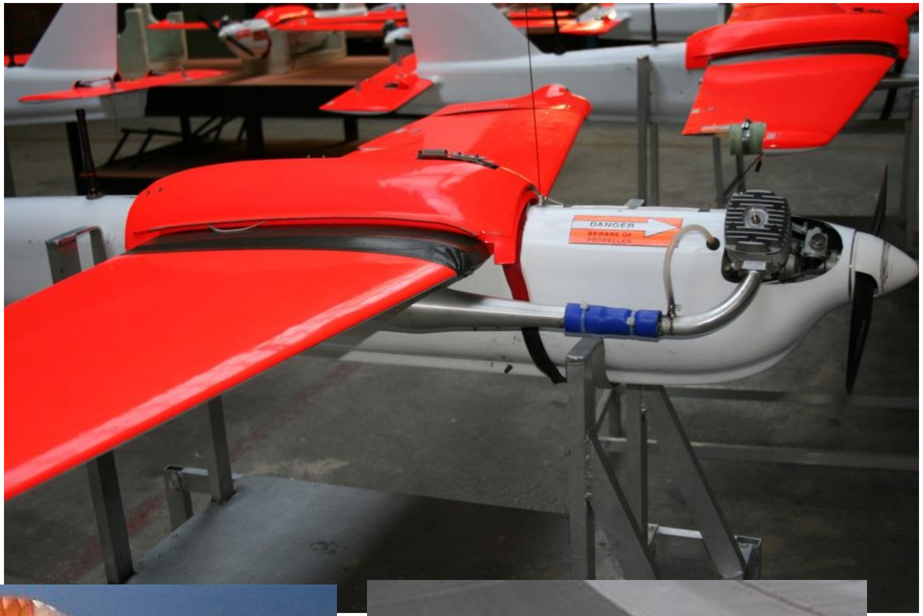


Take-off

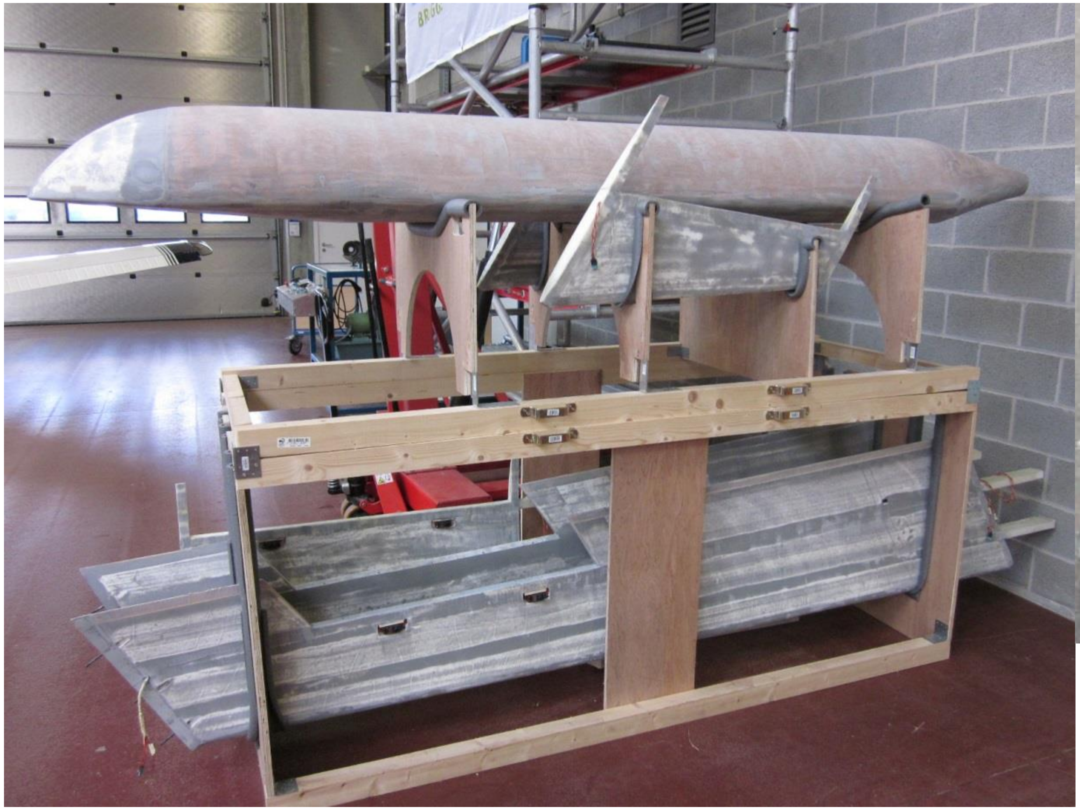



Recovery





Transport



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Handling

Maintenance

- Parts, structure, systems, when, how…?

Multicopters

Multicopter

- Special type of helicopter
- Has three or more rotors/propellers
- Often rotors are fixed-pitch $\Rightarrow$ propellers
- Control of multicopter is by varying speed of each propeller
- Very robust, simple and cheap
- Name multirotor = multicopter

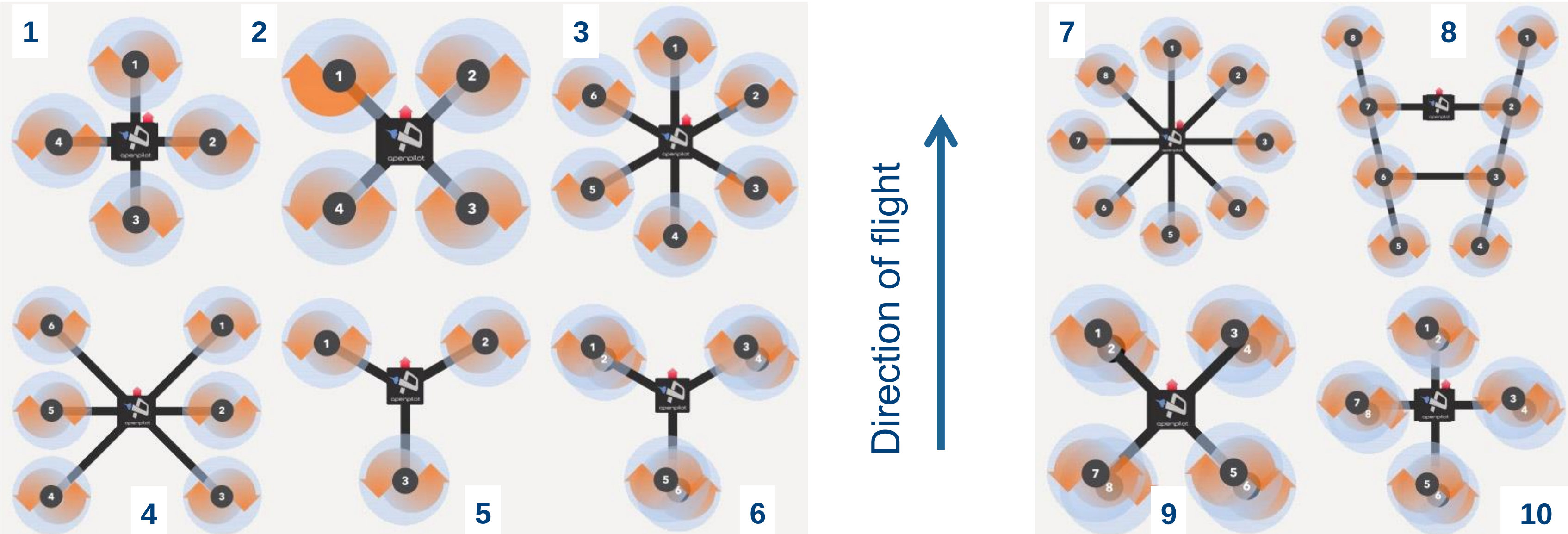
Types

- There is no upper limit to the number of propellers:
  4 propellers = quadcopter, 6 propellers = hexacopter,
  8 = octo, 10 = deca,…

Types

E-volo VC200
First (unmanned) flight 2013
Manned flight testing 2014

Configurations



1) Quad +
2) Quad X
3) Hexa +
4) Hexa H
5) Tri
6) Hexa Y
7) Octo Conventional
8) Octo V shape
9) Octo Coax X
10) Octo Coax +

New configurations are still being conceived!!

Special versions

- Tilt rotor/ tilt wing



- With wing



- …

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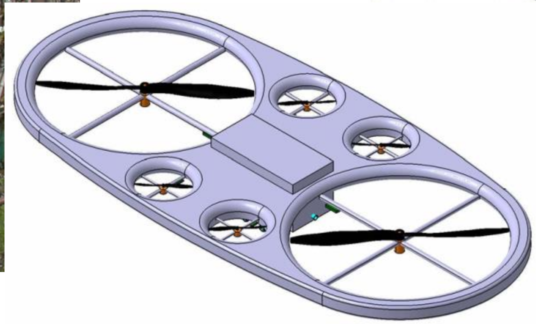
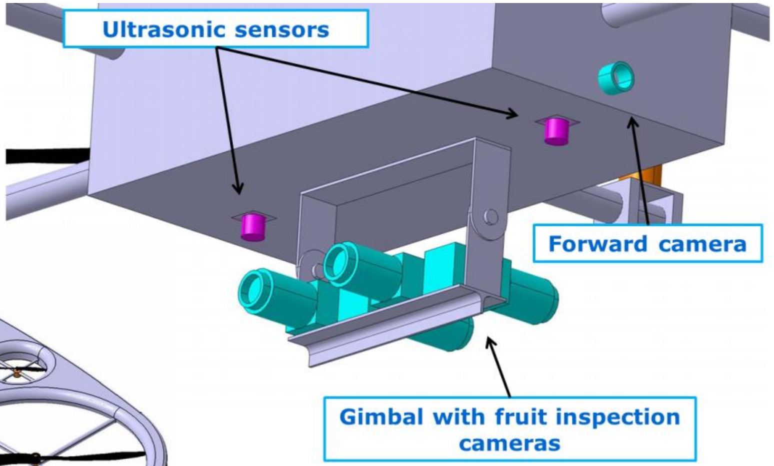
Special versions

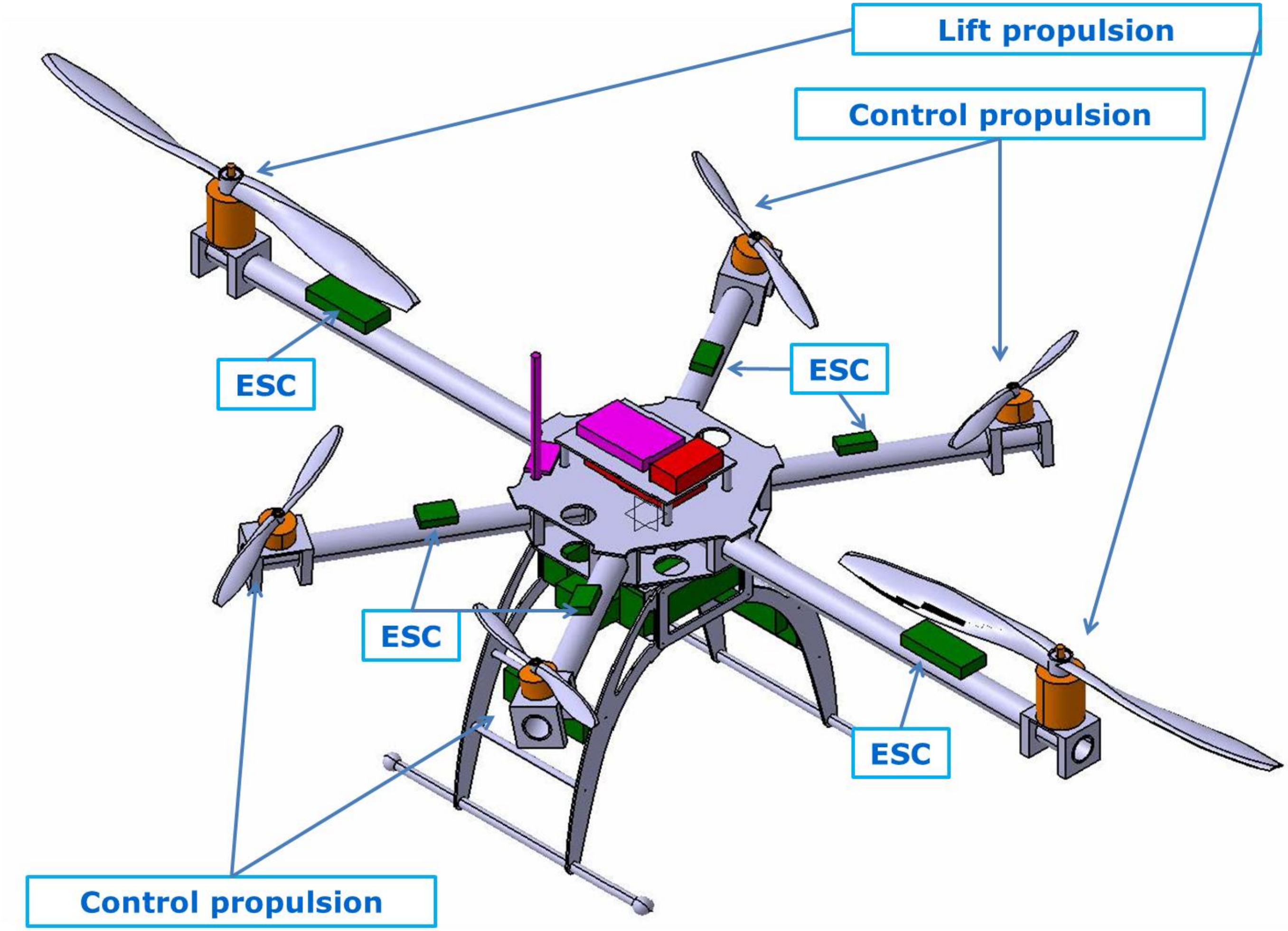
- PhD Research:
  - Design & Control of an autonomous rotary RPA for inspection of orchards
  - Harvest yield estimation



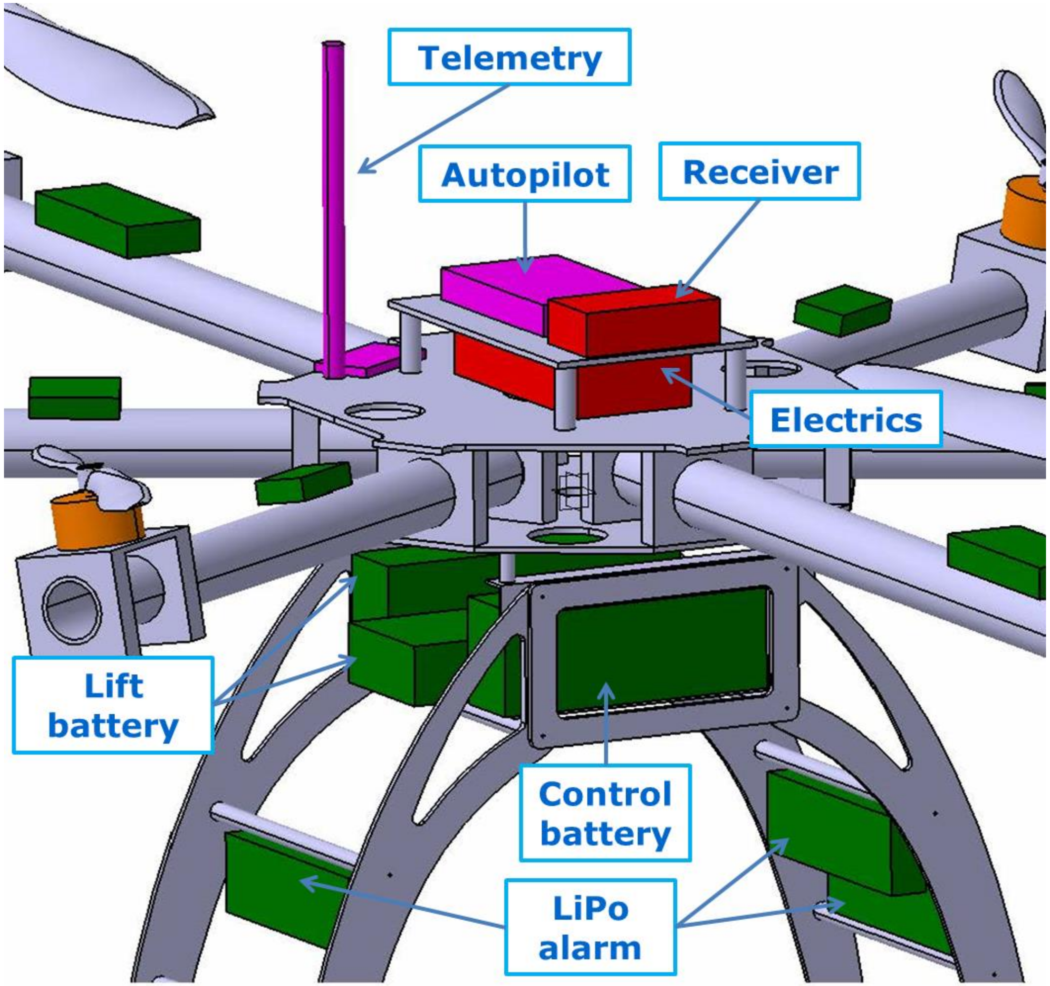


Components

Components

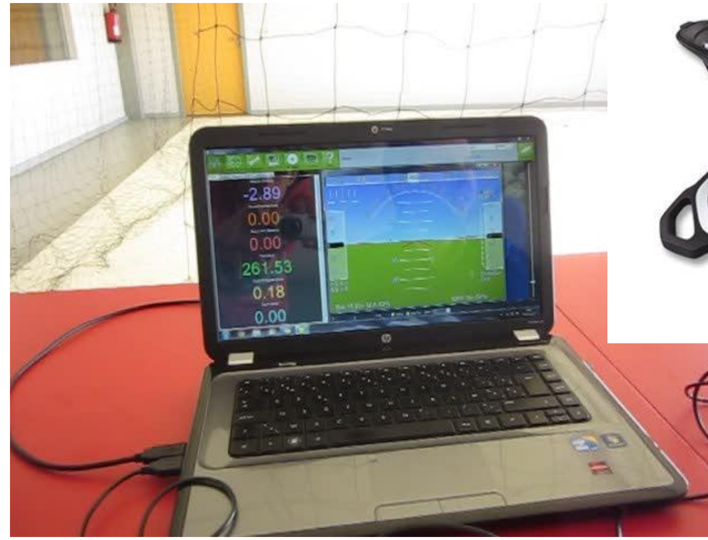

Lift propulsion
Control propulsion
ESC
ESC
ESC
ESC
ESC
Control propulsion

Components



Telemetry
Autopilot
Receiver
Electrics
Lift battery
Control battery
LiPo alarm

Components


-2.89
0.00
0.00
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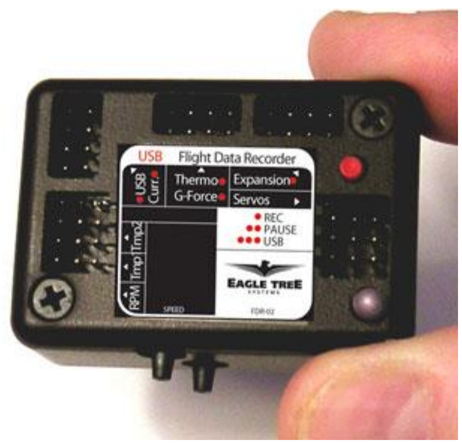
Elevator
Throttle
Aileron
Rudder
Futaba
T8FG
SUPER
FASST
14


USB Flight Data Recorder
Thermo
Expansion
G-Force
Servos
REC
PAUSE
USB
EAGLE TREE
RPM
Tmp
Tmp2
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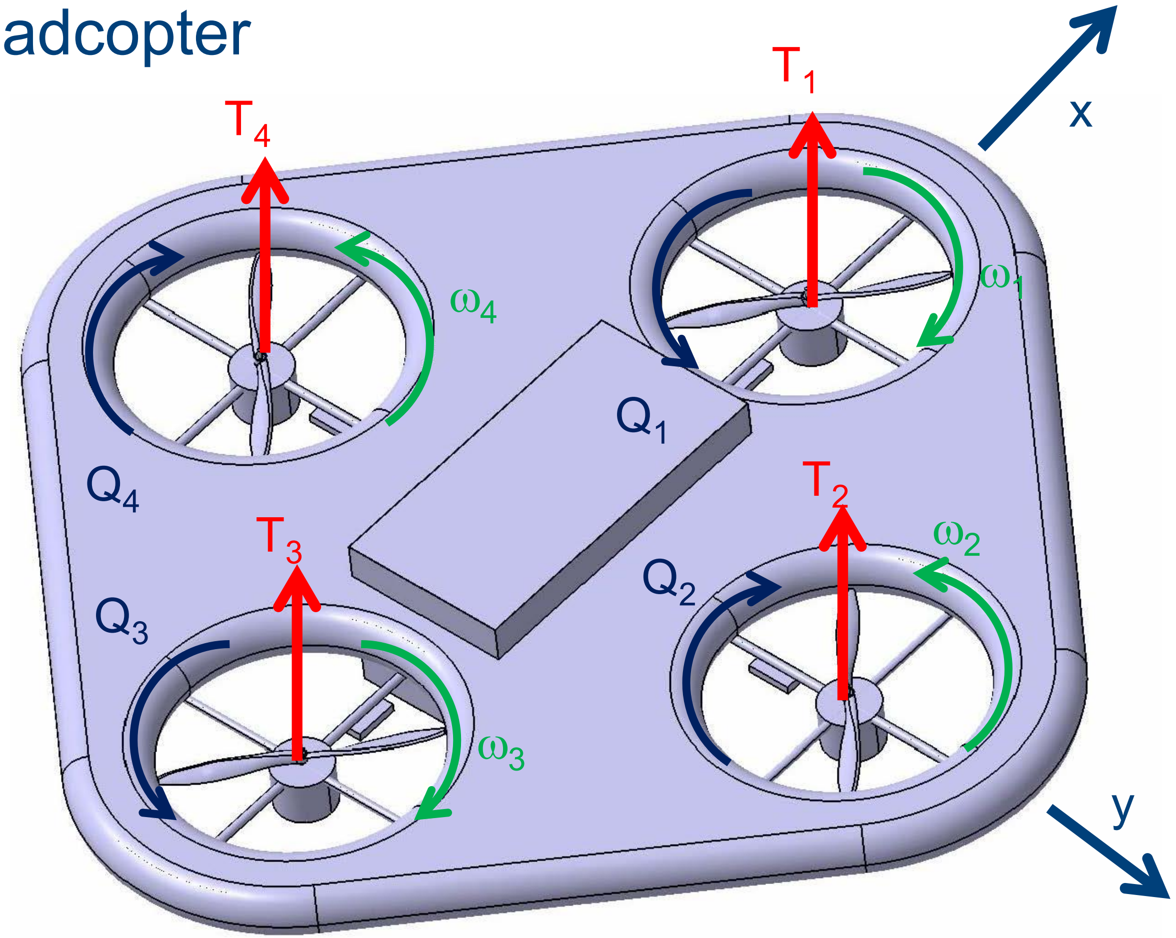
Curr.

Multicopter control

- For example: quadcopter



T= Thrust

ω = propeller speed

Q = Torque

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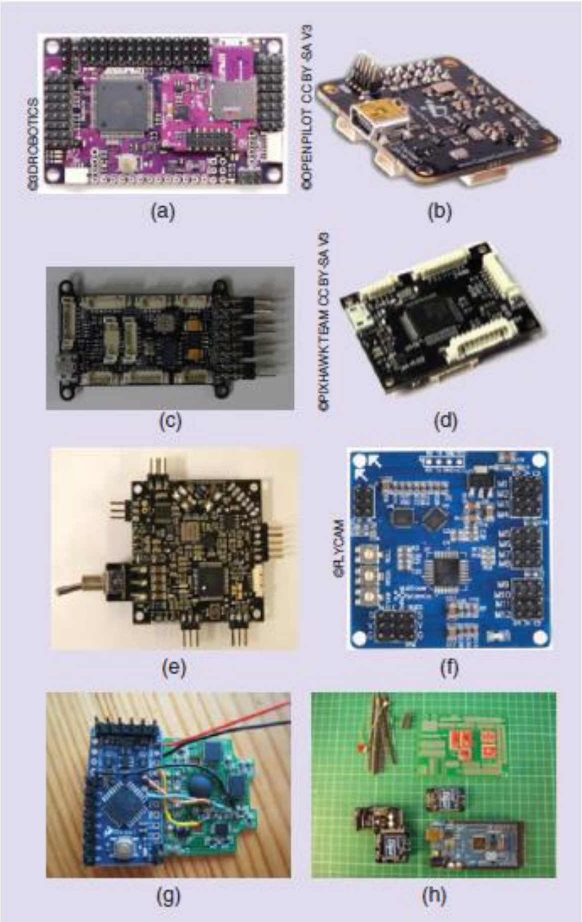
Autopilot

- Multicopters are inherently unstable $\Rightarrow$ autopilot!
- Autopilot = computer that stabilises and controls the multicopter
- Use info from sensors to evaluate the current state of the multicopter and command the motors to achieve a desired state
- Both open-source and corporate autopilots exist

Autopilot examples

- OpenPilot
- Paparazzi
- Mikrokopter
- Kkmulticopter
- Multiwii
- Aeroquad
- Arducopter
- Pixhawk

- Micropilot



APM 2.6

- ArduPilotMega 2.6 open source autopilot
  - Mission planner software on laptop
    for inflight real-time status
  - Suitable for fixed-wing and rotary RPA
  - Includes:
    - 6DoF Inertial Measurement Unit
    - 3-axis magnetometer
    - Barometric pressure sensor
  - Combines with 3DR telemetry link and GPS
  - Size: 7x4x1cm, Total weight: 72g

New: PixHawk

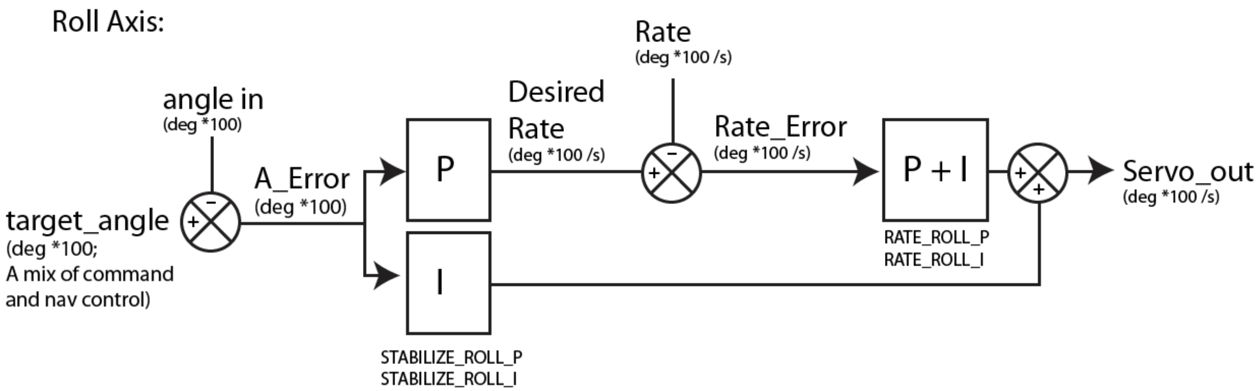
PID controller (1)

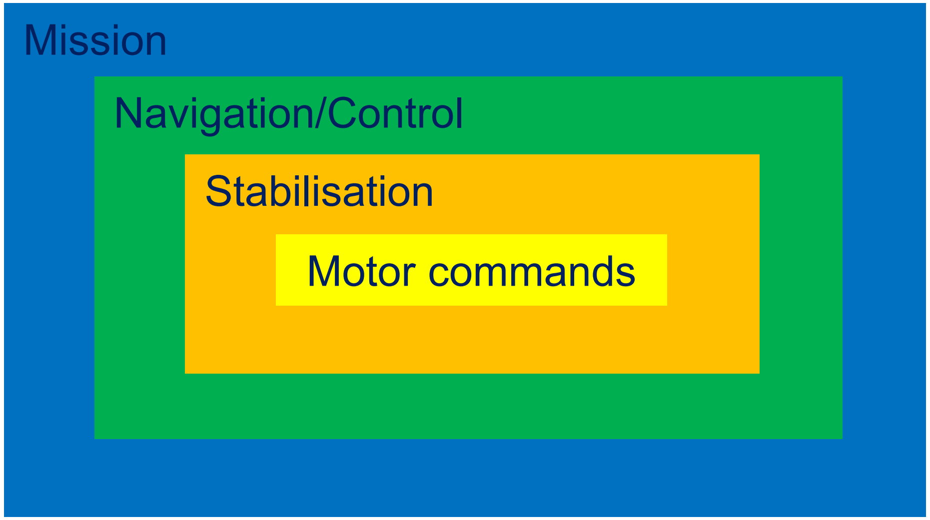
- Proportional-Integral-Derivative controller

- Controller looks at the error between the actual input and the desired input and translates this error into a correcting output

- Consists of three parameters that do the “translation”
  - Proportional parameter
  - Integral parameter
  - Derivative parameter

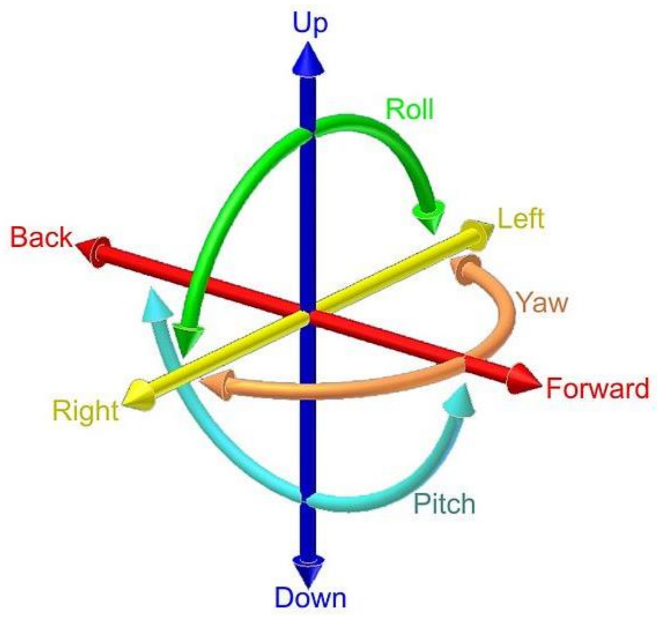
Autopilot control levels





Onboard sensors

- Inertial Measurement Unit (IMU)
  - 6DoF accelerations : $\ddot{x}, \ddot{y}, \ddot{z}, \ddot{\varphi}, \ddot{\theta}, \ddot{\psi}$
  - Integrated over time to give velocity and position
  - Large drift over time



- Global Positioning System (GPS)
  - Absolute position
  - Used as a correction for IMU drift

Onboard sensors

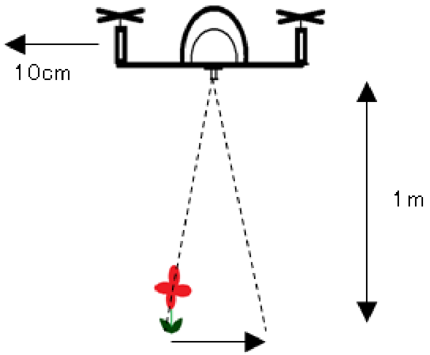
- Magnetometer
  - Magnetic heading

- Barometric pressure sensor
  - Altitude
  - Climb speed

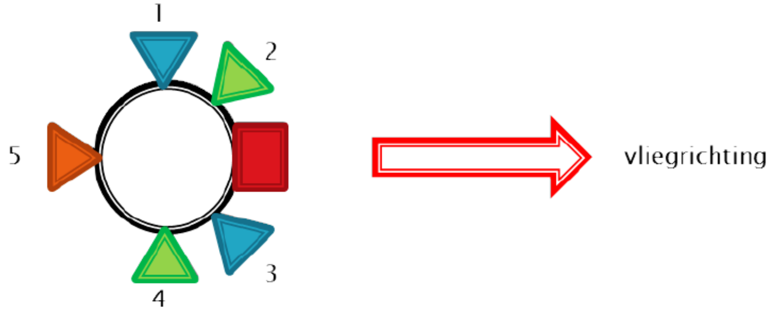
- Ultrasonic altitude sensor (optional)
  - Height above the ground

Optional onboard sensors

- Optical flow sensor
  - Films the ground and detects horizontal movement
  - Takes pitch, roll and altitude into account



- Navigational (Ultrasonic) sensors
  - Detect walls, ceiling and floor
  - Prevents collision (indoor)



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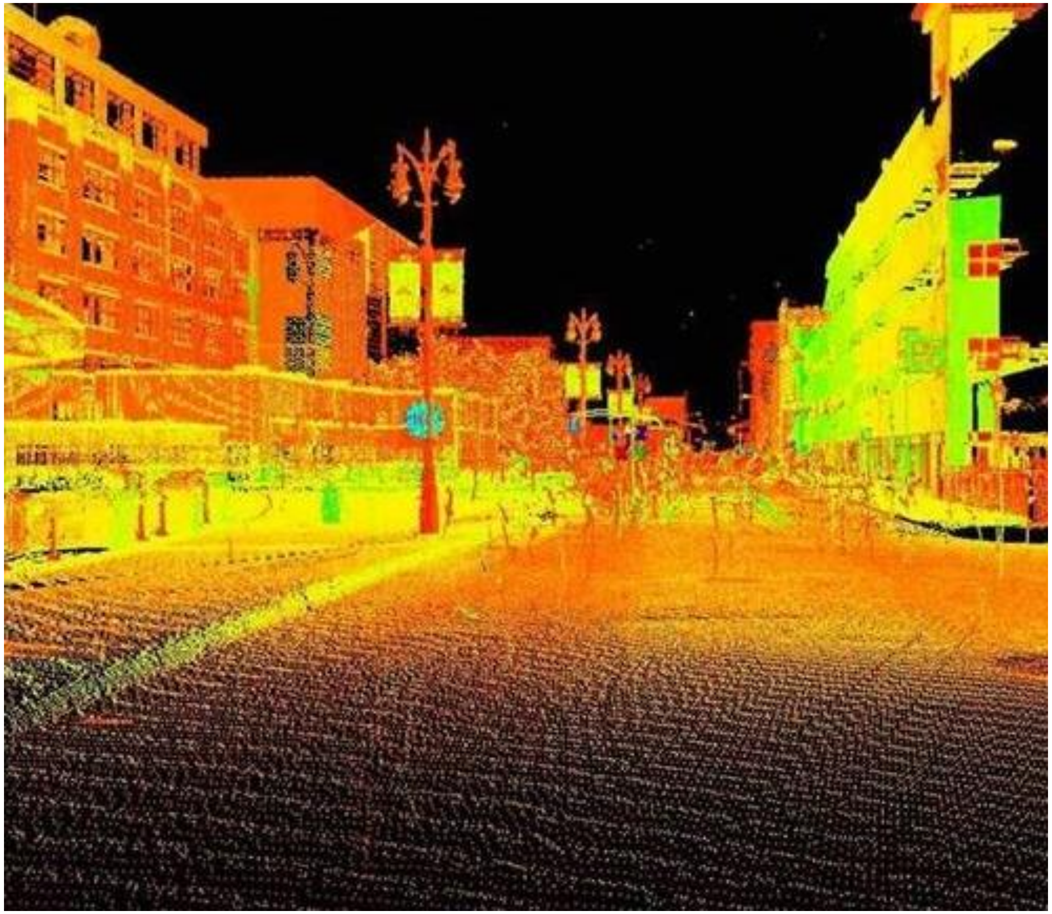
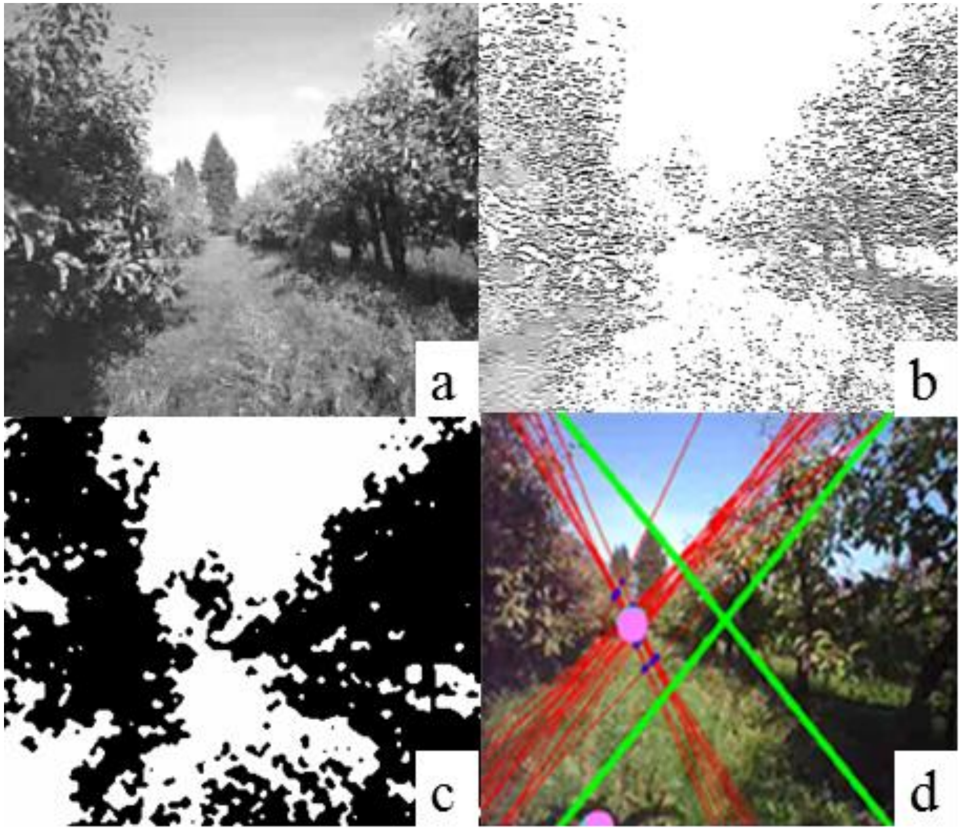
Optional onboard sensors

- Laser scanner
  - Scans environment
  - Builds its own map for navigation



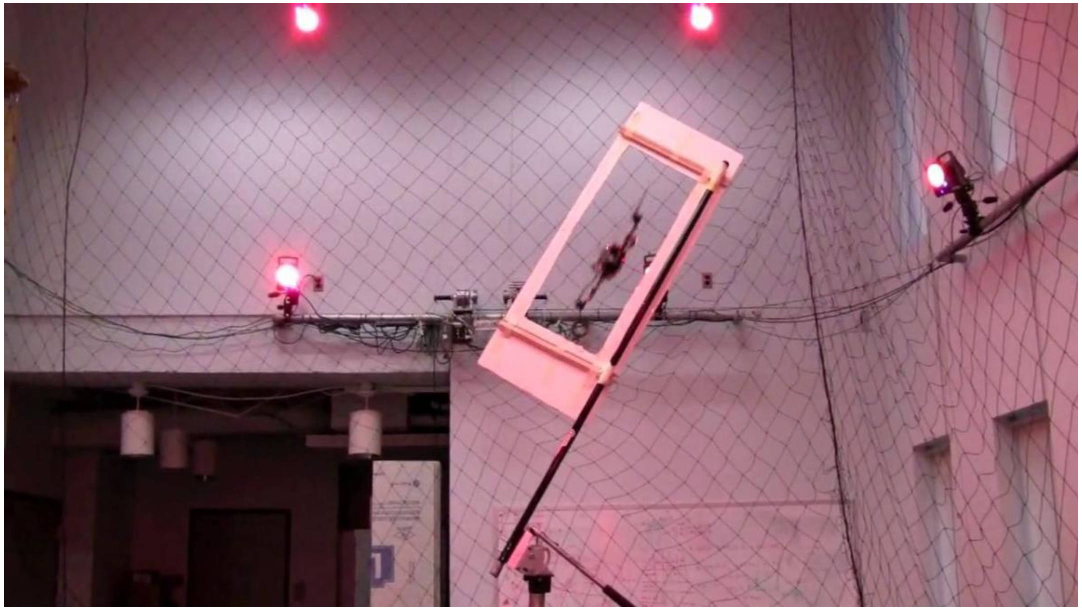
Optional onboard sensors

- Forward camera
  - Image processing
  - Pilot FPV or automatic navigation (object recognition)



Indoor off-board sensors

- Vicon motion capture system
  - Room full of cameras (20x MX T40 cameras)
  - Determine 6D pose of (multiple) vehicle(s): x, y, z,θ, ϕ and ψ
  - Very accurate (millimetres) and fast (up to 2000Hz)



Optional onboard additions

- Camera gimbal
  - Mounts camera
  - 1D, 2D or 3D
  - Compensated for roll, pitch and yaw vehicle
  - From pocket camera up to cinematic cameras
- Navigational LEDs
  - Red, white and green
  - Marginal power consumption

Research @ KU Leuven

- PMA – Mechatronics and Robotics, Prof. Joris De Schutter
- ESAT – TELEMIC, Telecommunications and Microwaves, Prof. Sofie Pollin
- ESAT – PSI, Processing Speech and Images, Prof. Tinne Tuytelaars
- Thomas More – EAVISE, Embedded Artificially intelligent Vision Engineering, Prof. Toon Goedemé
- BIOSYST – M3-BIORES, Measure, Model & Manage Bioresponses, Prof. Eddie Schrevens
- Kulab – Propolis, Processing Polymers & Lightweight Structures, Prof. Frederik Desplentere

Multicopter example: ATX8

- http://www.aerialtronics.com/
- Endurance: 8 – 20min
- Range: 600m – 2km
- Payload : 2.75kg
- Wind: up to 12m/s (40km/h)
- Very modular design
- Cameras:
  - Digital Single Lens Reflex-camera (DSLR)
  - FS700
  - RED

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Multicopter example: ATX8

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Multicopter example: ATX8

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Multicopter example: ATX8

Multicopter example: ATX8

Their new **Altura Zenith ATX8**

Monocoque structure!

Flight Demo

- AR.Drone Parrot 2.0
  - Dimensions: 52x52cm
  - Weight: 400g
  - Battery: 3S1500 LiPo
  - Endurance <12min
  - Embedded computer/autopilot
  - Ultrasound altimeter 6m range
  - Forward camera (1280x720pix, 30fps)
  - Downward camera (320x240pix, 60fps)

  - Safe to fly outside flight lab
  - Watch out for Wifi hotspots!

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