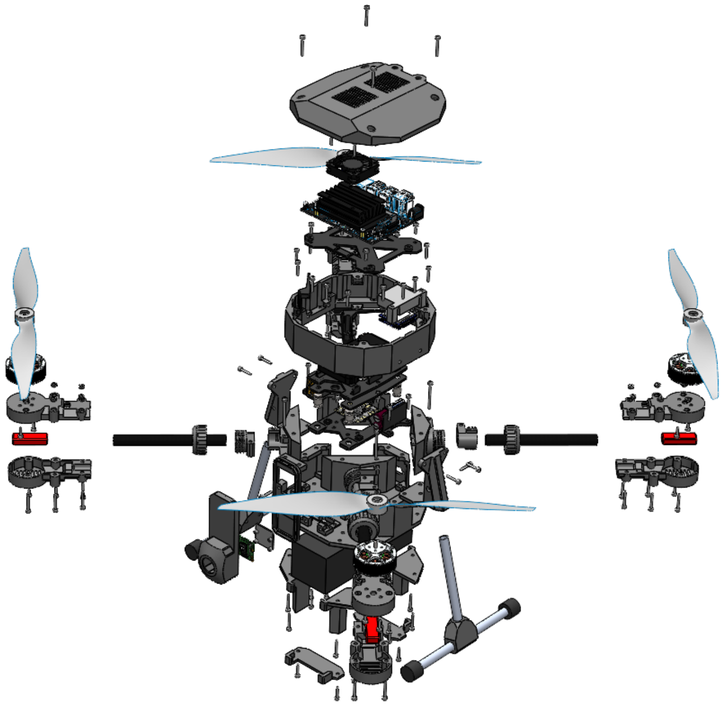
Robust Mechatronics

UAVs as Mechatronic Systems: Design and Applications

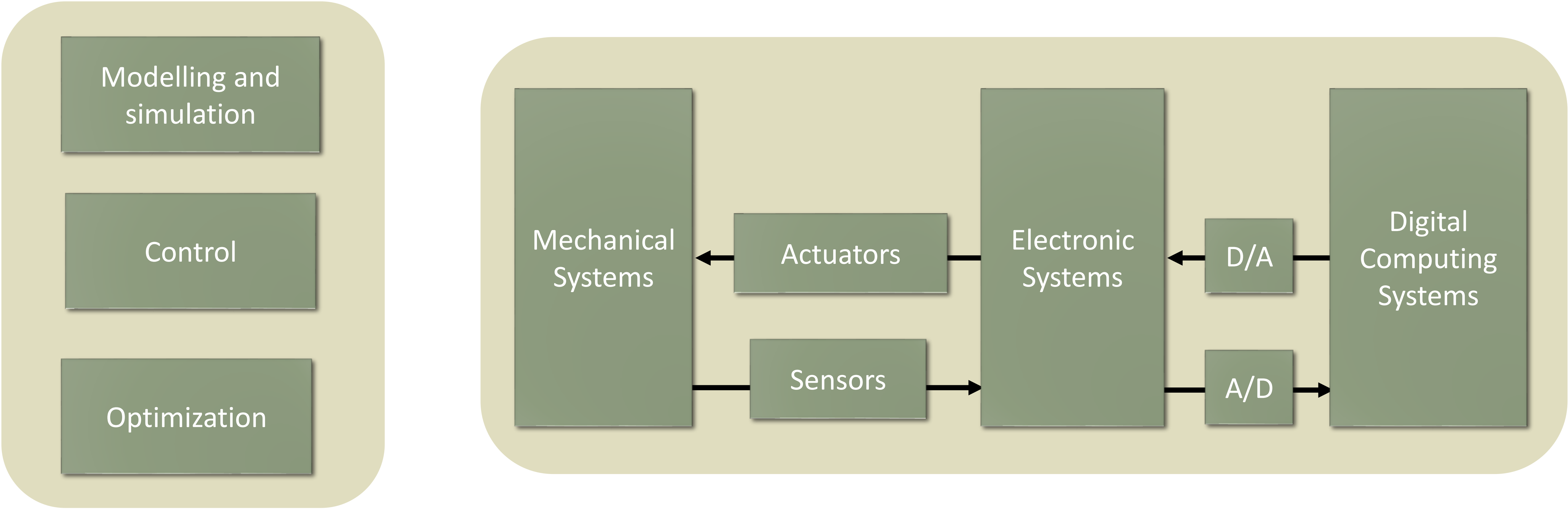


Dr Loukas Bampis, Assistant Professor
Mechatronics & Systems Automation Lab

Basics of mechatronic systems

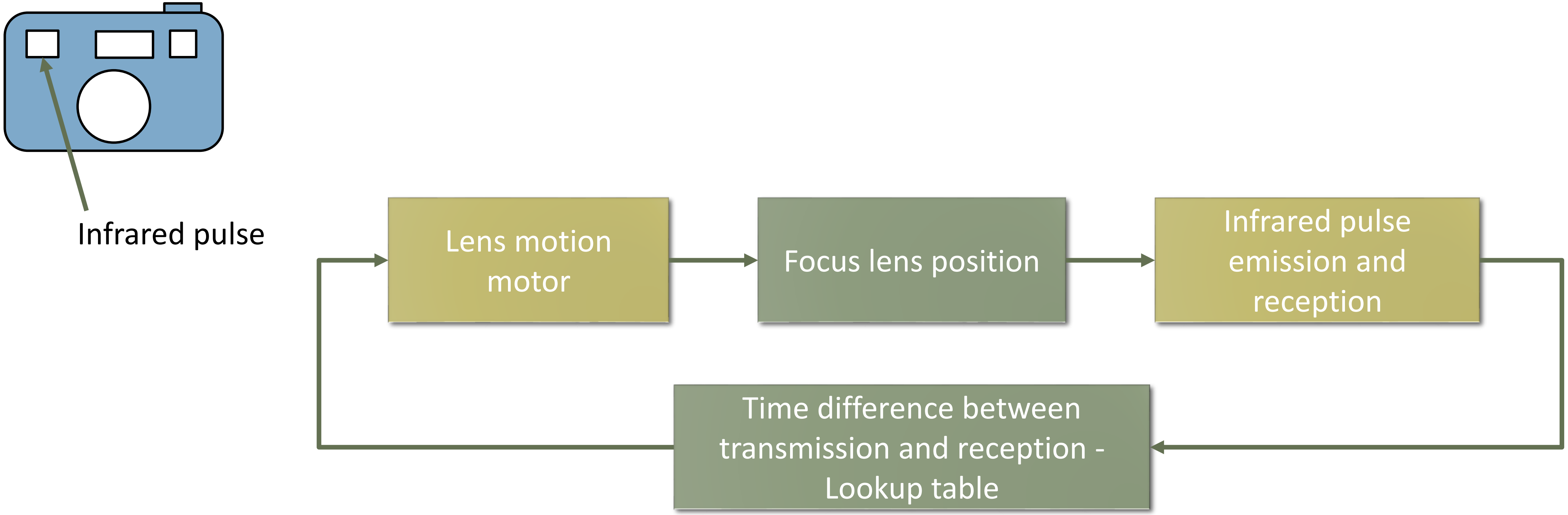
- Mechanical elements
  - System components and components requiring control
- Sensors
  - Perception of the state of mechanisms and environment
- Actuators
  - Movement and control of mechanisms
- Digital Computing Systems
  - Implementation of reasoning actions

Basics of Mechatronic Systems



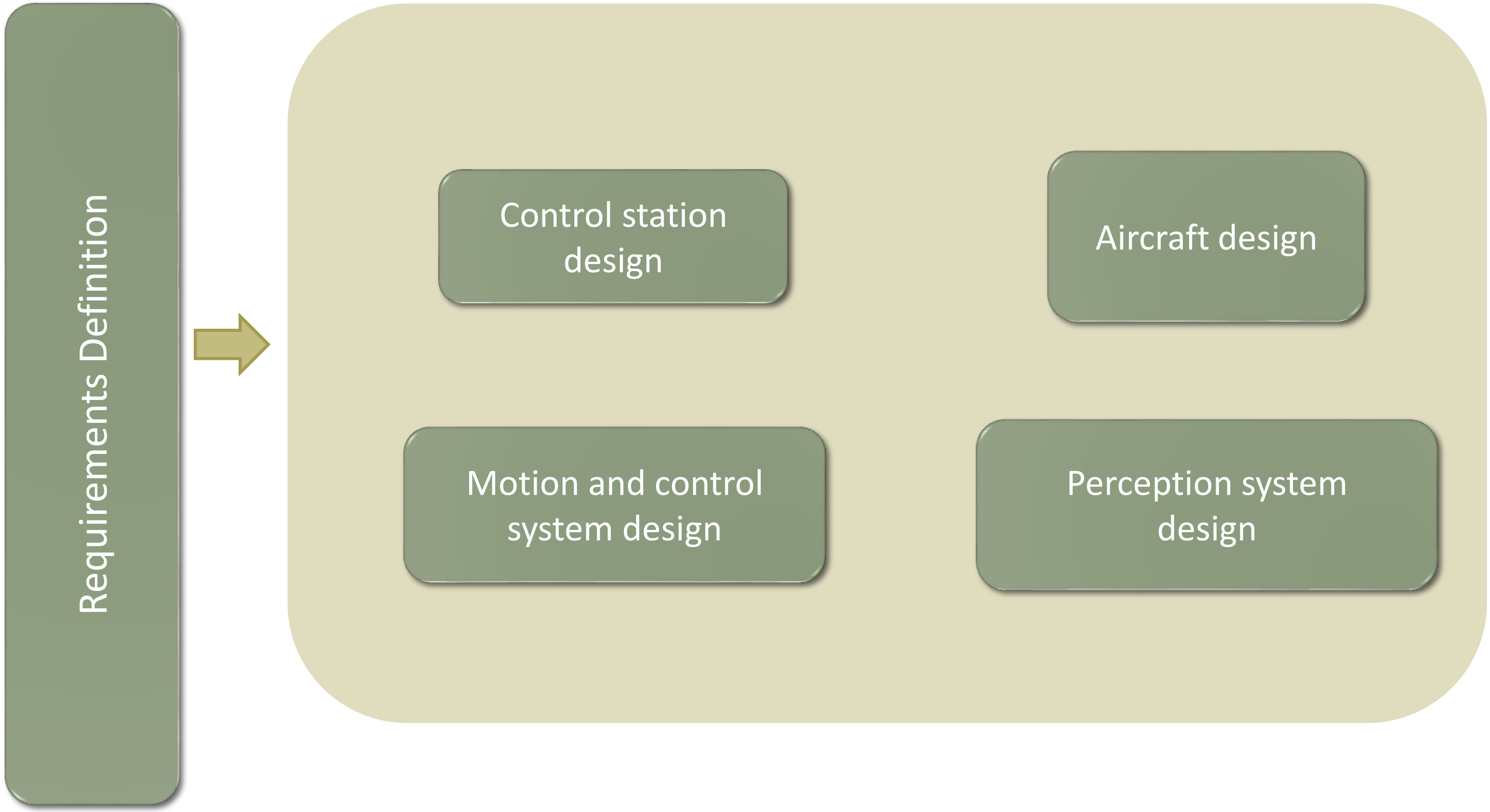
A Simple Example of a Mechatronic System

Digital camera with autofocus



Unmanned Aerial Vehicles

Unmanned Aerial Vehicles Design



Unmanned Aerial Vehicles Design

Requirements Definition

Control station design

Aircraft design

Motion and control system design

Perception system design

Control station design

- Operator interaction with the aircraft
- Exchange of information and command

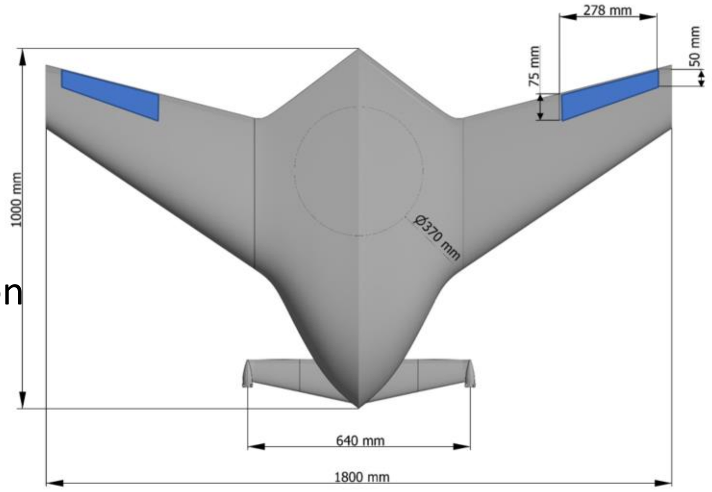
Unmanned Aerial Vehicles Design

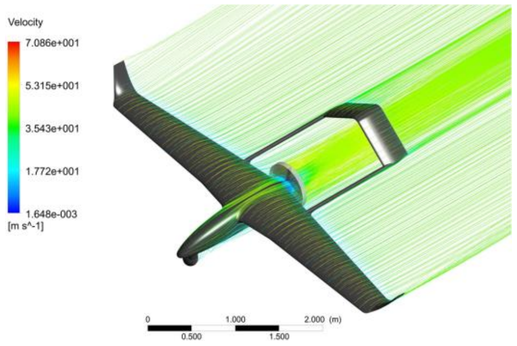
Requirements Definition

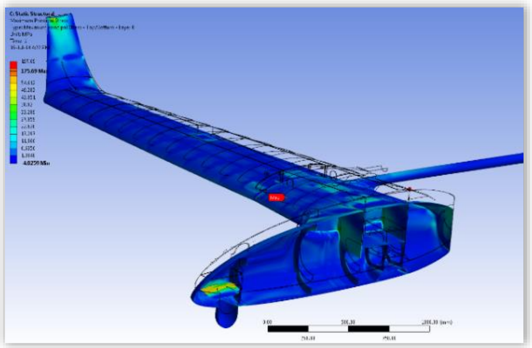
- Control station design
- Aircraft design
- Motion and control system design
- Perception system design

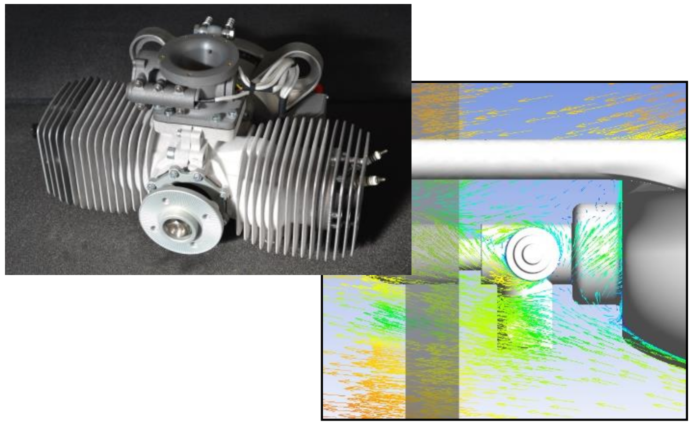
Aircraft design

- Aircraft platform selection
- Aerodynamic study
- Material strength study
- Propulsion system study









Unmanned Aerial Vehicles Design

Requirements Definition

Control station design

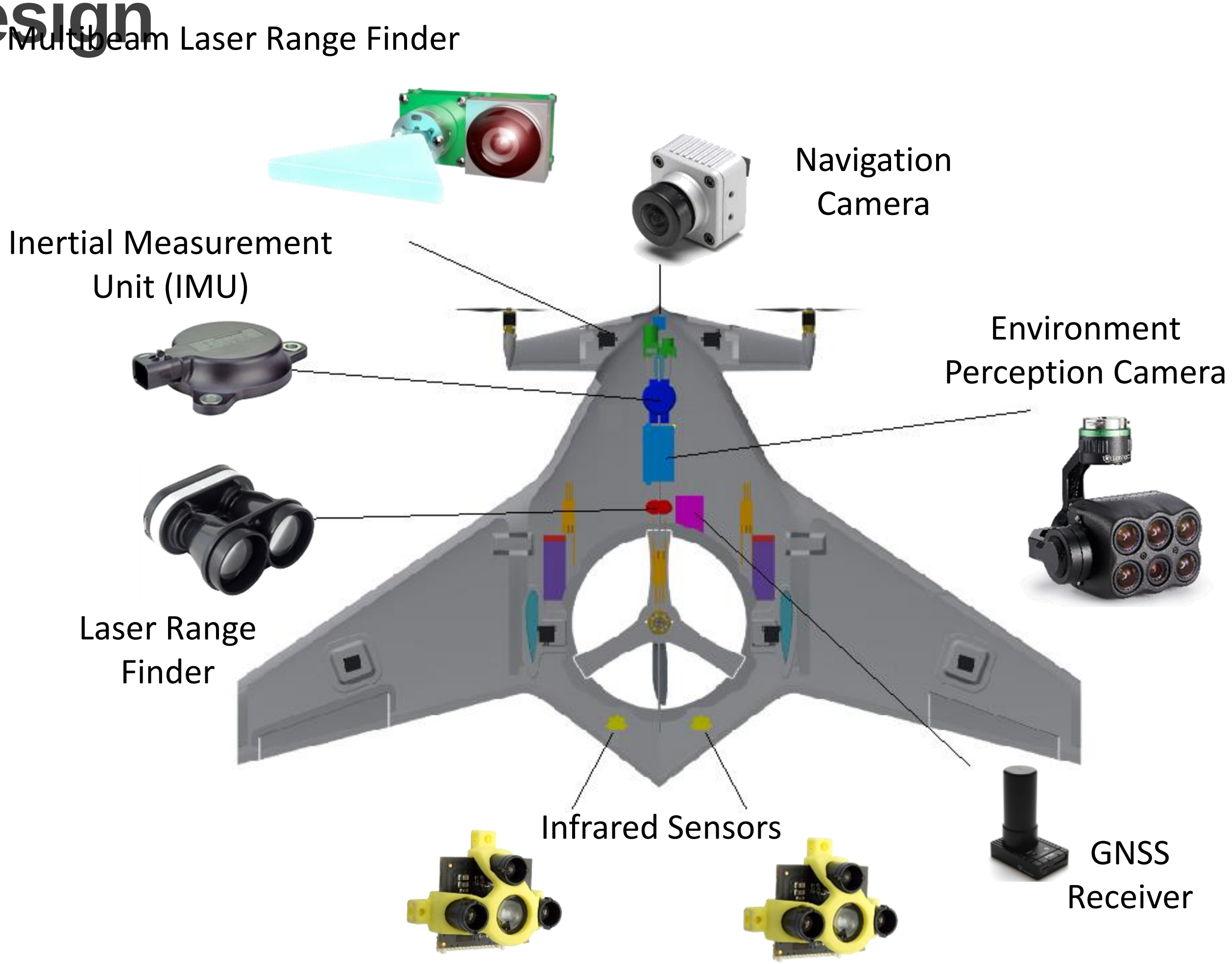
Aircraft design

Motion and control system design

Perception system design

Perception system design

- Responsible for receiving measurements and information from the environment
- Use of sensors and computing units



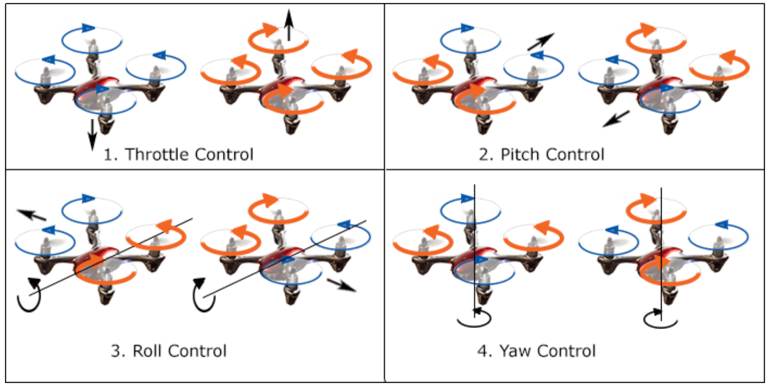
Unmanned Aerial Vehicles Design

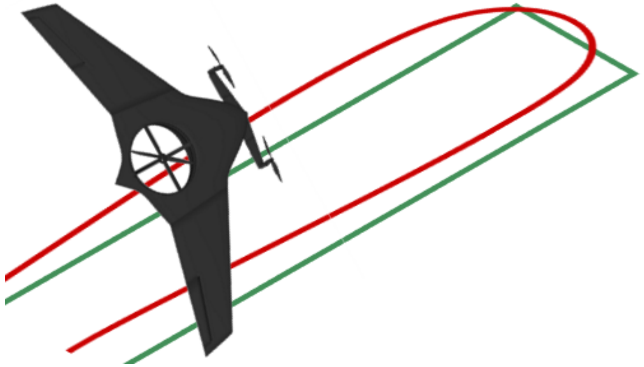
Requirements Definition

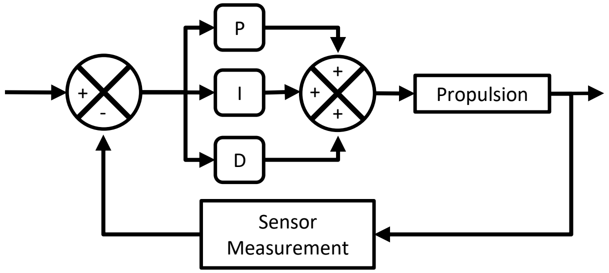
- Control station design
- Aircraft design
- Motion and control system design
- Perception system design

Motion and control system design

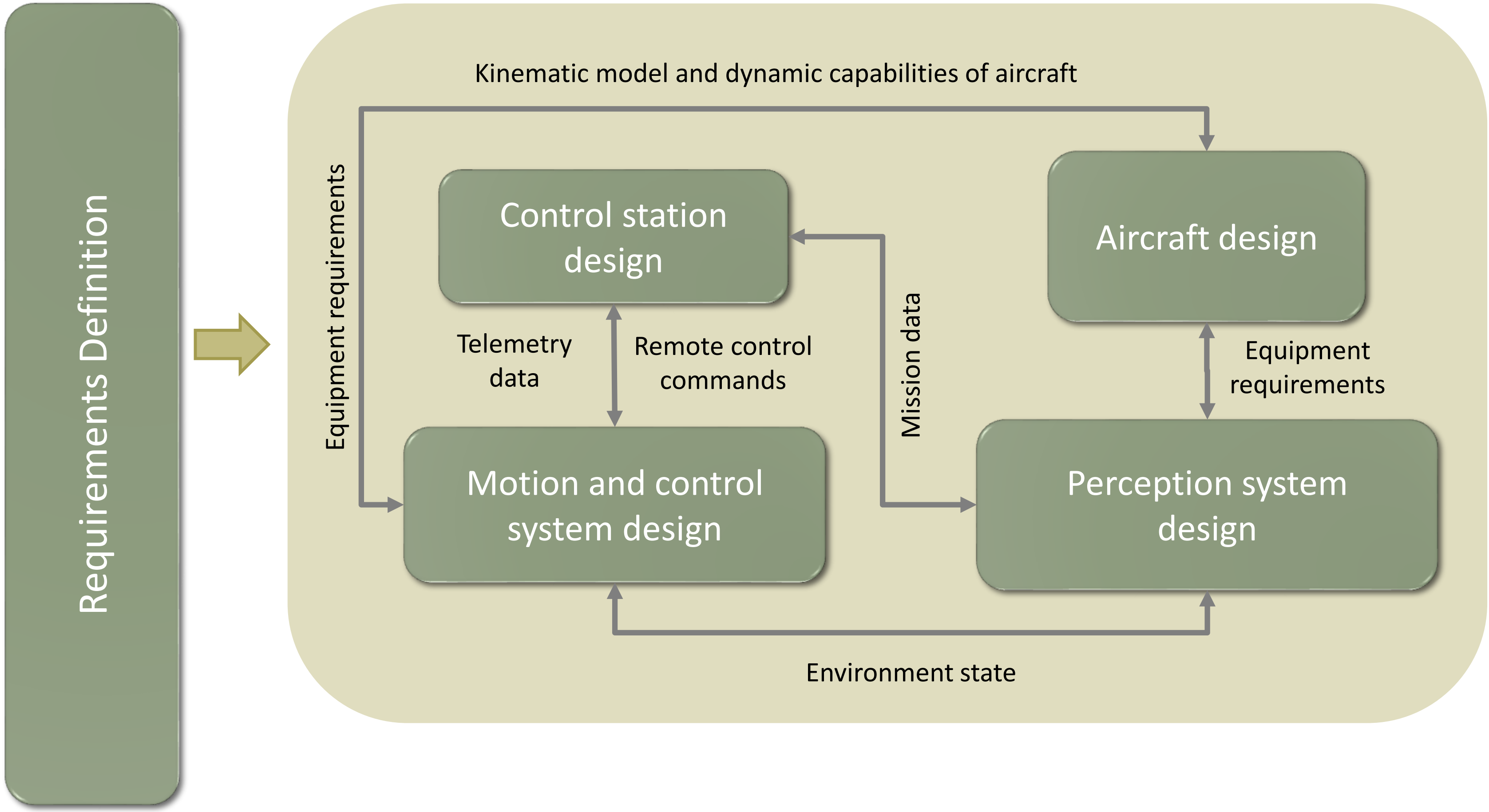
- Responsible for planning and executing motion commands
- Control motors and other movable parts



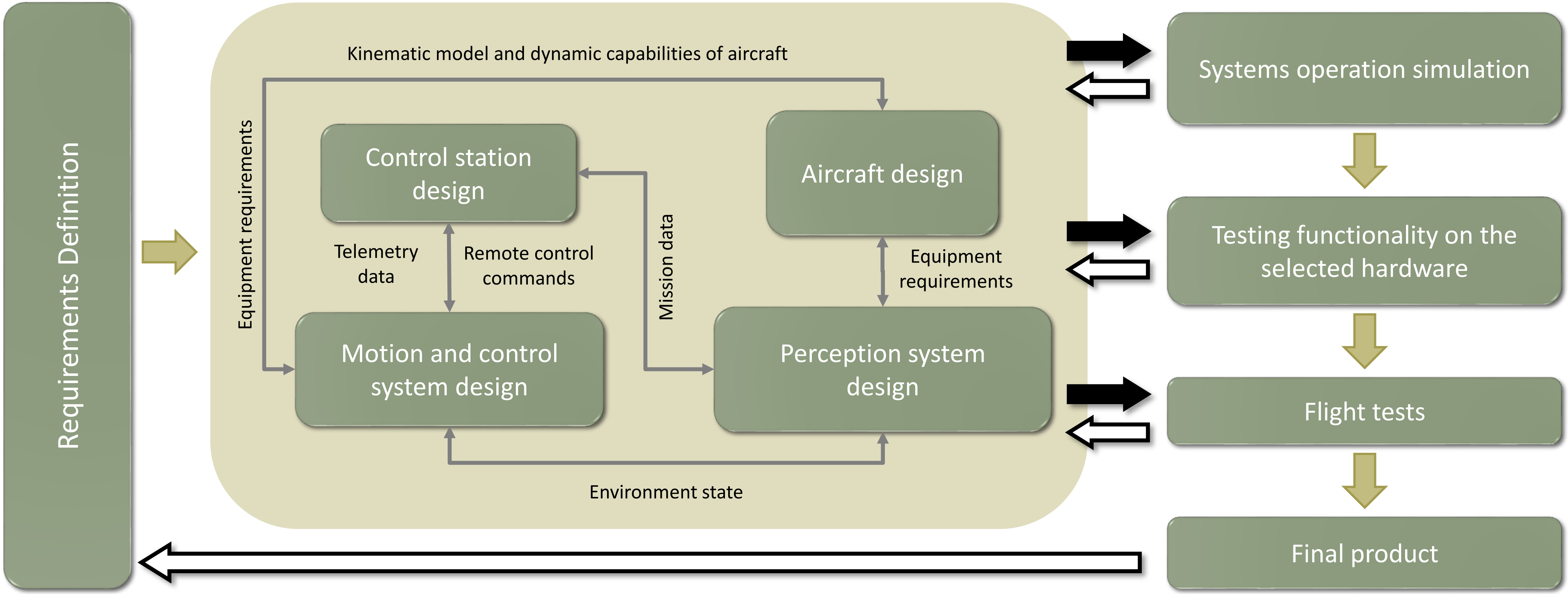




Unmanned Aerial Vehicles Design



Unmanned Aerial Vehicles Design



UAVs' subsystem analysis

Control station design

UAVs' subsystem analysis

Control station design

Capabilities:

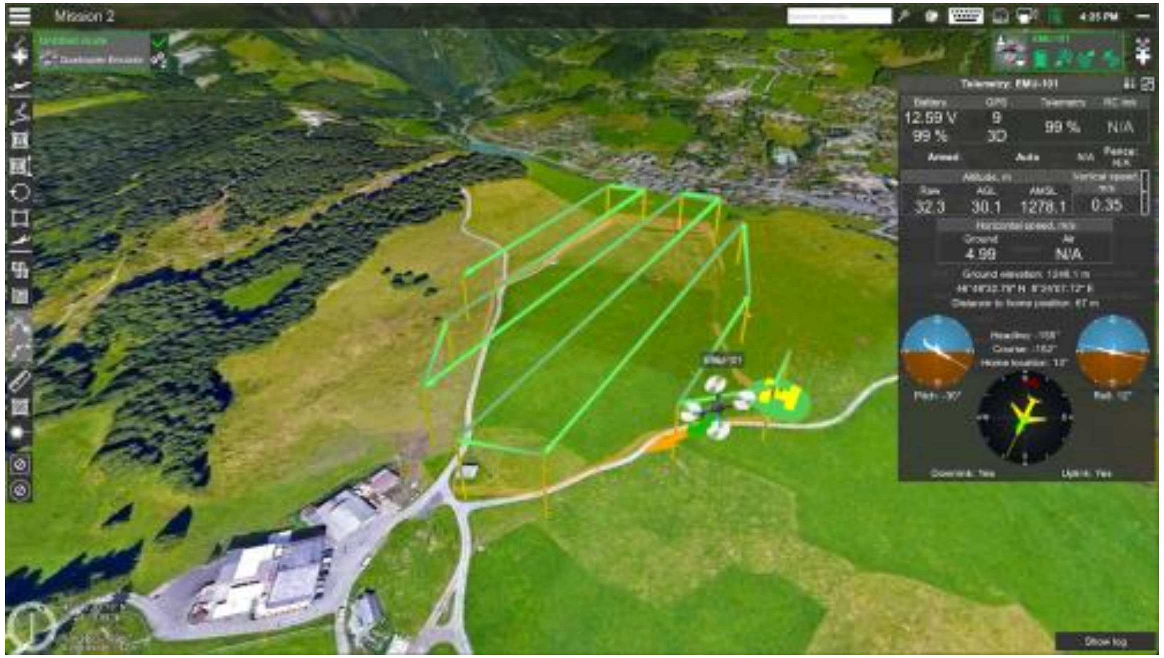
- Remote control
  - Direct manual control aircraft remotely

UAVs' subsystem analysis

Control station design

Capabilities:

- Remote control
  - Direct manual control aircraft remotely
- Telemetry
  - Receiving mission data
  - Publishing waypoints
  - Publishing commands (e.g., landing, target tracking)

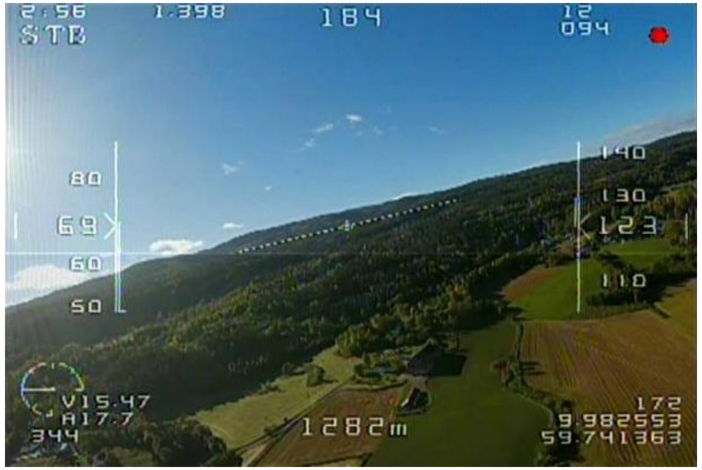


UAVs' subsystem analysis

Control station design

Capabilities:

- Remote control
  - Direct manual control aircraft remotely
- Telemetry
  - Receiving mission data
  - Publishing waypoints
  - Publishing commands (e.g., landing, target tracking)
- Video stream
  - Ground surveillance
  - First Person View



UAVs' subsystem analysis

Aircraft design

Fixed Wing	Rotary-wing	Hybrid
Low Endurance 	Single-rotor 	Fixed-wing VTOL (Vertical Take-Off and Landing) 
Medium Altitude-Long Endurance (MALE) 	Mulitirotor 	Tilt wing 
High Altitude-Long Endurance (HALE) 	Coax copters 	Tilt engine 

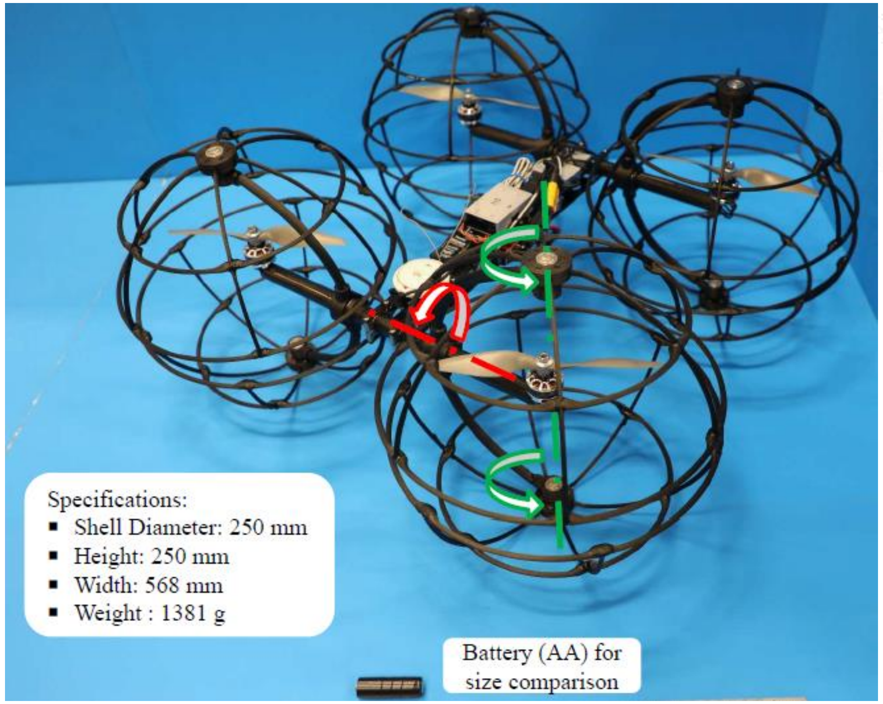
UAVs' subsystem analysis

Aircraft design

Fixed Wing	Rotary-wing	Hybrid
Horizontal Take-Off and Landing (HTOL) Short Take-Off and Landing (STOL)	Vertical Take-Off and Landing (VTOL)	• Vertical Take-Off and Landing (VTOL) • Horizontal flight
Increased take-off/landing requirements	Reduced take-off/landing requirements	Reduced take-off/landing requirements
Reduced energy consumption during flight	Increased energy consumption during flight	Reduced energy consumption during flight

UAVs' subsystem analysis

Aircraft design



UAVs' subsystem analysis

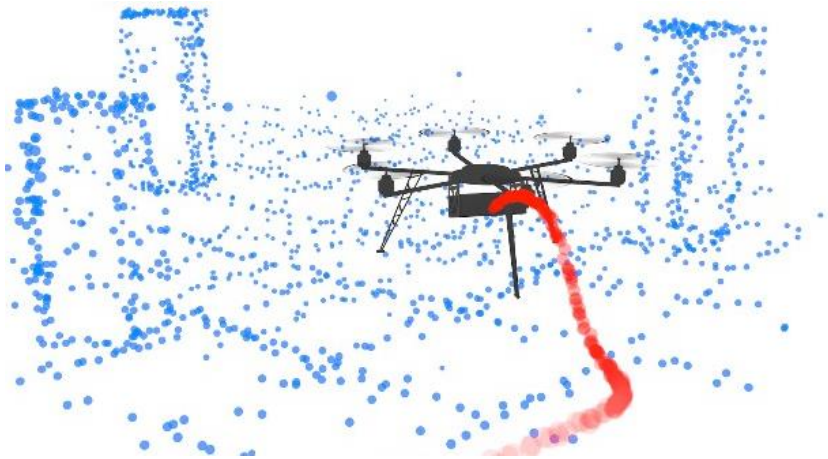
Perception system design

UAVs' subsystem analysis

Perception system design

Available sensors IMU, GNSS, Distance, Cameras

- Localization

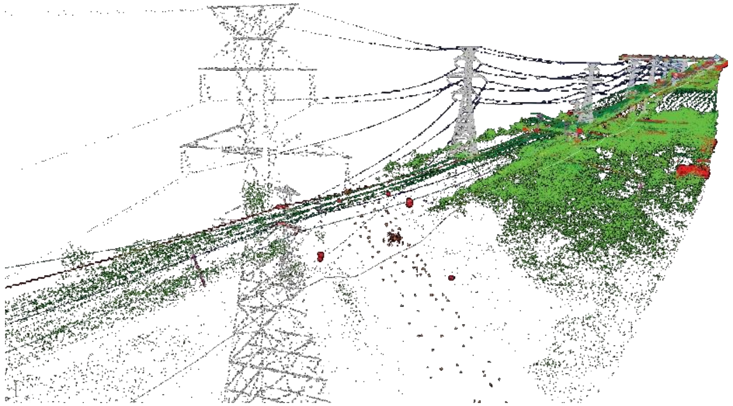


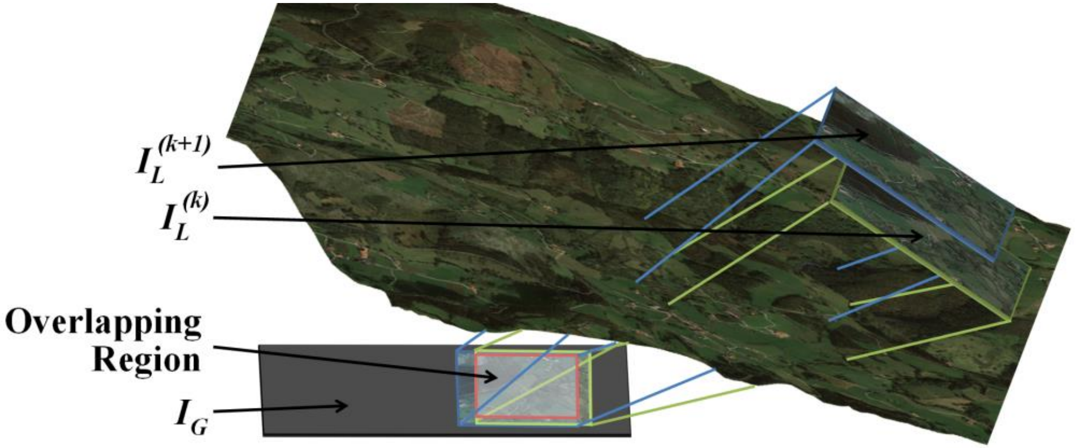
UAVs' subsystem analysis

Perception system design

Available sensors IMU, GNSS, Distance, Cameras

- Localization
- Mapping



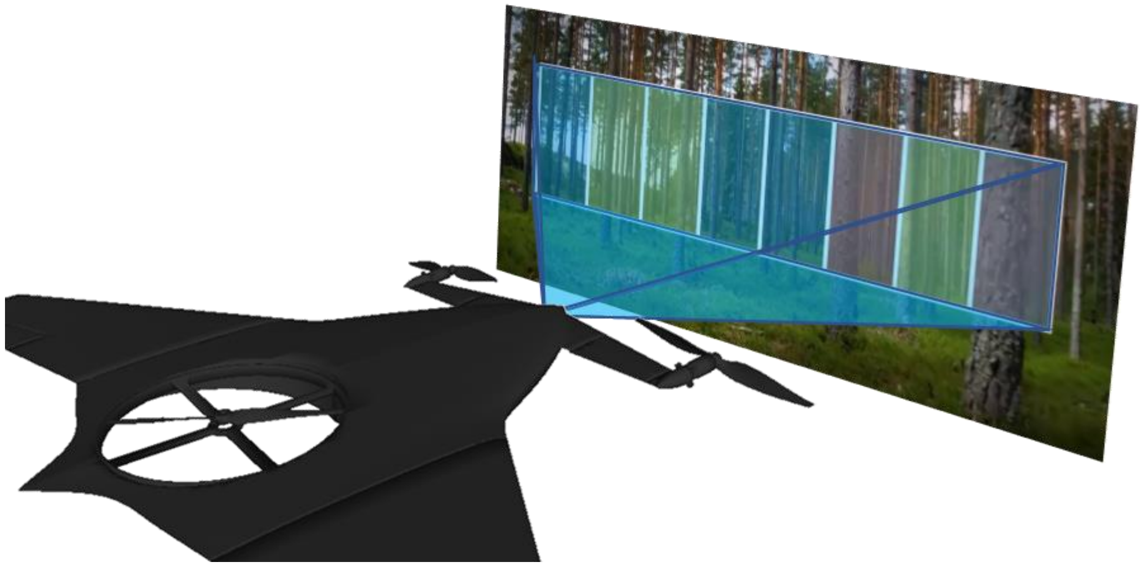


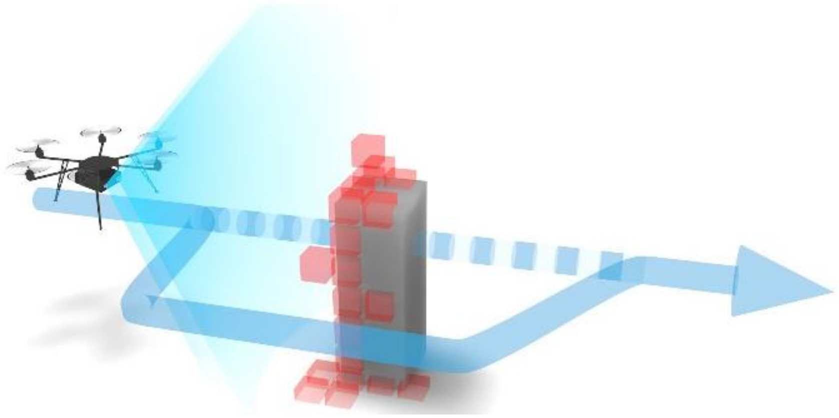
UAVs' subsystem analysis

Perception system design

Available sensors IMU, GNSS, Distance, Cameras

- Localization
- Mapping
- Obstacle detection



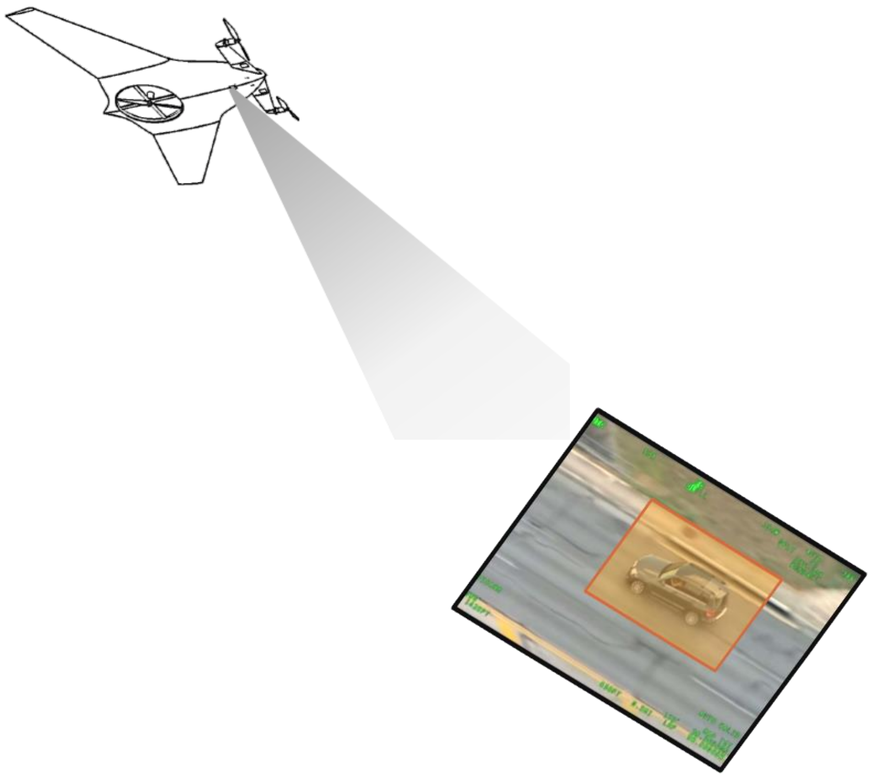


UAVs' subsystem analysis

Perception system design

Available sensors IMU, GNSS, Distance, Cameras

- Localization
- Mapping
- Obstacle detection
- Target tacking

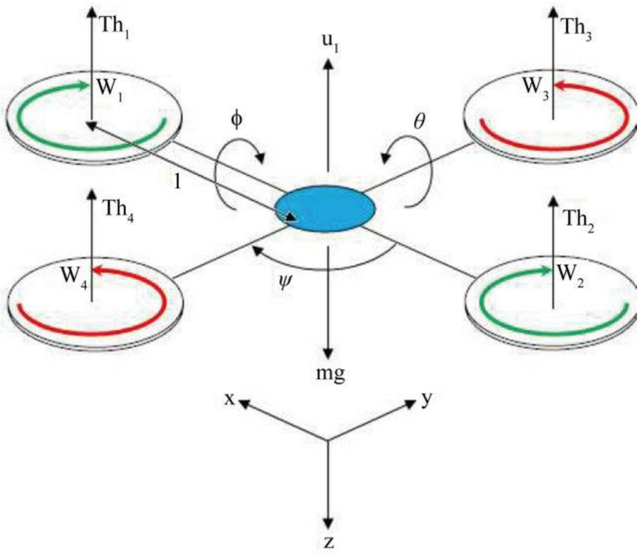


UAVs' subsystem analysis

Motion and control system design

Aircraft design data

- Kinematic model and aircraft dynamics



$$F_i = K_f \times \omega_i^2$$

$$M_i = K_m \times \omega_i^2$$

$$M_y = (F_1 - F_2) \times L$$

$$M_x = (F_3 - F_4) \times L$$

$$m\ddot{r} = F_1 + F_2 + F_3 + F_4$$

$$I_{zz} \times \ddot{\psi} = M_1 + M_2 + M_3 + M_4$$

$$I_{yy} \times \ddot{\theta} = F_1 - F_2 \times L$$

$$I_{xx} \times \ddot{\varphi} = F_3 - F_4 \times L$$

UAVs' subsystem analysis

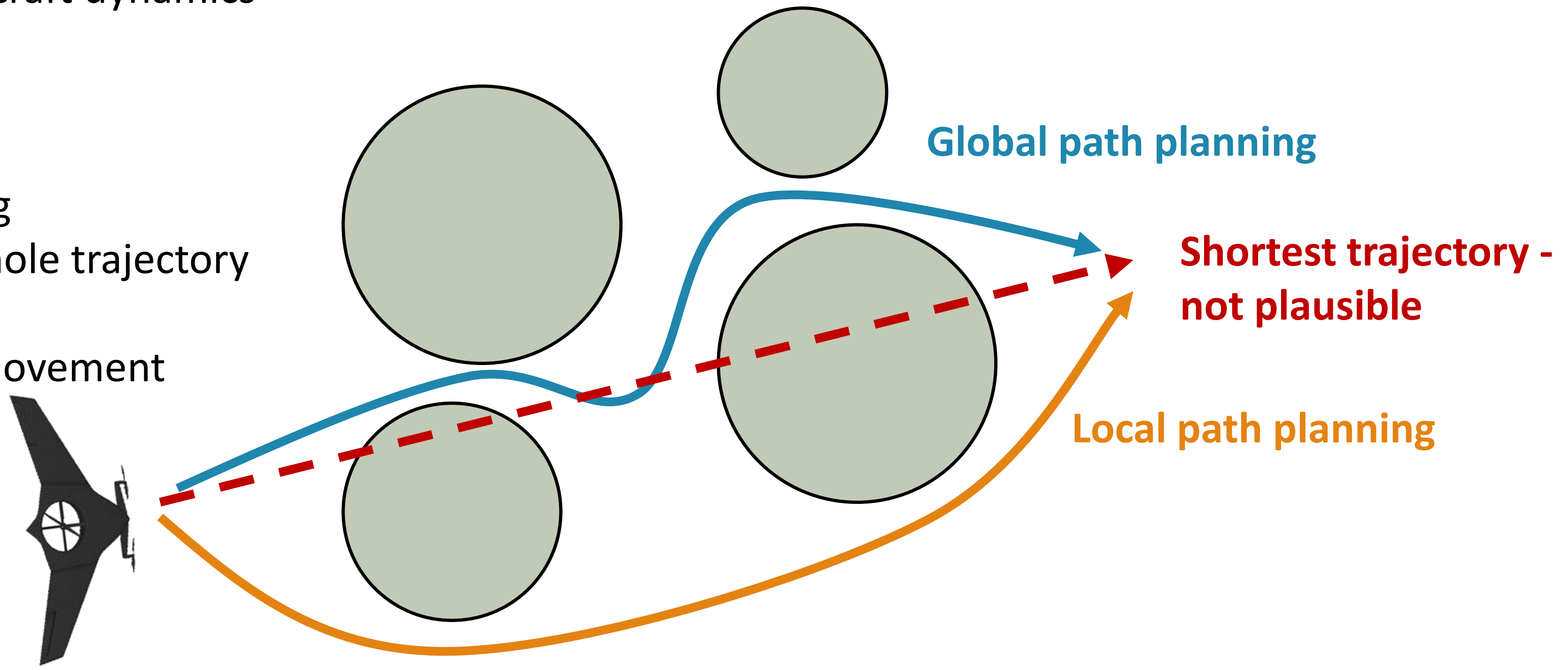
Motion and control system design

Aircraft design data

- Kinematic model and aircraft dynamics

Waypoints data

- Path planning
  - Global path planning
    Computing the whole trajectory
  - Local path planning
    Computing next movement



UAVs' subsystem analysis

Motion and control system design

Aircraft design data

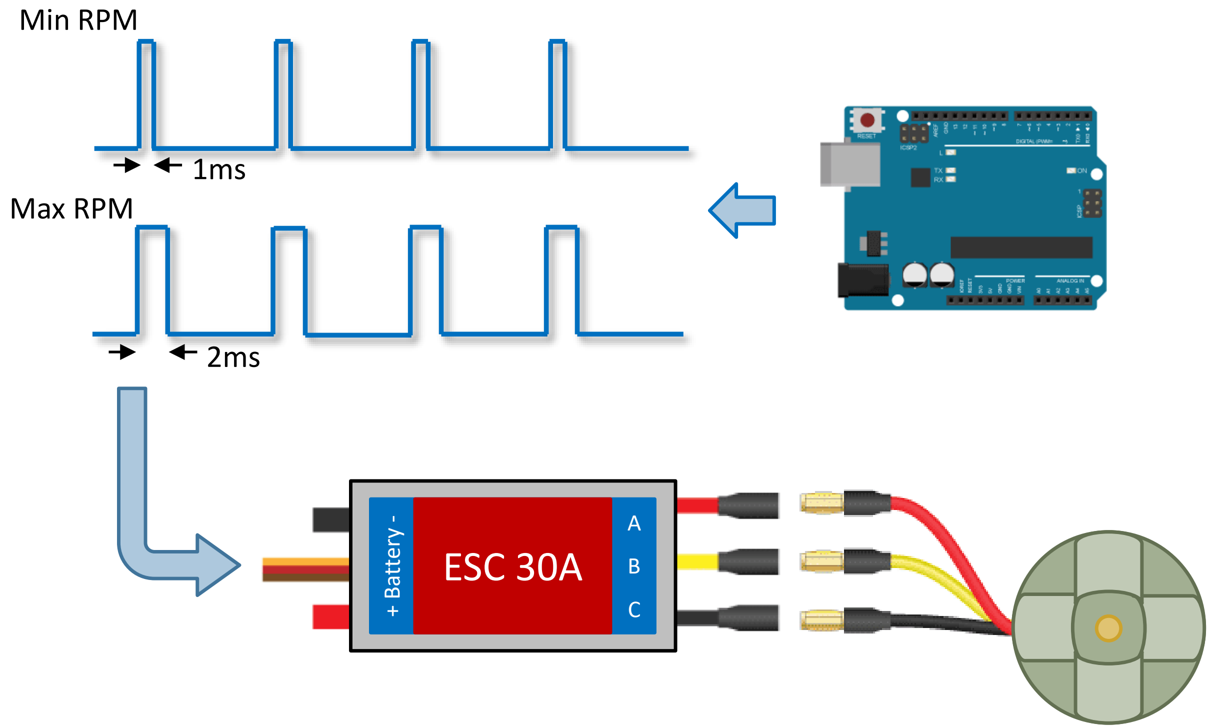
- Kinematic model and aircraft dynamics

Waypoints data

- Path planning
  - Global path planning
    Computing the whole trajectory
  - Local path planning
    Computing next movement

Trajectory data or user control commands

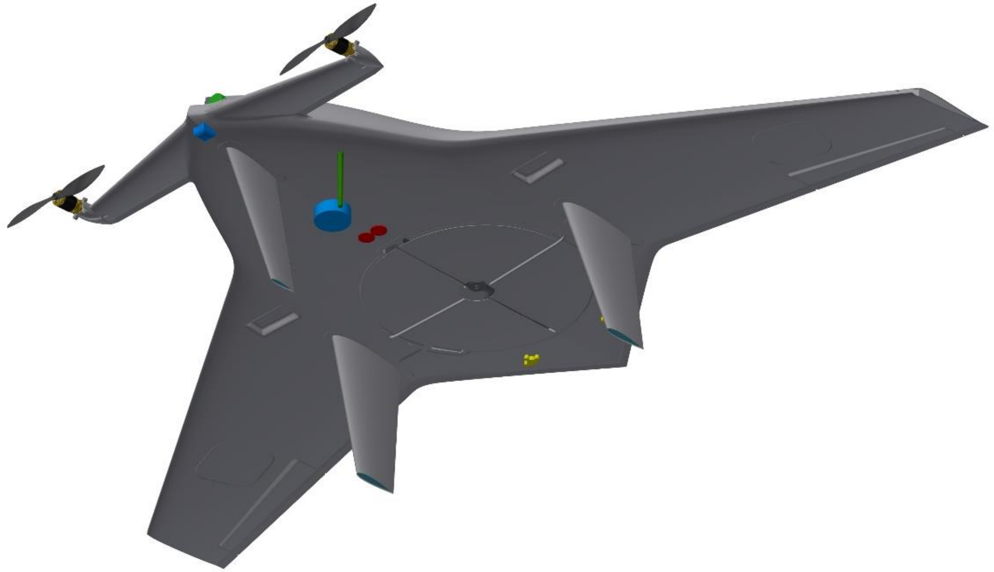
- Motor control



UAVs’ Applications

The MPU system

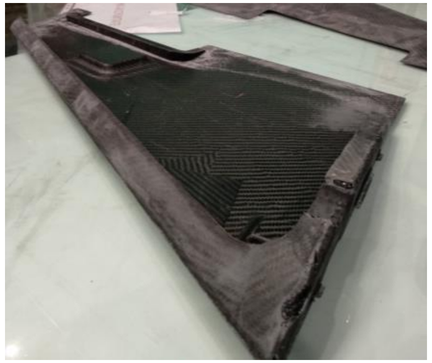
MPU



UAV as a Mechatronic System: Design and Applications

UAVs' Applications

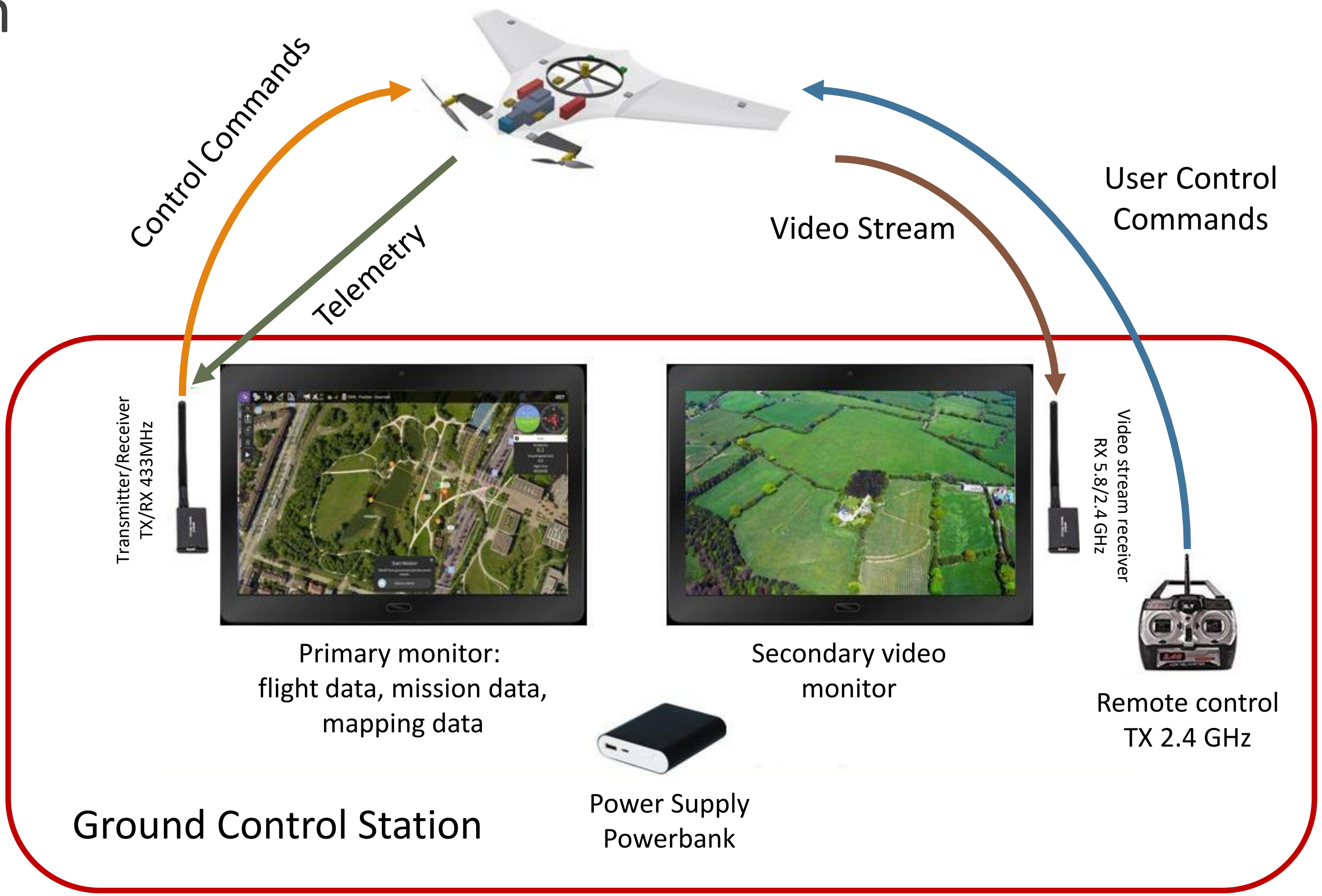
The MPU system



Τελικά Χαρακτηριστικά MPU	
Maximum Take-Off Weight (MTOW	4.5 kg
Payload	0.5 kg
Wingspan	1.8 m
Wing Loading (W/S)	6.15 kg/m^2
Cruise speed	65 km/h
Maximum speed	125 km/h
Stall speed	25 km/h
Endurance	120 min
Flight altitude	1500 m

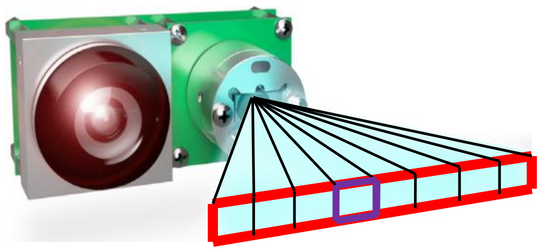
UAVs' Applications

The MPU system



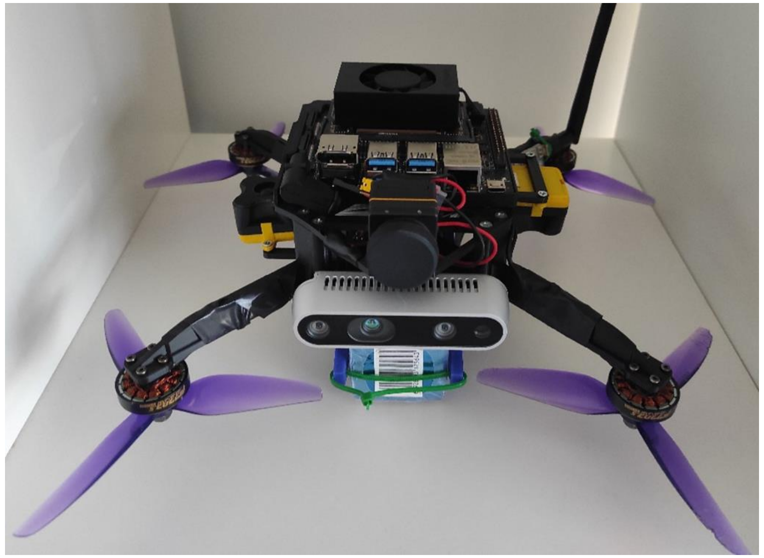
UAVs' Applications

The MPU system



UAVs' Applications

The MIDRES system



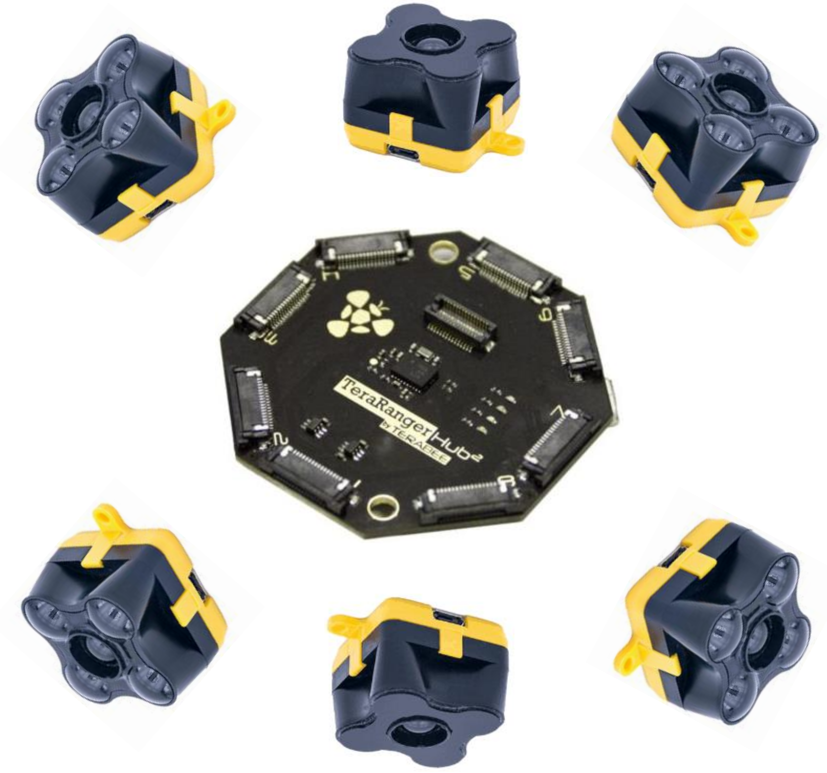
UAVs' Applications

The MIDRES system

Laser Rangefinders
15m/3m

Thermal camera

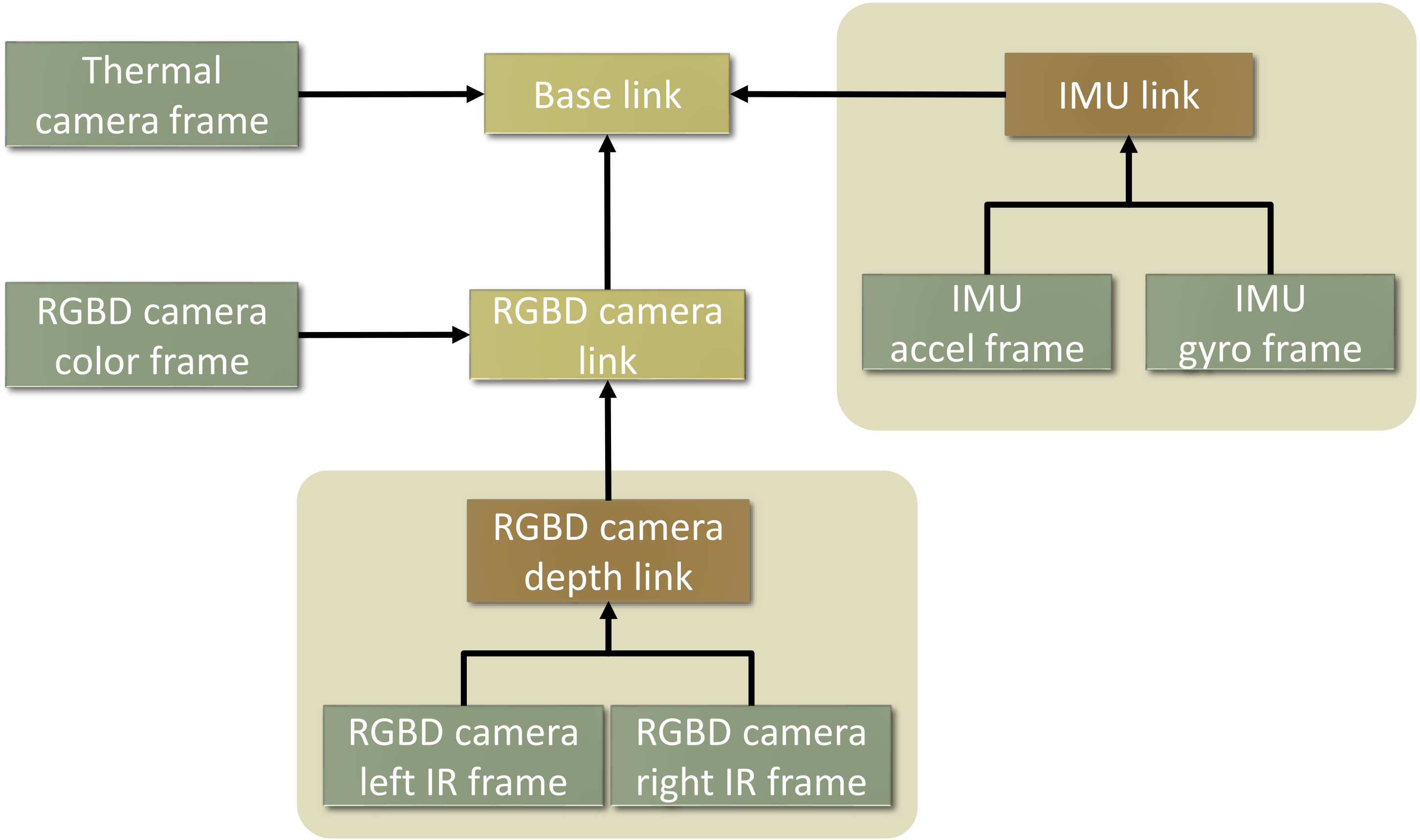
RGBD camera + IMU



Compute Unit

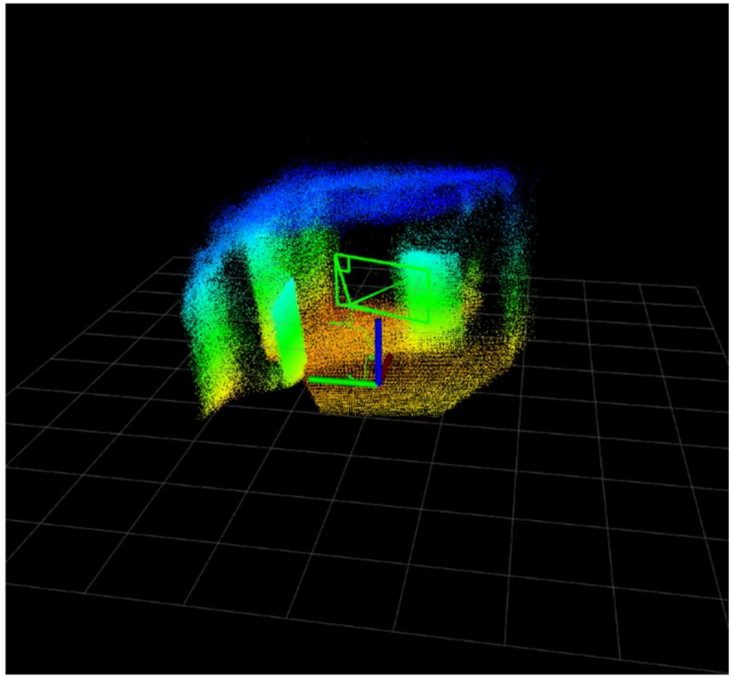
UAVs' Applications

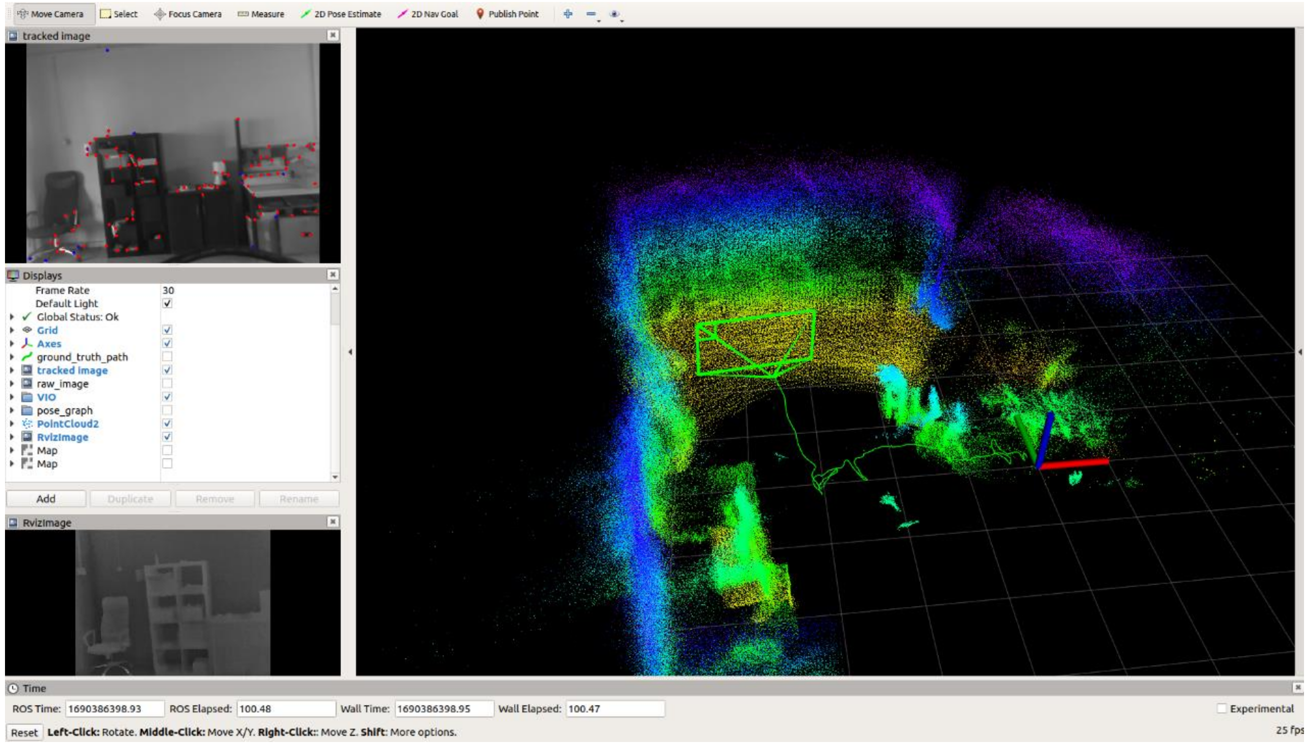
The MIDRES system



UAVs' Applications

The MIDRES system



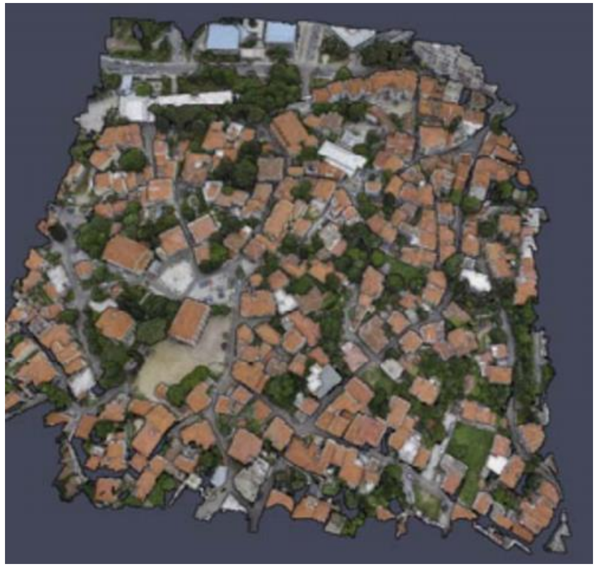


UAVs' Applications

The MIDRES system

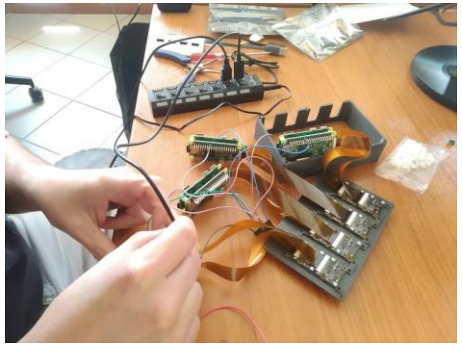
UAV Applications

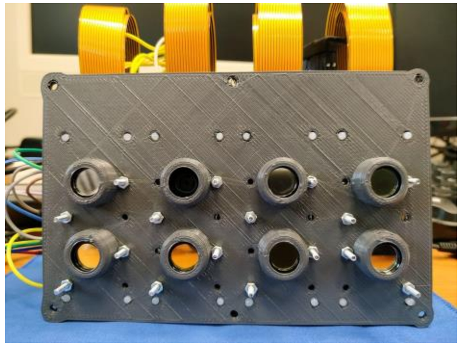
The Estia system



UAVs' Applications

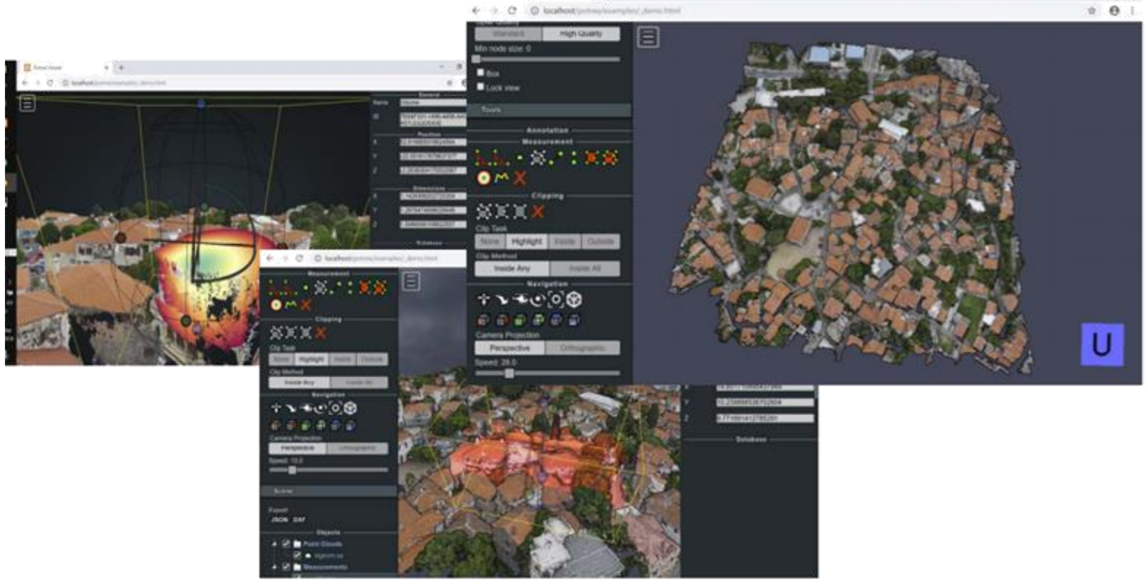
The Estia system

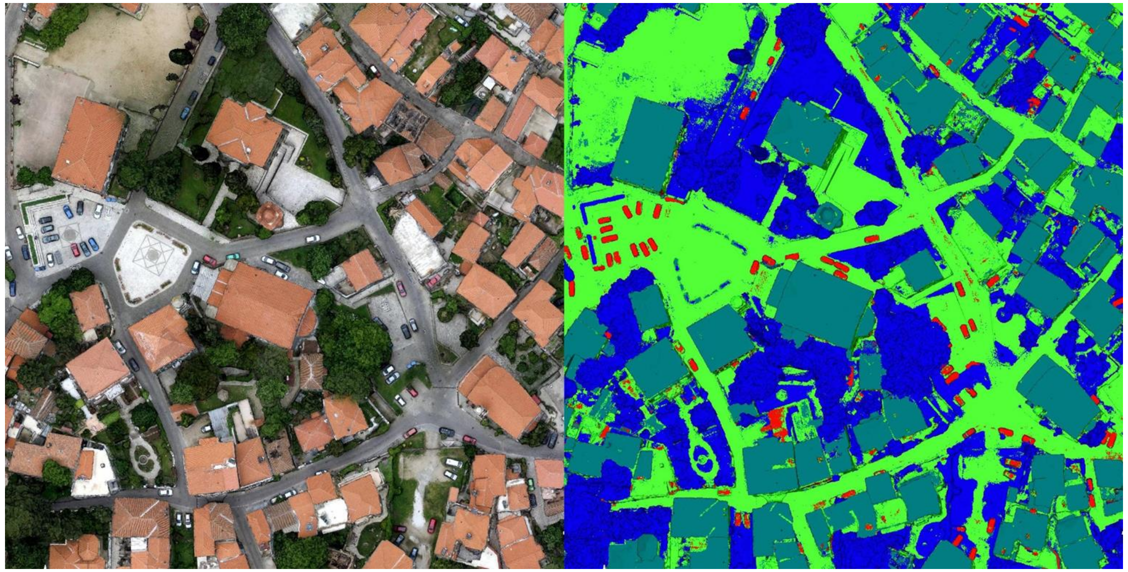




UAVs' Applications

The Estia system



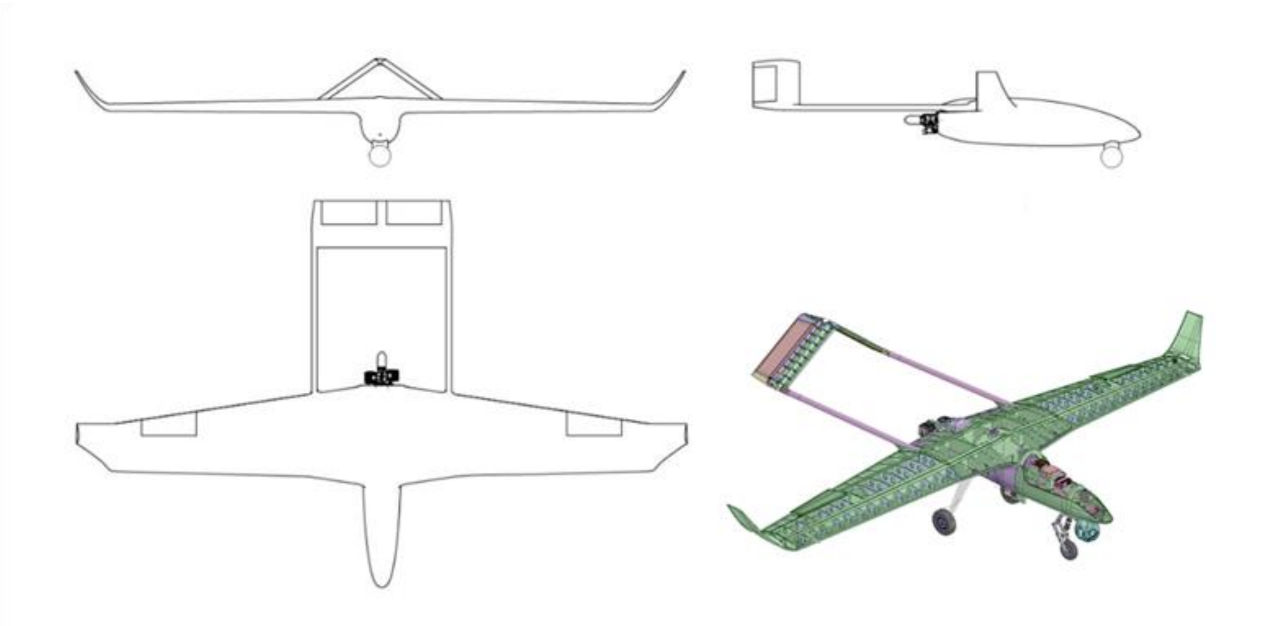


UAVs’ Applications

The HCUAV system

HCUAV

HELLENIC CIVIL UNMANNED AERIAL VEHICLE

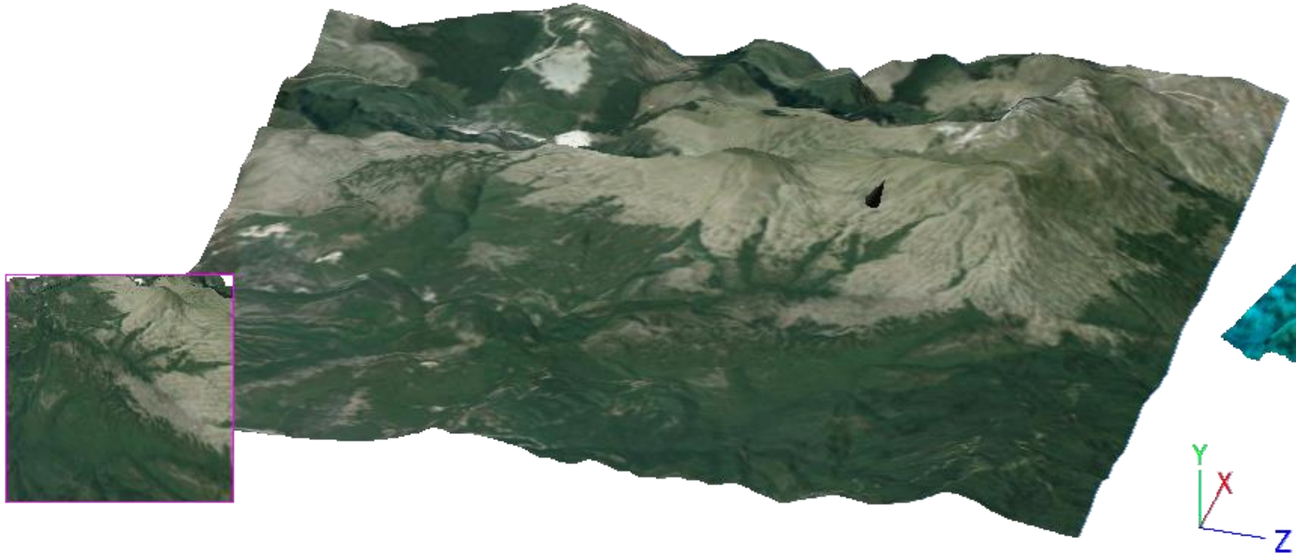


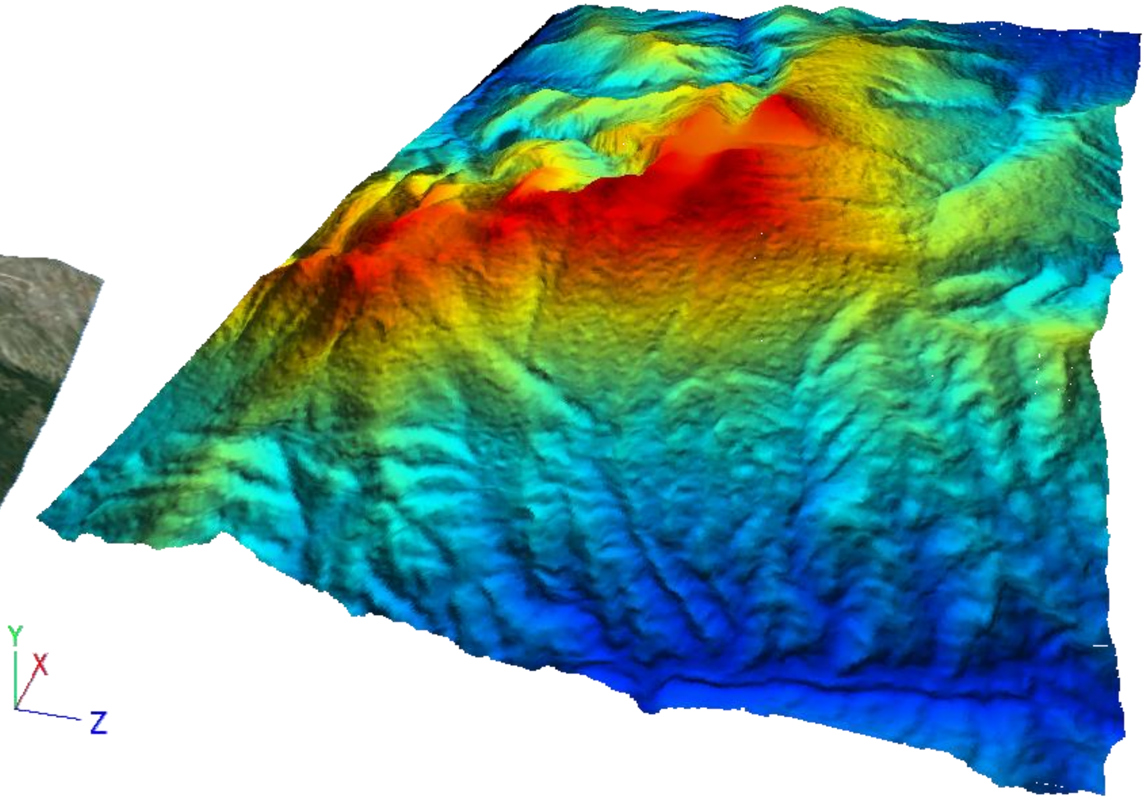
UAVs' Applications

The HCUAV system

UAVs' Applications

The HCUAV system





UAVs' Applications

The HCUAV system