COMP4DRONES

Framework of Enabling Technologies for Drones

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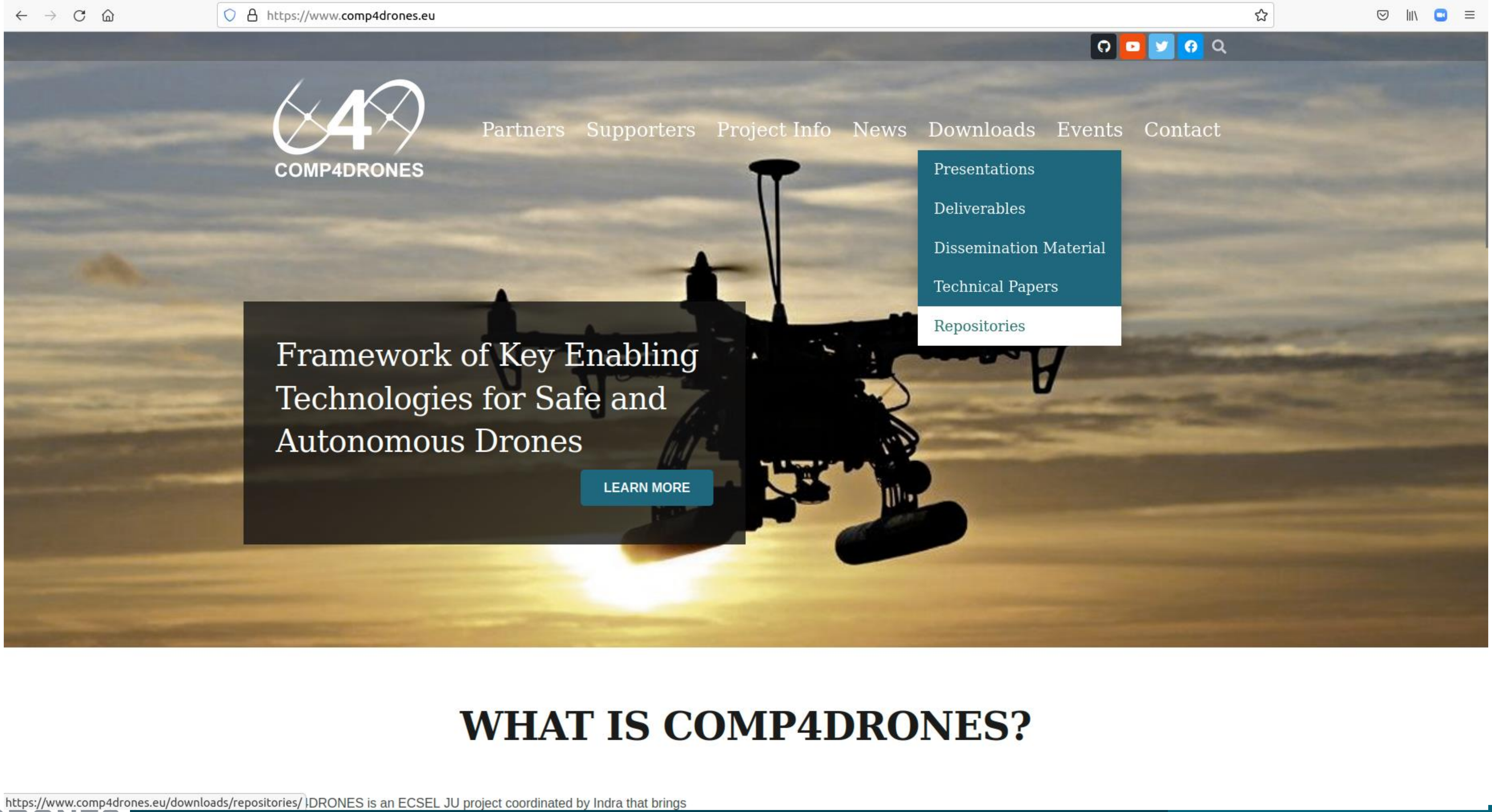
Project Web Presence: https://www.comp4drones.eu/

2022

COMP4DRONES Project Overview

https://www.comp4drones.eu/



ECSEL & SESAR JU Complementarity

COMP4DRONES provide a **framework** of key enabling technologies for **safe and autonomous drones** that will leverage their **customization and modularity** for civilian services

U-space is a set of new **services** relying on a high level of digitalisation and automation of functions and specific procedures designed to support **safe, efficient and secure access to airspace** for **large numbers of drones**.

Project Objectives

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Provide a **framework** of key enabling technologies for **safe and autonomous drones** for civilian services

Easing the integration and customization of drone **embedded system**

Enabling drones to take **safe autonomous decisions**

Ensure the deployment of **trusted communications**

Minimizing the **design and verification** efforts for complex drone applications

Ensuring **sustainable impact** and creation of an industry-driven community

Project Impact

Reinforcing the **ecosystems of drones industry** by providing methodology and a **reference** software **architecture framework** that meets performance and safety requirements

Improving innovation capacity by adopting a "**safe-by-design**" approach covering the activities of specification, design, implementation, and validation & verification

Enabling and easing delivery of **new services using drones in Europe**. The biggest security risk for drone use is not the drone itself, but the technology inside of it

Five Relevant Societal Domains

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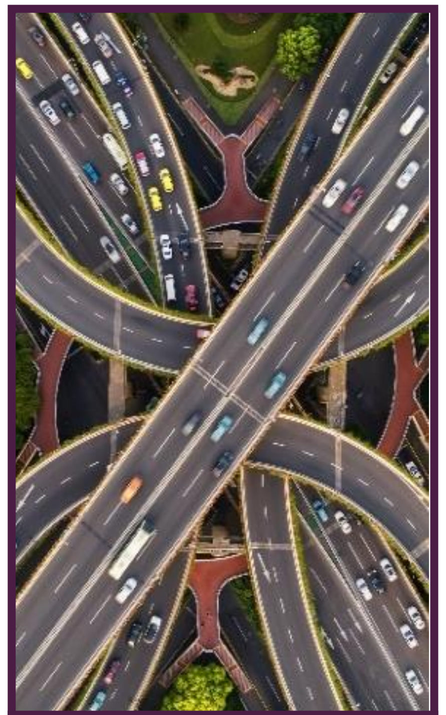
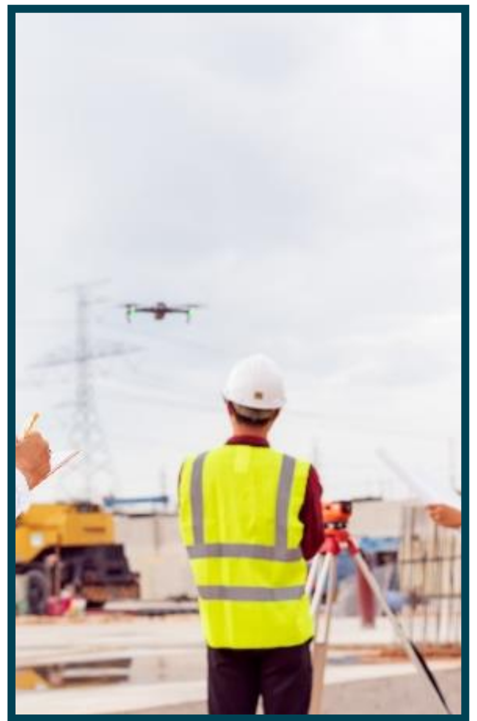


Transport

Drones for optimization of transport control, operation and infrastructure management



Construction

Drones for virtual design, construction and operation of transport infrastructures

Logistics

Logistics using heterogeneous drone fleets

Surveillance and Inspection

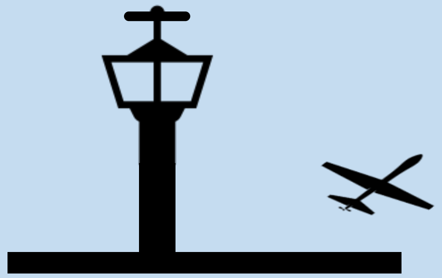
Drone and wheeled robotic systems for inspection, surveillance and rescue operations

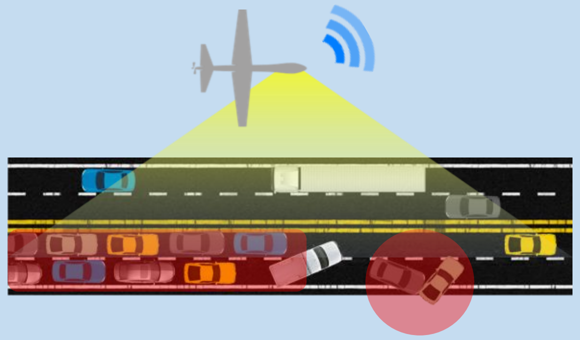
Agriculture

Smart precision agriculture: from drone to rover

UC1 Transport

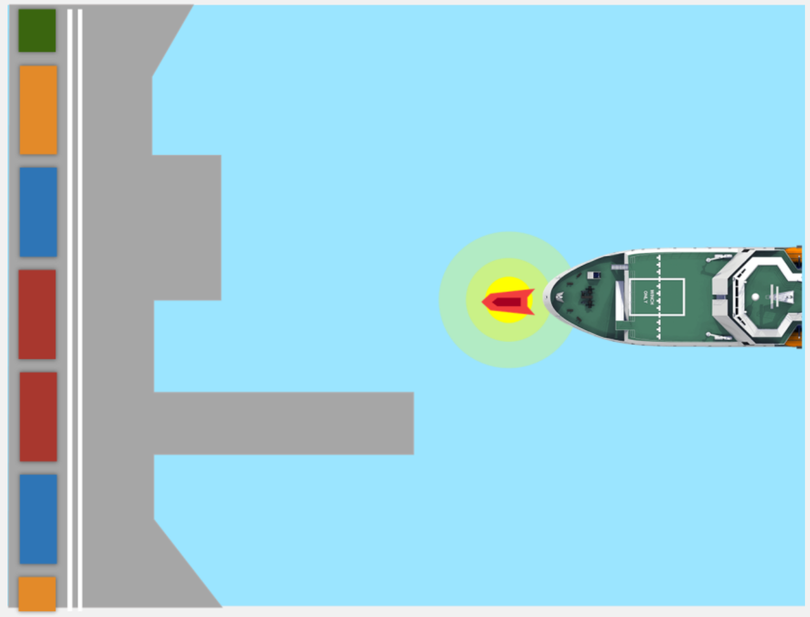
DEMONSTRATOR 1





Drone Facilities	Inspection of the infrastructure	Transport Control Center
Incorporate capabilities to request a drone's flight over an area of the infrastructure identified by its operators	To verify an incidence detected by the system (DAI/DAS)	Integration of the images/video captured to visualize what is happening in the infrastructure
	To inspect a zone in a specific way without associated incidents	Processing of the information to obtain other parameters of importance for its management

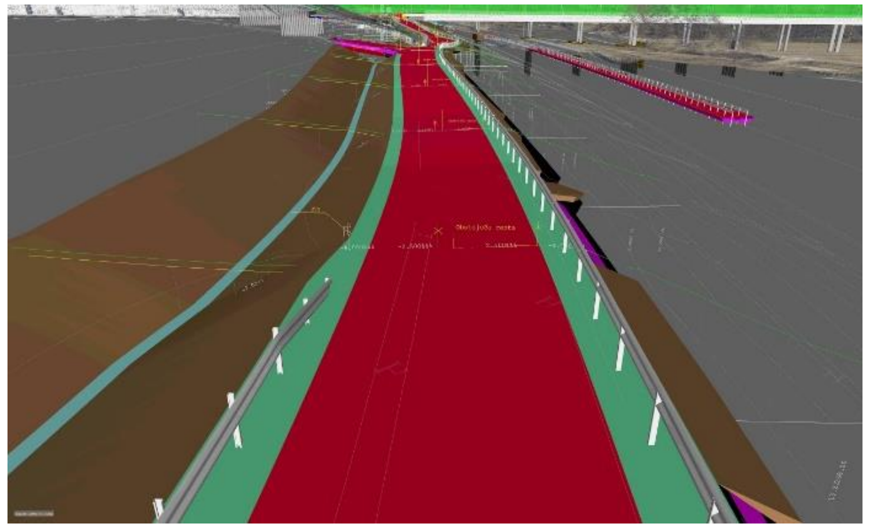
DEMONSTRATOR 2



- Deployment of drones as new sensors/elements for maritime activities and novel applications to support land and sea operations at ports
- Guidance of vessels arriving to the port

UC2 Construction (stopped 2021/03)

To develop the technology required to carry out any type of operation that allows the **Digitalization of the State of the Constructive Process of a Transport Infrastructure.**



- This allows to **reduce the costs and times of acquisition of data** in relation to traditional technologies; either by traditional surveying or terrestrial methods.
- The digitization of this process will allow generating products that allow approximating the development of construction in a **BIM Model**.

UC3 Logistics - METIS®

Demonstrator 1: Deployment of an Autonomous Communication System in hard-to-access areas

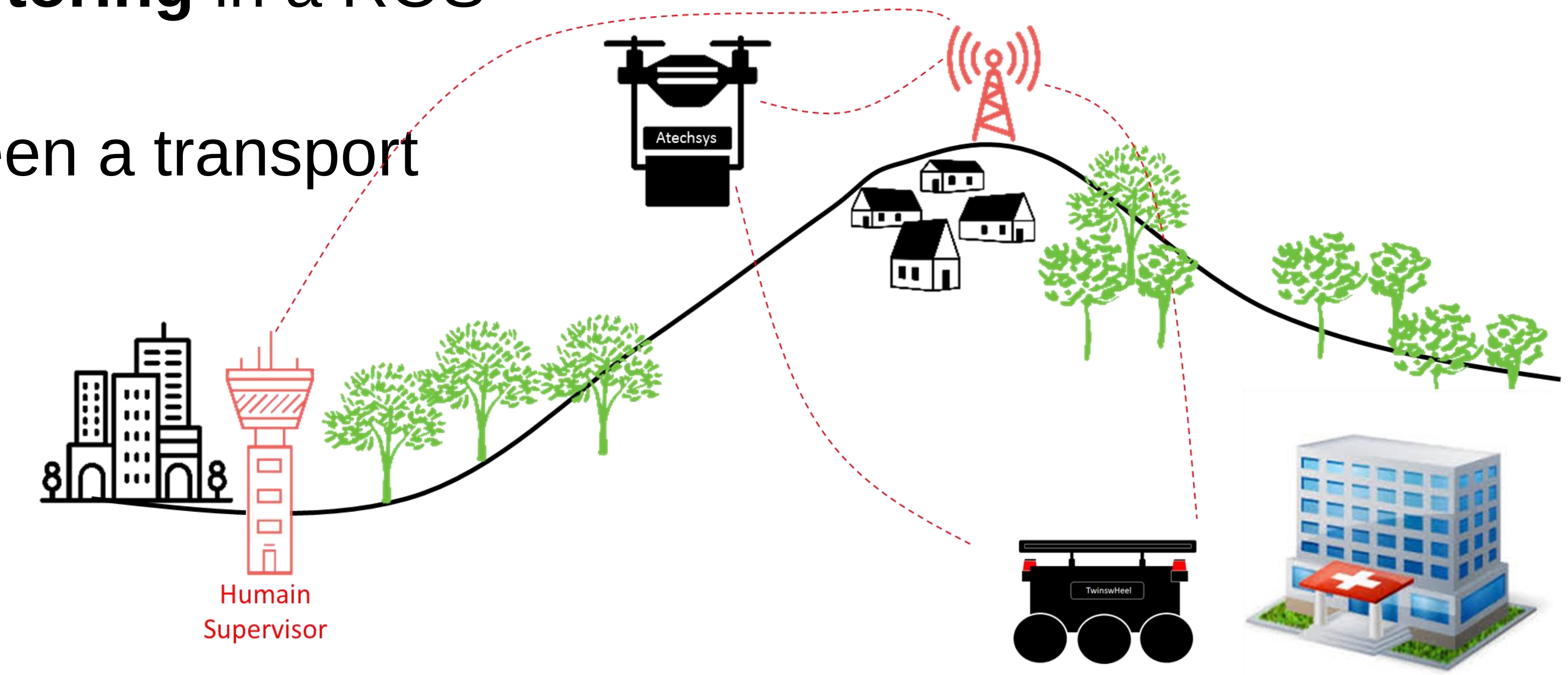
- Selecting and Managing an heterogeneous fleet of autonomous vehicles
- Using a communication infrastructure with redundant, secure, robust, dissimilar and deterministic abilities
- Navigating and sensing at the landing or dropping zone with a high positioning accuracy and a guarantee of absence of objects, people or animals
- Detecting and considering dynamically of aircrafts in the mission area and integrating vehicles of the system in air traffic management
- Reducing risks and complexity on interactions between system operators and autonomous vehicles

METIS® - https://www.youtube.com/watch?v=mp-9-mXny58

UC3 Logistics

Demonstrator 2: Logistics in 5G urban environment: Clinical Sample delivery in Hospital campus

- Develop a solution which will satisfy hospital requirements (special challenge is safety and security requirements).
- LMT will work on establishing and benchmarking 5G communication with special attention to **security of communications**.
- IMCS will work on integrating project results regarding object **recognition & avoidance** and **online safety monitoring** in a ROS node.
- Atechsys and SOBEN will work on **coupling** between a transport drone and a logistics droide in a periurban area



UC4 Surveillance Inspection

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Demonstrator 1: Inspection of offshore turbines structure with hyperspectral technology carried by autonomous drones

Objectives
1. Reduce costs of inspection (at least 20% lower)
2. Increase reliability of inspection
3. Increase inspection frequency
4. Reduce time for single inspection

Novel technologies / improvements
1. Hyperspectral cameras can improve detection of material imperfections
2. Safe autonomous navigation, 3D SLAM

UC4 Surveillance Inspection

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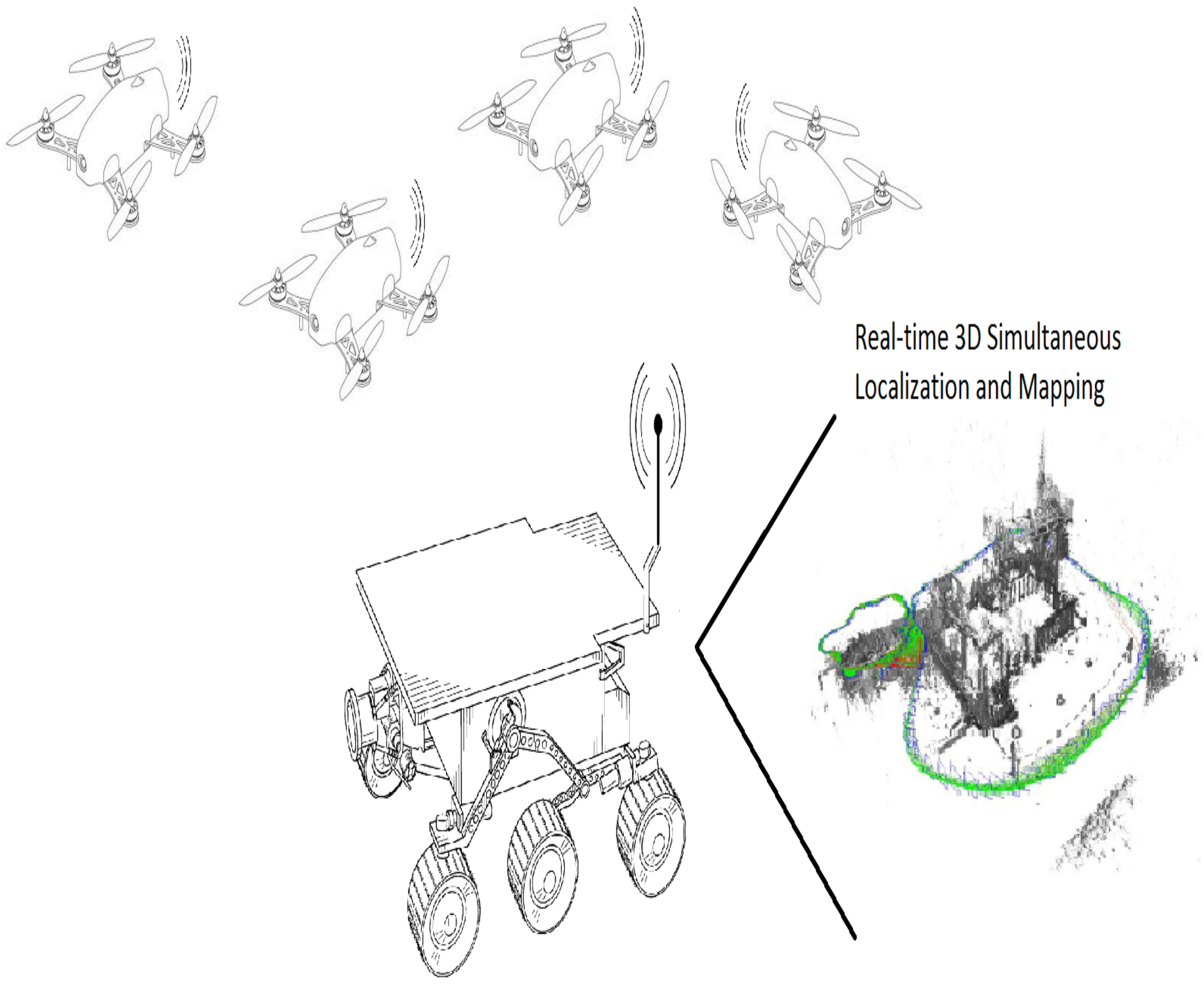
Demonstrator 2: Fleet of multi robot navigating and mapping in an unknown environment

Objectives

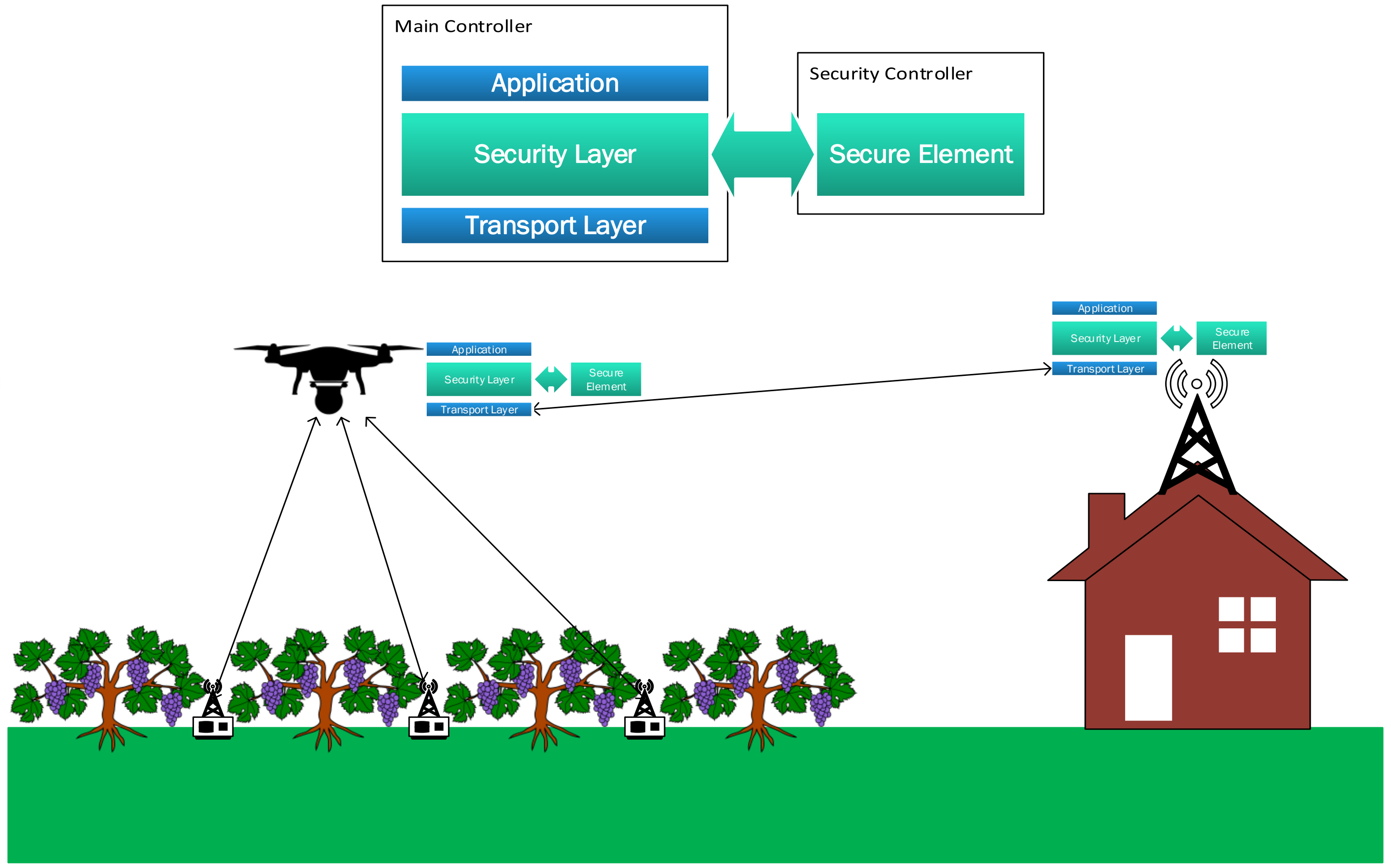
1. Reduce costs for surveillance
2. Increase reliability via automated process
3. Increase frequency of surveillance
4. Automatic detection of anomalies
5. Reduce time of single inspection

Novel technologies / improvements

1. Real-time data analytics and close-loop dynamic control
2. Safe autonomous navigation, 3D SLAM



UC5 Agriculture



Wide Crop monitoring: Multiple tasks Demonstrator

This use case will demonstrate the smart agriculture and precision farming technologies developed in COMP4DRONES for the **Agricultural domain**.

Wine production, specific tasks Demonstrator

Main topics

- real-time monitoring
- more accurate analysis
- trustworthy interaction between land-bound sensors and drones as gateways.

Two-demonstrators approach allows full coverage of topics:

✓ *crop monitoring, focusing on health and growth crop management*

✓ specific technology needs of **wine cultivation**

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October 2019 January 2023

50 Partners

indra — Project Coordinator

cea — Technical Coordinator

29.76M€

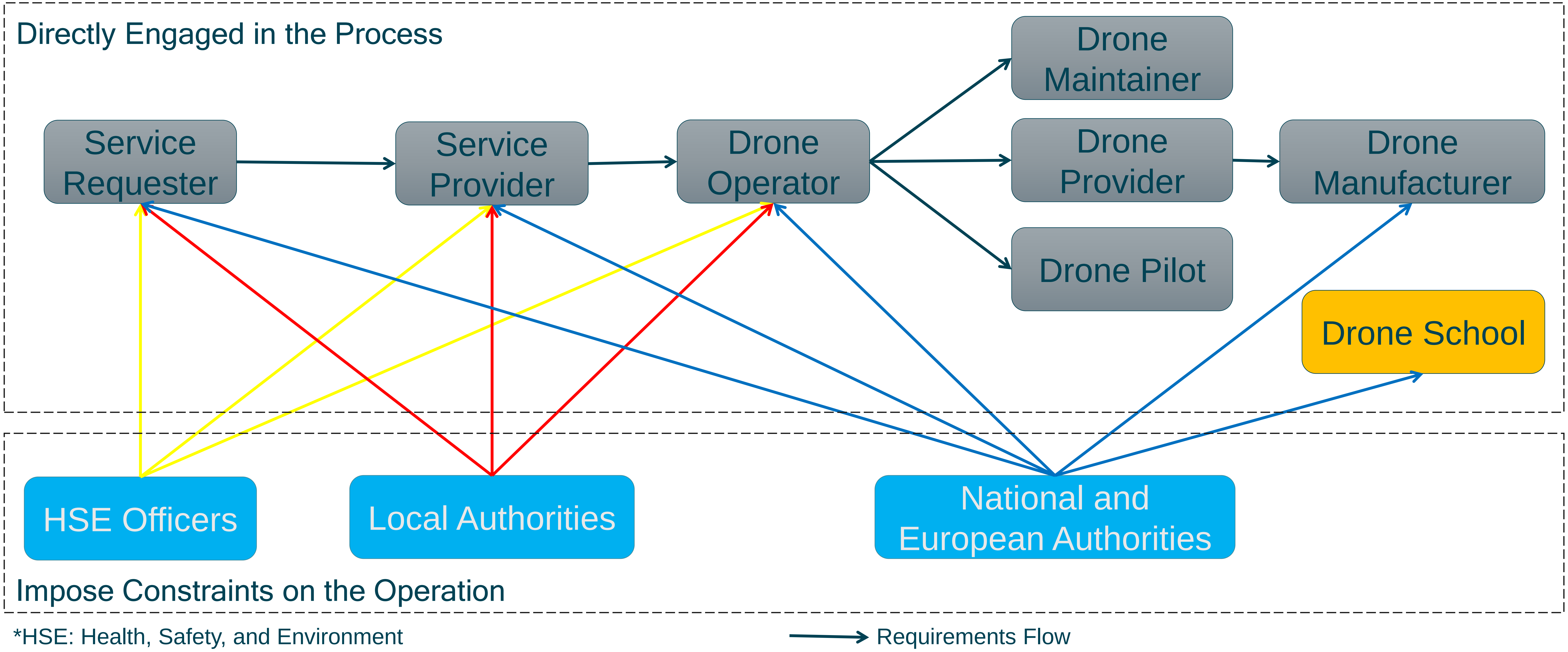
Budget

ECSEL Joint Undertaking

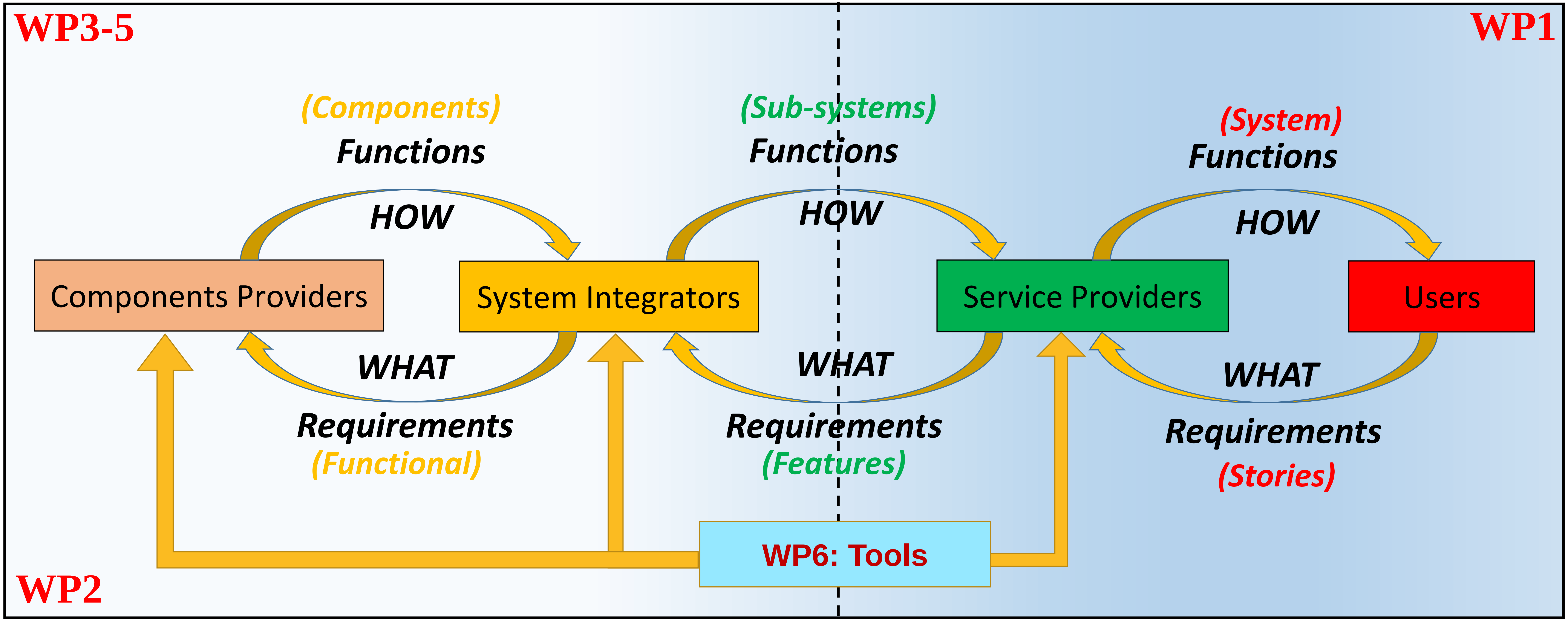
Electronic Components and Systems for European Leadership

This project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 826610. The JU receives support from the European Union's Horizon 2020 research and innovation programme and Spain, Austria, Belgium, Czech Republic, France, Italy, Latvia, Netherlands.

Drone Service Stakeholders



COM4DRONES Consortium - Stakeholders



Key Enabling Technologies Classification

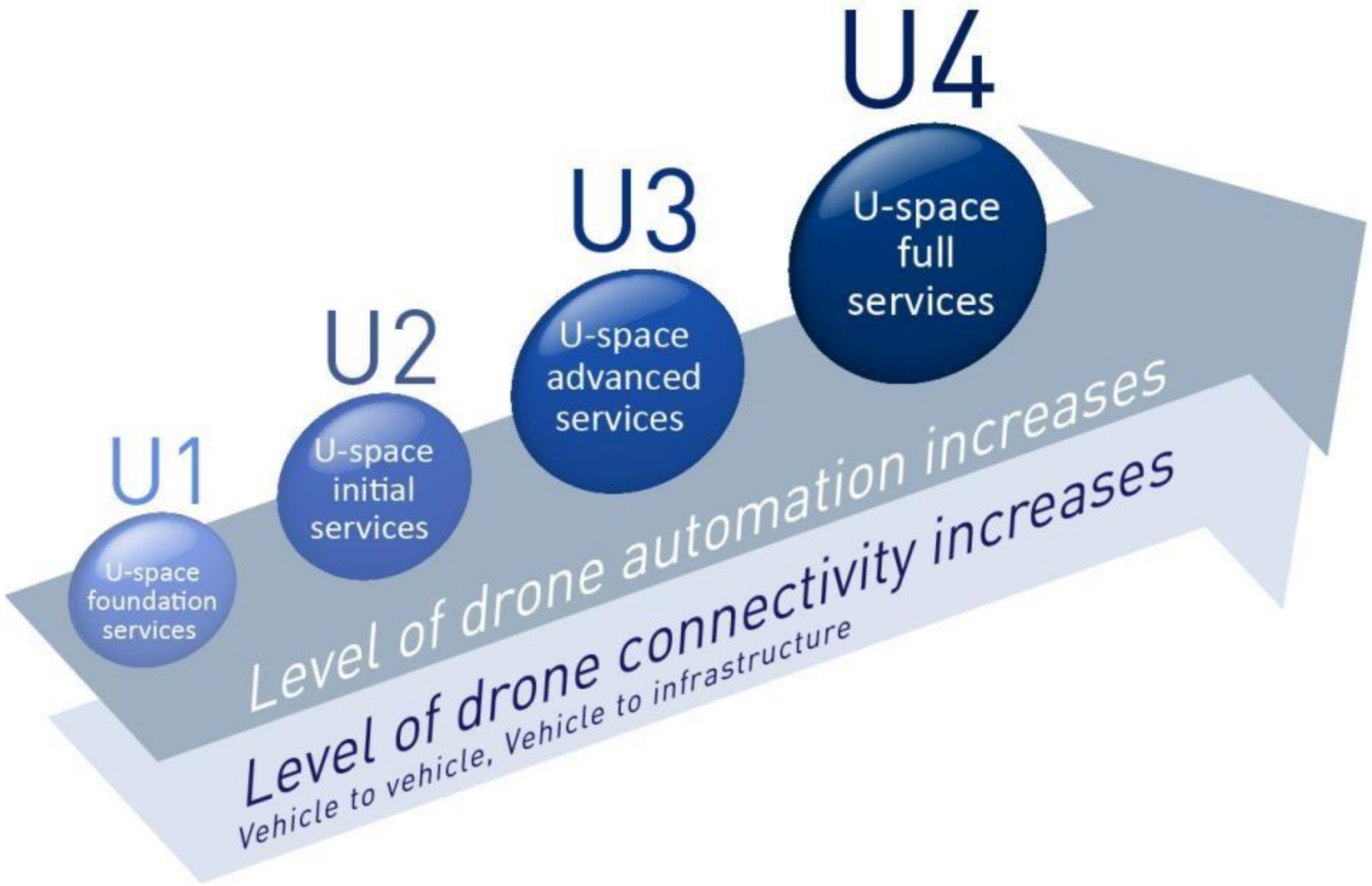
Key Enabling Technologies Classification

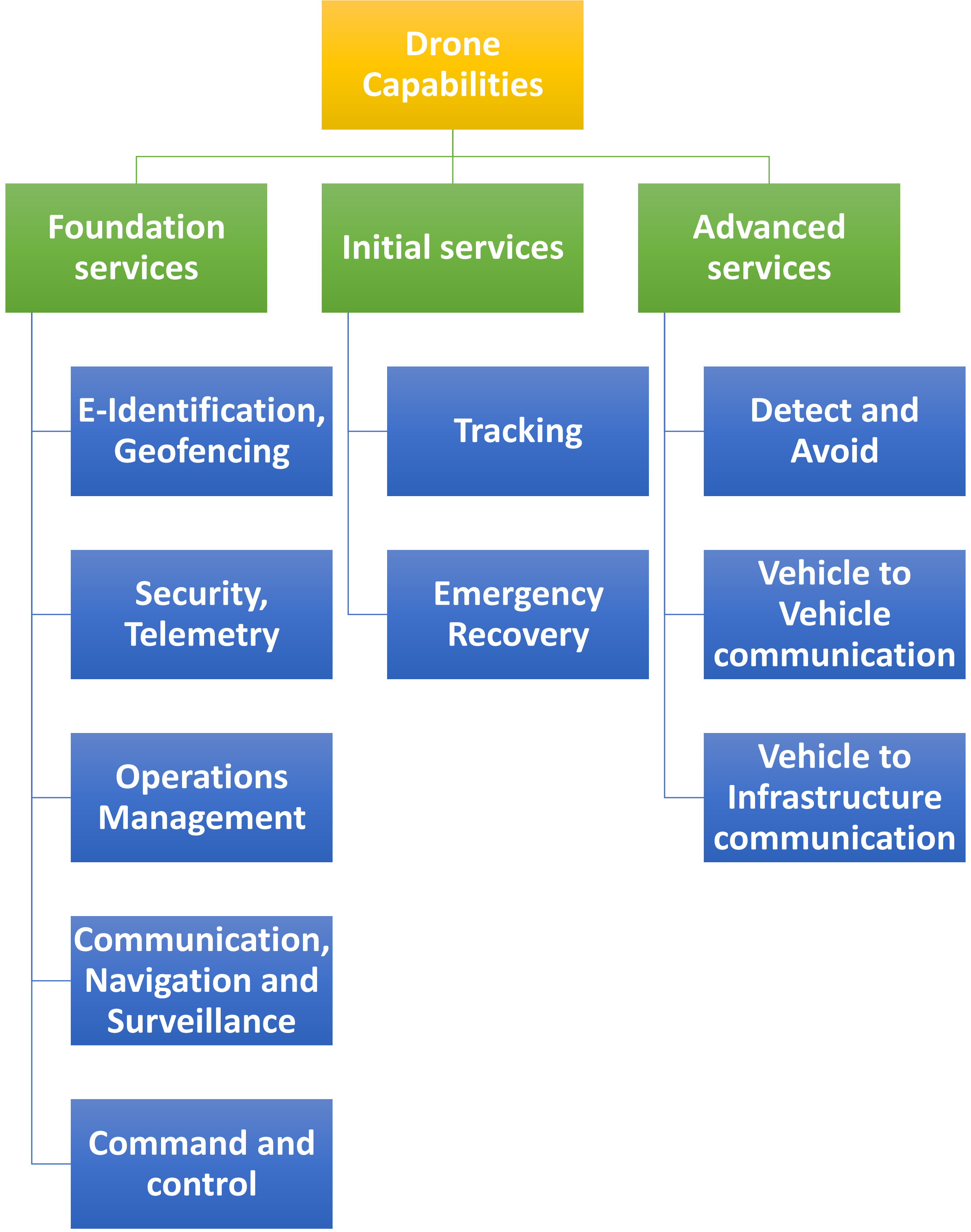
Based on the drone usages (common and mission specific operations), the key technologies are identified an classified into four groups:

- **U-space[1] Capabilities** (e-identification, geofencing, navigation, etc.)
- **System Functions** (flight control, flight navigation, positioning, etc.)
- **Payload Technologies** (optical sensors, in-situ sensors, microwave sensors, etc.)
- **Tools** (user requirements, data analytics, system design, implementation, etc.)

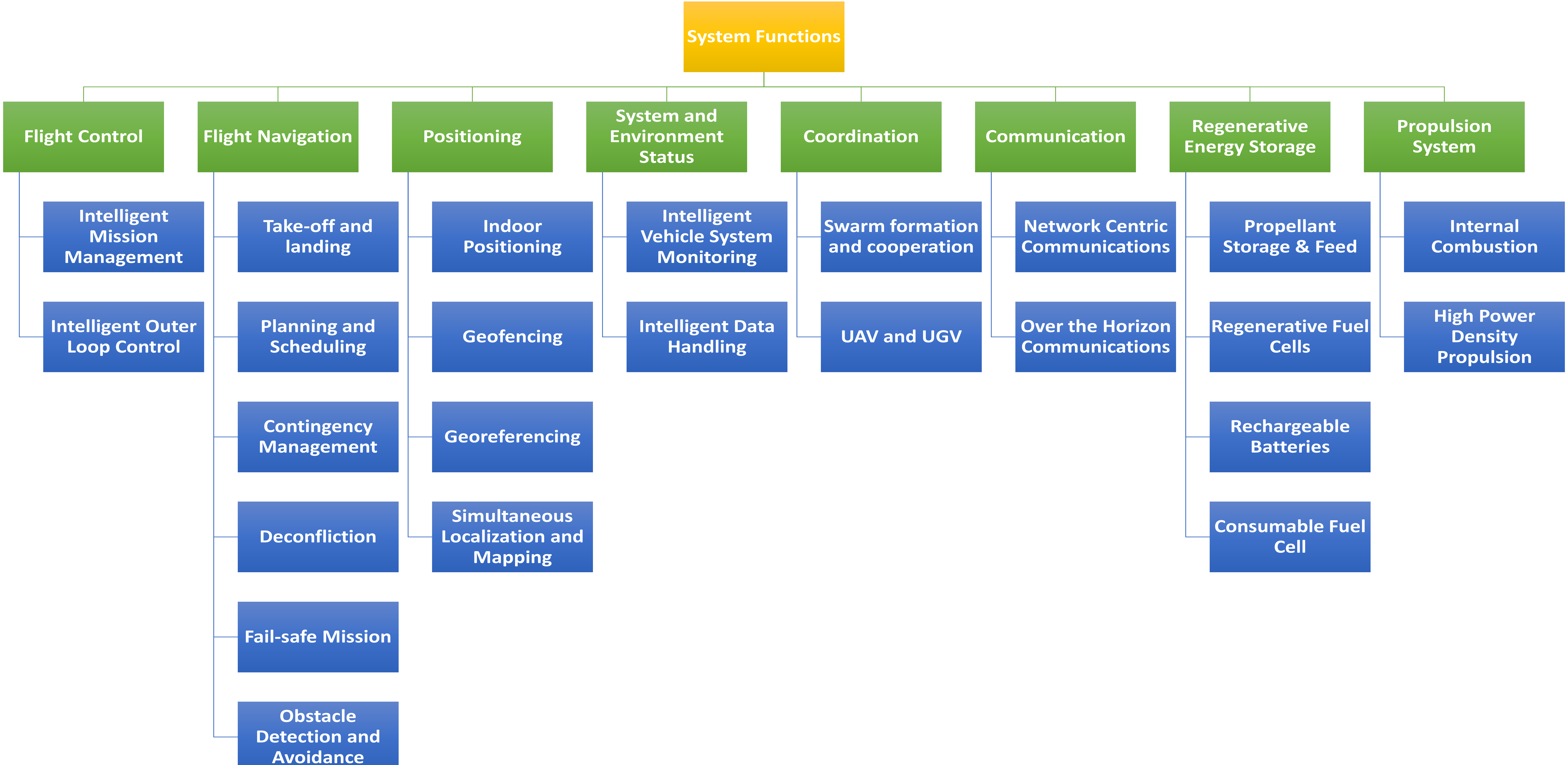
[1]U-Space is a set of new services and specific procedures designed to support safe, efficient, and secure access to airspace for large numbers of drones.

KETs: U-space Capabilities





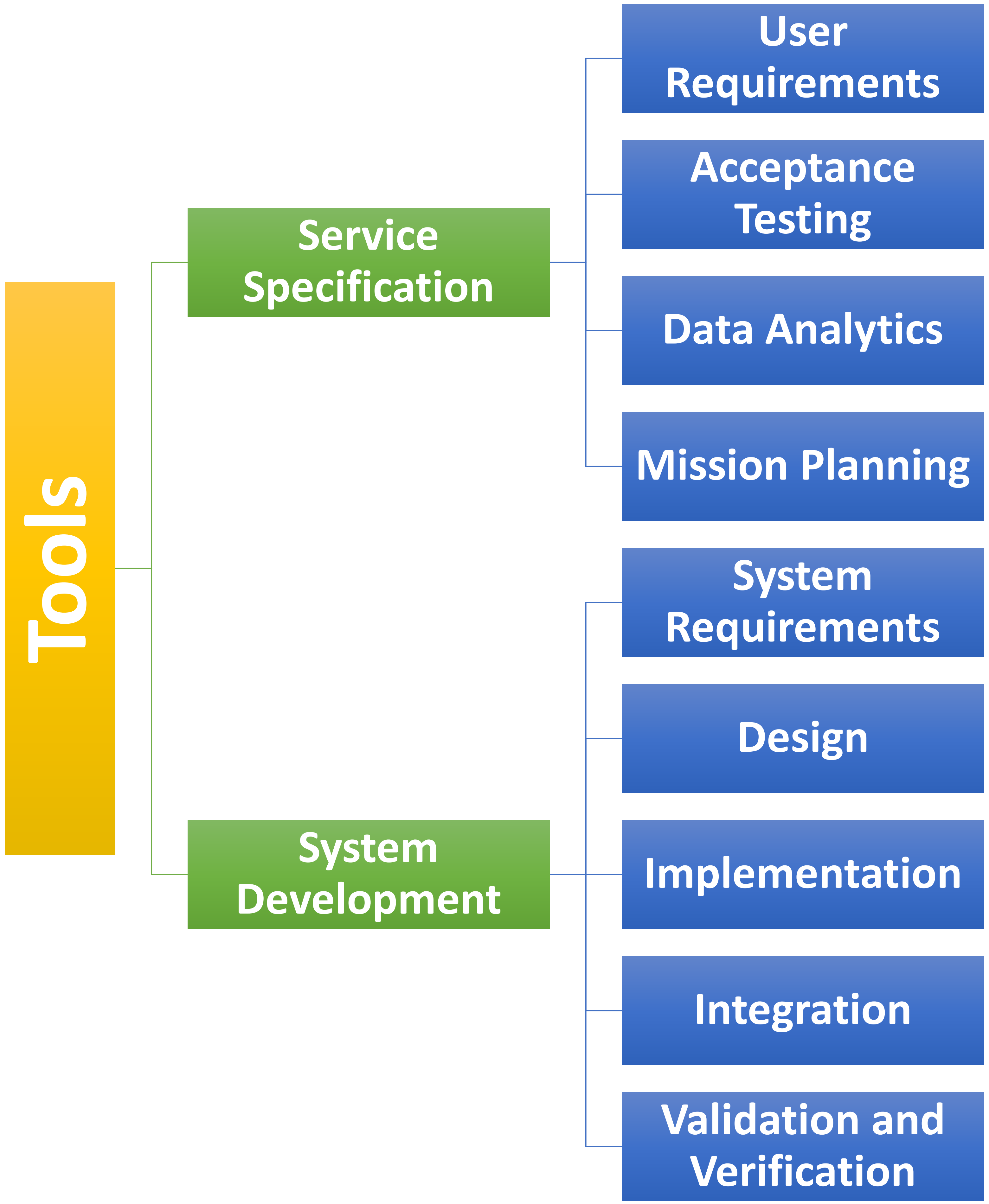
KETs: System Functions



KETs: Payload Technologies

- **Payload Technologies**
  - **Optical Sensors**
    - Active Optical: LIDAR
    - Passive Optical
  - **Microwave Sensors**
    - Active Microwave
    - Passive Microwave
  - **In-situ Sensors**
    - Microsystems-based Chemical Sensor Arrays
    - Chem. Detection
    - Meteorological Data
    - CO2 Detection
  - **External sensors**
    - Drop Sondes
    - Geophysical Sensors
    - Weather station
    - Perimeter sensors

KETs: Tools


Tools
Service Specification
User Requirements
Acceptance Testing
Data Analytics
Mission Planning
System Development
System Requirements
Design
Implementation
Integration
Validation and Verification

C4D Reference Architecture

Building Blocks and Interaction Patterns of Unmanned Aerial Systems

Motivation for Reference Architecture*

- A reference architecture is *structure* and respective *elements* and *relations* that provide templates for *concrete architectures* in a particular domain or in a family of systems.

- Reference architecture benefits include:
  - Reduction of the development costs.
  - Quicker delivery of a solution
  - Increase quality
  - Improvement of the interoperability of the software systems.
  - Improvement of the communication inside the organization because stakeholders share the same architectural mindset.

*Silverio Martínez-Fernández, Claudia P. Ayala, Xavier Franch, Helena Martins Marques, Benefits and drawbacks of software reference architectures: A case study, Information and Software Technology, Volume 88, 2017, Pages 37-52,

Integrated Modular Architecture and Generic Components

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Easing the customization of drone systems

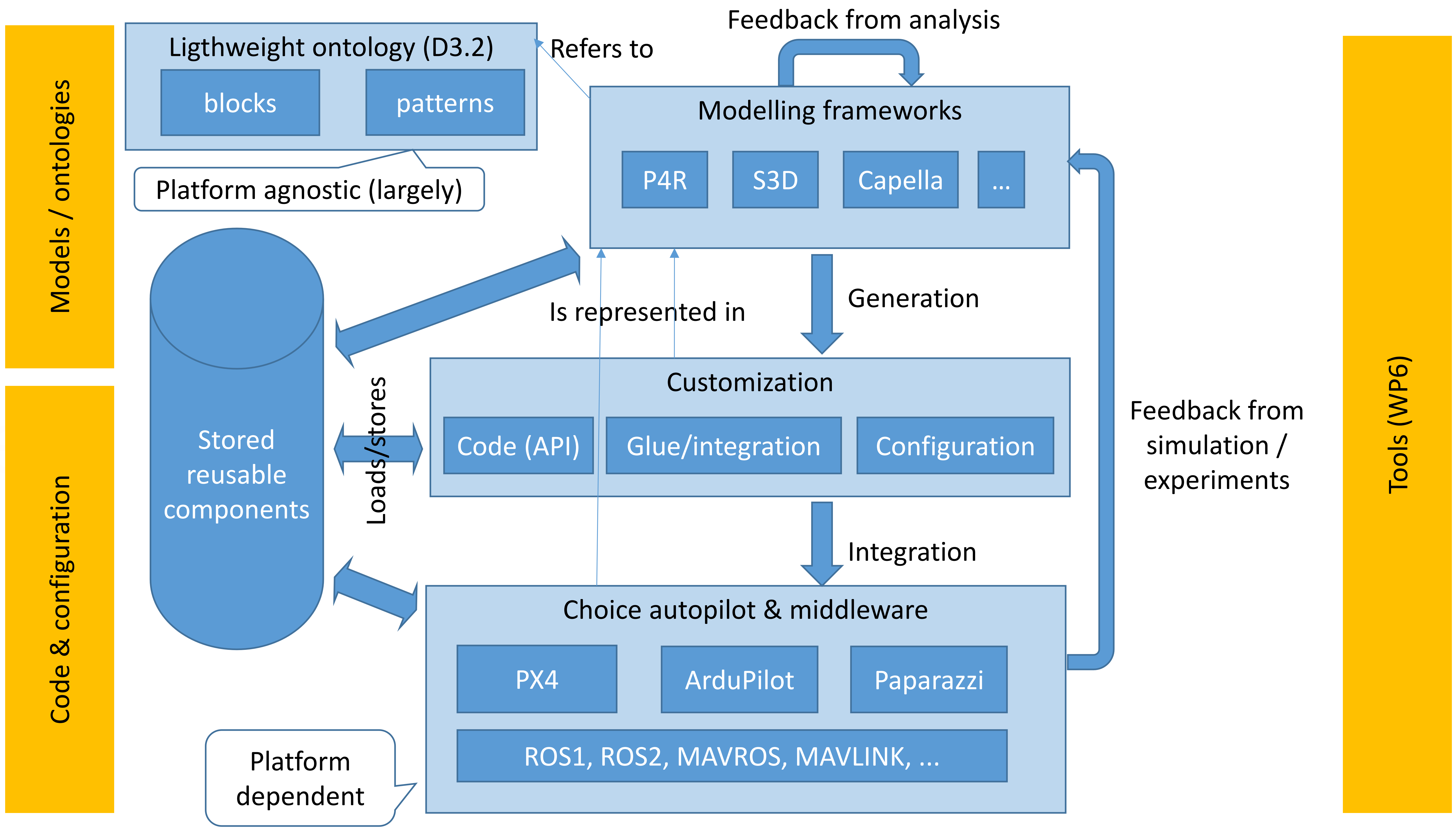
Make drone system architecture modular

Developing qualified components conform to the modular architecture

Reference architecture of a flexible embedded platform

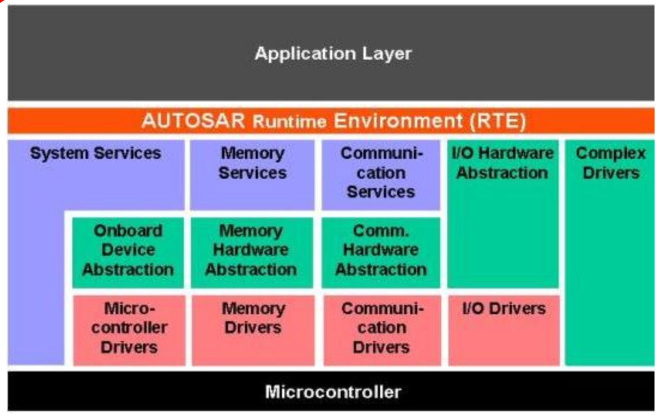
Setting-up of a common repository of qualified components

C4D Model-Based Design Workflow

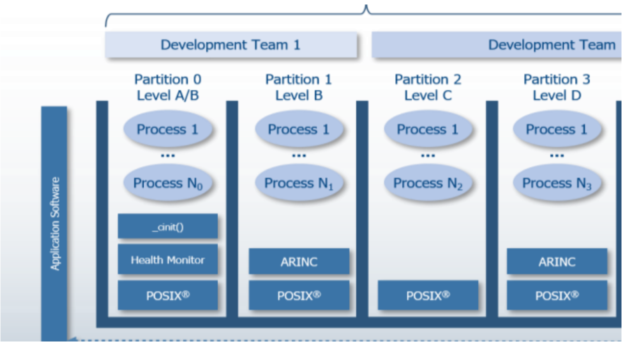


Reference Architecture Methodology

State of the art Embedded Software Architectures



Automotive domain

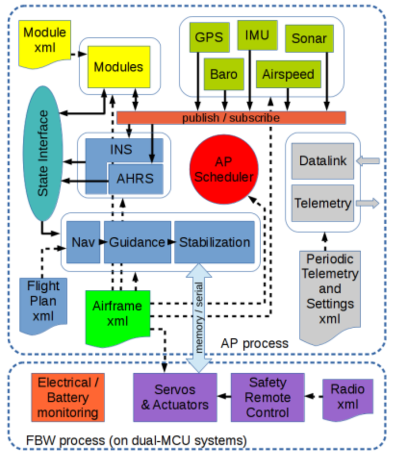


Avionics domain

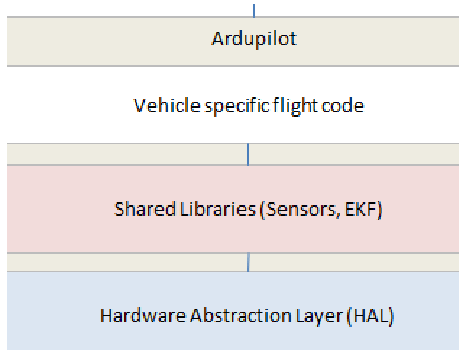
Robotics domain

Partners Practices
+
HW, SW & Architectural Requirements

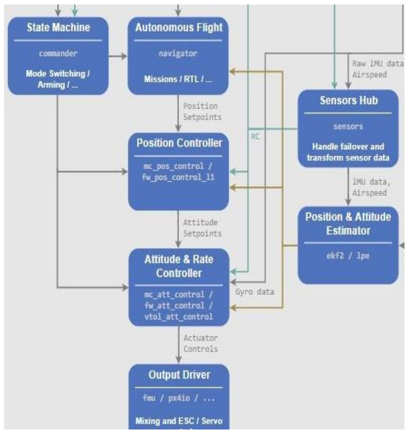
Paparazzi



Ardupilot

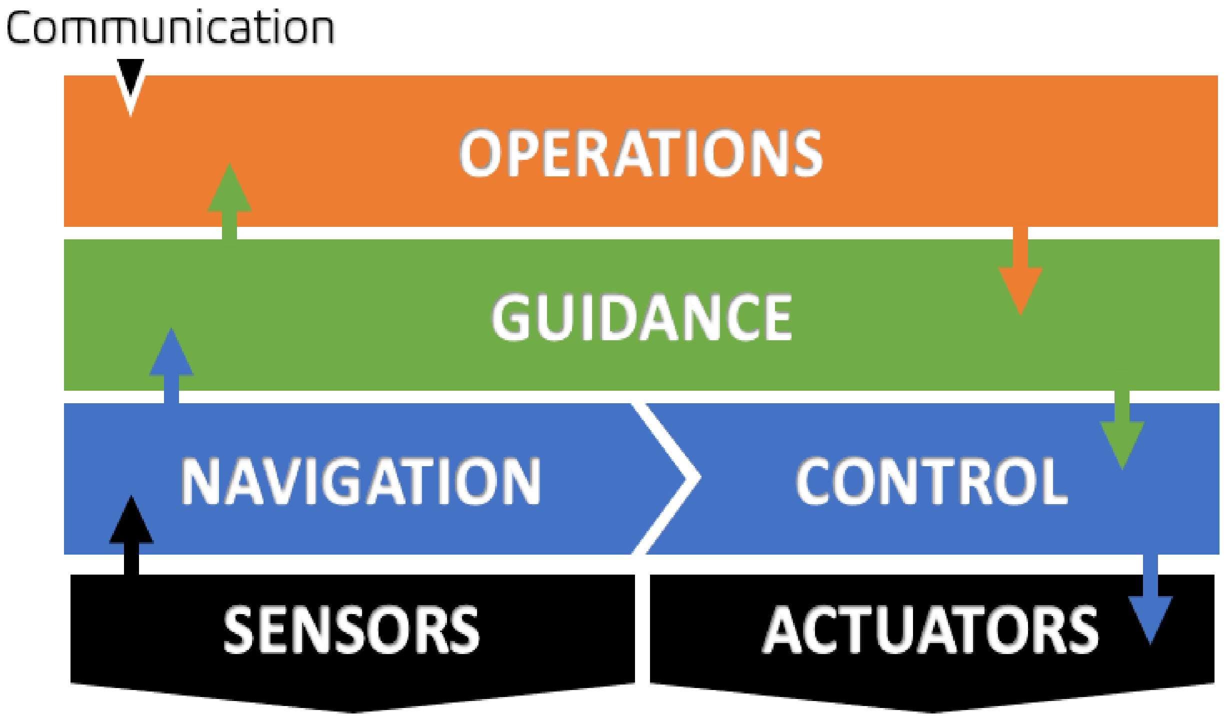


PX4

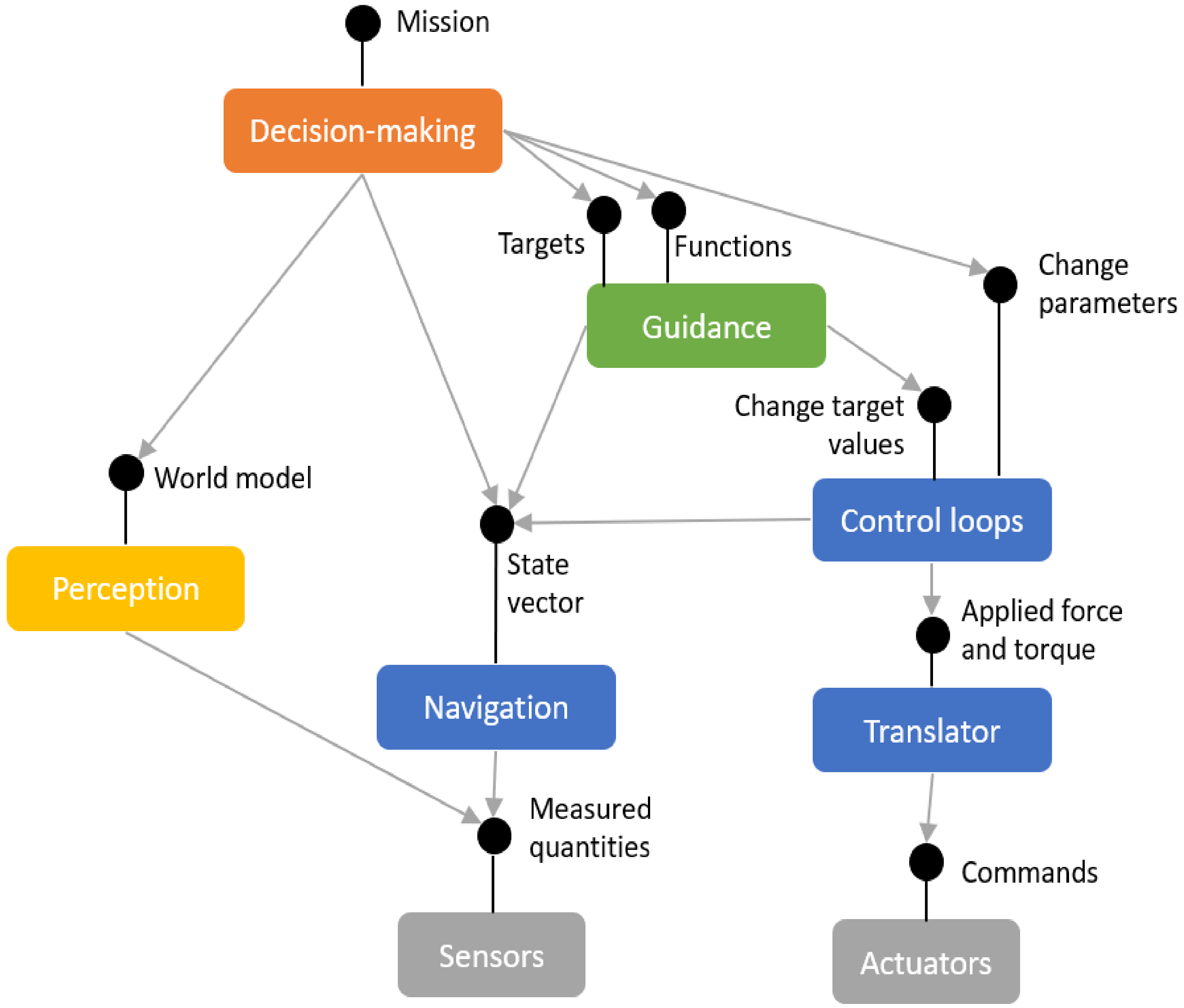


State of the art Drone Autopilots

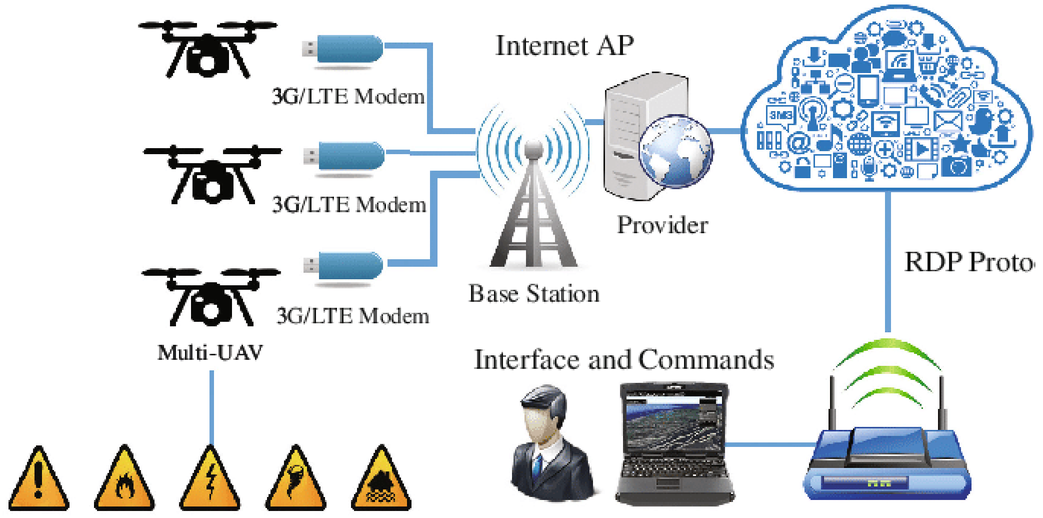
Initial Architecture

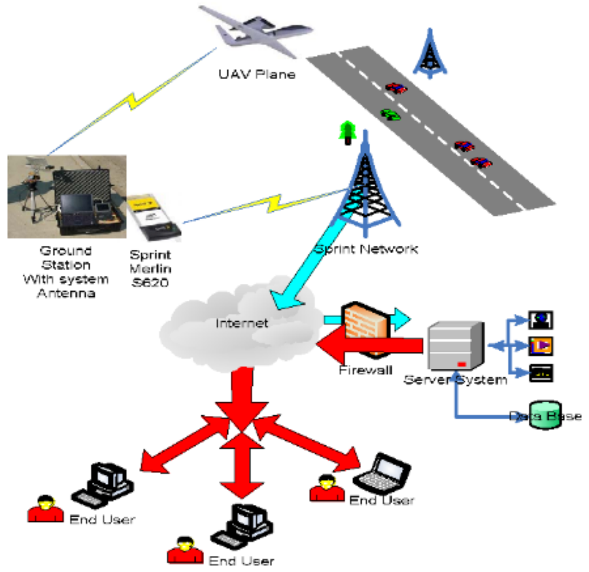


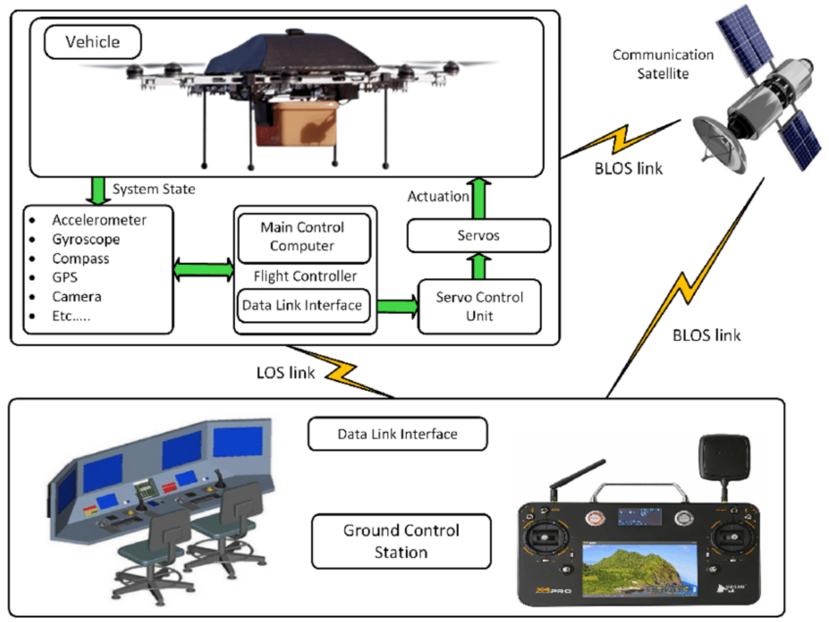
Physical World



What is Unmanned Aerial System (UAS)?

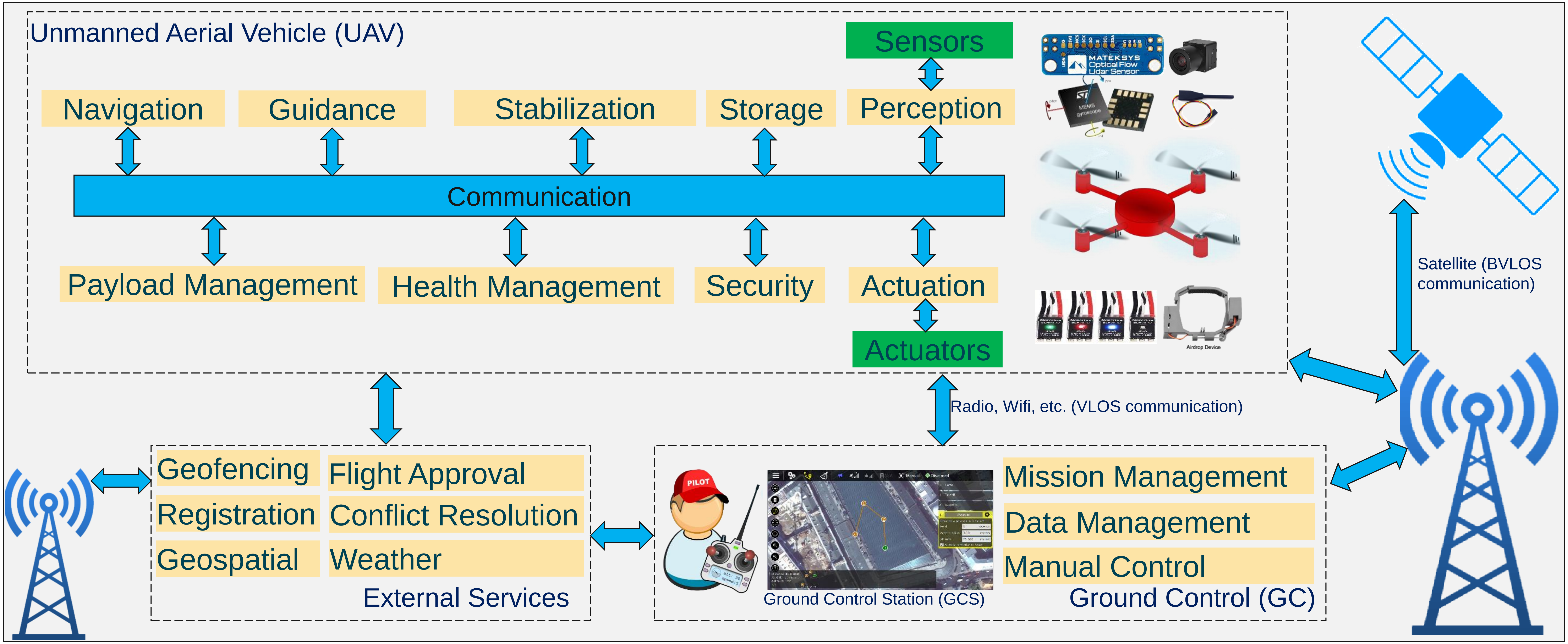




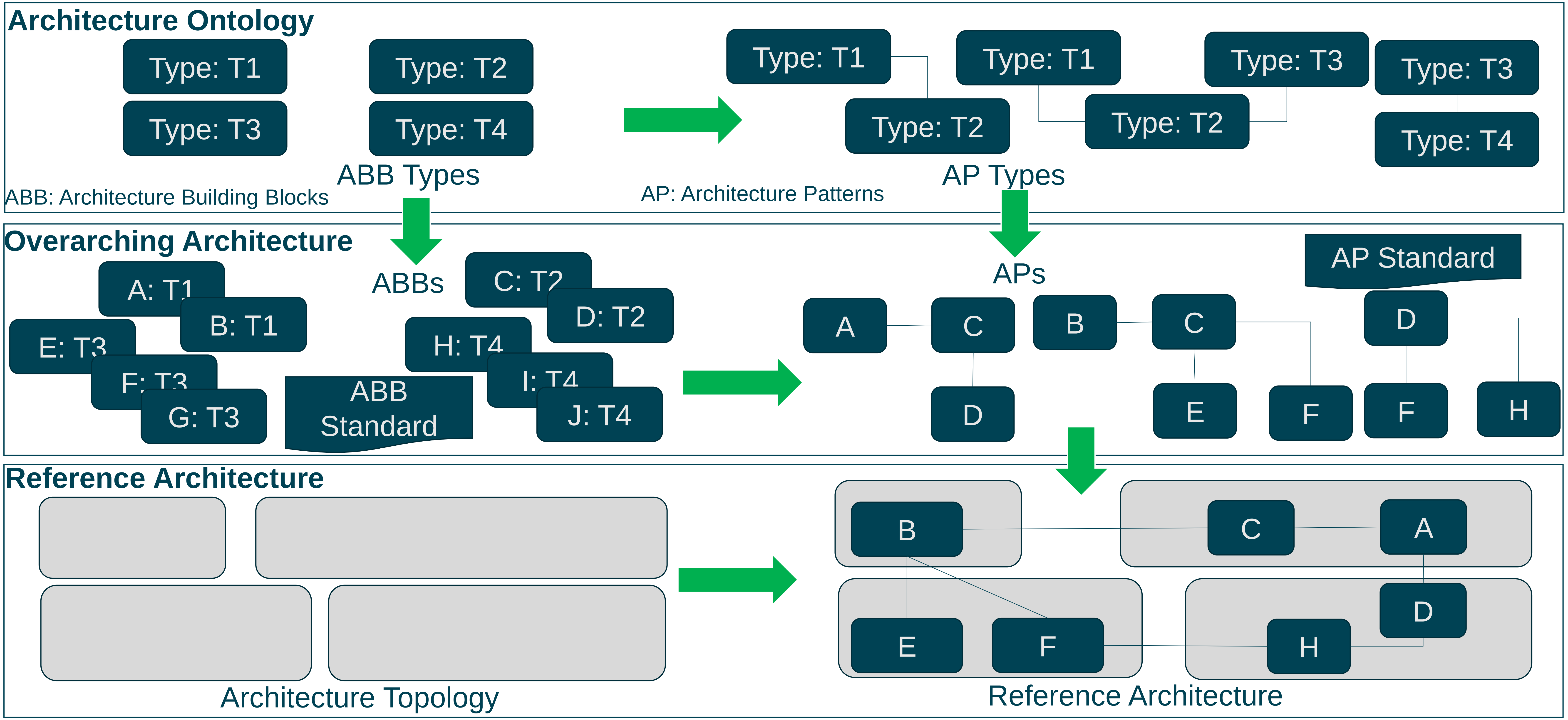


Sensors	**UAV Avionics** (Acquisition + Guidance + Navigation + Control + Power Management + Health Management)	**Communication System** (C2Link + Service data exchange)	**External Infrastructure** (GCS – UTM – Storage - etc.)
Actuators	**Payload and its Management**		

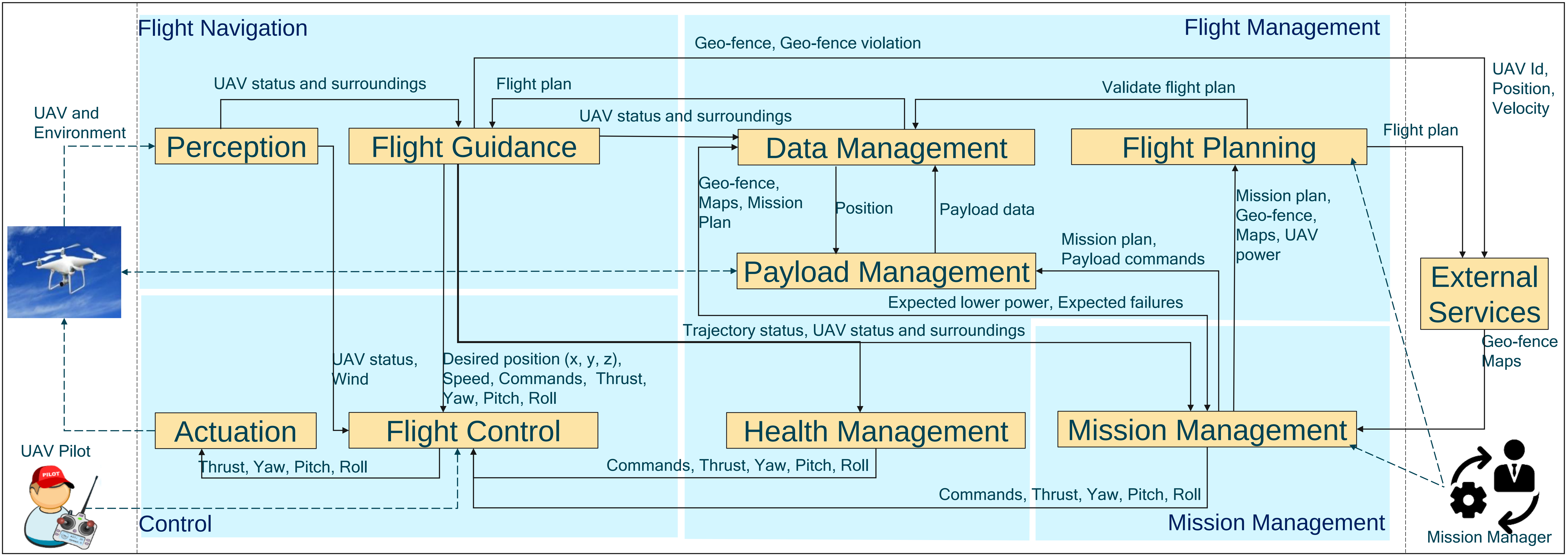
General Structure of UAS



Strategy for Defining Reference Architecture



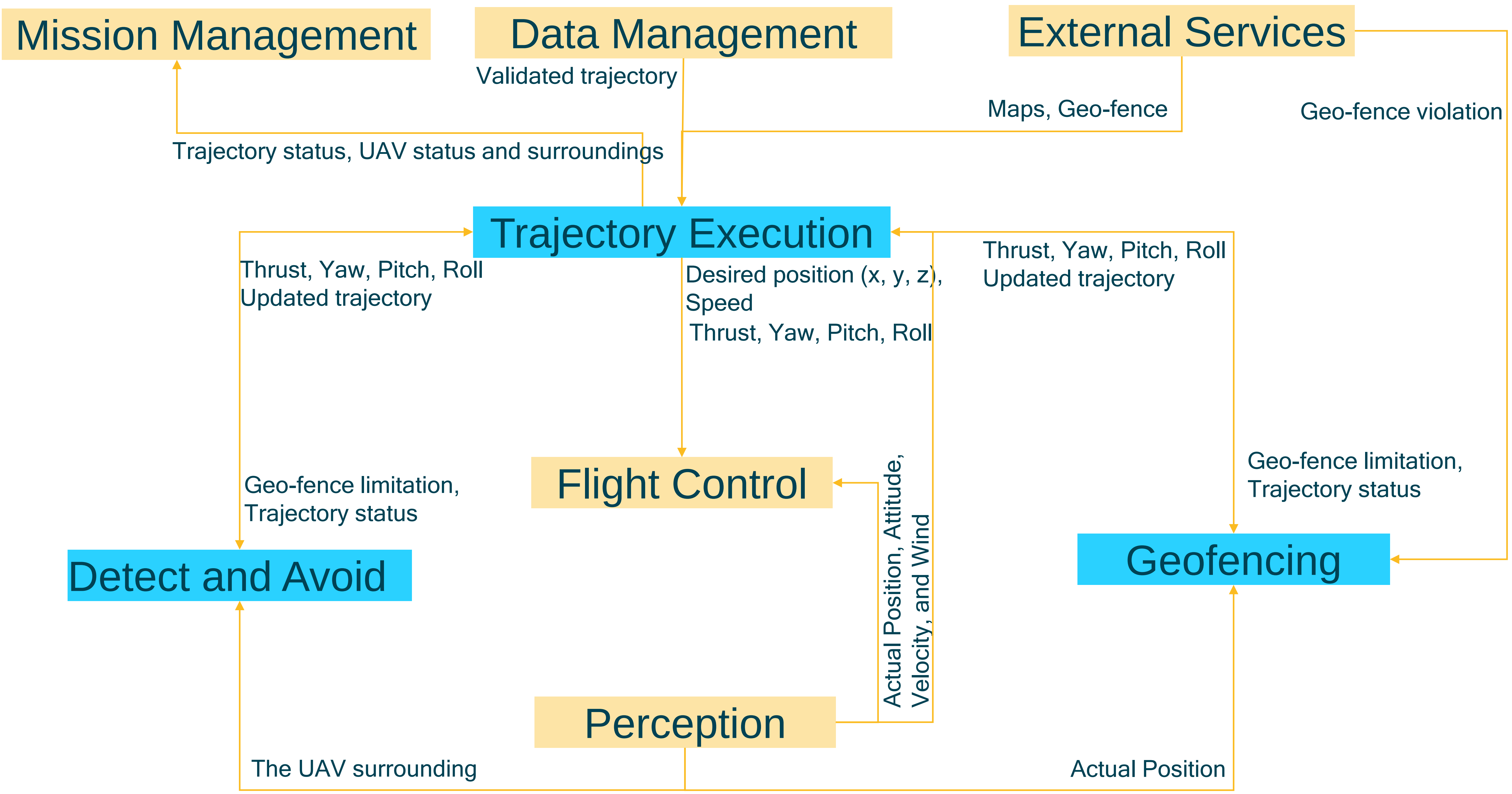
UAS Blocks and Patterns



*__UAV status__: Actual Position, Attitude, Velocity, Power Level, Engine(s) status, …
*__UAV surrounding__: Wind, Temperature, Static and dynamic obstacles, …
*__Commands__: Take off, Land, Return home, ….

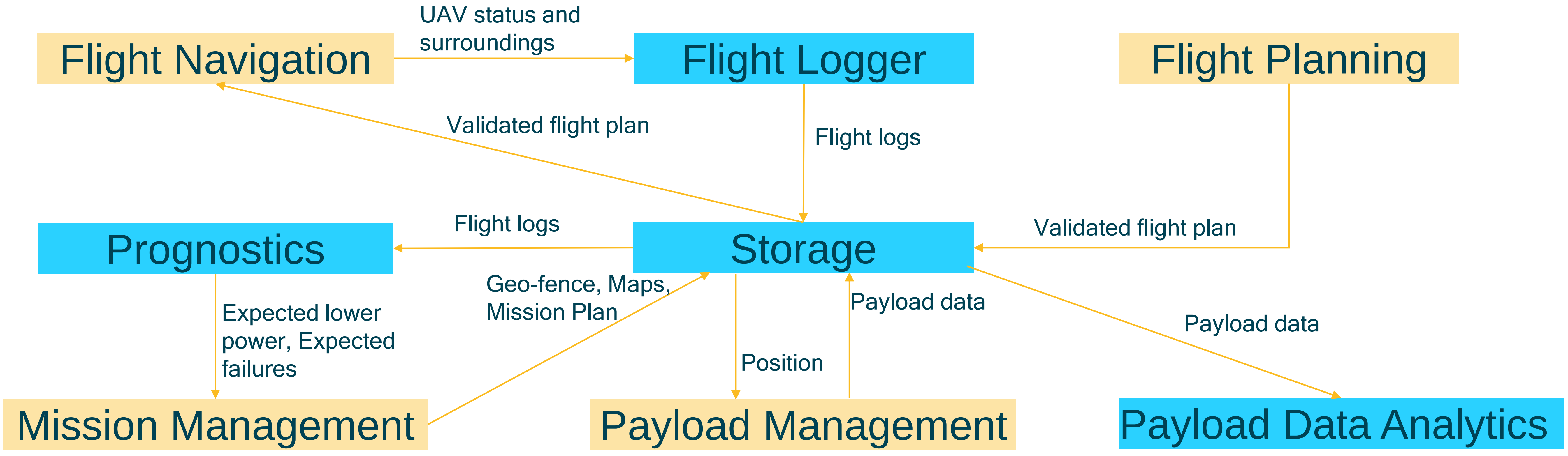
UAV Blocks – Navigation

- Mission Management
- Flight Planning
- Flight Navigation
  - Trajectory Execution
  - Detect and Avoid
  - Geofencing
- Flight Control
- Perception
- Actuation
- Health Management
- Payload Management
- Data Management



UAV Blocks – Data Management

- Mission Management
- Flight Planning
- Flight Navigation
- Flight Control
- Perception
- Actuation
- Health Management
- Payload Management
- Data Management
  - Prognostics
  - Flight Logger
  - Storage
    - Access Control
    - Data Operations
  - Payload Data Analytics



Expected Failures: sensors, actuators, communication link, software

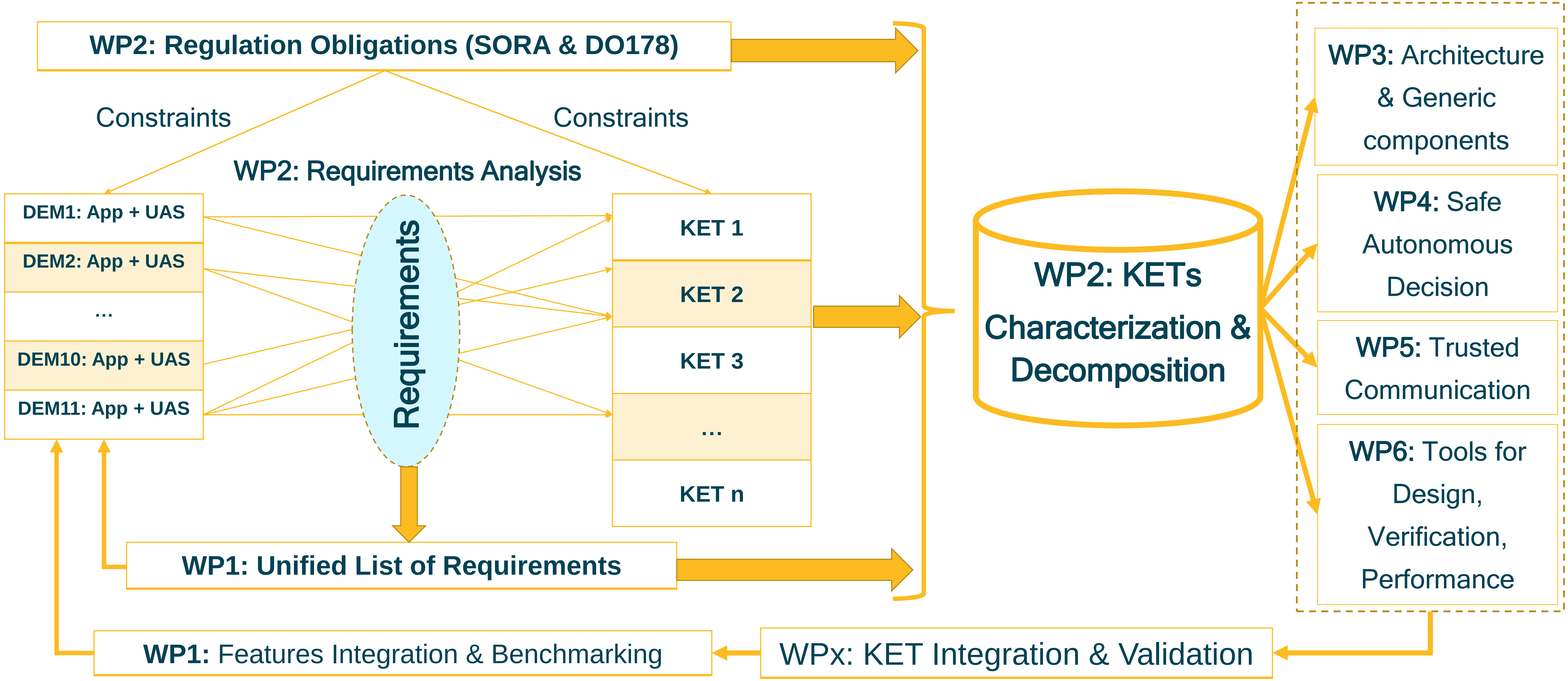
UAS Building Blocks

https://comp4drones.github.io/Component_repository/

- Mission Management
  - Mission Planning
  - Mission Supervision
- Flight Guidance
  - Trajectory Execution
  - Detect and Avoid
    - Obstacle Detection
    - Collision Avoidance
  - Geofencing
    - Geo-Awareness
    - Preservation
  - Command Executor
    - Take-off
    - Return
    - Landing
    - …
- Flight Planning
  - Trajectory Planning
  - Trajectory Validation
- Flight Control
  - Position Control
  - Attitude Control
  - Stabilization
- Health Management
  - Power Management
  - Fault Management
  - Diagnostics
- Payload Management
  - Payload Coordinator
  - Payload Controller
  - Data Acquisition
- Data Management
  - Prognostics
  - Flight Logger
  - Storage
    - Access Control
    - Data Operations
  - Payload Data Analytics
- Perception
  - UAV Status
    - Attitude and Heading
    - Position
    - Velocity
  - UAV Surrounding
    - Obstacles
    - Weather
  - Sensors’ Drivers
- Actuation
  - Mixer
  - Drivers
- Communication
  - Data Link
  - Telemetry
  - Security
  - Internal

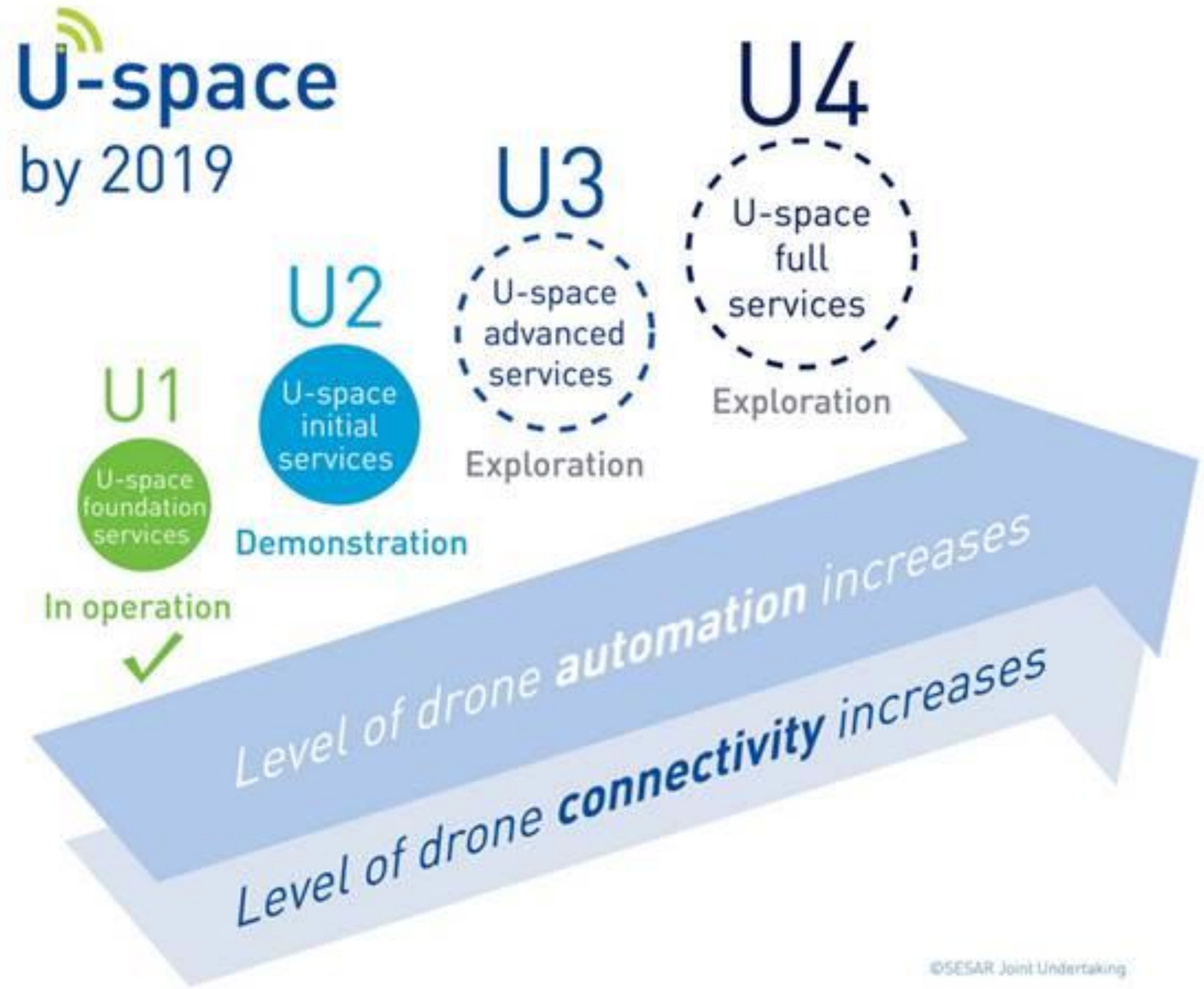
Key Enabling Technologies Development

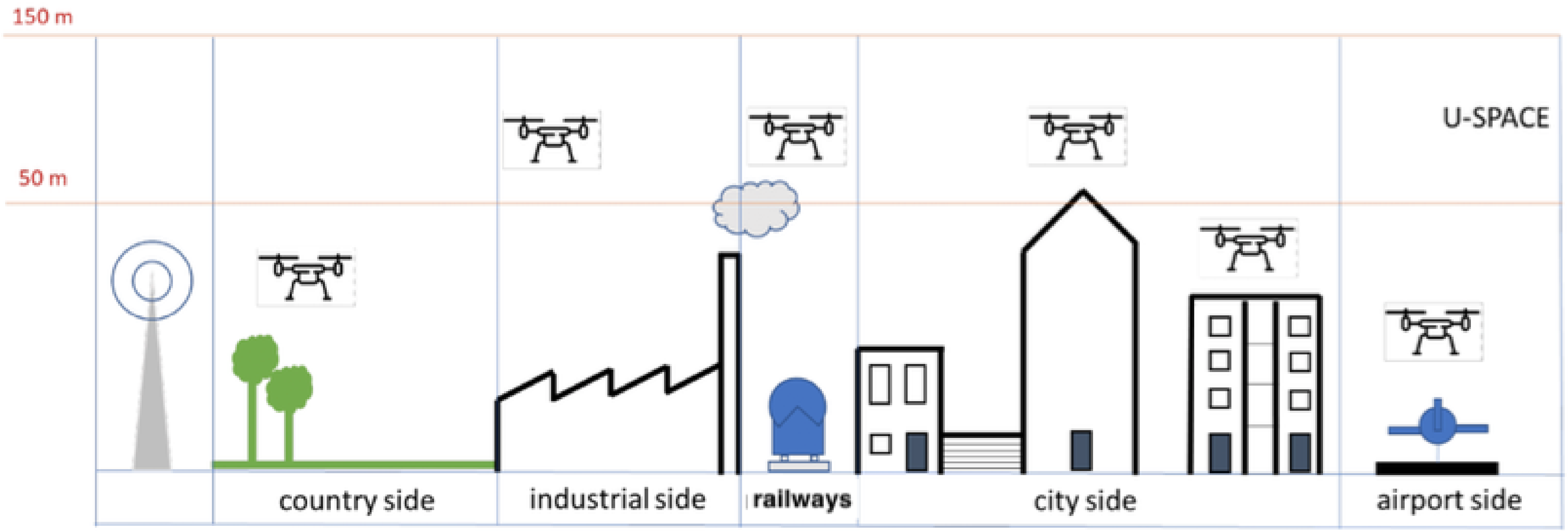
Methodology for the Identification of KETs



*KET: Key Enabling Technologies

Uses Cases require advanced technologies





- Safe operation is #1 priority
  - Need for highly robust connectivity (LoRA, WiFi, 4G/LTE,5G)
    - Flight planning and management (strategic deconflicting)
    - Deconflicting on shorter timescales (FLARM, ADS-B)
  - Need for sensor technology for "last second" collision avoidance
    - Other drones, obstacles (industrial and urban environments)
    - No reliance on connectivity
  - Need for novel smart system functions
    - Safe decision-making strategies
    - Attention mechanisms (data rate can be very high)
    - Deconflicting, high level of autonomy

Safe Autonomous Decisions

The main contribution of safe autonomous decisions group is to design and develop a safe and reconfigurable control and navigation subsystems. It includes the following specific contributions:

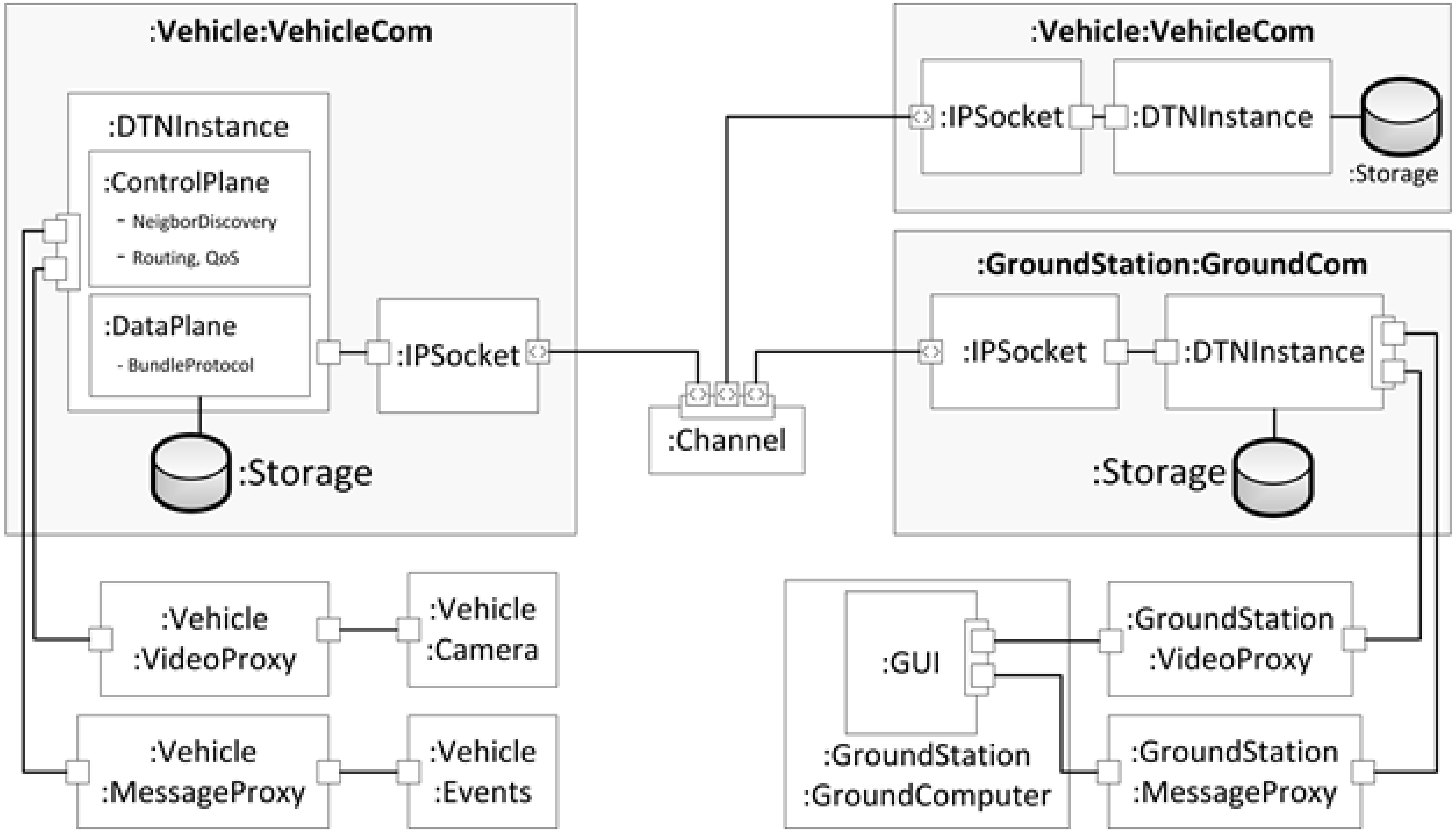
- **Sensory systems**
- **Aggregation of collected data**
- **Safety and dynamic control**
- **State monitoring of navigation**
- **Decision strategies based on control theory**
- **Artificial intelligence algorithms for enhancing sensory information**
- **…**

Trusted Communication

Trusted communication refers to ensuring robust and efficient drone communications. It includes the following specific contributions:

- **Distributed intrusion detection system with in-drone machine learning**
- **Security management toolchain for drone monitoring and control**
- **Detection of navigation system failures**
- **Navigation system with anti-jamming and anti-spoofing features**
- **Robust and enriched communication among beacons**
- **…**

Communication Reference Architecture

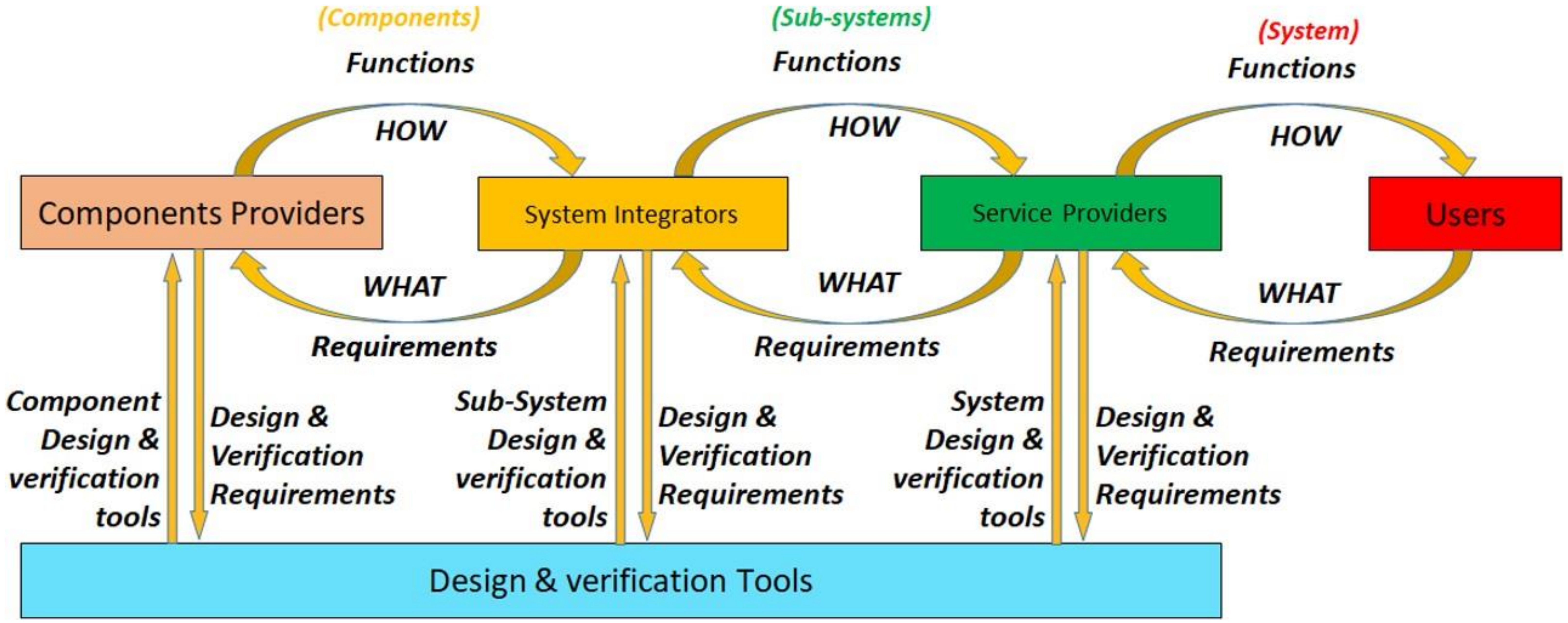


Minimizing the Design and Verification

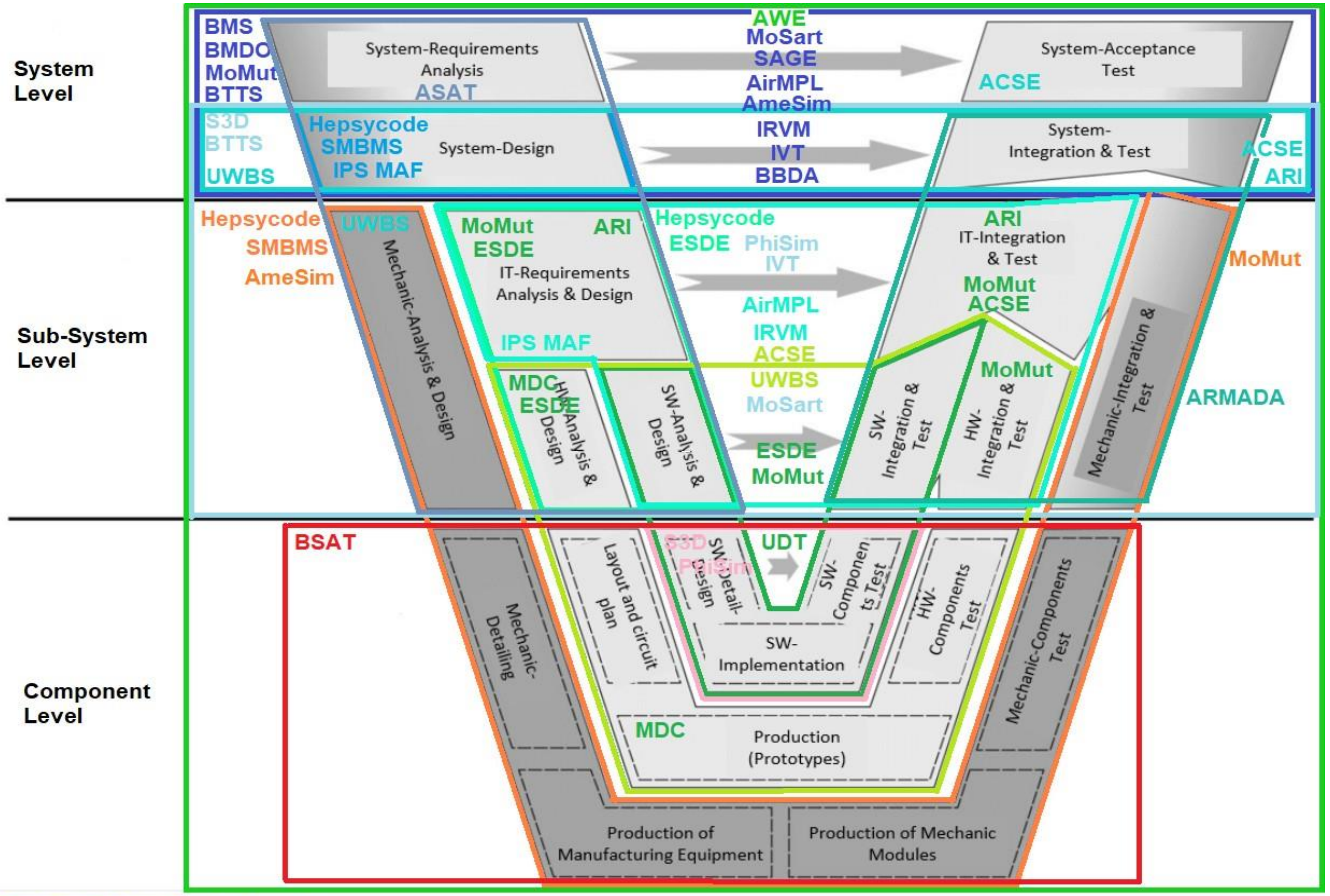
The objective of this work is to define and set-up a system engineering framework and development workbench adapted to drone applications. The work includes the following specific contributions to existing tools:

- **Digital stakeholder acceptance test bench**
- **Accelerators programming model for onboard compute**
- **Develop workflows for the drone domain**
- **Modeling language to support drones' specificities in term of temporal behavior**
- **Multi-Dataflow Composer**
- **….**

Design Technology requirements along the drone value chain.



C4D coverage of the development V-Cycle



BMS: BUT Modeling & Simulation
BMDO: BUT Mission Design & Optimization
UDT: UNIMORE Development Tools
SMBMS: SM Battery Management System
AWE: AIT Workflow Engine
BTTS: BUT Testing Tool Set
UWBS: UWB Batery Simulation
IRVM: IKERLAN Requirement Validation & Monitoring
IVT: IKERLAN Validation Toolchain
ASAT: AIT Security Analysis Tool
BSAT: BUT Safety Analysis Tool
BBDA: BUT Big Data Analysis
ARI: AIT ROS Infrastructure
ACSE: ALM Cloud Simulation Environment

C4D Repository - Wiki

https://wiki.comp4drones.eu (not finalized yet)

https://c4d.lias-lab.fr/index.php/Component_repository

Main page
Comp4Drones component repository
Tools repository as a table
Tools repository in the V Cycle (in construction)
Help about MediaWiki

Tools

What links here
Related changes
Special pages
Printable version
Permanent link
Page information

Page | Discussion | Read | View source

Component repository

This repository aims at providing common components usable in different application domains, in particular those covered by project use-cases.

The requirements for using a components will be listed, as well as a documentation on how to use it. The component itself will be hosted by the partner who provides it.

Components list

ID	Contributor	Title
WP3-01	IKERLAN	Safety function - Pre-Certified SOM
WP3-02	EDI	Modular SoC-based embedded reference architecture
WP3-03	BUT	Sensor information algorithms
WP3-04	HIB	Computer Vision Components for drones
WP3-10	IFAT	Component for trusted communication
WP3-13	ENAC	Paparazzi UAV
WP3-14_1	ENSMA	Collision avoidance and geo-fencing
WP3-14_2	ENSMA	Distributed control of multi-drone system
WP3-15_1	ACORDE	UWB based indoor positioning
WP3-15_2	ACORDE	Multi-antenna GNSS/INS based navigation
WP3-16	SCALIAN	EZ_Chains Fleet Architecture
WP3-19_1	IMEC	Hyperspectral payload
WP3-19_2	IMEC	Hyperspectral image processing
WP3-20	MODIS	Multi-sensor positioning

Training and demonstrations

COMP4DRONES

UIMP - Summer School

TECHNOLOGIES FOR FUTURE SERVICES AND BUSINESS MODELS BASED ON SAFE AND AUTONOMOUS DRONES

July 18-22, 2022, Santander, Spain

Course Description

The course aims to provide interested participants with a research roadmap and state-of-the-art in enabling technologies for drones. The course, derived from the research activities in the COMP4DRONES project, covers key technologies in this domain, such as smart sensing, trusted communication and model-based system engineering. The technologies will be demonstrated on four industrial application domains for drones (transport, logistics, agriculture, supervision and inspection).

The 5 days program has been structured by devoting each day to a specific topic. Concretely, the reference architecture for drones, the required SW in smart, autonomous drones, the trusted communication for swarm applications and the technologies enabling the development of UAV-based services. A final panel with the main stakeholders in the field will discuss current barriers and future developments. The course will count with outstanding lecturers from industry and academia.

The course is targeted to engineers and managers in companies providing drone-based services, researchers in industry and academia, entrepreneurs and public in general interested in the last technologies supporting the development of those complex services.

Registration: https://lnkd.in/eN8wD_vW

ECSEL Joint Undertaking

Lectures

1) Comp4Drones: Key enabling technology framework for drones
2) Safe Integration of UAV in the Airspace
3) UAV Architecture and Challenges: C4D Reference Architecture
4) C4D Reference Architecture Implementation on the Paparazzi autopilot
5) Artificial Intelligence with grid cells and synthetic data
6) Neuromorphic sensors and processing systems for drone applications
7) Risk Analysis and Certification Frameworks for Critical Trusted AI Applications
8) U-SPACE regulation and simulation
9) Cellular connectivity and telecommunication infrastructure for UAS solutions
10) A positioning solution for long indoor infrastructures relying on robust and enriched ultra wideband (UWB)
11) Autonomous Drones for Infrastructure Inspections: Design and Challenges
12) Drone development from existing vehicle technologies
13) Building An All-European HPC Processor using Open technologies
14) Modeling and Simulation of UAV-based Services
15) Model Based Development and Testing: case study cryptography
16) Droneport: From Concept To Simulation and Prototype
17) Use-Cases Demonstrations

Round Table: Innovation vs Regulation. Opportunities and Challenges; *Teresa Riesgo - Secretary General for Innovation – Spain, Nicholas de Kergolay - USPACE Expert – France, Javier Viejo Acosta - Business Development Director - INDRA – Spain, Emmanuel Grolleau - Full Professor - ENSMA - France*

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Final Project Technical Review

Where?
Galicia, Spain

When?
First week of October 2022

Format:
2-days workshop + Flights

More information soon …

COMP4DRONES

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Project Web Presence: https://www.comp4drones.eu/ , https://twitter.com/ECSEL_C4D , https://www.youtube.com/channel/UCUH27sjlF7ECC7lcH9gCRSA