Guidance, sensing and monitoring strategies for autonomous vehicles

1st French-Danish Workshop on Unmanned Systems

DTU - Copenhagen - 25 & 26 February 2015

ONERA

THE FRENCH AEROSPACE LAB

retour sur innovation

Understanding what we are talking about before starting!

RPAS, a new era for aviation (EC, 2014)

Need for standardisation, regulations, terminology…

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Unmanned system: What are we talking about?

"Drone" used in many languages, not used in regulatory publications – but chosen by EU MPs!

Unmanned Aerial Vehicle (UAV)

- Designation not really true as the system is composed of an aircraft, a pilot station and a data link

Unmanned Aircraft … System (UAS)

- It is a system, not only an aircraft
- The aircraft is unmanned
- The system may be manned or unmanned

Unmanned System: to be understood as UAS?

Autonomous vehicles: What are they?

Reference : ICAO UAS Study Group (UASSG)

UAS can be "autonomous" (i.e. they do not allow pilot intervention in the management of the flight)

or

Remotely-piloted aircraft (RPA), which are unmanned aircraft piloted from a Remote pilot station (RPS)

Only the latter are currently considered by ICAO suitable for standardised international civil operations, due to **unclear responsibility** for the autonomous portion of the flight

End 2014: UASSG has been replaced by RPASP

Needs for a commonly agreed terminology

Reference : ICAO UAS Study Group (UASSG) & ICAO RPAS manual, to be published this year

- ***Remotely Piloted Aircraft Systems (RPAS)*** are a subset of Unmanned Aircraft System (UAS)
- ***A Remote pilot (RP)*** is a person charged by **the operator** with duties essential to the operation of a remotely-piloted aircraft and who manipulates the flight controls, as appropriate, during flight time
- ***A Remote pilot station (RPS)*** is the component of the remotely-piloted aircraft system containing the equipment used to pilot the remotely-piloted aircraft

Needs for a commonly agreed terminology & rules

However, on February 15 & 23, 2015, FAA unveiled proposed rules:

- *Pilots of a small UAS would be considered "operators"* ☹
- About swarms: *No person may act as an operator or visual observer for more than one unmanned aircraft operation at one time*
- About autonomy: *FAA official on media call: Autonomous flight is allowed if operator is in place to jump in if needed and drone is within sight*

ANCHORS Project

High-level mission management for a team of cooperative vehicles

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Context

European **ANCHORS** project

Goal: definition of techniques for managing **crisis situations** based on a team of **cooperative vehicles**

Context

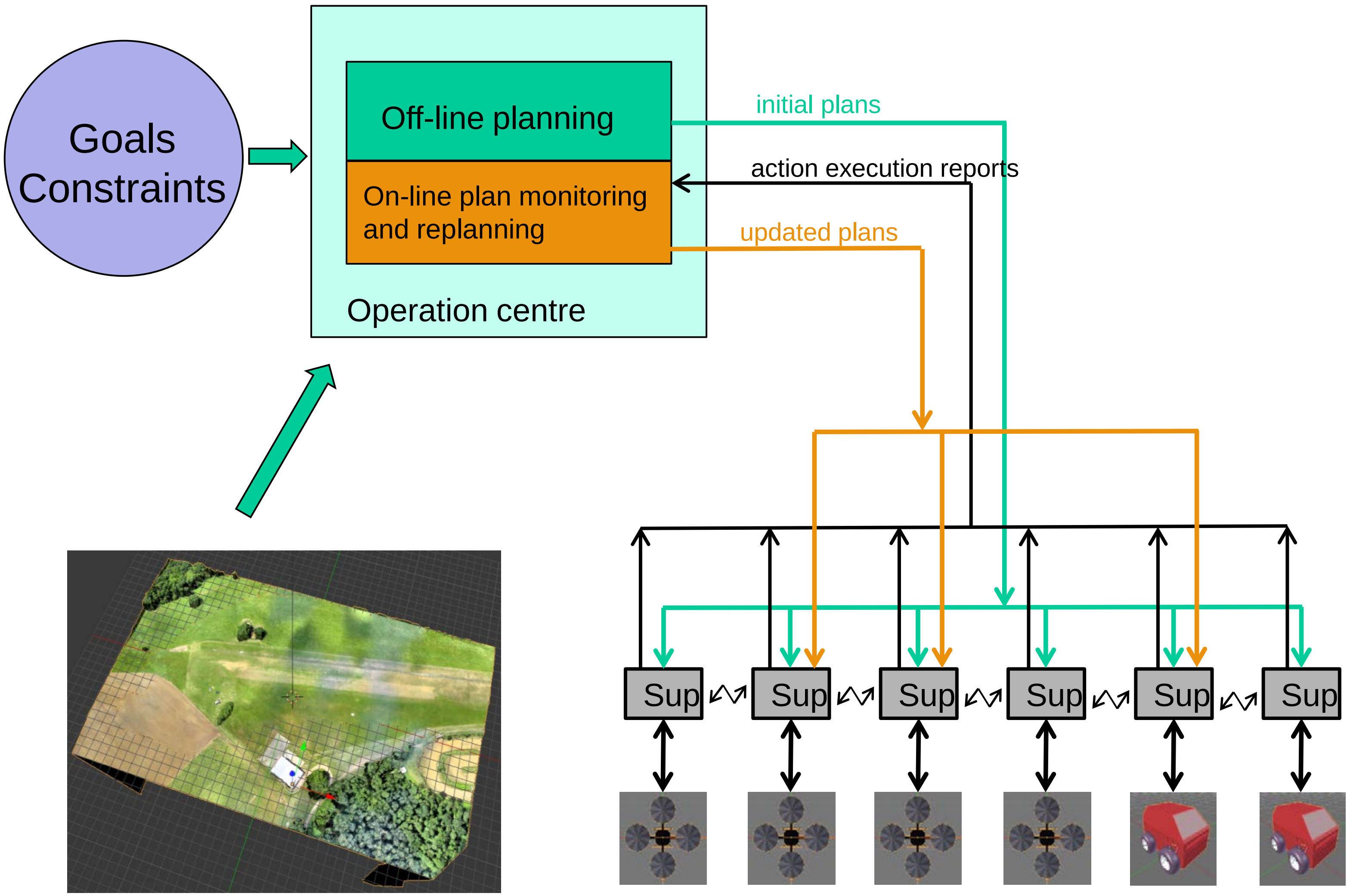
Deployment of **ground and aerial vehicles**:

- for realizing **sensing** operations (radioactivity measure, video stream...)
- for building an **ad hoc wireless communication network**, to transmit sensed data in real-time to an operation centre

Main hypotheses and constraints:

- the environment is sufficiently known to enable **area exploration planning** and communication propagation constraints estimation
- aerial electrical robots have a limited range and need **periodic charging** that is provided by ground robots

Chosen approach



Autonomous operations

Vision based localization and mapping
Autonomous exploration of unknown areas
Fleet of Cooperative vehicles

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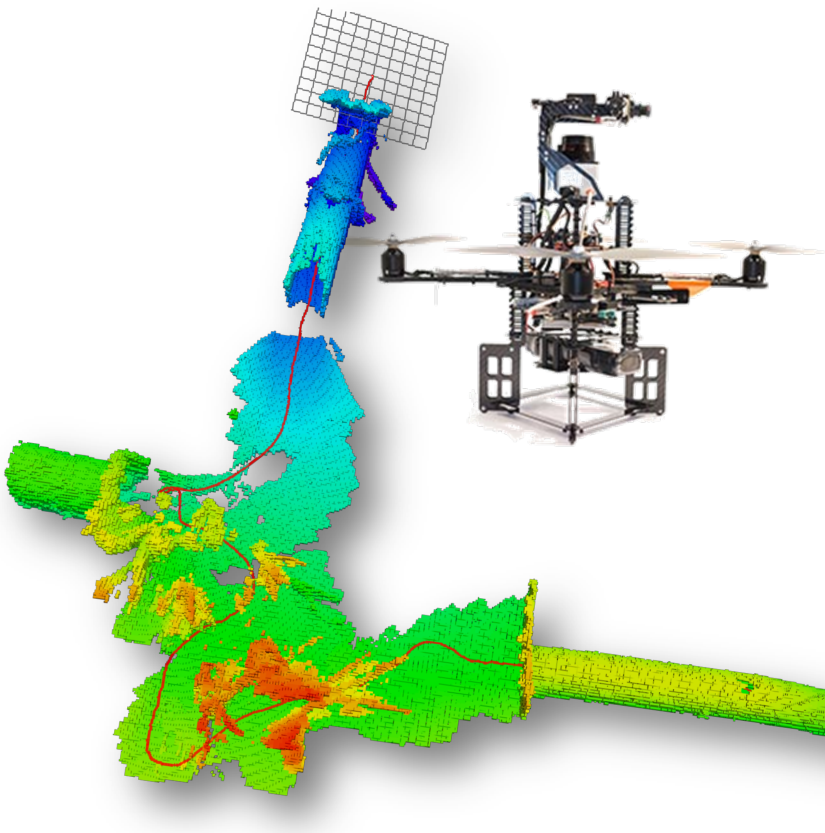
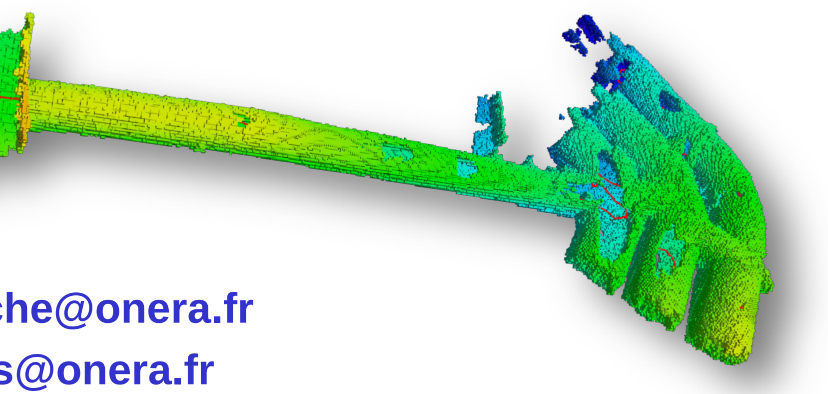
Vision-based localization and mapping

- Stereo-vision for self-localization and 3D environment reconstruction
- Embedded real-time solution (>20 Hz) on quadrotor RPAs

- Centimetric accuracy
- Useful in GPS-denied environments
  - Indoor
  - Urban (building occlusions)
  - Plants (electromagnetic disturbances)
- Navigation in cluttered places
  - Autonomous inspection and mapping
  - Search & rescue

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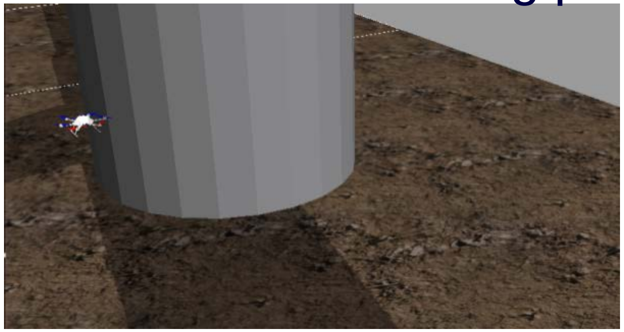
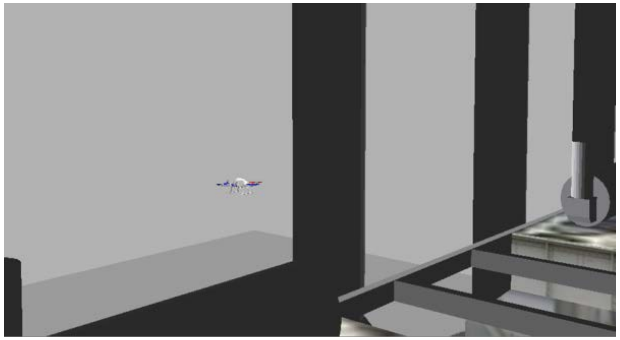
Autonomous exploration of unknown areas – Guidance strategies

Vision-based exploration + Model Predictive Control

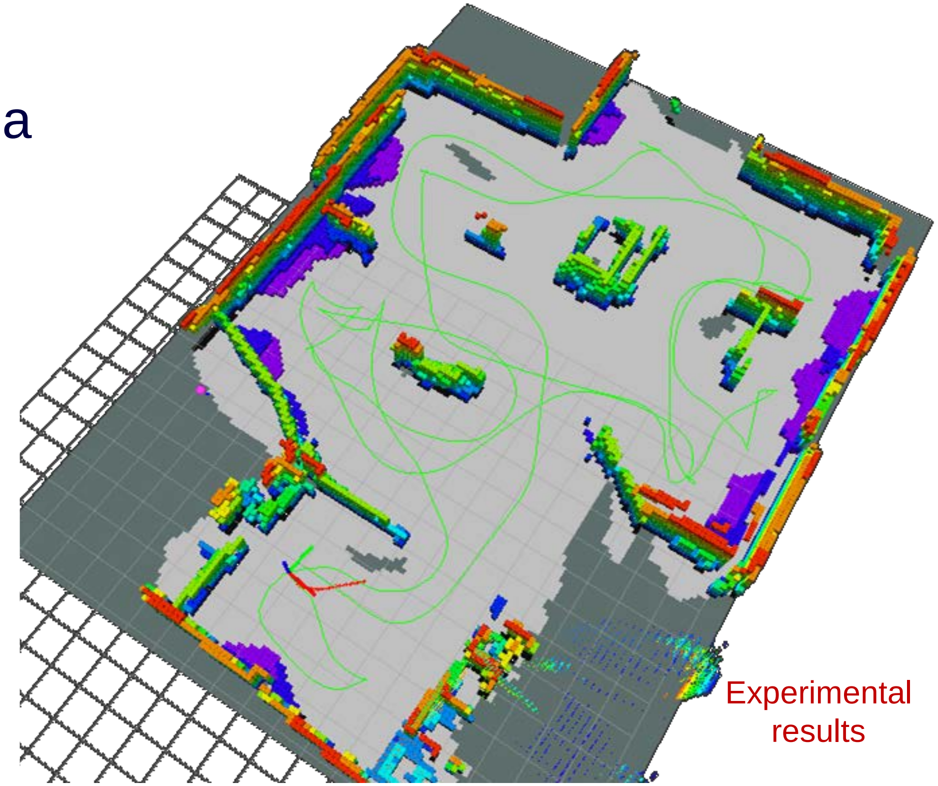
Online trajectory definition

- Obstacle avoidance
- Maximization of explored area
- Return to starting point





FP7 EUROC competition



Experimental results

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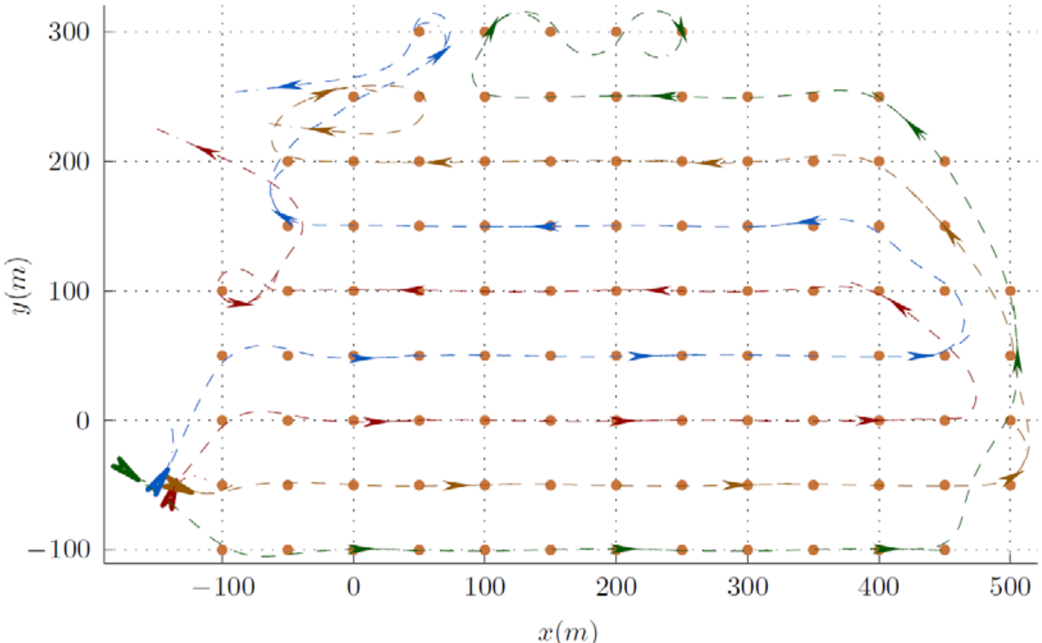
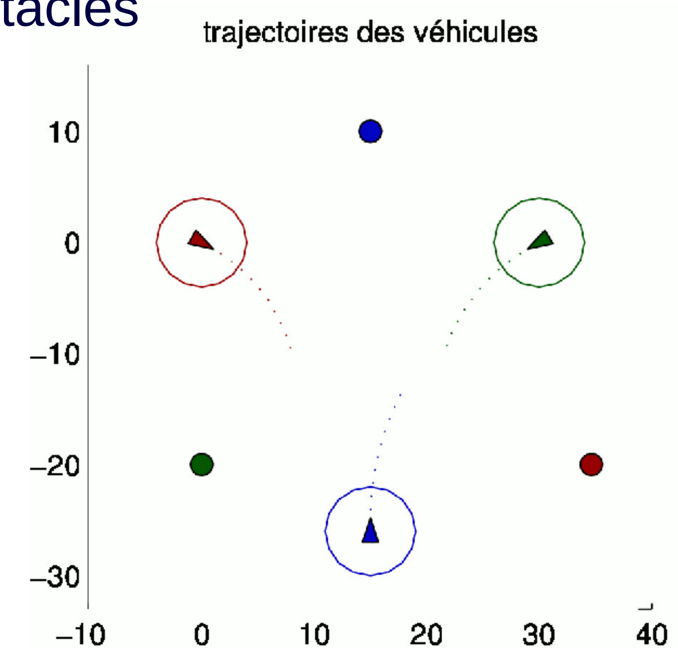
Fleets of cooperative vehicles

- Global objective for a fleet of vehicles, such that the cooperative mission is more efficient than the sum of individual missions
- Cheaper individual vehicles with complementary sensors
- Formation flight with common goal
- Faster autonomous exploration of unknown areas
- Decentralized implementation: reduced communication and robustness to vehicle loss
- Collision avoidance between vehicles and with obstacles



Cooperative exploration

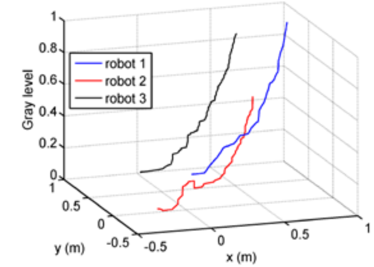


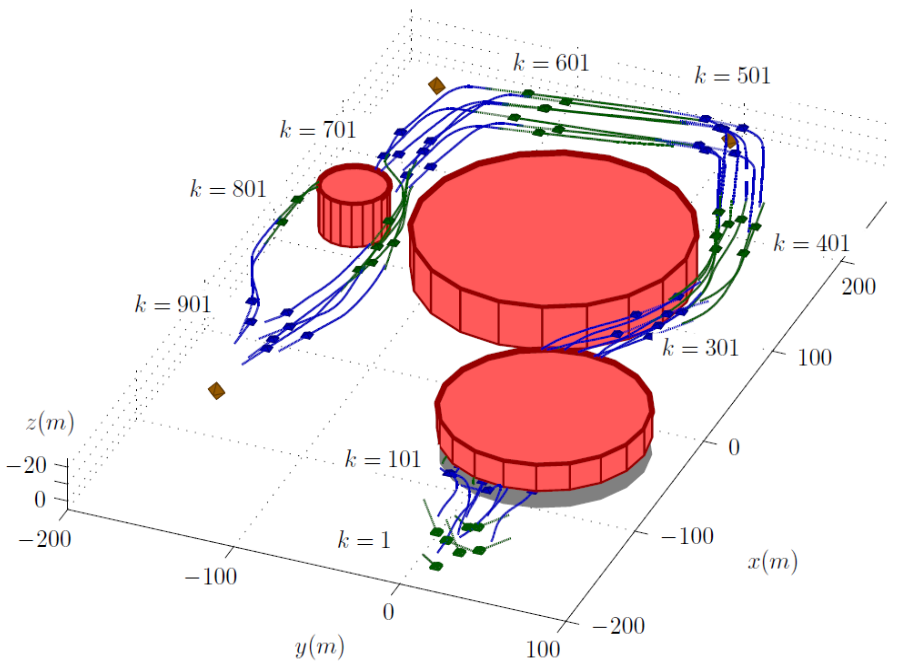
Collision avoidance

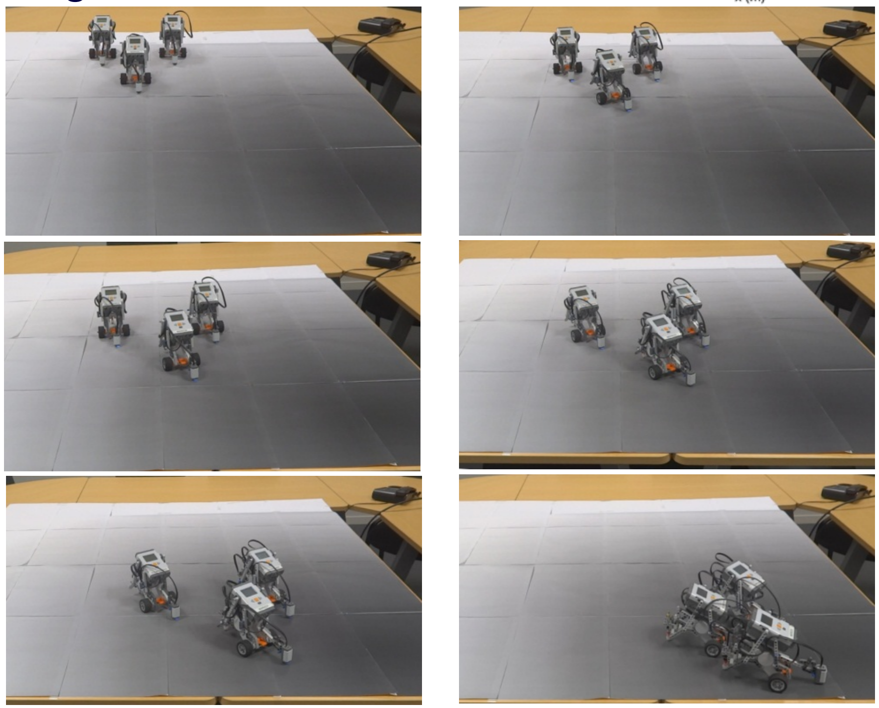
Fleets of cooperative vehicles

Applications :

- Zone surveillance with small UAs (warehouse, plants, …)
- Source localization (fire, gas, intrusion)
- Tracking of mobile objects with multiple points of views
- Massive deployment of sensors on a large area







Formation flying with obstacles

Maximum seeking

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How to use several UAs in a formation…

… and to comply with civil regulations?

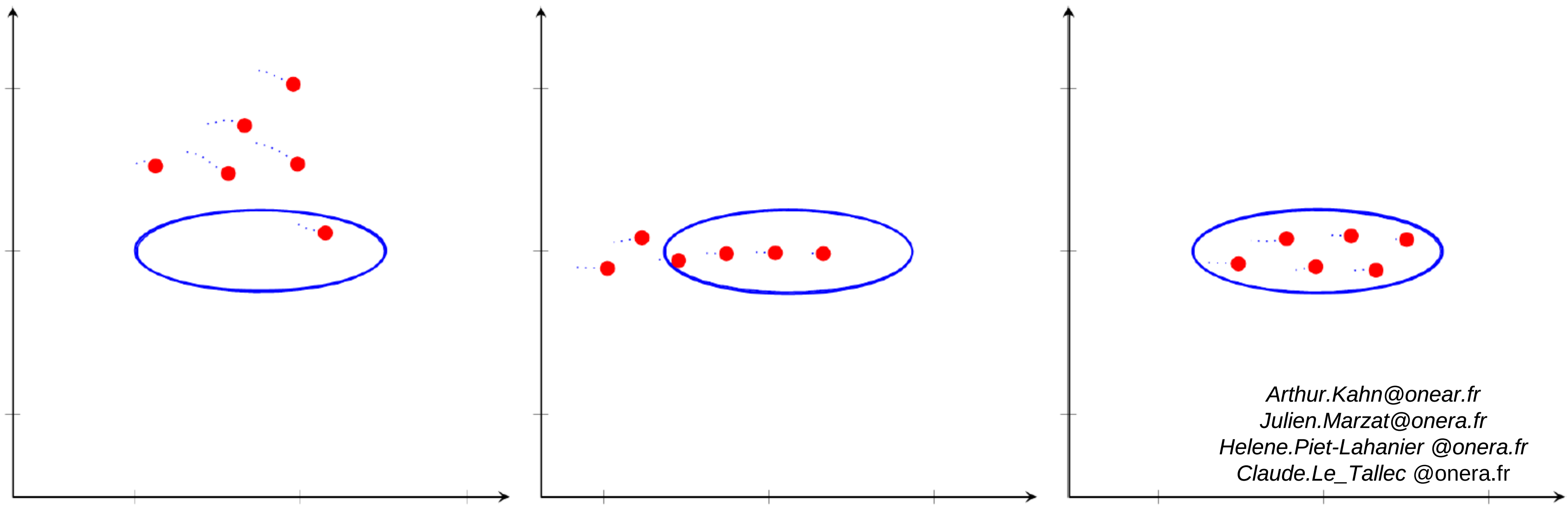
Make a single RPA from a swarm:

- An upper control layer is used to control the motion and shape of a virtual RPA structure to fulfil the goals and constraints of the required mission
  - trajectory of the fleet
  - adaptation of the structure to the environment

- A decentralized lower automatic control layer, embedded in each vehicle, computes its individual motion so as to remain inside the structure and avoid colliding with the other vehicles
  - the RPA is built by a manufacturer who guaranties its airworthiness
  - UAs are parts of the RPA
  - UAs look like parts of a conventional aircraft but they are moving…

How it works?

- UAs are gathering within an ellipsoidal RPA structure
- The formerly autonomous **parts of the RPA** are making **a single RPA**
- Once the RPA is built, all its parts remain within the limits of the ellipse whose shape adapts to avoid obstacles



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Supervision of multi-UAs operations

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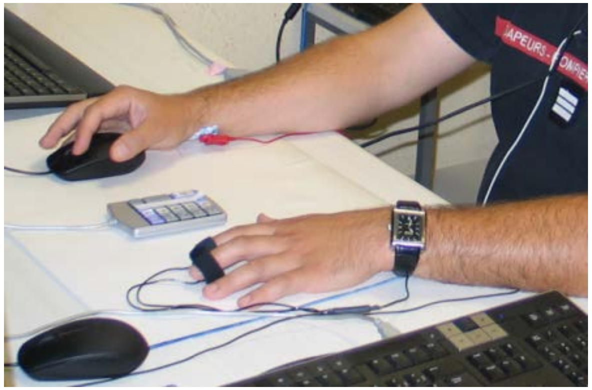
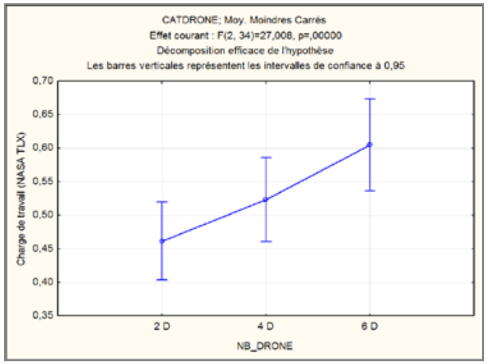
Supervision of multi-UAs operations

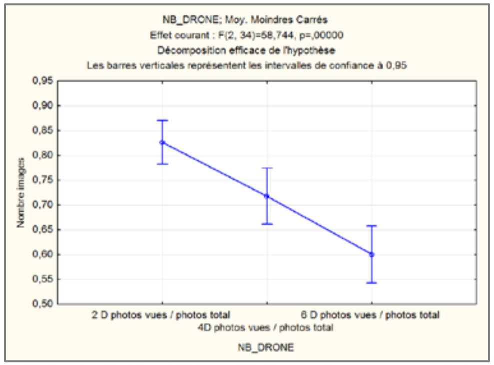
DARIUS

Objective: specify and evaluate a supervision display for multiple Unmanned Aircraft operations

- Simultaneous monitoring of up to 6 video streams.
- Propose and evaluate various solutions for attention getting.







Development of an hybrid simulation platform for HSI research on UXVs

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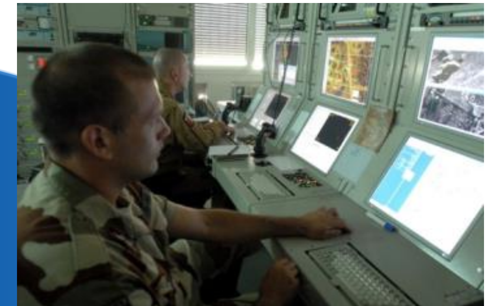
Prototyping facilities for innovative Human - System Interactions



Civil & Military Operations

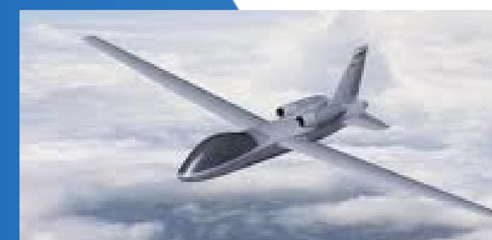
Psychophysiological measurements

ECG, EEG, EMG

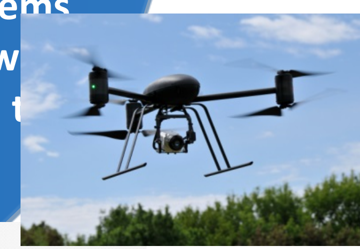
Eye, Head & Gesture tracking

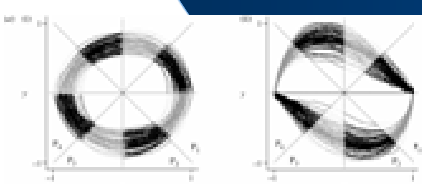
Innovative Concepts of Interaction

Prototyping & Assessment in Simulation



Manned & Unmanned Aircraft Systems Simulation w Hardware in t loop

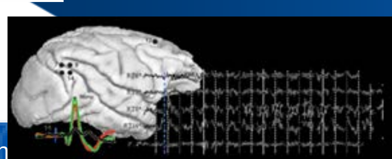




Tools & Methods for biometric data analysis

Modelling of Cognitive functions & Human activity

Situation Awareness & Workload analysis



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Automation and human sense of control in the context of UAS Detect & Avoid

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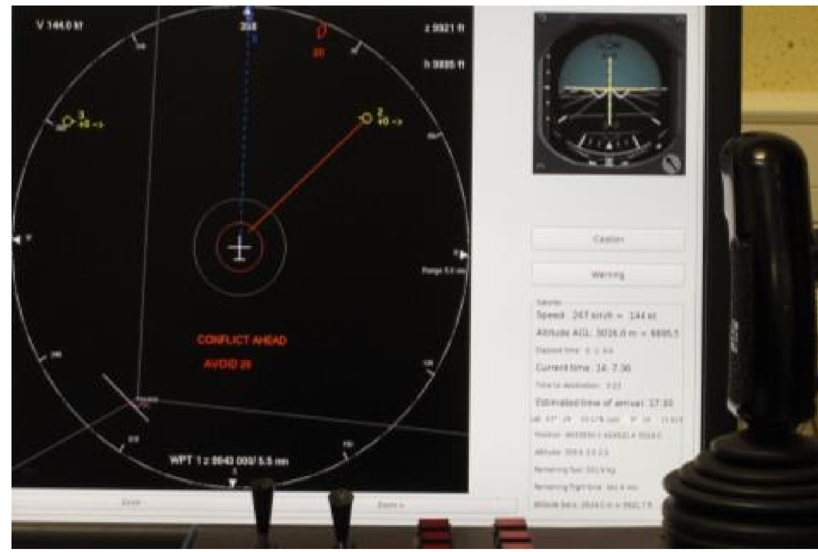
HTIL experiments on automation and human sense of control in the context of UAS Detect & Avoid

Objective: Mitigate the negative effects of automation based on knowledge and principles of cognitive sciences

Effects of automation levels and anticipatory cues (*prime*) on human performance and sense of control (*agency*)



Berberian, B., Sarrazin, J.-C., Le Blaye, P., & Haggard, P. (2012, March). Automation Technology and Sense of Control: A Window on Human Agency. *PLoS ONE, 7*(3), e34075.

Le Blaye, P., & Bollon, F. (2014, July 21 - 23). Avoiding out of the loop effects of automatic conflict avoidance: preliminary design and results. *5th International Conference on Applied Human Factors and Ergonomics (AHFE)*. Krakow, Poland.

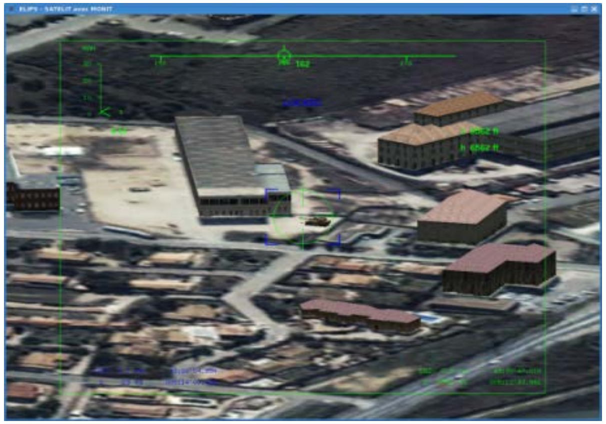
HITL experiments on the effects and mitigation of latency in UAS payload control

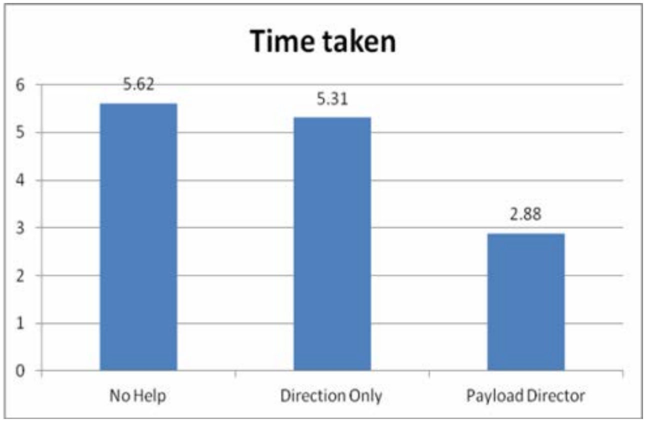
Objective: Identify and compensate the effects of latency / data transmission delays in a tracking task.

Latency is an issue specific to UAS, depending on the type of command and control link (RLOS, BLOS).

Effects on tracking performance and human sense of control.

Evaluation of compensation solutions (*payload director*).





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Automated Navigation in Urban Environment

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Objective

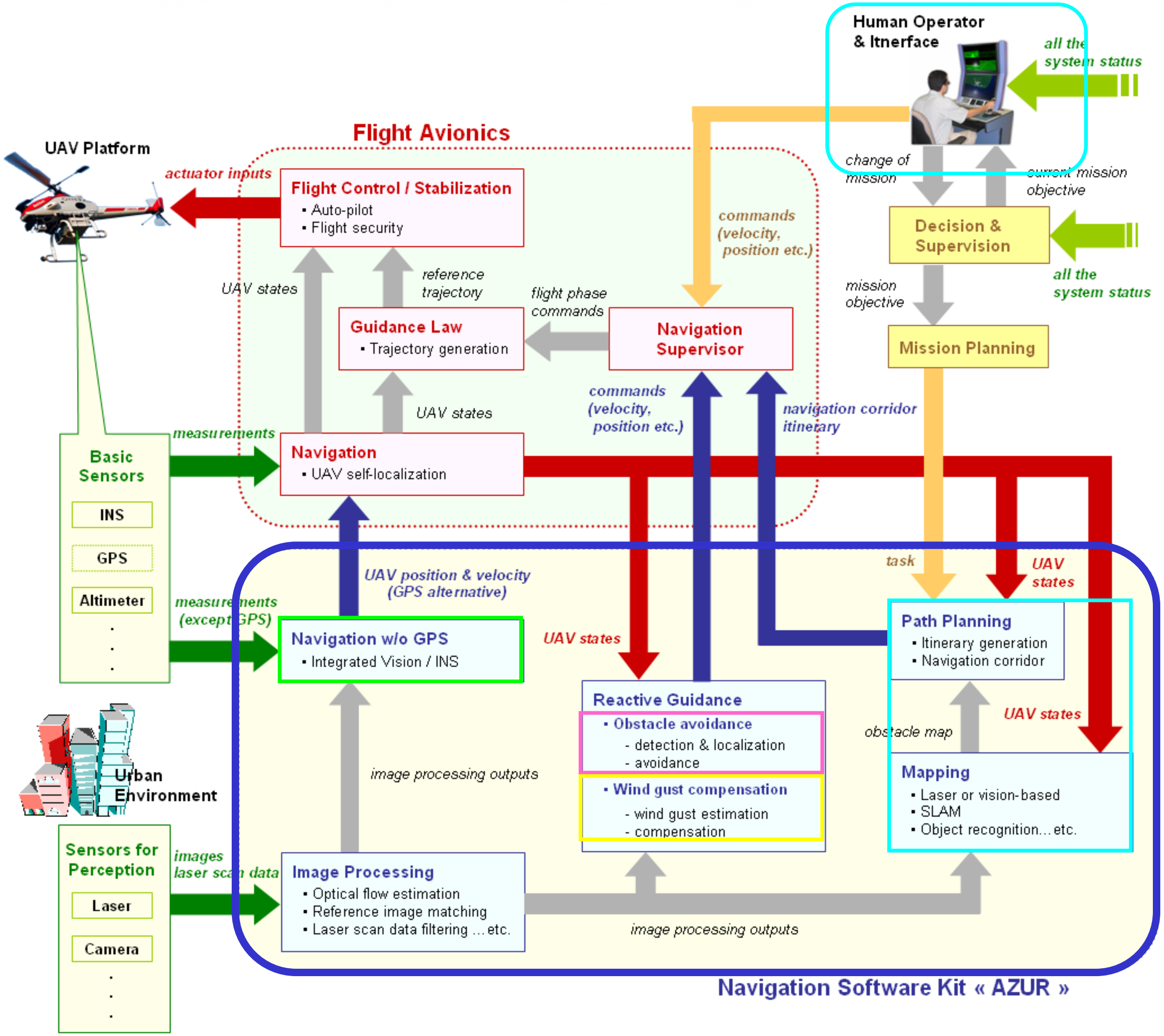
❖ Navigation Software Kit «AZUR»

Onboard navigation software for safe operations of UAs in an urban environment

❖ Flight demonstration

- Development of prototype onboard a UA
- In-flight validation of system functions
- Realization of a mission scenario in an urban environment

Navigation Software Kit « AZUR »



WBS 5 : Human Operator Intervention

WBS 0 : Robotic System Engineering

WBS 1 : Real-time update of environment map and path plan

WBS 2 : Reactive obstacle avoidance

WBS 3 : Navigation without GPS

WBS 4 : Wind gust estimation and compensation

WBS 6 : Exploration and Offline Mapping

And also…

In-flight autonomous coordination for fixed-wing aircraft

Autonomous take-off and landing

Vision-based autonomous landing for aircraft

Upset recovery in the presence of unexpected events

Heterogenous multi-vehicles coordination

Autonomous ground vehicle tracking

…

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Autonomy, navigation and swarming…

… a wide area for research!