Study of Anti-Drone Drone concept

***T. Lefebvre*, T. Dubot**

(ONERA/DCPS Toulouse)

&

ISAE projects (2nd and 3rd years students)

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THE FRENCH AEROSPACE LAB

retour sur innovation

Outline of the presentation

Intro

- ONERA/DCPS presentation
- Small drones flying at VLL: regulation & management
- Small drone threat problematics
- The ADD motivation

Methodology of the study

The ADD concept

- Nuclear power plant scenario
- ADD top level requirements
- Scope of architectures
- Focus on the threat

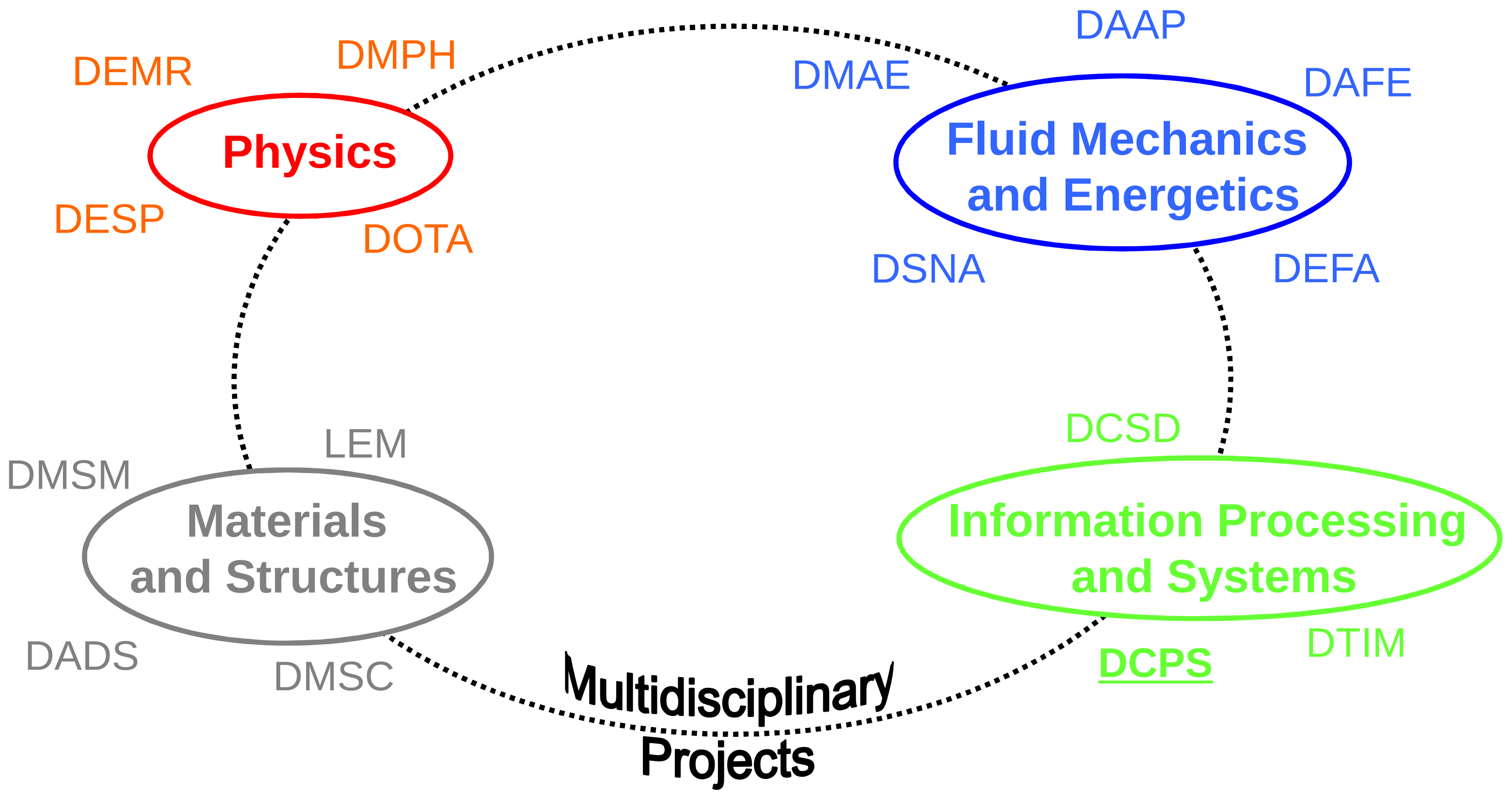
Assessing the ADD concept

- ADD design
- Interception strategies

Conclusion & perspectives

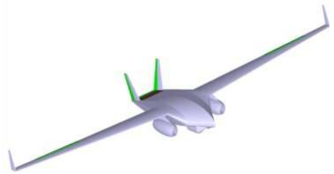
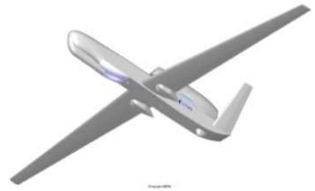
Onera – The French Aerospace Lab

The structure of Onera is based on 16 expert departments regrouped in 4 scientific branches

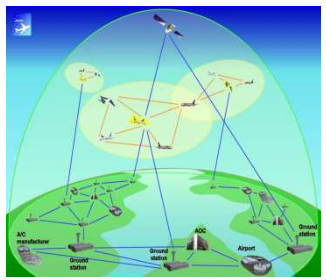
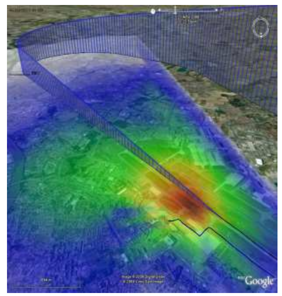


System Design and Performance Evaluation Department (ONERA/DCPS)

- Objectives
  - To promote synergy and complementarities between the expert departments within Onera
  - To develop competences in specific fields (system design, navigation and guidance, …)

- Domains of expertise
  - Performance of aerospace systems
  - **New concepts for aerospace vehicles**
  - Monitoring, tracking and defense systems
  - **Civil aviation and air traffic**

→ Recent focus on the development of common and integrated tools between design studies and ATM research

Ex: *long – term investigations for small RPAS flying at VLL*

Small drone flying at VLL: regulation & management

- Increase of small UAS VLL operations (<500ft)
  - National regulation, such as the [2012 French regulation on remotely-piloted aircraft]
  - French quick-start safety notice for model aircraft
  - Updates on-going and European harmonization with EASA
- Challenges
  - How to build a structure to accommodate industries and persons operating small UAS?
  - How to ensure the compliance to regulation?

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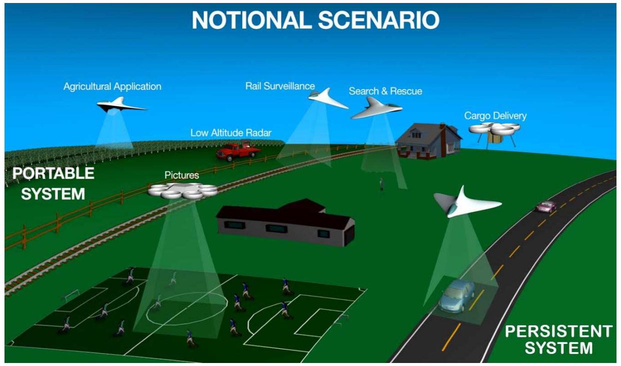

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ONERA

Small drone threat problematics

Safety

Security

Privacy

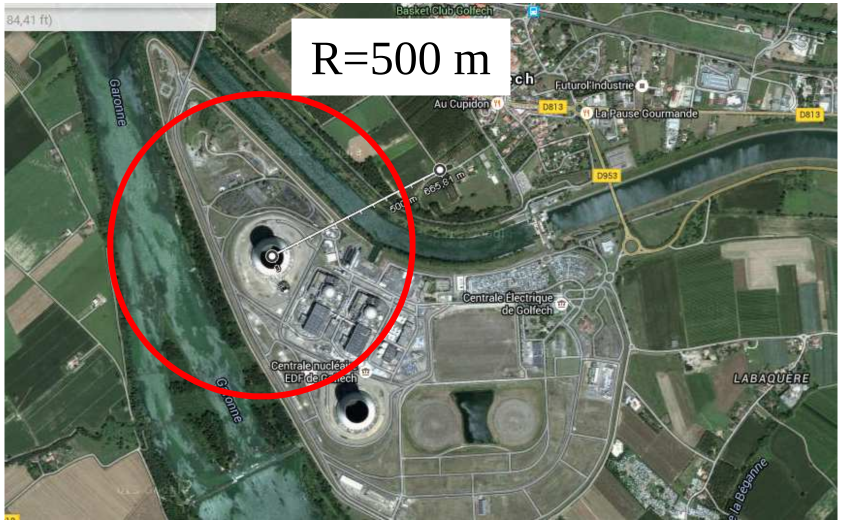
Getty/TMZ.com Composite

Motivation of the study

200,000 commercial drones in France

68 incidents reported since September

- **29 flights over nuclear power plants**
- **8 flights over military facilities**
- **Numerous flights dangerously close to airports**



GoogleMaps view of Golfech nuclear plant (near Toulouse)

A DJI Phantom 2 drone is equipped with three pounds of mock explosive (January 2015 - DHS conference)

Anti Drone System overview

Function	Detailled function
Watch and detection	
Threat evaluation and decision	**Vehicle characterisation**
	Vehicle identificiation
Action	**Electronic neutralisation**
	Physical neutralisation
	Payload neutralisation
Threat identification	**Vehicle localisation (follow)**
	Pilot localisation
	Pilot Identification

Anti Drone System overview : Anti Drone drone concept

Function	Detailled function	ADD relevance
Watch and detection		**-**
Threat evaluation and decision	**Vehicle characterisation**	**+**
	Vehicle identificiation	**-**
Action	**Electronic neutralisation**	**++**
	Physical neutralisation	**++**
	Payload neutralisation	**++**
Threat identification	**Vehicle localisation (follow)**	**+++**
	Pilot localisation	**+**
	Pilot Identification	**-**

ADD concept : comparison with other solutions

Neutralization

Anti-UAV Defense System

	Cost	Efficiency	Range	Collateral damage
Physical neutralization	+ +	- - -	-	- -
Helicopter	-	- -	+ + +	- -
Interferences	-	+ +	- - -	- - -
LASER	- - -	+ + +	+	-
Drone	+	+	+ +	+ +

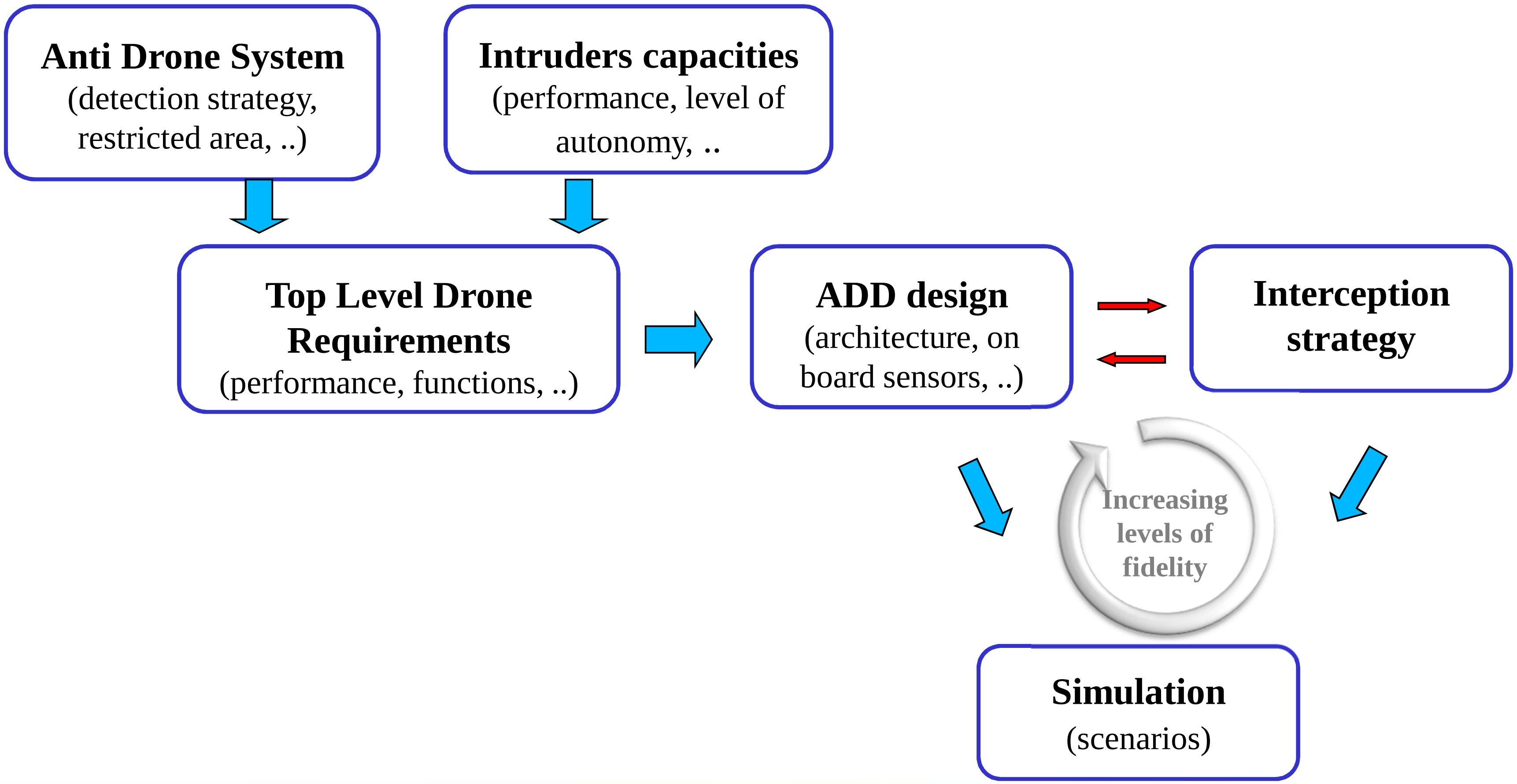
French army helicopter

US navy laser

ADD

Proposed Methodology for ADD study

- Objective : **evaluation of ADD concept in nuclear plant scenarii**
- Proposed methodology



Scope of the study

- **Anti Drone System :**
  - Nuclear power plant protection
  - Restricted area to protect (1 km diameter)
  - On ground detection for intruders in higher range (5 km = regulation)

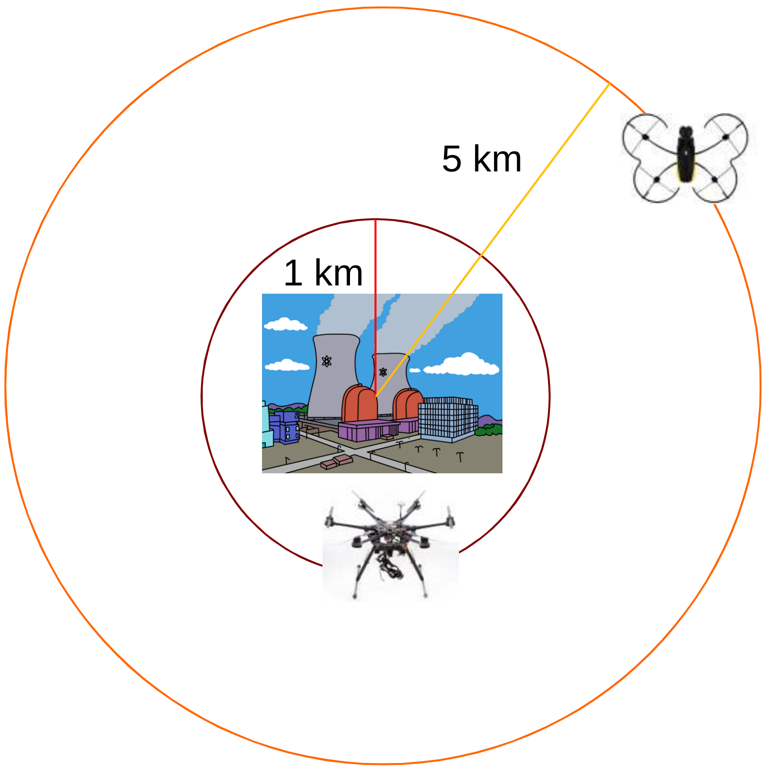
- **Anti Drone Concept**
  - **Sentinel** drone:

  lighter & fast, equipped with cameras
  - sent to assess the threat
  - proceed to identification

  - **Interception** drone:

  active when entering restricted area
  - neutralization function

→ Focus on **interception** drone



ADD architectures

- **Interception drone : main requirements**
  - High performance (low speed capabilities / high speed to reach the intruder)
  - High payload (neutralization)
  - High level of automation (interception phase)
  - Minimizing collateral damage

- **Potential architectures:**
  - **Classical** configurations :

  Fixed wing → low speed performances ?
  Optimized multi rotors → compromise ?

  - **Hybrid** configurations

  Tail-sitter, tilt rotors, ..
  → Increased performances
  → More complex design


Fixed wing

Ambulance drone (TUD)



Vertex hybrid concept


X plus one concept

- **Strong coupling between on-board sensors / interception strategy / ADD design**


DJI Inspire


CyPhy LV1

Threat analysis

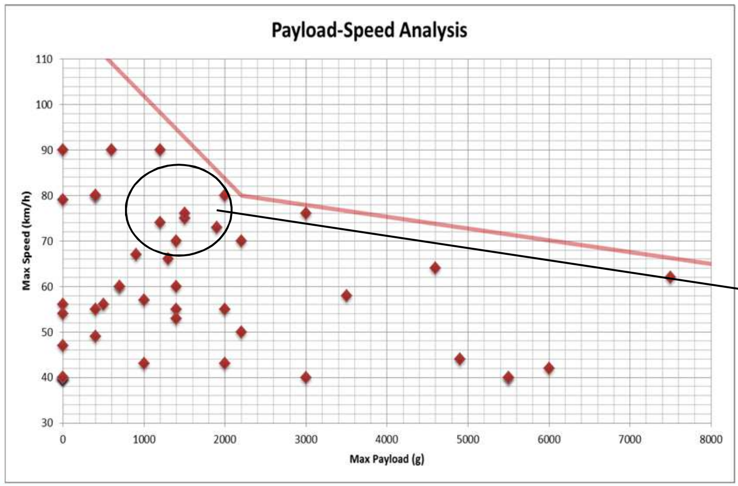
- **Focus on intruders capacities :**
  - **Current generation**:

  Hobbyist drone, guidance systems per radio or GPS waypoints

  - **Next generation** :

  DIY drone with higher levels of autonomy (relying on specific sensors) and high performances

- **Focus on current generation**



The mainstream drone

- **Size: 350 cm**
- **Empty Weight: 600 g**
- **Motor: 920 Kv**
- **Propeller: 9.5 in**
- **Battery: 3S / 5200 mAh**
- Operating Life: 20 min
- Maximum Speed: 70 km/h
- Maximum Payload: 1400 g

ADD design approach (ISAE students)

- Choice for drone architecture:
  - **Multi rotor**

    high maneuverability, VTOL capacities and efficient enough in restricted intervention area (target time of intervention < 3 minutes)

  - 2 means for interception (increasing harm):
    - **Radio jammer** : 1st neutralization step

      neutralization of radio guided drone (piloted / most unpredictable trajectory)

      → either "land" or "return home"

    - **Net Gun** : 2nd neutralization step

      Focus on GPS guided drone

      Surface : 2x2 m, range 3-7 m, linked to the drone

  - Need to have high payload capacity to land safely with the intruder!

ADD Design: proposed solution

6 rotors

ISAE - ONERA 2015

Radio jammer

Net gun

ISAE - ONERA 2015

Main figures	Value*
Weight (kg)	≈ 10 kg
Max Payload (kg)	≈ 6.5 kg
Max autonomy (min)	10 min
Autonomy at max capacity (min)	3 min
Max speed (km/h)	<90

* Calculations performed on http://ecalc.ch/xcoptercalc.php?ecalc&lang=fr

ADD interception strategies (ISAE students)

- Central part of the ADD concept:
  - Need to identify/develop **specific laws** for ADD interception

→ dependent on the selected « tracking sensors » (3D camera, 3D laser, ..)
→ dependent on their integration on the ADD (independent movement, "strap-on", ..)

Inte RealSense concept

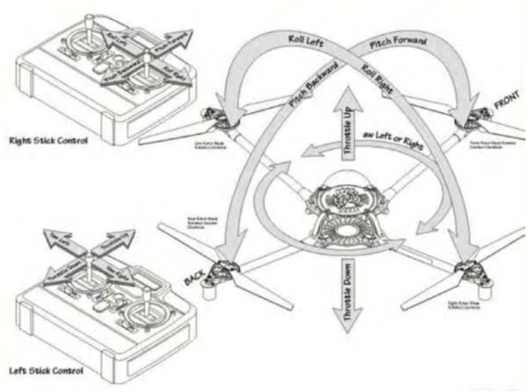
⇒ Develop simulation capabilities to assess the laws efficiency
Need to include the drones performance and behavior (ADD and target)
Capability to increase the simulation "realism"

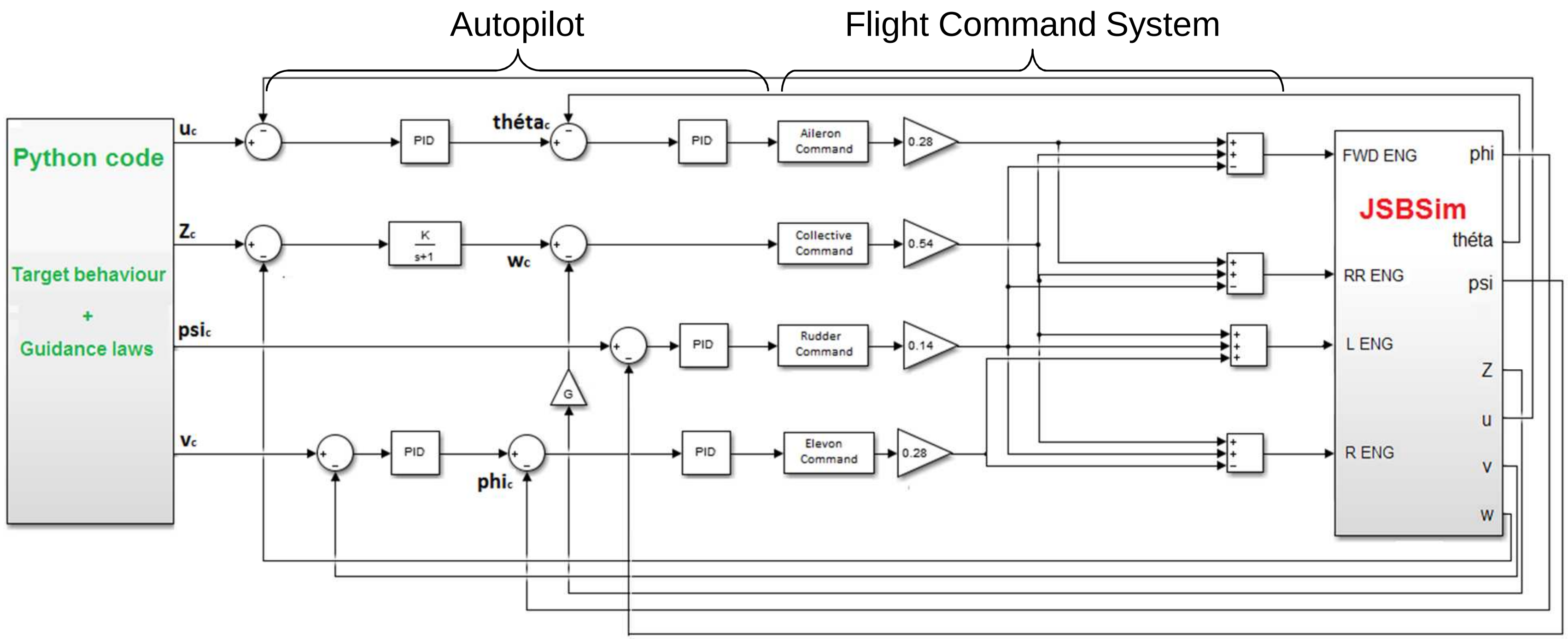
- Use of drone 6 D.O.F model

- Use of **JSBsim** tool (use within ONERA/DCPS) → capabilities to model flight dynamics and control for an aircraft (open-source software)

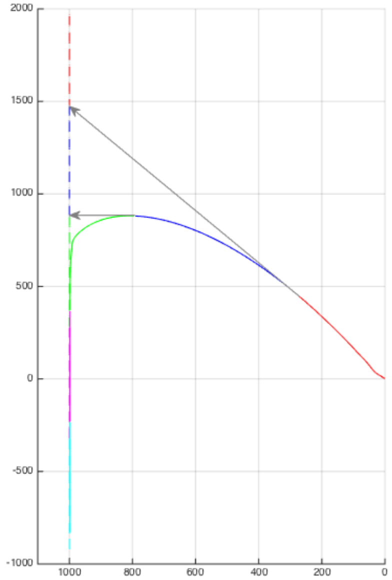
Simulation process

- Start from quadcopter JSBsim file
- Developp an autopilot (control of velocity vector to follow guidance law)
- Performed JSBsim simulation (ideal intruder behaviour)





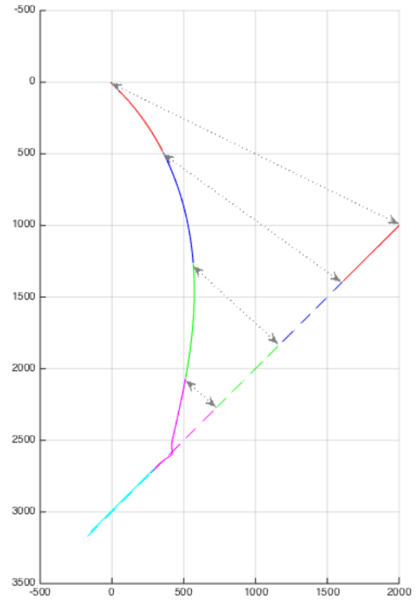
Interception strategy: standard laws



- **Pure Pursuit law:**

Consists in pointing the tracker's velocity vector towards the evader at any time

Tracker's velocity > evader's velocity → guaranteed interception



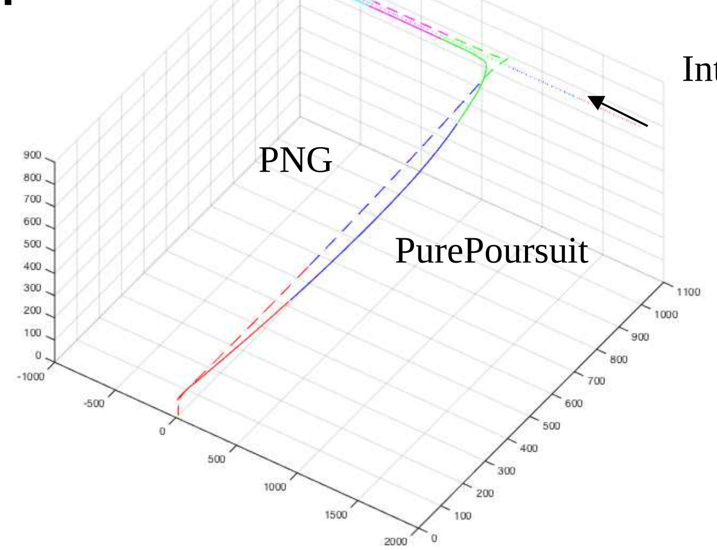
- **Proportional Navigation Guidance law:**

Line of Sight (LOS): line joining the tracker and the evader

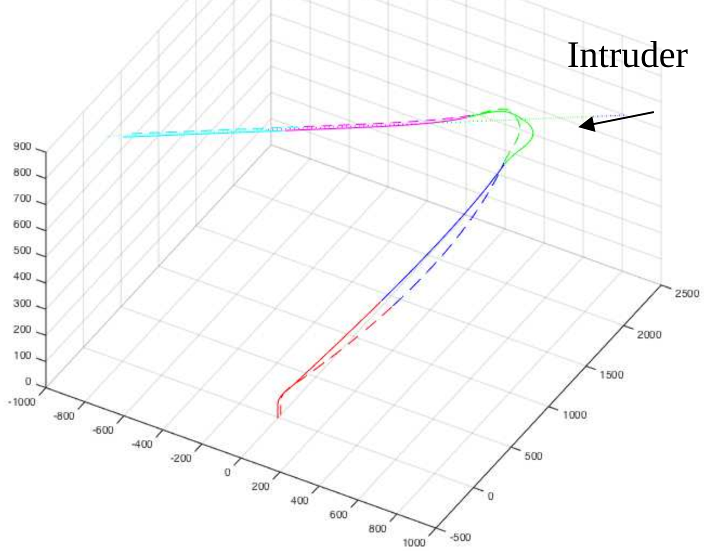
Consists in controlling the direction of the tracker's velocity vector so that its rate of turn is made proportional to the rate of turn of the LOS

Simulation of various 3D scenarios

Scenario 1: target's trajectory tangential to the protected area



Scenario 2 : target going through the protected area



→ PNG quicker for first encounter (≈ 2 min)
→ Better performance for PP (interception time ≈ 3.5 min)

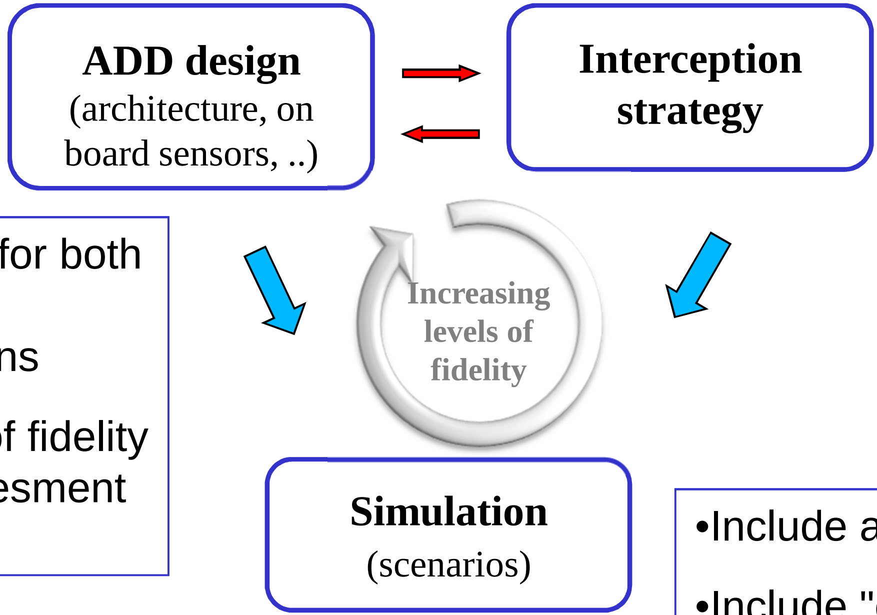
→ Similar time for first encounter (≈ 3 min)
→ Better performance for PP (interception time ≈ 4.5 min)

➡ Simulation tool enables to recognize classical properties of these laws (more scenarios were evaluated)

Conclusion

- A first assessment loop has been perfomed on the ADD concept and produced valuable results : preliminary design, simulation tool , …

- Next steps ?



- Define the sensors for both "autonomy" and "interception" functions
- Increase the level of fidelity for performance assesment

- Need to developp more complex guidance laws
- Evaluate and select the most adapted sensors

- Include a model of intruder drone
- Include "environment"
- Include sensors behaviour

Conclusion & Challenges

- Extended conclusion
  - Methodology applicable to other use cases (airports,…)
  - Need to validate these first results by experiments

- Perspectives
  - How to regulate the ADD (state aircraft?)?
  - Multi-targets: in case of a swarm threat or use of decoy
  - Impressive performances of « DIY » aircraft models

ONERA

Worst scenario ?

Fake video ! (https://www.youtube.com/watch?feature=player_embedded&v=GS3nb4bwHKQ)

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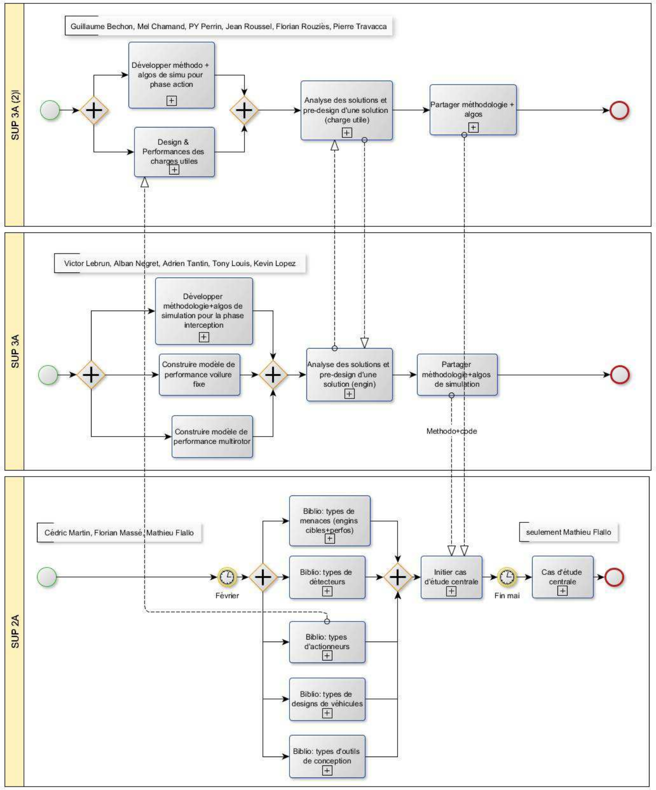

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