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UAV Multilevel Swarms for Situation Management

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Abstract

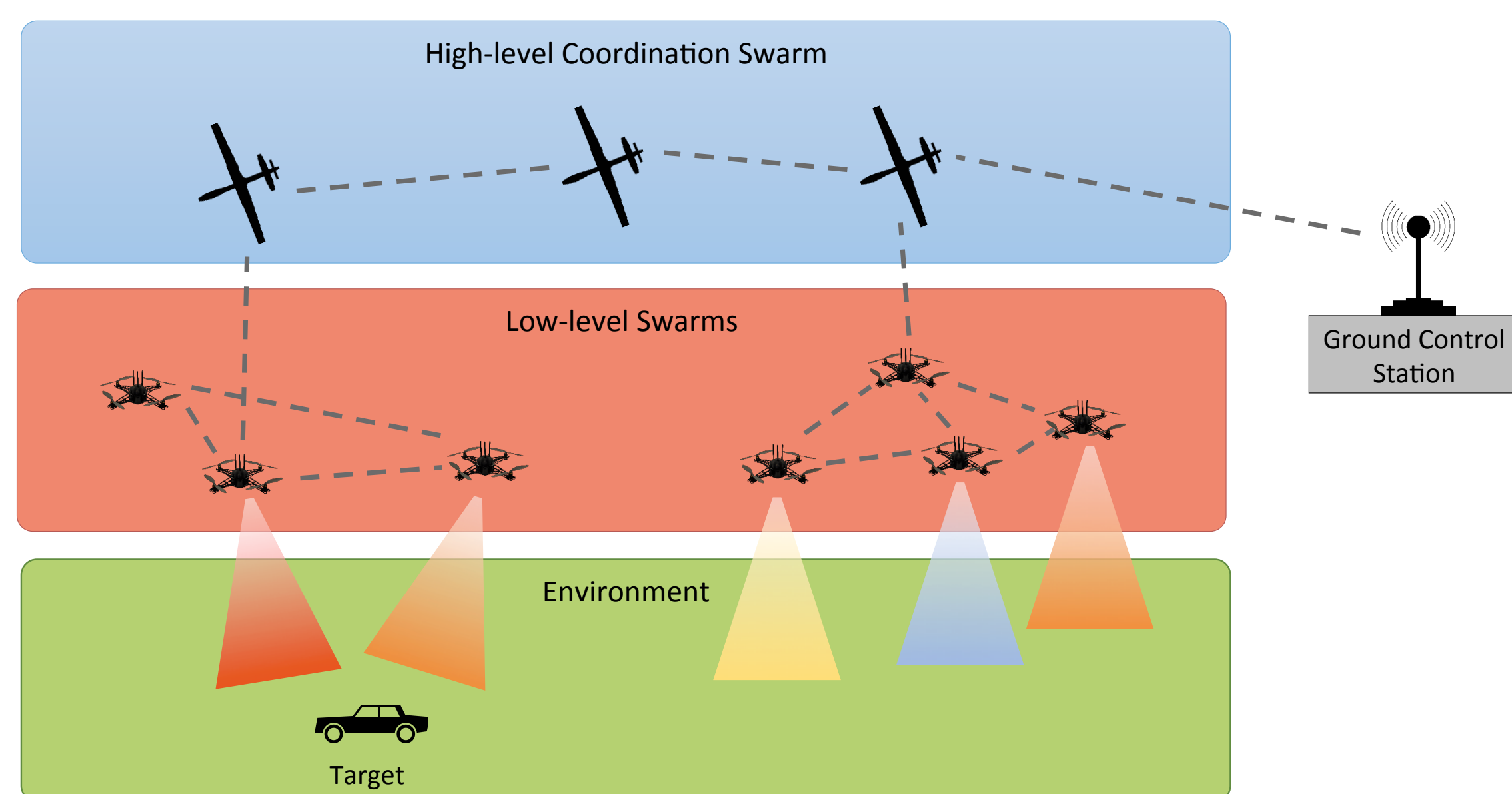
The development and usage of Unmanned Aerial Vehicles (UAVs) quickly increased in the last decades, mainly for military purposes. Now, this type of technology is also used in non-military contexts mainly for civil and environment protection: search & rescue teams, fire fighters, police officers, environmental scientific studies, etc. Al-

though the technology for operating a single UAV is now mature, additional efforts are still necessary for using UAVs in fleets (or swarms). Therefore the **ASIMUT project** (Aid to Situation Management based on MULTimodal, MULTiUAVs, MULTilevel acquisition Techniques). The major challenge of this project consists in handling several fleets of UAVs including communication, networking and positioning aspects. This motivates the development of novel multilevel cooperation algo-

rithms which have not been widely explored, especially when autonomy is an additional challenge. Techniques to optimize communications for multilevel swarms are also required. Finally, **distributed and localized mobility management algorithms** that cope with conflicting objectives such as connectivity maintenance and geographical area coverage must be provided.

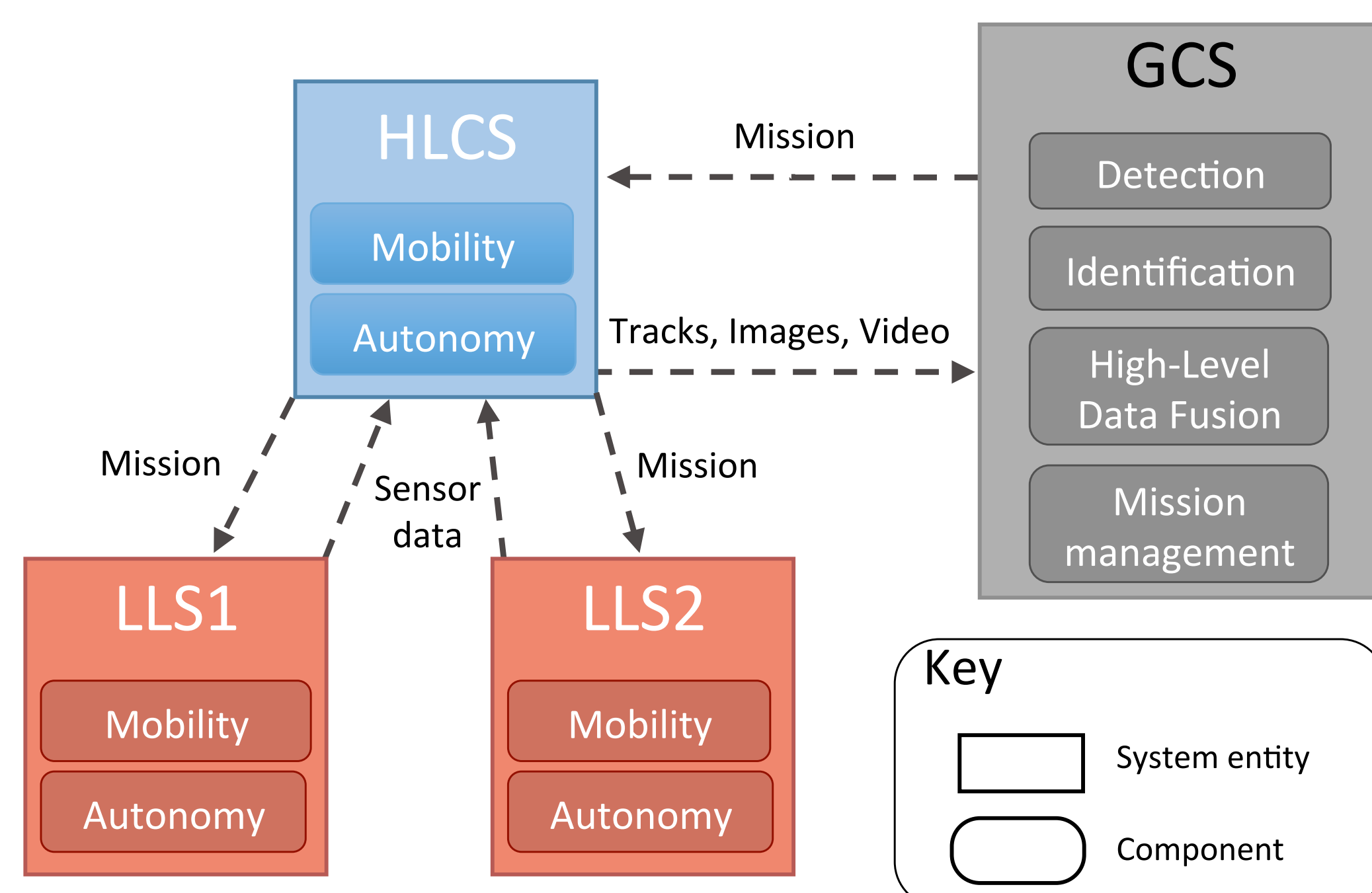
1 ASIMUT Project

The main goal of the ASIMUT project is to address scenarios where a mission is to be achieved based on data fusion coming from different sensors in a number of UAVs that constitute a swarm.



Swarms of UAVs collaborating.

Developing innovative algorithms based on learning techniques dedicated to fusion of data provided by airborne sensors embedded in a swarm of UAVs. From early warning process where data are provided by the UAV swarm payload, the target localization, monitoring and classification processing are performed using these techniques.



Interaction module system.

(GCS: Ground Control Station, HLCS: High Level Coordination Swarm and LLS: Low Level Swarm)

Swarms are composed of fixed-wing and multi-rotor UAVs. The role of the HLCS is to manage the tasks assigned by the GCS or autonomously created by the HLCS in reaction to an event occurring in the environment. Finally the LLS role is to collect data and track vehicles in specific areas of this environment.

2 Swarm decisional autonomy and mobility management

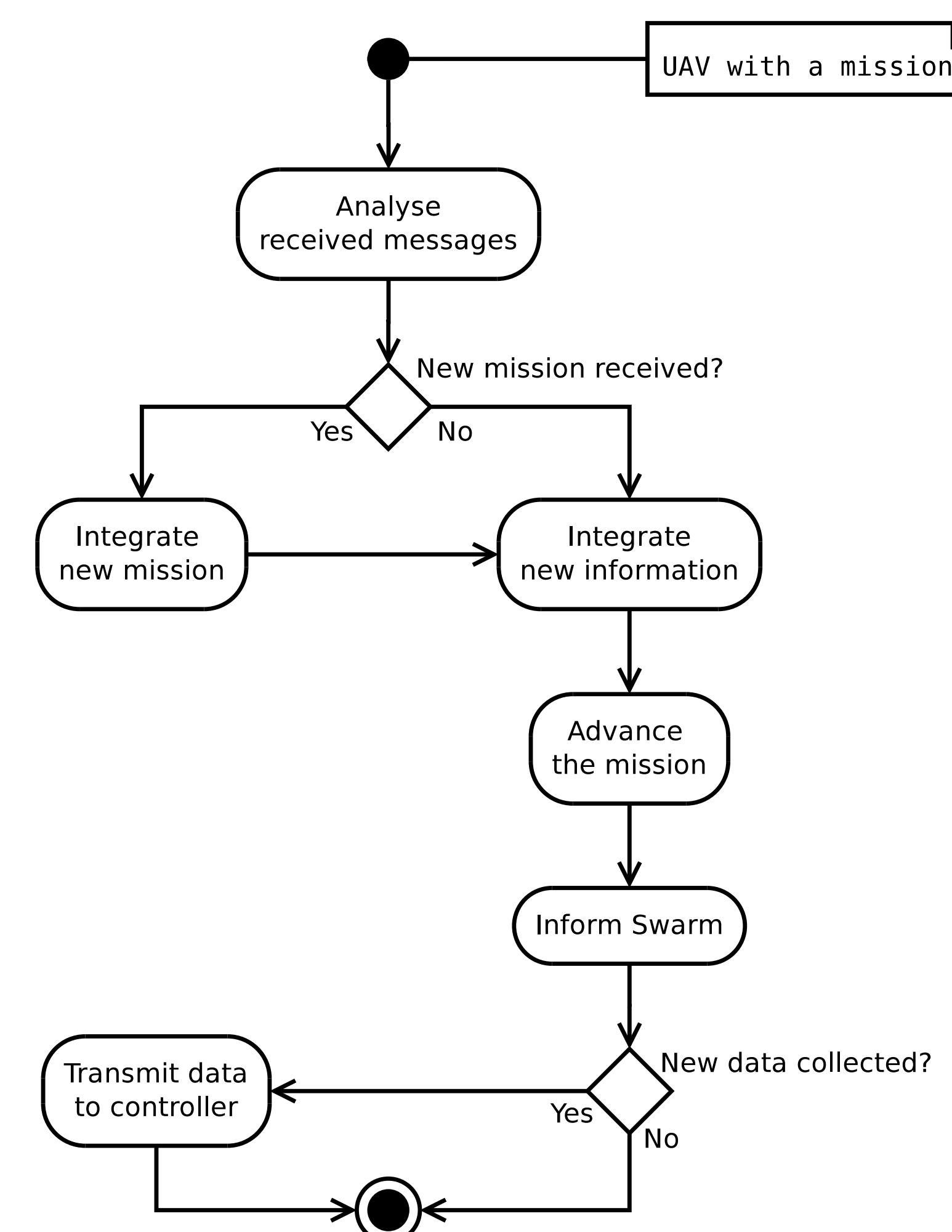
- Swarm decisional autonomy: The **CARUS project** [1] went a step further than the state-of-the-art on autonomous swarms of UAVs. The authors achieved a theoretical and experimental study of a swarm of UAVs with autonomous decision, which purpose was to monitor and solve issues on specified interest points
- Mobility management: Some promising approaches are inspired by nature, and more precisely by ant colonies. **Ant Colony Optimization** (ACO) is a set of probabilistic techniques for solving computational problems, which can be reduced to finding good paths through graphs. Initially proposed by Marco Dorigo in 1992 in his PhD thesis [2], ACO has found applications in many domains. The main idea is that ants use the environment to **exchange information via pheromone deposit** which concentration influences their behavior. This process is called **stigmergy**. UAVs deposit repulsive pheromones in visited geographical areas so as to prevent other UAVs from revisiting the same places too early [3]. Additional objectives are considered such as network connectivity as recently proposed by Schleich *et al.* for surveillance scenarios [4].

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3 Mission decision and execution

ASIMUT will focus on **online and decentralized mobility management techniques**. More precisely it will rely on bio-inspired techniques to ensure the optimization of the autonomous UAV swarms movements.



Activity Diagram describing the communication process of a UAV

The UAVs mobility should be as hard to predict as possible to prevent possible attacks. Two approaches are considered, either using stochastic or deterministic processes. For the surveillance movement, we plan to compare the usage of randomness to a behavior obtained from chaotic dynamical systems inspired by the domain of mobile robots [5].

4 Conclusions

The ASIMUT project requires:

- **Intra-level and inter-level cooperation** the latter being without doubt an area that has not been widely explored, especially when autonomy is also a challenge
- **Management and the optimization of the interactions between the swarms** that participate in the mission and **how their local decisions and work impact the behavior of the other swarms**
- **Development of distributed and online mobility management algorithms**. The latter deal with potentially conflicting objectives such as coverage, connectivity preservation and bandwidth efficiency

These innovations will be combined as a global framework for the ASIMUT project and evaluated via state-of-the-art simulations; a preliminary step before its real-world deployment.

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