planet
PLAtform for the deployment and operation of heterogeneous NETworked cooperating objects

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SEVENTH FRAMEWORK PROGRAMME
EUROPEAN COMMISION

4
VOLUME

COORDINATOR MESSAGE

One more year has passed and the PLANET project is coming to an end. It seems that it was yesterday that we started looking at the issues of putting together dozens of cooperating objects to solve a common task. Four years later, we have implemented a full-fledged platform able to support a wide variety of cooperating objects. We have also been able to demonstrate the platform itself and the integration of all technologies in two main sites: The Doñana National Park and ATLAS. You are welcome to visit out homepage and watch the impressive videos featuring Wireless Sensor Networks, Unmanned Aerial Vehicles and Unmanned Ground Vehicles cooperating through the PLANET Platform. The focus of this last year has been in the integration of all the working pieces including deployment and control algorithms, distributed simulation environments that can cope with virtual and real devices at the same time, as well as visualization and control tools. From a coordination point of view, these past years have been intensive, challenging but also extremely rewarding. It has been a pleasure to work with great professionals that are not only amazing experts in their respective fields, but have been committed to the project in a remarkable way. It is only through this combined effort that PLANET has been able to finish successfully. I would like to thank all of the institutions in the consortium for their work and to the European Commission for their continuous support and encouragement. My special thanks goes to CSIC and to FADA-CATEC for their unconditional help in the field, allowing us mere mortals to surmount the challenge of working outside of our offices. PLANET is finished, but not so the research itself. We hope to continue the work started with PLANET in further collaborative projects and endeavors. See you soon!

http://www.planet-ict.eu/
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Coordinator of PLANET

PLANET PROJECT

Platform for the Deployment and Operation of Heterogeneous Networked Cooperating Objects

PLANET platform supports optimal and adaptive deployment and operation by means of mobile cooperating objects, i.e. vehicles, networked with static nodes. The platform is validated in two complementary scenarios: the monitoring of the Doñana Biological Reserve with very high ecological value and very sensitive to the impact of pollution, and the highly automated airfield scenario in which security plays an important role and where wireless communication and cooperative techniques pose significant challenges.

PLANET EXPERIMENTS AIRFIELD AND DOÑANA

Along 2014, PLANET team has been working in both scenarios of this project: The automated airfield and the Natural Park of Doñana.

OBJECTIVES

Two main objectives were pursued in these experiments:
•Test the integration of the different cooperating objects (UAVs, UGVs, wireless sensor networks) with the PLANET framework.
•Perform experiments that emulated some of the PLANET use cases.

AIRFIELD EXPERIMENTS

In the airfield scenario, PLANET is working in integrating its framework with a very clear application: to support the operation of an UAV airfield in an autonomous way. Several use cases have been defined and tested this year which represent different situations that can take place in the airport (presence of intruders in the airport, communications breakdown, sensor network healing...). They have been solved thanks to the cooperation between mobile and static objects.
The experiments took place on September 2014, from Monday 22th to Thursday 25th in the experimental Flight Centre ATLAS located in Villacarrillo (Jaén, Spain). Results of previous years experiments allow the different cooperating objects to share a communication framework that is able of coordinating, controlling and monitoring all the systems that are involved in PLANET. By using this framework, it was completed the automated airfield operation scenario whose objective was to ensure safe taking-off and landing operations in normal situations.
This year experiments were focused in five different applications: emergency communications service, sensor healing service, intruder detection and security service provisions and emergency landing procedure.

Emergency communication service

The scenario of the emergency communications service describes a local emergency situation occurring when the airfield ATC Tower stops functioning properly due to a nature disaster (e.g., earthquake), or problems in communication system with UAS. This experiment was introduced to demonstrate how the PLANET framework can be used to assist in deploying a new temporal degraded network infrastructure allowing at least the diverting the flight or attending the landing of UAVs that cannot be diverted

Figure 1: *ATLAS Flight Centre*

PLANET EXPERIMENTS AIRFIELD AND DOÑANA

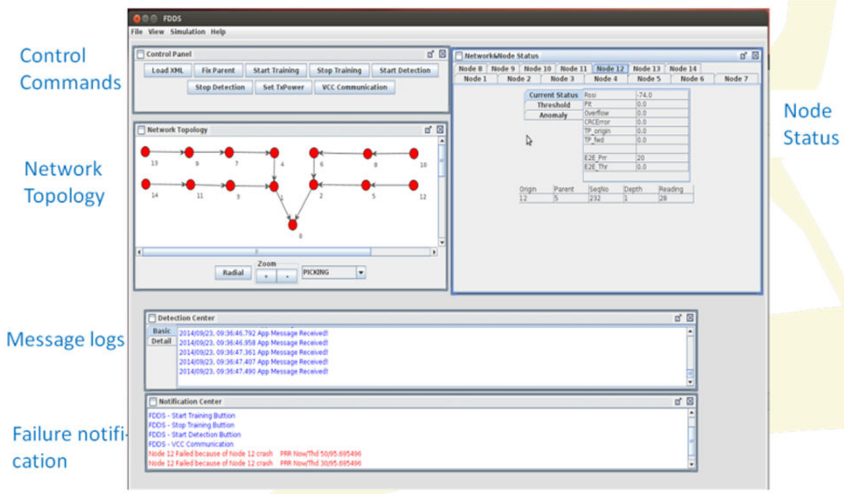

Figure 2: *Detection of a faulty node.*

Just few second after the communication breakdown, an UGV parked in the airfield is sent to an optimal position along the field to seamlessly operate a backup infrastructure network, and making able ATC systems and PLANET COs. to communicate each others. DDS-based communication network plays a key role in the depicted scenario, since it affects the achievement of the PLANET Infrastructure mission, upon the intrinsic satisfaction of the requirements: Scalability, data delivery resiliency and heterogeneity.

Sensor healing service

For the sensor healing service, similar experiments were performed last year. In this scenario the capability to autonomously solve a faulty sensor situation is shown as a normal operation of the automated airfield. Several PLANET components cooperate to substitute a faulty sensor with a newly deployed one and permit safe operation without substantial impact on the network operability. For fulfilling this task, several steps are necessary. First of all, the deployed sensor network status has to be visualized and monitored continuously. If a failure is detected (Figure 2) the Visual Command Center commands an UGV to go to the location of the broken sensor (Figure 3) and replace it for restablish the network (Figure 4).

Figure 3: *UGV approaches to a faulty sensor.*

Figure 4: *UGV dropping a sensor.*

Intruder detection and security service provision

For unexpected intrusion situations in the airfield, two different approaches are possible: physical and software attacks. The objective of these experiment is to demonstrate the PLANET support to an existing intrusion detection system in an Highly Automated Airfield Scenario. For the physical intruders, a perimeter sensor network is deployed along the automated airfield and the monitoring process begins. If One intruder comes across the airfield perimeter; UGS Network detects this situation and sends related intrusion alarm data to VCC, in this moment a cooperative object is sent nearby the location in which the intrusion has been detected (Figure 5), leveraging its capabilities to enhance the awareness on what is happening in that place. In the other hand, in the software attacks scenario, a Network Surveillance is essential to detect, or to avoid malicious network attacks, which can result in abnormal or incorrect behaviour of the target system.

Figure 5: *Physical Intruder Detected*

For solving this situation, the security architecture STaR is integrated in the Intrusion Detection System of the airfield to block the data packets from the malicious attacker in order to ensure the correctness of the system operations. Figure illustrates the IDS link status during the monitoring periods in all different cases. It can be clearly seen that IDS performs correctly when it is safeguarded by STaR and keep the same accuracy and the attacker fails to penetrate the network.

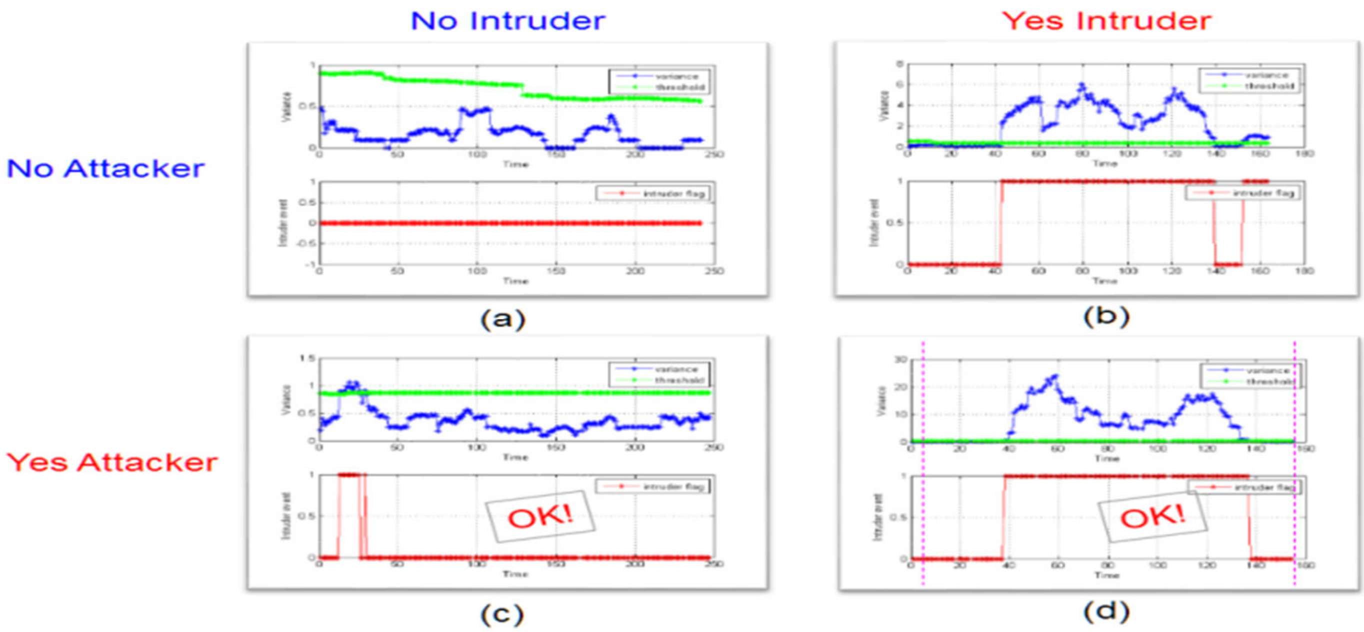

Figure 6: *Set of experiment cases with STaR.*

Emergency landing scenario

In the emergency landing scenario this experiment assumes an emergency situation of a communication blackout where the network of the airport is not available for UAVs-to-airport interactions. When this communication blackout occurs, a message about the blackout needs to be propagated among the UAVs. UAVs that are aware of the blackout situation try to form an alternative ad-hoc mesh network to relay communication messages between them and resolve the landing destination and sequence. Once the emergency mesh network is formed, efficient approaches for data routing and landing scheduling are required to determine the assignment of runways and for deciding the order in which the UAVs will perform the landing maneuver. In this experiment the UAVs did not have any communication with Ground so the only way for landing safely was a direct communication between them by using the air segment (Figure 7)

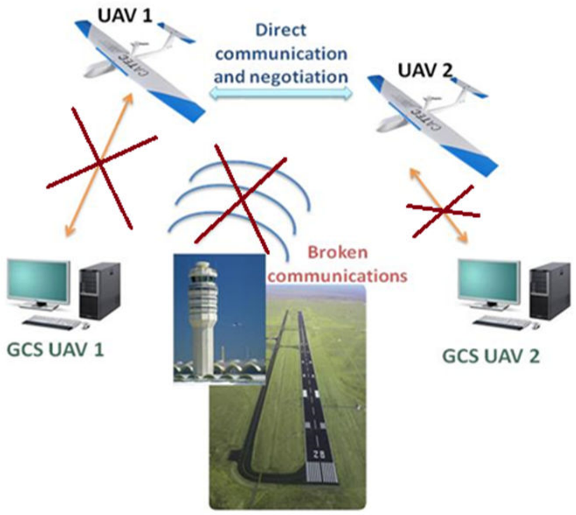

Figure 7: Emergency landing scenario.

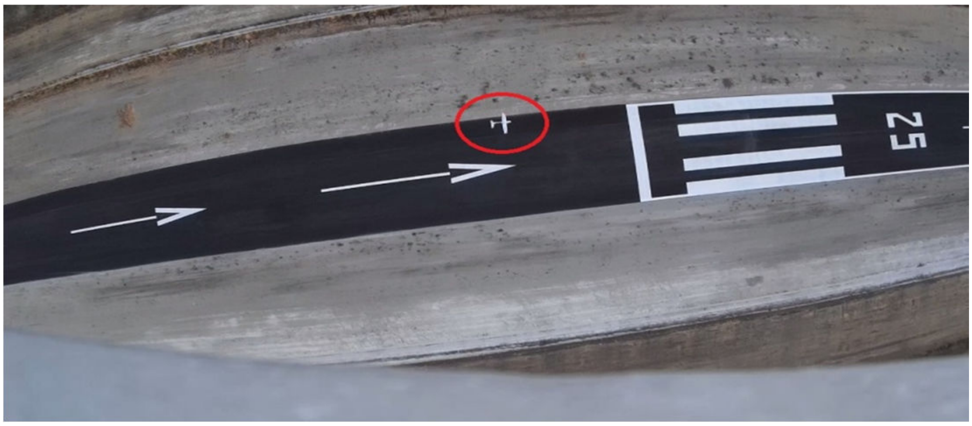

Figure 8: Waiting for landing.

Figure 9: Landing.

In the communication between the UAVs, they interchange its identification number and a value that decides the order in which they will land. This value is calculated by using several parameters as the remaining level of battery, the altitude, the distance to the landing point or a priority value that depend on the type of UAV and mission that it perform. With this information all the UAVs involved in the landing procedure build the same table. Through the table, the first UAV is allowed to land and the other aircraft wait at different altitudes and orbits that depend on the order in the table.

Figure 8 shows a moment in which the first UAV is landing and another UAV is waiting. Figure 9 shows the last UAV landing.

PLANET EXPERIMENTS AIRFIELD AND DOÑANA

DOÑANA EXPERIMENTS

Regarding the adaptation of the PLANET platform to the scenario, in the previous years of the project it was developed the software needed to provide a full environmental monitoring application, and not just the deployment part of it. The PLANET platform was adapted to be used with the existing ICTS infrastructure in order to use the available hardware, permanently deployed in the reserve. This year all tasks that implement the functionality of the application have been completely tested: surveillance of pollution events, monitoring of animals, and deployment and monitoring of events in inaccessible areas using collaborative techniques.

Figure 10: Doñana experiments

POLLUTION MONITORING

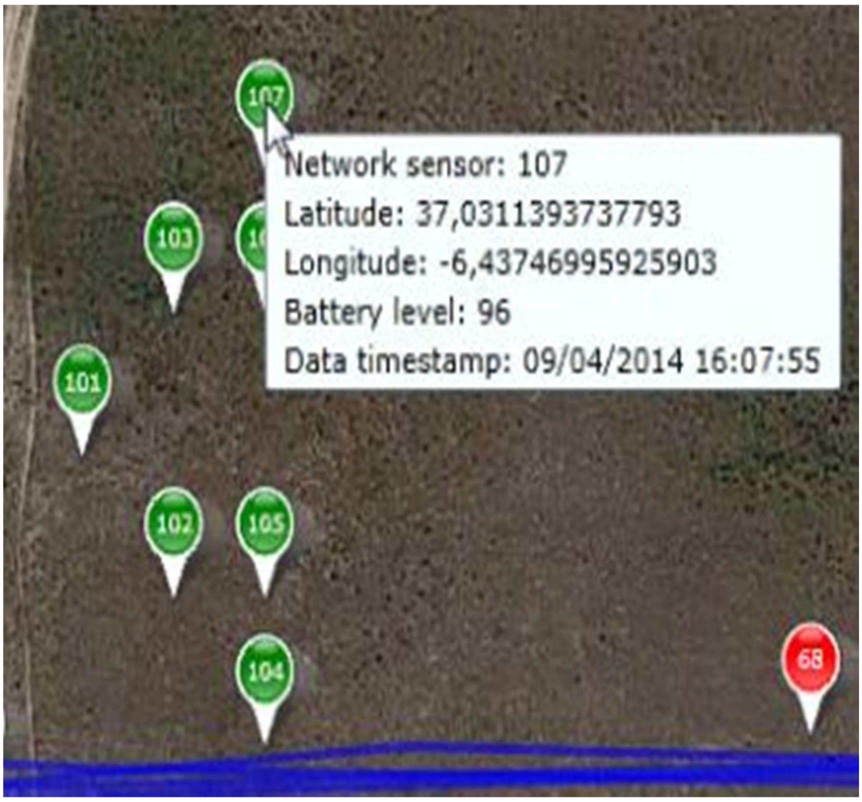

Figure 11: Network sensors in Doñana.

The pollution monitoring takes place in a natural environment where it is very important to foresee and predict pollution processes. Besides, when pollution events occur, it is necessary to obtain data different than the usual, more often or as accurately and quickly as possible. Departing from the results obtained in 2013, in the last set of experiments a complete pollution monitoring task has been performed demonstrating the capabilities of PLANET for using it as a biological tool. The scenario starts with a sensor infrastructure previously deployed in the natural park, in this case the ICTS. The visualization tool of PLANET (VCC) is connected to the data base that contains the information of the ICTS.

PLANET EXPERIMENTS AIRFIELD AND DOÑANA

By visualizing the user interface (Figure 11) it was detected that existed some locations where there were not enough information for some parameters of interest so the users decided to deploy in these zones additional sensor nodes by sending a fixed-wing (Figure 12). Once the new static sensor networks was working, if was considered important to collect data from a specific location, so a fixed-wing UAV and an UGV were commanded from the VCC (Figure 13) to obtain the information from the network sensor (Figure 14)

Figure 12: Fixed-wing UAV in a deployment task.

Figure 13: Route commanded to the fixed-wing

Figure 14: UGV collecting data

Due to the existence of marshes in the natural Park, sometimes it is necessary to have a complete and actualized map of the water zones. By using the VCC, it was commanded the UAV to perform a mosaic that showed the current state of a water zone (Figure 15). Once the mosaic was obtained, an user could see in it that there were something uncommon in a specific zone of the marshes, in this moment it was command an helicopter to obtain a water sample (Figure 16)

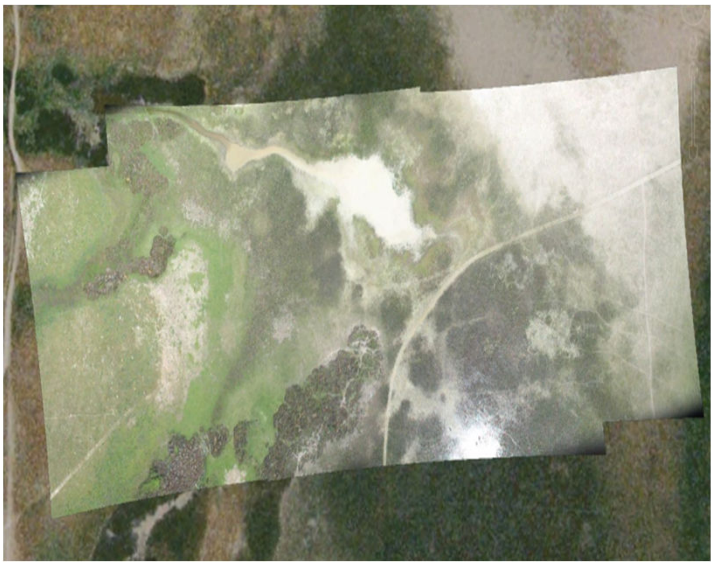

Figure 15: *Mosaic performed by the fixed-wing*

Figure 16: *Helicopter taking samples of water*

Because some parameters in the water sample were not normal, it was decided to deploy water sensors in order to have monitored the marsh (Figure 18). Once the water sensors were deployed, periodically a UGV was commanded to obtain the data measured by the sensors (Figure 19)

Figure 17: Water sensor deployment sequence.

Figure 18: UGV obtaining data from water sensors.

PLANET EXPERIMENTS AIRFIELD AND DOÑANA

Sometimes group of biologists need images and information of difficult access zones. In these cases PLANET allows sending a helicopter that deploys a little UGV (Figure 19). This UGV(Figure 20) acts as a ground mobile sensor acquiring data from deployed sensors or recording video, in this way it is possible could obtain the required information

Figure 19: Helicopter recovering little UGV

Figure 20: little UGV

MONITORING OF ANIMALS

Obtaining high resolution spatial data on the location and activity of animals is becoming very relevant in ecology. It has been an interesting problem to explore for the biologist in Doñana Biological Station (CSIC) the dependency between the movement of Retuerta's horses and the quality of vegetation. Thus, localizing and tracking Retuerta's horse becomes the key step of study towards the answer.
This scenario, animal monitoring and tracking, requires sensor deployment on the wild horses in Donana Biological Reserve (DBR) in order to study the behaviour and activities of monitored horses. To carry out the horse monitoring scenario in PLANET, in September 2013, more than 30 horses in DBR were mounted with sensor-integrated collars. Several static base stations were also deployed and integrated with the ICTS stations to collect horse data. The collected data is logged locally and can be accessed via SSH.

Figure 20: Marked horses in wild

The DCS is in charge of automating the process of data collection and visualization. It incorporates the PLANET communication middleware to deliver the data to the end user in a seamless way. In this case, the DCS was integrated with a UGV platform (Figure 21), and performed a data collection task by the UGV driving close to horse herds.

Figure 21: UGV as a base station

UGV Position was tracked and recorded during its motion together with DCS data; once UGV enters in the coverage field of horse collars, data collection phase starts and horse position data is recorded. Figure 22 shows the reconstruction of UGV path towards horses using NMEA raw data (15186 positions) recorded during the experiment:

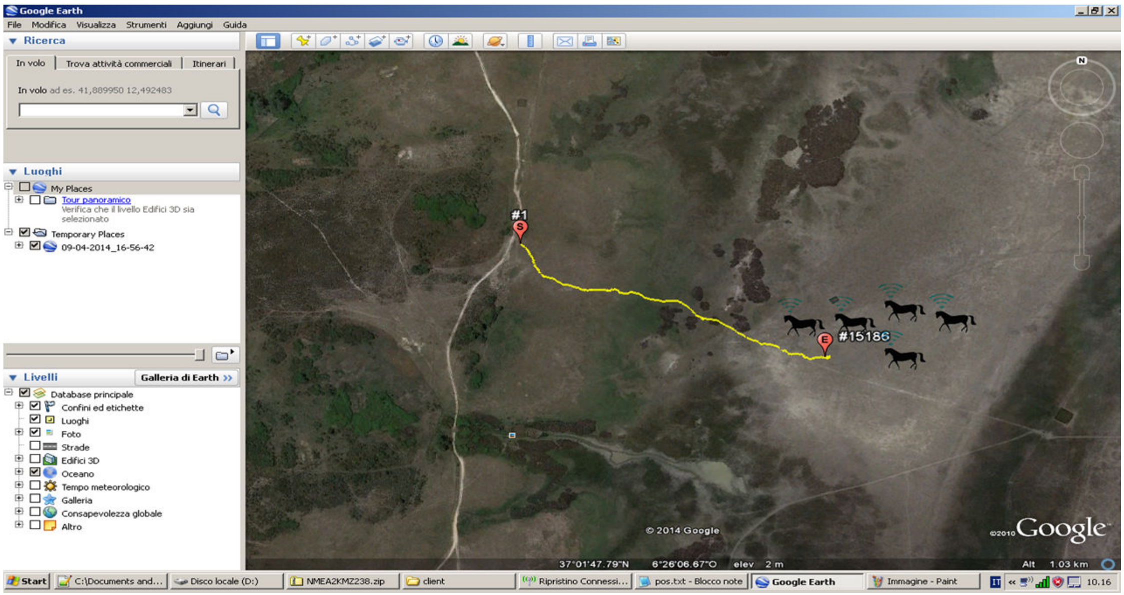

Figure 22: UGV track.

In this experiment the UAV acts as a mobile data sink/data MULE, which refers to a mobile data collecting point. In this case, the UAVs are used as data mules to collected data from the sensor nodes tagged on the animals (Figure 23). The UAV flew over some areas in Doñana where the horses were expected to be. Figure 24 shows the trajectory of a flight performed during the last set of experiments. When the horses were detected (Figure 25), the UAV flew orbiting over the horses at different altitudes in order to know the maximum altitude in which it is possible to capture data. It was tested that with the current implementation, it is possible to acquire data up to 600 meters.

Figure 23: UAV in monitoring task.

Figure 24: UAV trajectory in monitoring task.

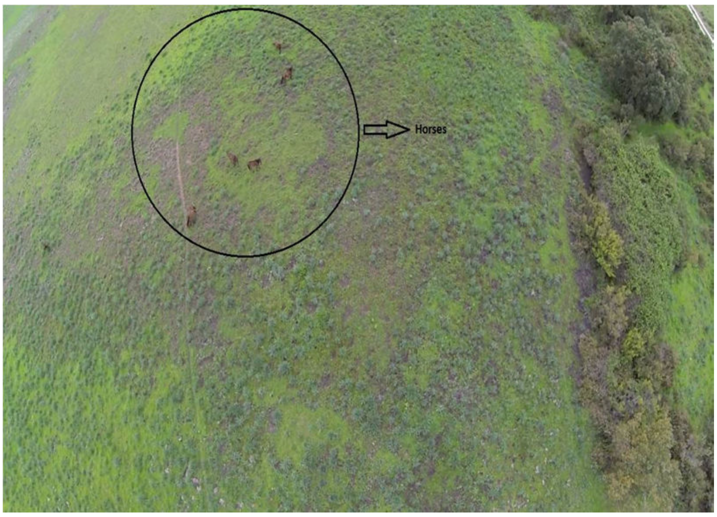

Figure 25: Detection of horses from UAV.

The UAV successfully managed to collect data from the nodes on the horses so it is possible to conclude that the use of the PLANET network for monitoring and tracking horses has been validated.

Related to the insects scenario, in order to improve the results obtained in 2013, a new tool was designed and implemented in the UAV LOCOMOVE. This tool it is shown in Figure 26.

Several tests were performed in September (Figure 27) and some insects were captured that are currently being studied by biologist of Doñana.

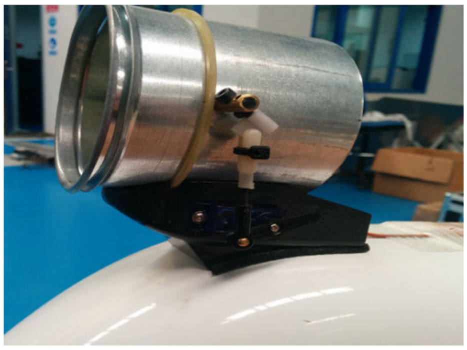

Figure 26: Capture tool.

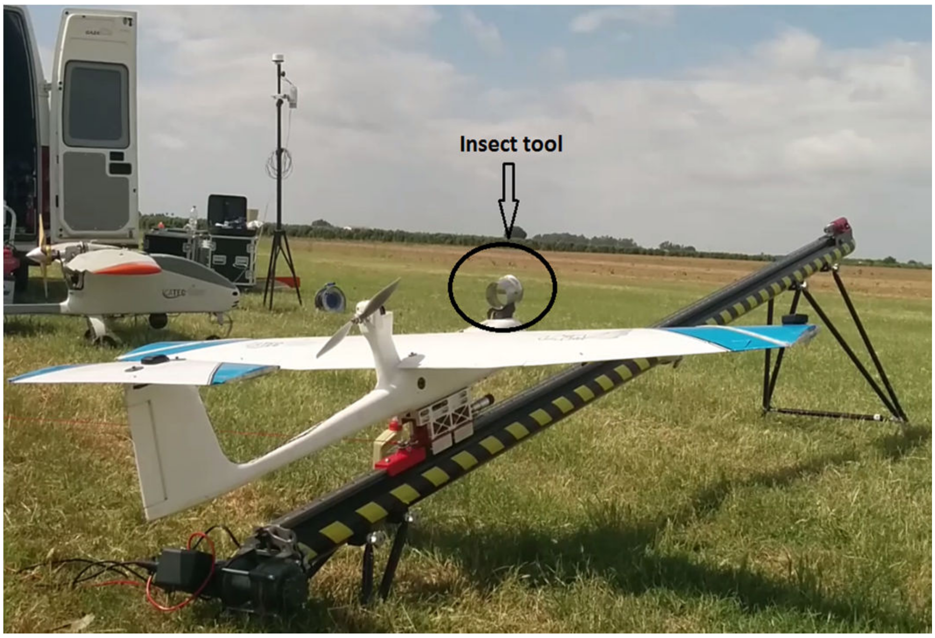

Figure 27: LOCOMOVE.

Based on the results obtained it has been demonstrated that PLANET is able to deal with the proposed biological issues: pollution monitoring, animal monitoring and tracking, documentation of animals and aerial stratification of bats and insects.

P L A N E T
I N T E G R A T E D   F R A M E W O R K

The design and development of the PLANET integrated framework have undergone three phases. After the previous two phases, we have achieved a full-featured PLANET Integrated Framework for efficient deployment, maintenance and operation of heterogeneous Cooperating Objects (COs). The main features of each component have been implemented and several enhancements have been made. At the last stage of the project, the integrated framework is tested with various experiments and its capability is demonstrated by its role in supporting the use cases defined for two validation applications in PLANET: Wildlife Monitoring and Automated Airfield (see Figure 28). The main features of the framework components applied in these application are described below.

Figure 28: *PLANET integrated framework for two validation applications*

- **The PLANET Visualiser and Command Centre (VCC)**

VCC is an important PLANET framework component and plays an essential role for user inputs, status visualization and inter-component communication. In both applications, VCC provides a variety of graphical interfaces for user commands and for data as well as CO status visualization. The Web-based design of VCC allows one or multiple users interacting with the COs and simultaneously viewing the status of the application and cooperating objects. The data or message formats required for user commands and display follow the standardized formats so that they are compatible with different web-based techniques and therefore can be easily integrated. Figure 29 shows the various graphical interfaces designed for different use cases such as horse data tracking, UAV/UGV data collection and airfield surveillance.

Figure 29: VCC for Both Wildlife Monitoring and Automatic Airfield applications

- **The PLANET Planner and Simulator**

In PLANET, existing CO simulators are integrated via the PLANET platform to coordinate the simulation operations and to handle time synchronization and other issues. Figure 30 depicts the different simulation modules required for simulating all PLANET use cases. These components are divided into two different categories. The first category represents the "Core Components" of the PLANET Platform. Each of those components replicates the functionality of its corresponding counterpart. The second category represents the "Application Components". For example this second category includes an Obstacle Detection System (ODS) which allows considering obstacles within a simulation for the airfield related use cases. Currently, a set of simulators have been augmented with the PLANET platform to simulate CO interactions for the application scenarios. Example simulators are the ones for VCC, Airfield Management System (AMS), UAV and wireless sensor networks (WSNs) as shown in Figure 31.

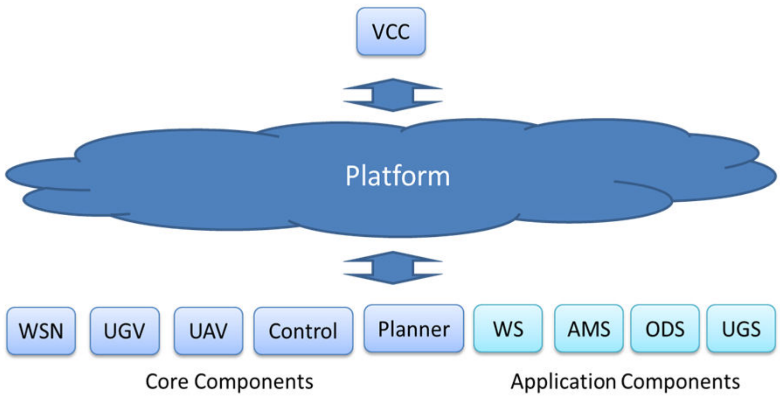

Figure 30: Simulation modules

Figure 31: PLANET integrated CO simulation tools. From the right to the left: VCC-, AMS-, UAV- and WSN-simulator

- **The PLANET Control and Platform**

The PLANET Control and Platform enable the coordination and the communication between cooperating objects. Through the registration routine, all COs that performs application tasks are managed and monitored by the Control, and the inter-communication between COs is achieved by publishing/subscribing communication messages in the format of Google Protocol Butters. In PLANET, the messages are categorized into different groups and each group is assigned with a designated channel. In the applications, the messages are basically divided into three types: command, data and communication messages. Command and data messages normally exist a causal relation, in which the data messages are the response to the command messages. In contrast, the communication messages are defined for status exchange between cooperating objects. To support efficient message handling and processing, a set of message channels have been defined, as illustrated in Figure 32.

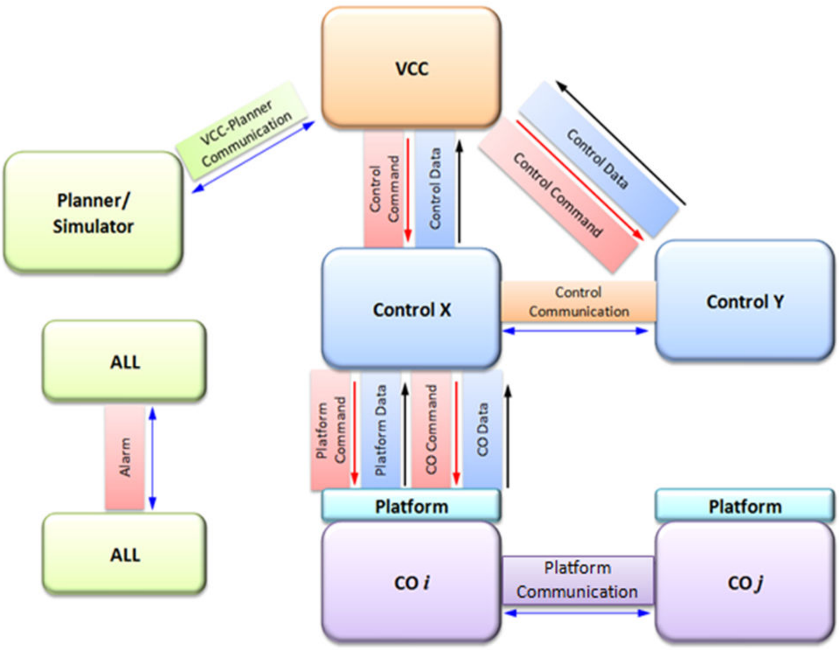

Figure 32: Message channels defined for CO communication

- **The Sensor Nodes and Data Collection Stations**

For the animal monitoring in Donana Biological Reserve (DBR), about 40 horse collars equipped with the Prospeckz 5 sensor platform have been mounted to monitor the movement of wild horses. To collect the horse sensor data, several static data collection stations (DCS) have been installed at DBR ICTS stations as shown in Figure 33. In order to achieve higher data collection rate, a mobile data collection is also constructed using a UGV integrated with the ALIX3 board from PC Engines for DCS. The mobile data collection has been used in DBR for collecting horse data in the contact distance of wild horses. In addition to horse sensors, a water sensor has been designed for DBR pollution detection and several IPR sensors are deployed for the perimeter security service scenario for intrusion detection on the airfield.

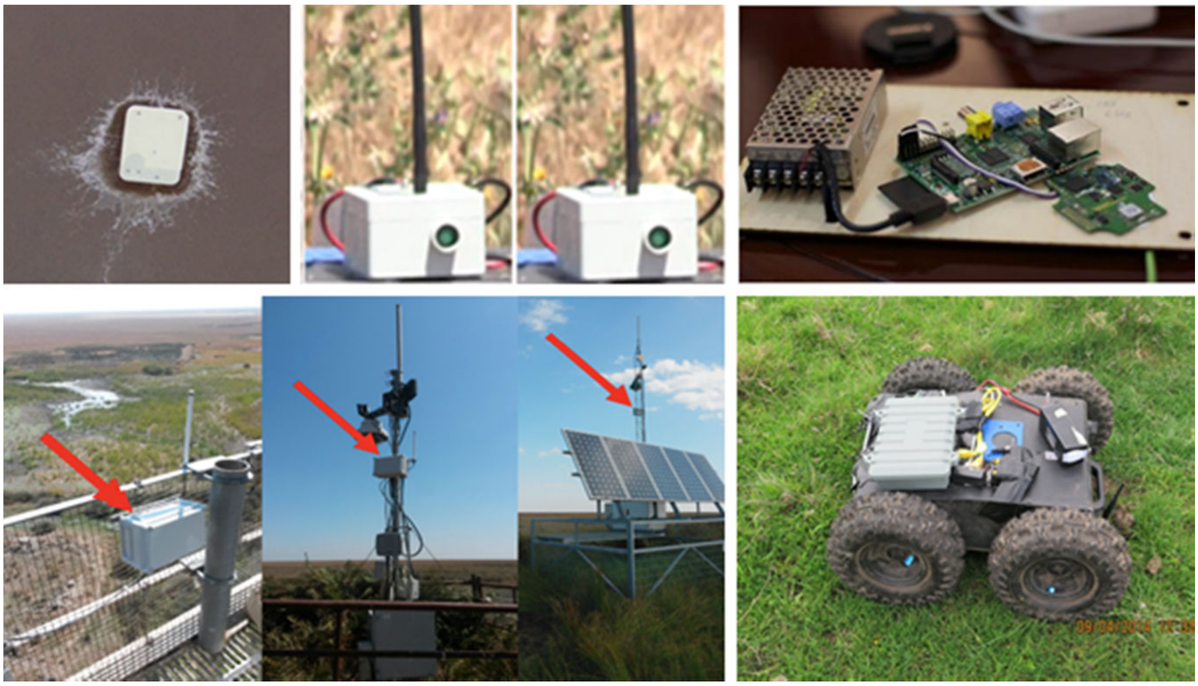

Figure 33: Sensors and data collections stations for the PLANET applications

- **The Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs)**

The development of the autonomous vehicles has continued evolving after the second phase. In PLANET, in addition to data collection and topological image mosaicking for the applications, the UAVs (including fixed-wing and rotary-wing UAVs) are performing their tasks as deployment tools, which carry sensor nodes and deploy them at specified locations. The DLR's helicopter has been augmented with mechanic devices for water sensor node deployment and mobile UGV retrieval as illustrated in Figure 34. As for the fixed-wing UAV, a LOCOMOVE UAV is equipped with an insect trap for the study of aerial stratification of bats and insect in DBR (see Figure 35); several SkyWalker UAVs are used to demonstrate automatic landing in a communication breakout situation at the airport.

Figure 34: Helicopters as CO deployment and retrieval tools

Figure 35: The UAV for capturing insects

The UGV platform acts as two roles in PLANET: mobile data collection (DCS) and mobile sensors. In the DBR pollution monitoring use case, the DCS-integrated UGV is used to collect data from the water sensor, which was deployed by the helicopter as described previously; in the animal monitoring use case, it is used to collect data from the horses that are away from the static base stations (shown in Figure 36). In the Airfield, the UGV is integrated with a video camera for perimeter security surveillance. Moreover, in case of sensor failure, the UGV is also capable of re-deploying a sensor node for network healing and ensures the network integrity (illustrated in Figure 37).

Figure 36: The UGV as a mobile DCS in DBR

Figure 37: A UGV is performing the airfield perimeter monitoring task

In summary, the main feature of the PLANET integrated framework has been implemented and the capability of the framework has been successfully demonstrated in various application scenarios regarding network deployment, management and data collection with autonomous vehicles. We expect the design of the PLANET integrated framework can initiate a new autonomous deployment paradigm, and can facilitate more efficient usage of CO networks in a variety of potential applications.

INVITED PROJECT

SMARTKYE: Smart grid KeY nEighbourhood indicator cockpit.

Future Smart Cities will rely upon their districts/neighbourhoods to be monitored and managed efficiently in the smart grid era. However the various neighbourhoods might significantly differ from each other and follow their own goals. The infrastructure on the districts is expected to be highly heterogeneous e.g. with public lighting system, urban heating system, public buildings, commercial centres, electric vehicles, micro-generation, residential prosumers, etc. There is a need for tools to enable the monitoring of Key Performance Indicators at district-wide level, being able to assess the behaviour of the Energy Infrastructure deployed in the neighbourhoods based on real-time analytics and take the necessary business decisions.

SmartKYE strategic goal is to develop a system for the future smart grid neighbourhood that will enable better business decisions to be made based on real-time fine-grained data. Key end-users targeted are the public authorities who can monitor and manage key indicators in neighbourhoods with the goal of better energy efficiency and CO_2 reduction. SmartKYE will design, develop and validate in a smart city an open service platform for massive gathering of heterogeneous energy data, enabling its easy adoption and deployment by third parties as well as build cockpits that would empower the decision making process of the stakeholders.

SmartKYE final results:

- A common Service Oriented Architecture, Information Models and Interfaces
- An Open Energy Services Platform integrating with the different Energy Management Systems
- A Business oriented Cockpit
- A Monitoring and Control oriented Cockpit
- Large Demonstration in two scenarios: 22@ district in Barcelona and the area of Lasithi in Crete

Project Coordinator: Antonio Marqués, ETRA I+D
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Partners: ETRA I+D (Spain), University of Duisburg-essen (Germany), SAP AG (Germany), Barcelona Digital (Spain), Institute of communication and computer systems – National technical University of Athens (Greece), HEDNO S.A. (Greece), FICOSA FICO-TRIAD SA (Spain)

Duration: 30 months .From 01/11/2012 to 30/04/2015

Total cost: 3.127.874€

Website: http://smartkye.eu/

PLANET AT A GLANCE

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Partners: Universität Duisburg-Essen (Germany), ETRA Research and Development (Spain), SELEX Galileo (United Kingdom), Boeing Research and Technology Europe (Spain), Flying-Cam S.A. (Belgium), SELEX Sistemi Integrati (Italy), Consejo Superior de Investigaciones Científicas (Spain), Andalusia Foundation for Aerospace Development (Spain), University of Pisa (Italy), University of Edinburgh (United Kingdom), Deutsche Luft- und Raumfahrt (Germany), Association for Research and Industrial Cooperation of Andalusia (Spain),

Duration: 48 months from 01/10/2010

Total cost: 6.951.613 €