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An Innovative Cloud-based Supervision System for the Integration of RPAS in Urban Environments

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Abstract

This paper proposes the outline of a Cloud-based supervision system for Remotely Piloted Aircraft Systems (RPAS), which are operating in urban environments. The novelty of this proposed concept is dual: (i) a Cloud-based supervision system focusing on safety and robustness, (ii) the definition of technical requirements allowing the RPAS to fly over urban areas, as a possible evolution of drone use in future smart cities. A new concept for the regulatory issues is also proposed, compared with existing worldwide regulations. The Cloud framework is intended to be an automated system for path planning and control of RPAS flying under its coverage, and not limited to conventional remote control as if supervised by a human pilot. Future works will be based on the experimental validation of the proposed concept in an urban area of Turin (Italy).

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Keywords: Remotely Piloted Aircraft Systems; Cloud robotics; Smart cities.

1. Introduction

The developments of new enabling technologies have been extended to Remotely Piloted Aircraft Systems (RPAS) or more generally Unmanned Aerial Systems (UAS). The key strengths of these systems are the mission versatility, the reconfigurable architecture and favourable the benefit-cost ratio. In this paper, a novel vision for a Cloud-based RPAS supervision system, focusing on safety and robustness of fully-autonomous missions in urban areas. Therefore, the aim of this paper is the design of a Cloud-based system for different types and classes of drones, to be integrated

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in an urban environment. Starting from the work presented by Capello et al. (2017), the authors propose a new concept, in which the following three main actors are involved: observer, pilot and pilot-in-command. The risk is expected to be reduced thanks to the integration of a Cloud system, supporting the operations for the desired mission with higher computational capability and wider data access.

The wide diffusion of Cloud Robotics, due to faster data connections (both wired and wireless) providing reduction of latency and packet loss and enhanced robustness, is opening new opportunities toward the development of distributed RPAS operations.

The goals of Cloud-based framework are related to the reduction of time and costs of implementation and to the improvement of performances for autonomous missions, through the achievement of the desired operational requirements. The proposed system can be applied to a wide range of situations for missions in urban areas. The list of practical applications is very wide, well beyond the boundaries of conventional remote sensing scenarios: thermal monitoring of buildings, citizens science, support to people with limited mobility, emergency missions, urban monitoring, tracking of pollutants released by industries, detection of asbestos, care of urban greenery, law enforcement, protection of soft targets (security), cultural heritage in archaeological sites within urban areas, mapping of solar power production, delivery of goods and small packages.

The implementation of multi-modal multi-vehicle fully autonomous RPAS applications, using traditional technologies requires a high budget in terms of costs, complexity and time to overcome the limitations of on-board weight fractions and hardware. For this reason, researchers have started to propose Cloud-based systems, instead of trying to implement the mission plan and the control systems on-board the drone itself, taking advantage of the computational performances of on-ground computers. As presented by Mahmoud et al. (2015), monitoring and accessing UAS resources via traditional communication system can be translated in several restrictions and limitations. Indeed, Mahmoud et al. (2015) introduce a UAS Cloud platform and components for distributed systems through cloud computing, including a set of services and Application Programming Interfaces (APIs). A cloud-based web application that provides real-time flight monitoring and management for UAS is presented by Itkin et al. (2016), in which different applications are proposed, but no regulations or experimental tests are included. Advantages of the research proposed by Itkin et al. (2016), is the dynamical map and path planning, including collision avoidance. In a similar way, Lee et.al. (2017) focused their research on keeping low-level object detection and short-term navigation on-board, moving the high computation to an off-board computer, such as dynamic mapping functions. Another interesting application is related to disaster sensing, in which the limited computational capability and the low energy resource of small RPAS present a significant challenge to real-time data processing. Luo et.al. (2015) proposed a Cloud-based framework integrating video acquisition, data scheduling, data off-loading and processing. An issue of this research is that only real-time data processing and information feedback services are demanded to the Cloud.

Indeed, even if control and monitoring of RPAS have been well studied by Gupta et al. (2016) and Zhu et al. (2015), the applications to a real environment is still precluded or strongly limited due to current aviation regulations.

The present activity aims to propose experimental tests (within the research agreements among Politecnico di Torino and TIM (the leading Italian telecommunication company) Telecom Italia S.p.A., as reported by Primatesta et al. (2017)) in order to verify the performance, the robustness and the level of risk of the approach, considering the implications of both existing and new regulations, as introduced by Capello et al. (2017). Moreover, a key feature is the flexibility in the development of complex flight strategies, providing an increase of safety and an enhanced in flight behaviour in terms of handling qualities. As proposed by the Chinese aviation authority and reported by the Library of the Congress (2016), a comprehensive regulation framework is required for the use of a Cloud based supervision system. Hence, a revision of regulatory issues performed by the principal aviation authorities is also mandatory for a full exploitation of aerial robotics in cities and over critical infrastructures.

The paper is structured as follows. Section II presents an overview of the regulations. Section III describes the implementation and operation rules proposed in this research project. Section IV presents an outline of the aerial vehicles available for urban applications and Section V explains the Cloud concept. Section VI details the experimental testing activity. Concluding remarks are summarized in Section VII.

2. Regulation Analysis

Many regulatory authorities have already published rules to bound the exponential use of unmanned configurations into the national and international airspace, as described by the Library of the Congress (2016).
These regulations are based on common principles, such as the categorization of UAS based on their Maximum Take Off Mass (MTOM), operational requirements (VLOS: Visual Line Of Sight, day-light, etc.) and several altitude limitations (50 m, 120 m or 150 m, etc.), according to the analysed regulatory authority.

The aim of this Section is to analyse different current regulations in order to identify how the Cloud-based UAV concept is eventually dealt with. In particular, only a country in the world, People's Republic of China, has already introduced the UAV Cloud-based concept inside its regulation with specific requirements, as reported by Zhang (2016), while projects are in progress in US, as reported in NASA (2015) and Global UTM Association (2017), and Europe, as presented in EASA (2017a,b), led by respective authorities, to identify the key aspects in order to define a Cloud management system.

2.1. China

CAAC (Civil Aviation Administration of China) has published Provisions for the Operation of Light and Small Unmanned Aircraft (for Trial Implementation) on December 29th 2015 to regulate the authorized flying of unmanned configurations. The Chinese authority has identified seven categories of UAS, based on Empty Mass, MTOM and, eventually, the kind of application, as presented by Wei et al. (2016).

The innovative element of the Chinese regulation is the definition of an online real time supervision system. CAAC has defined the UAS Cloud as a dynamic database management system which monitors flight data (including location, altitude and speed) in real time and which has an alarm function for UAS flying within the electronic fence. The electronic fence is a software and hardware system in which specific areas are identified as prohibited and it has the function to prevent aircraft from entering such areas, as in Wei et al. (2016). If the UAS is connected to the UAS Cloud, it is able to identify the restricted areas where it is forbidden to fly over, such as airports and danger zones. The Cloud provider should submit a report every six months to CAAC to report the numbers of UAS, operators, difficulties, drawbacks and accidents. The aircraft must have a SIM card on board, while operators can supervise its operations using a mobile applications, as defined by Wei et al. (2016).
Finally, CAAC has defined three basic figures which must supervise operations during the mission:

- the Pilot: he/she operates the UAS and he/she is responsible for the safety of operations;
- the Pilot-In-Command: he/she collaborates with the pilot, taking final decisions, in particular during an emergency. He/she does not pilot the vehicle.
- the Observer: he/she is a trained person who visually observes the UAS and assists the pilot.

The UAV Cloud system was expected to be opened to the public in 2016 by China AOPA (Aircraft Owners and Pilots Association), but it has not been opened yet. For all UAS that do not have to connect to the UAS Cloud, CAAC only requires clear information about the configuration, without a formal registration. Moreover, UAS can fly both in VLOS and BVLOS (Beyond Visual Line Of Sight) conditions. VLOS can be performed only in daytime, and the UAS must give the air route priority to manned aircraft both in VLOS and in BVLOS.

2.2. United States of America

Until August 2016, Section 333 of the FAA Modernization and Reform Act (FMRA) of 2012 presented in FAA (2012) was valid to regulate UAS operations. On August 29th 2016, 14 CFR Part 107 Regulation became effective, as described in FAA (2016). As reported by Skyward (2016), Part 107 is less restrictive than Section 333 because NOTAM and airworthiness certification are not required anymore, the pilot's certificate has been changed, and only some operational limitations have been introduced. In Part 107 the Visual Observer is no longer mandatory if there is the Pilot with a remote pilot airman certificate or two crew members with the operator under the direct supervision of a person with a remote pilot certificate (Remote Pilot-In-Command).

Both in Section 333 and Part 107, a UAV Cloud management system has not been defined, but FAA is collaborating with NASA since 2015 in the definition of the UTM Cloud-based software creating GUTMA (Global UTM Association).

The aim of the project is to enforce safe low-altitude civilian UAS operations. The system provides to pilots and ground operators information able to maintain separation among aircraft, reserving areas for specific routes and giving news about weather conditions and restricted airspace. The Cloud-based system has four technical capability levels:

- Technical Capability Level One: it involves field-testing of rural UAS operations for agriculture, firefighting and infrastructure monitoring.
- Technical Capability Level Two: it has been demonstrated in October 2016 for applications that operate BVLOS in sparsely populated areas. The system provides flight procedures and traffic rules for longer-range applications.
- Technical Capability Level Three: it will include cooperative and uncooperative UAS tracking capabilities to ensure collective safety of manned and unmanned operations over moderately populated areas and it is planned for January 2018.
- Technical Capability Level Four: it will involve higher-density urban areas for autonomous vehicles used for news-gathering and package delivery, and will offer large-scale contingency mitigation. It will be demonstrated in 2019.

An UTM (UAS Traffic Management) stakeholder is defined as an individual, a team or an organization with an interest in unmanned aircraft traffic management. Finally, the technical infrastructure system has been defined as: Communication infrastructure, Navigation infrastructure, Surveillance sensors/infrastructure, Spatial data infrastructure and Meteo sensors/infrastructure.

2.3. Europe

The aim of EASA (European Aviation Safety Agency) is that "drones should be integrated into the existing aviation environment in a safe and proportionate manner and this integration should foster an innovative and competitive European drone industry, creating jobs and growth", as reported by EASA (2015).

Many European countries have already published own regulations. Although they are based on common principles, these regulations define different safety requirements that cause a burden for the industry and a lot of confusion among UAS operators.

The aim of EASA is to publish a unique regulation for all UAS whose MTOM is below 150 kg and which operate in Member States. On May 2017, EASA has issued Introduction of a regulatory framework for the operation of drones Unmanned aircraft system operations in the open and specific category, EASA (2017a), with the aim to harmonize regulations and to mitigate the risks of operations.

As well as FAA is designing the UTM System, EASA is developing the U-Space concept to cope the incredible UAS market and airspace dimensions, as it has been presented by EASA (2016) in the Warsaw Declaration.

It is a set of new services and procedures designed to support safe, efficient and secure access to airspace by UAS. Considering that the majority of unmanned operations are performed at Very Low Level (VLL) (< 500 ft), especially in high density populated areas, a safe integration of UAS into the airspace is needed. As reported by EASA (2017b), there is a need to separate vertically and horizontally.

Moreover, the UTM System has the following features:

- it is a set of services sold and delivered by a set of providers;
- it relies on a high level of digitalization and automation of functions;
- it is able to support commercial or non-commercial UAS operations in all operating environments and in all types of airspace;
- it provides an extensive and scalable range of services, including the following three fundamental ones: electronic registration, electronic identification and geofencing.

Finally, the U-Space is defined in four steps as the UTM System of FAA.

- U1: definition of services providing electronic registration, electronic identification and geofencing.
- U2: definition of services to support the management of UAS operations (flight planning, flight approval, tracking, airspace dynamic information, interfaces with Air Traffic Control (ATC)).

- U3: definition of services to support more complex operations in densely populated areas (management and assistance in conflict detection, more reliable means of communication, etc.)
- U4: definition of full services, providing integrated interfaces with manned aviation, supporting the full operational capability of U-Space and relying on a very high level of automation, connectivity and digitalization of both the UAS and the U-Space system itself.

There is a current discussion between EASA and SJU (SESAR Joint Undertaking) to define activities and rulemakings about the U-Space concept in a forthcoming future, as described by SESAR (2017).

2.4. Italy

ENAC (Ente Nazionale Aviazione Civile), the Italian aviation authority, in synergy with ENAV (Ente Nazionale per l'Assistenza al Volo), the Italian company responsible for air traffic and navigation services, has already published a RPAS Regulation, as reported by ENAC (2015) and a guideline for harmless RPAS, as described in ENAC (2016), in Italy. As well FAA and EASA, also ENAC has classified RPAS in different categories, according to their MTOM and the kind of over flight area.

In ENAC (2015), the Agency splits up the RPAS in two groups: RPAS with a MTOM under 25 kg and RPAS with a MTOM in the range 25-150 kg. Moreover, operations have been classified in specialized operations (no-critical and critical operations) and R&D (Research & Development) activities. There is also a subcategory of the RPAS less than 25 kg. As a matter of fact, if the RPAS has a MTOM that is less than 0.3 kg and the speed is less than 60 km/h, with protected blades, all flight activities are classified as non critical. All operations must be performed in VLOS, within a maximum height equal to 150 m AGL (Above Ground Level) and a maximum horizontal distance from the operator equal to 500 m.

In the Italian RPAS Regulation, as well as in all other European regulations, the Cloud management system concept is not dealt with, waiting for a unique European vision of the subject.

3. A new concept

The proposed architecture and the relative regulation framework are based on the same previously described key aspects, in particular the take off mass categories and the operational limitations, but additional requirements are mandatory for the experimental validation.

Different mass categories are considered worldwide. In China seven categories have been identified by CAAC, in US FAA has only defined MTOM below 25 kg, while in Italy the value of 25 kg as MTOM threshold value has been identified by ENAC, together with some subcategories. Moreover, operations have to be generally performed in VLOS, although BVLOS is already allowed in China. Afterward, RPAS must maintain a safe altitude from people on the ground, such as 50 m in Europe, 120 m (400 ft) in USA and 150 m in Italy.

Finally, the only regulation that also has introduced the Cloud-based concept inside is the Chinese regulation, as reported in Section 2.1. Although USA and Europe have not introduced yet this innovative concept applied to UAV, some project, NASA UTM System and U-Space, respectively in USA and in Europe, are in progress with the aim to define a Cloud management system.

Therefore, considering the analyzed regulations and the international projects about the Cloud-based UAV concept, a proposal of a new regulation will be suggested in this Section. This regulation must include the main features of

the current regulations, as previously reported, such as mass categorization and operational limitations in terms of distances, but also some preliminary requirements and definitions of the Cloud-based UAV concept.

An unmanned configuration can fly in a Cloud-based framework if the following requirements are satisfied:

- MTOM < 25 kg.
- Specific technical requirement: electronic identification and geofencing function.
- All users must follow a registration process to record their UAV, achieving a unique and unequivocal registration number. In particular, the unmanned configuration must include a SIM card that allows to users and regulators to identify it by a mobile application.
- A UAV mission can be performed if three different figures are involved:

    - The Pilot: he/she must operate the unmanned configuration. He/she must have a pilot certificate, meeting specific requirements. This figure is responsible for the safety of the entire mission.
    - The Observer: he/she observes the operations.
    - The Pilot-In-Command: he/she assists the pilot to take final decisions during an emergency. Before the take off, he/she must verify that the UAV meets all requirements enforced by the authority, while during the flight, he/she must verify the satisfaction of the operational limitations.
- Operations must be performed in dedicated areas with specific features:
    - A maximum altitude: 120 m AGL.
    - VLOS flight condition.
    - The flight is forbidden close or inside an emergency scenario, unless the UAV has a specific permission by the local authority, close to aerodromes, over critical infrastructures such as prisons, military facilities, outdoor events (such as concerts, etc.), nuclear power plants.

The population density is an important requirement that must be defined a priori, to indicate restricted and prohibited areas, but also the test areas.

4. Classification of the Aerial Vehicles

Among the various types of RPAS exploitable in urban environments, the most suitable ones appear to be the fixed (airplanes - see Fig. 1) and rotary wing models (multicopters - see Fig. 1) which have complementary features and are also suitable for working in a coordinated manner. Fixed wing models are interesting as they are able to fly fast over large areas with considerable endurance. On the other hand, rotary wing models are able to analyze closely a particular area hovering, landing and taking off more easily.

A comparative analysis is presented (see Fig. 2 and Fig. 3), based on the data provided by the manufacturers for a number of models large enough to give us a general overview, in particular, 37 fixed wing and 45 rotary wing vehicles have been analyzed.

An important factor is certainly played by the maneuverability, enhanced by small size, low inertia (low weight as well) and in the case of fixed wing vehicles, by low cruising airspeed, which also allows lower turning radius, vital for handling in urban areas. A fixed wing platform with approximately 1.80 m wing span is widely representative of the category, while for multicopters, the maximum size is commonly below 1 m.

Among the analyzed factors, the mass is one of the peculiar features as it affects the kinetic energy in case of impact and the potential damage for humans after a major power or control failure. As a matter of fact, as reported by Novaro Mascarello et al. (2017), the unmanned vehicle in case of loss of control could hurt people, causing severe injuries. The level of offensiveness of RPAS is correlated to many factors and many efforts are carried out by the main regulatory authorities to enforce the public safety, defining configuration requirements to design harmless vehicles.

According to Novaro Mascarello et al. (2017), the 1-2 kg vehicle mass interval is therefore the most populated (both for fixed and rotary wing cases) and it seems to be the most suitable considering the payload and the endurance capabilities. This result is confirmed by the comparative analysis performed in the present paper.

In the aforementioned context, the LOS communication range and the flight endurance are equally important, as a metric of link robustness and in-flight persistence. Since the diversity of features, the performances of the two types of RPAS are very different. In the fixed wing case the flight endurance interval of interest is 30-60 min, while for rotary wing vehicles, the endurance falls in the 15-30 min range.

Analyzing the cruising speed, in the case of fixed wing RPAS, the minimum airspeed is quite high, given the absence of flaps for the majority of cases, differently from the multicopters, where the minimum airspeed is achieved in hovering flight, but with a significant penalty in terms of maximum airspeed, as a consequence of configuration dependent drag. In the former case, there is a significant concentration around the value of cruise airspeed of 18 m/s, while in the latter case, a more homogeneous distribution over an interval ranging from 3 to 10 m/s is observed.

Finally fixed wing vehicles are mainly taking off by hand launch while multicopters can take off and land vertically, with a visible advantage with respect to the former category that also requires an open strip for landing.

Fig. 1 An example of fixed and rotary wing model (MAVTech Agri 1900 and Q4L (Micro Aerial Vehicles Technology, 2017)).

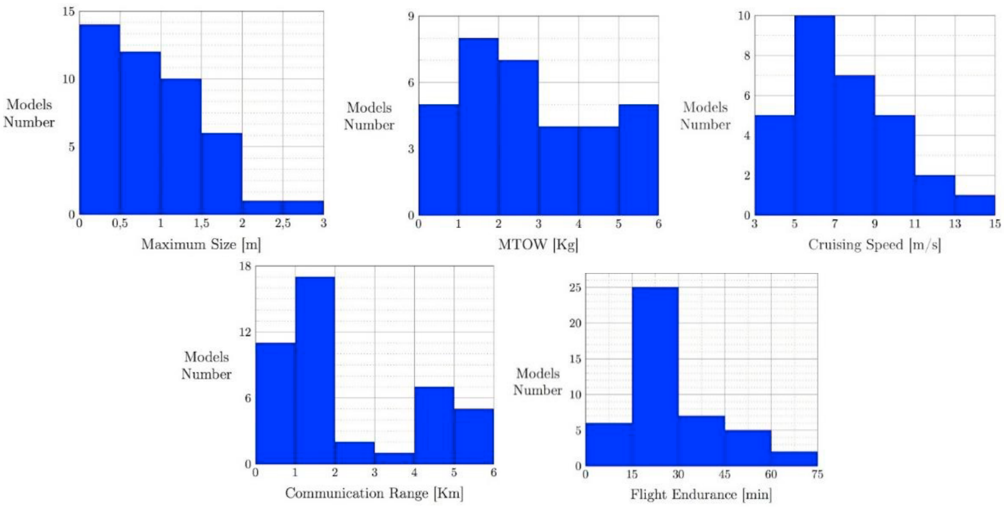

Fig. 2 Maximum size, maximum take off weight, flight speed for the rotary wing models, communication range and flight endurance for the rotary wing models.

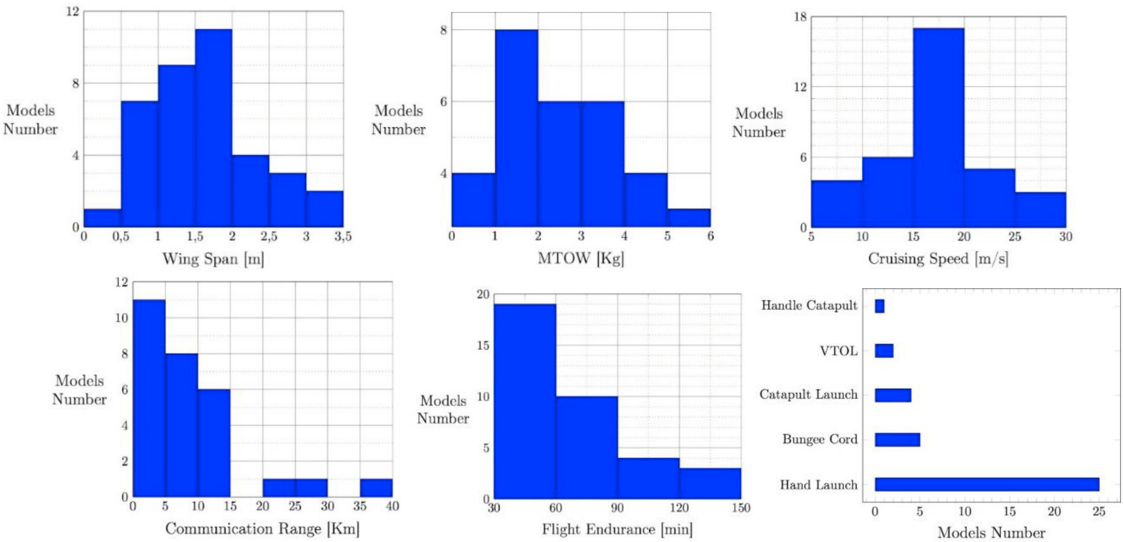

Fig. 3 Wing span, maximum take off weight, flight speed for the fixed wing models, communication range, flight endurance and launch methods for the fixed wing models

5. System Architecture: the Cloud

The proposed framework is based on five layers, each of them has a specific role and is connected to the others. A drop-down connection between two layers implies a bi-directional communication channel, as presented by Primatesta et al. (2017).

The Cloud includes map and risk-aware path planning generation, and control layers. Important novelty elements are: (i) the definition of a dynamic risk-map, and (ii) an on-board Control System which is able to perform emergency maneuvers, if communication with the Cloud is poor or missing.

The Cloud and the RPAS are connected through a wireless network and Internet mobile technologies (4G and 5G in the near future). The connection quality is monitored by the On-board Control System. If a bad connection is revealed, the on-board control takes over to enforce strategies for a safe navigation. The functionalities of the five layers are illustrated in the following.

The *Map Generation Layer* creates a dynamical map in order to assess the risk in the navigation area, encapsulating information from the on-board sensors and from external sources, i.e., environmental sensors, crowding of areas through mobile phone data, news streams, etc.

The *Path Planning Layer* computes a convenient path for the RPAS between a starting and a final point, taking into account the risk-map given by the Map Generation Layer. In this layer, two different processes are considered:

(i) an off-line path generation in which a preliminary optimal global path is evaluated, considering only the static information related to the environment, and (ii) an on-line path generation, in which a real time adaptation of the off-line path is performed, according to changes in the risk-map.

The *Control System Layer* includes two components, namely On-board and On-Cloud controllers. The On-Cloud Control System Layer directly sends the desired commands to the Hardware Layer and performs diagnostic and failure detection in normal operational conditions.

The *On-board Control System Layer* is designed to guarantee flight safety in any condition, and is activated only if a bad connection is observed. This layer is implemented considering the limited capabilities of the on-board micro-controller.

Finally, the *Hardware Layer*, which includes sensors and actuators, receives the control commands and actuates the control devices in accordance to the signals obtained from the Control layers. Also, it transmits information acquired by the on-board sensors to all the layers in the architecture. Details about this layer are related to the specific on-board hardware present on the RPAS, which is assumed available from design specifications, and it is out of the scope of this paper.

6. Experimental tests

A test campaign (starting in 2017) has been scheduled in order to evaluate performances of the Cloud-based framework. Results of these tests will be reported to the local Italian authorities (ENAC and ENAV) in order to support the introduction of such Cloud system in the current regulations. The test campaign will be focused on validation of the Cloud-based framework based on 4G/5G mobile connectivity.

For instance, in the city of Turin, several areas have been identified with different values of population density, close to important roads or highways, railways, close to infrastructures and with several obstacles.

The first test sessions will be held in the area of Parco della Pellerina, in Turin (see Fig. 4), as designated main area.

The criteria followed to select the test areas are:

1. the area shall be within the urban boundaries of the city of Turin;
2. the area shall contain few obstacles (natural and man-made) and obstacles (if presents) shall not compromise the safety of the flight;
3. the area shall not be crowded during the flights sessions;
4. the area shall be far from critical areas, such as airports.

The scopes of the test campaign are:

- to test the connection of the RPAS to the Cloud with 4G/5G mobile technology;
- to test the Cloud system comprehensive of the three layers: the Cloud shall generate the trajectory the RPAS must follow, preventing overfly of forbidden areas and flying within the electronic fence defined during the setup of the test, avoiding collisions with other RPAS flying within the same fenced zone (such RPAS are only simulated, they are not actually present during the test);
- to test the interaction with the autopilot and the related safety issues in case of lost connection.

During the tests the Pilot-In-Command has the authority to override the Cloud control or the On-board Control System in order to guarantee the safety of the flight.

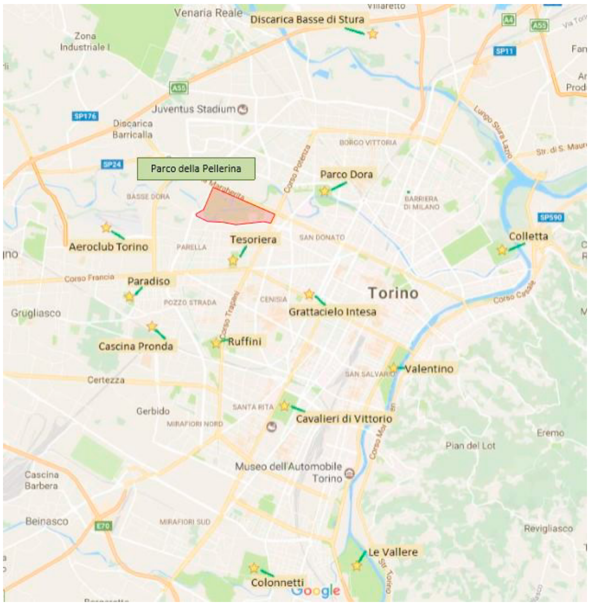

Fig. 4 The main test area in Turin.

7. Concluding remarks

New concepts for a Cloud-based framework supervising the intelligent navigation of aerial vehicles have been proposed, to realize fully-autonomous missions for RPAS, while increasing the overall safety of operations. Urban areas are special cases and require to consider a wide range of applications, even in risk critical environments. The main advantage of the proposed framework is the definition of specific requirements based on the use of the Cloud and allowing the access to data available on the Internet, especially useful for real time risk assessment and in-flight collision avoidance.

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References

Capello, E., Dentis, M., Novaro Mascarello, L., Primatesta, S., Regulation Analysis and New Concept for a Cloud-Based UAV Supervision System in Urban Environment, 4th RED-UAS, Workshop on Research, Education and Development of Unmanned Aerial Systems, October 3-5, 2017, Linkoping, Sweden.

EASA, Concept of Operations for Drones. A risk based approach to regulation of unmanned aircraft, 2015. Available at: https://www.easa.europa.eu/easa-and-you/civil-drones-rpas

EASA, Notice of Proposed Amendment 2017-05 (A), Introduction of a regulatory framework for the operation of drones - Unmanned aircraft system operations in the open and specific category. Available at: https://www.easa.europa.eu/easa-and-you/civil-drones-rpas, 2017a

EASA, Notice of Proposed Amendment 2017-05 (B), Introduction of a regulatory framework for the operation of drones Unmanned aircraft system operations in the open and specific category. Available at: https://www.easa.europa.eu/easa-and-you/civil-drones-rpas, 2017b

EASA, Warsaw Declaration - Drones as a leverage for jobs and new business opportunities, Warsaw, 2016. Available at: https://ec.europa.eu/transport/modes/air/european-unmanned-aircraft-warsaw-declaration en.

ENAC, Aeromobili a pilotaggio remoto con caratteristiche di inoffensività, LG 2016/003-NAV, June 2016. Available at: https://www.enac.gov.it

ENAC, Remotely Piloted Aerial Vehicles Regulation Issue No. 2 dated 16 July 2015, Revision 1 dated 21 December 2015. Available at: https://www.enac.gov.it/la normativa/normativa enac/regolamenti/regolamenti ad hoc/info-122671512.html

FAA, Operation and Certification of Small Unmanned Aircraft Systems, Docket No.: FAA-2015-0150; Amdt. Nos. 21-99, 43-48, 61-137,91-343, 101-9, 107-1, 119-18, 133-15, and 183-16, 2016. Available at: https://www.faa.gov/news/fact sheets/news tory.cfm?newsId=20516.

FAA, Section 333 of the FAA Modernization and Reform Act of 2012 (FMRA), 2012. Available at: https://www.faa.gov/uas/beyond the basics/section 333/

Global UTM Association, UAS Traffic Management Architecture, 2017.

Gupta, L., Jain, R., and Vaszkun, G., Survey of Important Issues in UAV Communication Networks, IEEE Commun. Surv. Tutor., Vol. 18, pp. 1123 - 1152, 2016.

Itkin, M., Kim, M. and Park, Y., Development of Cloud - Based UAV Monitoring and Management System, Sensors, MDPI Journal, Vol. 16 (11), pp. 1-19, 2016.

Lee, J., Wang, J., Crandall, D., Sabanovic, S., and Fox, G., Real-Time Cloud-based Object Detection for Unmanned Aerial Vehicles, 1st IEEE International Conference on Robotic Computing (IRC), April 10-12, 2017, Taichung, Taiwan.

Luo, C., Nightingale, J., Asemota, E. and Grecos, C., A UAV - Cloud System for Disaster Sensing Applications, 2015 IEEE 81st Vehicular Technology Conference (VTC Spring), May 11-14, 2015, Glasgow, UK.

Mahmoud, S. and Mohamed, N., Toward a Cloud Platform for UAV Resources and Services, 2015 IEEE 4th Symposium on Network Cloud Computing and Applications, June 11-12, 2015, Munich, Germany.

Micro Aerial Vehicles Technology, 2017. Available at: http://www.mavtech.eu/

NASA, First Steps Toward Drone Traffic Management. Available at: https://www.nasa.gov/feature/ames/first-steps-toward-drone-tra c-management, 2015.

Novaro Mascarello, L., Guglieri, G., Quagliotti, F., Fraschetti, S., and Gervasio, S., A Comprehensive Approach for the Safety Analysis of Remotely Piloted Aircraft Systems, 7th EASN International Conference, September 25-29, 2017, Warsaw, Poland.

Primatesta, S., Capello, E., Antonini, R., Gaspardone, M., Guglieri, G., and Rizzo, A., A Cloud-based Framework for Risk-aware Intelligent Navigation in Urban Environments, 2017 International Conference on Unmanned Aircraft Systems, June 13-16, 2017, Miami Marriott Biscayne Bay, Miami, FL.

SESAR Joint Undertaking website, 2017. Available at: https://www.sesarju.eu/

Skyward, Part 107 compared to the 333 Exemption, 2016. Available at: https://skyward.io/part-107-resources/

The Library of Congress, Regulation of Drones, Global Legal Research Center, 2016.

Wei J., Ellett E. T., Ellman L., Rizzi P. R. and Zhou L., China Launches First Operational Rules for Civil Unmanned Aircraft, Global Media and Communications Watch- The International Legal Blog for the Tech, Media and Telecoms Industry, January 21st 2016. Available at: http://www.hlmediacomms.com/2016/01/21/china-launches-first-operational-rules- for-civil-unmanned-aircraft.

Zhang L., Regulation of Drones - Peoples Republic of China, The Law Library of Congress, Global Legal Research Center, 2016.

Zhu, L., Yin, D., Yang, J., and Shen, L., Research of remote measurement and control technology of UAV based on mobile communication networks, Proceedings of the IEEE International Conference on Information and Automation (ICIA), August 810, 2015, Lijiang, China, pp. 2517 - 2522.