

# Drones as an Integral Part of Remote Sensing Technologies to Help Missing People

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**Abstract:** Due to the versatility of the drone, it can be applied in various areas and for different uses and as a practical support for human activities. In particular, this paper focuses on the situation in Italy and how the authorities use drones for the search and rescue of missing persons, especially now that a 10-year plague that has afflicted Italy with a large number of such incidents annually. Knowledge of the current legislation, the implementation of the drone with other instruments, specific pilot training, and experiential contributions are all essential elements that can provide exceptional assistance in search and rescue operations. However, to guarantee maximum effectiveness of the rescue device, they should seriously consider including teams with proven expertise in operating drones and count on their valuable contribution. Besides drones' capacity to search large areas, thereby reducing the use of human resources and possibly limiting intervention times, to operate in difficult terrain and/or dangerous conditions for rescue teams, remote sensing tools (such as GPR or ground penetrating radar) as well as other disciplines (such as forensic archeology and, more generally, forensic geosciences) can be implemented to carry out search and rescue missions in case of missing persons.

**Keywords:** drone; UAV; remote sensing; GPR; missing people; rescue people

## 1. Introduction

The term “drone”, according to current usage, refers to the remote piloted aircraft (RPA) category of flying objects. These are instruments of different sizes and specifications capable of flying without a pilot on board. The objects' flight is controlled by an on-board computer, and the drone is operated by a pilot operating from the ground via radio [1–4].

During the Great War, the first prototypes had already found use in the military: The controlled Aerial Target radio was designed by Captain Archibald Low and built by the Royal Aircraft Factory (RAF) for defense and bomb attack purposes [1].

The related technology made great progress in the interwar period, with the design of devices equipped with an autopilot capable of taking off directly from warships. The first unmanned aircraft were mainly designed for espionage and bombing, or used for training anti-aircraft gunners [5].

Although those early specimens did not entirely conform to the modern configuration of unmanned aerial vehicles, they can be considered in all respects the precursors of most contemporary technological drones. Today's devices are no longer used exclusively by the military, and there has been an important transition towards smaller and more technologically advanced models for use by companies and individuals in different sectors and for different purposes. It was towards the early 2000s that many

industries began to produce models with smaller dimensions and lower prices, which contributed to a significant increase in their diffusion and their use both professionally and for recreation [2–6].

The International Civil Aviation Organization (ICAO) assigned the following technical appellation to drones in 2015: Remotely piloted aircraft system (RPAS); in Italian: Sistemi Aeromobili a Pilotaggio Remoto (SAPR). Although there is a global agreement on the terminology that defines drones, some Anglo-American organizations have opted for the abbreviation UAS (unmanned aerial system), which describes the entire operating equipment: The drone, the control station, and the wireless data connection. This name has also been adopted by the Federal Aviation Administration (FAA), the European Aviation Safety Agency (EASA), and the Unmanned Aerial Vehicle System Association (UAVSA) [7,8]. This emphasizes how flight operations must comply with a series of international rules and procedures imposed on air traffic, regardless of the device's classification or the absence of an on-board pilot.

The introduction of any new component in the aeronautical system needs to be defined and integrated by nations and industries through acceptance and compliance with internationally recognized rules that guarantee safe commercial and civil use for all aviation.

Consequently, the need arose for ICAO to create an operating manual, which was published for the first time in 2015 after three years of work, with contributions from different groups of experts. Subsequent revisions followed, and a protocol was established, with the aim of standardizing the rules for the 191 UN member countries that routinely interpret ICAO standards when referring not only to large RPAS but also to smaller models. The guidelines thus established the necessary certifications and limitations, depending on the take-off weight and the kinetic energy produced [5,9–11].

## 2. Materials and Methods

We can divide drones into three main categories as in Table 1.

**Table 1.** The three main categories of drones.

<b>Propeller structures—multicopters</b>	Mounted on fixed or extendable arms that allow flight with performance similar to that of a helicopter
<b>Planar structures—fixed wings</b>	Equipped with wings and therefore more similar to airplanes capable of exploiting currents and air flows
<b>Hybrid technology—aircraft</b>	Able to combine the performance of the fixed wing with that of a multi rotor

There are several hybrid models with propellers and drive wheels or tracks for maneuvering on rough terrain, models with floats for planing on water, and underwater models.

Further classification of drones relates to weight/size (Table 2).

**Table 2.** Classification by weight and size.

<b>MAV (Micro Air Vehicle)</b>	With a maximum length of 15 cm
<b>sUAS (small Unmanned Aircraft Systems)</b>	Weighing less than 25 kg
<b>UAV (Unmanned Aerial Vehicles)</b>	For drones over 25 kg

Drones are becoming increasingly popular. However, their massive use is accompanied by the risks of uncontrolled flight over areas where public safety may be an issue, and that must be addressed. Flyovers in the vicinity of airports, for example, pose a serious threat to air traffic. Conscious of the risk, the authorities know that in the case of drone sightings, the only alternative they have is to proceed with the closure of flight activities, with imaginable operational and economic consequences. Despite rules prohibiting the flight of RPA within a 5-km radius of airports, accidents of this type have occurred frequently [2,4].

Worldwide, aviation authority reports list a series of near misses that could have actually had fatal consequences due to non-compliance by drone pilots. An emblematic case that brought to light the risk management problem occurred in September 2016, when the flight of a drone at Dubai's Al-Maktoum international airport resulted in the closure of the air space for about half an hour. A helicopter was raised in flight to resolve the dangerous intrusion but without success. As reported by the crew, the RPA moved too fast, turning at sharp angles so the helicopter was unable to follow. When they finally managed to locate it, it escaped again. The need arose, therefore, to find a solution that can realistically counter such threats [12].

A possible countermeasure could be the use of surveillance drones at airports, with a communication infrastructure capable of supporting multiple drones simultaneously, combined with a ground control structure. In 2017, the (second) ICAA (Italian Civil Aviation Authority) regulation entered into force in Italy, dictating the safety rules and flight conditions for UAVs. This law envisaged a significant new possibility: The use of drones in urban areas, as long as certain rules were respected (Table 3). These rules include the presence of a primary command and control system with software compliant with EUROCAE ED-12B (RTCA DO-178B) corresponding to a minimum of level D [8,13,14].

**Table 3.** Levels for DO-178B software (after [13,15]).

Failure Conditions	Software Level	Description
Catastrophic	A	Software that can cause or contribute to the failure of the system resulting in the loss of ability to continue safe flight and landing
Hazardous	B	Software that can cause or contribute to the failure of the system resulting in a hazardous or severe failure condition
Major	C	Software that can cause or contribute to the failure of the system resulting in a major failure condition
Minor	D	Software that can cause or contribute to the failure of the system resulting in minor failure condition
No Effect	E	Software that can cause or contribute to the failure of the system resulting in no effect on the System

With the issuance of EU regulation 2018/1139, which entered into force on 11 September 2018, the European Union defined the principles and rules of airspace by examining the various aspects of drones. Considering that RPAs use the same airspace as aircraft, it is of fundamental importance to standardize regulations in all European states [16].

The regulation was applied to all drones at the European level regardless of their weight, including those with a weight of less than 150 kg. Until that time, the responsibility of regulating smaller drones fell on the separate nations. This legislation leaves a margin of flexibility to the Member States, leaving the definition of some parameters to the national authorities in order to respect the principle of proportionality.

The salient aspects covered in the current regulation are those relating to the protection of personal data, operator training, design, production, maintenance, and the obligation to register, as well as establishing the essential requirements for unmanned aircraft. However, the risks they can represent for fundamental areas should also be considered, such as the following: Security, confidentiality, protection of personal data, and the environment. Hence, it falls on the European Commission to create an intervention forecast and implement specific acts [16].

In fact, this document represents only the first step on a path that will be completed in the first months of next year, in which the adoption of a single European regulation by the commission is expected. In the meantime, over the past year, the commission has consulted sector operators, citizens, businesses, and the EASA (European Aviation Safety Agency), who have expressed their views on the matter, with the common objective of achieving the best possible legislation. In the current regulations, the obligation to register is contained in Section VII—arts. 55–58 and in Annex IX, which defines the

essential requirements of unmanned aircraft, with the provision, as already mentioned, of intervention by the implementation of specific acts by the commission [16].

The legislation also draws the attention of operators to the question of the protection of personal data with provisions that limit the activity of drones in compliance with the rights guaranteed by the Union, relating to privacy and family life, as outlined in Article 7 of the Charter of Fundamental Rights of the European Union and those relating to the protection of personal data, referred to in Article 8 of the Charter and from Article 16 TFEU, and from Regulation (EU) 2016/679 of the Parliament and of the European Council [16,17].

The requirements relating to the registration of unmanned aircraft and those of their operators have also been established, always in consideration of the risks that unmanned aircraft can represent for the safety, confidentiality, and protection of personal data and the environment, for which reasons they need to be identifiable.

Thus, harmonized and interoperable national digital registration systems have been introduced on the D-Flight website, in which all information relating to drones and their operators has converged and been stored, in accordance with the provisions of the regulation and of the acts implemented based on the same.

The information stored in the registration systems must be easily accessible and drone operators must be registered in specific national lists if they use:

- Unmanned aircraft, which in the event of an impact can transfer kinetic energy greater than 80 joules to the human body; and
- Unmanned aircraft whose use involves risks to confidentiality, protection of personal data, security, or the environment.

The regulation shows a risk analysis related to the weight of the drone, the operations carried out, and the contexts of its use, and therefore a series of preventive, organizational, and technical measures are indicated, including protection from electronic interference, those relating to communication and anti-collision ("detect and avoid function").

The new rules confirm the need to adopt an adequate management system to ensure compliance with the requirements in order to monitor and predict security risks, with the aim of constantly improving the system. Furthermore, the importance of operator training has been emphasized, which represents a challenge for public entities, businesses, and citizens at this time [18].

#### *Flight Licenses and Certificates*

Professionally piloting an RPA involves a number of requirements [5,8]:

- Over 18 years of age;
- Psychophysical fitness;
- Basic aeronautical knowledge;
- The ability to fly an RPA; and
- Obtaining a certification that establishes the obligations and limits of the activity, which is of two types: The certificate or the RPA pilot license.

The RPA remote pilot certificate is issued by an authorized ICAA center and authorizes the holder to pilot drones of different categories with a mass of less than 25 kg in VLOS (visual line of sight) conditions, e.g., flight operations with visible controls in the absence of additional supports.

For psychophysical fitness, a LAPL (light aircraft pilot license) medical certification is required, issued by an aero medical examiner (AME), which is valid for 60 months if the pilot is under 40 years of age, but if the pilot was certified shortly before he turned 40, his certificate validity ceases at 42; after 40, the certificate must be renewed every 24 months.

The certification of aeronautical skills is issued upon passing a theoretical-practical exam to be taken at ICAA authorized centers.

There are three possible levels of flight certificates for the use of RPAS based on their weight [5,7,18]:

- **VL** Very Light from 0.3 kg to 4 kg;
- **L** Light from 4 kg to 25 kg; and
- **H** Heavy over 25 kg.

These certificates allow the holder to fly drones of different categories also based on their structures [19]:

- **Ap** Fixed wing;
- **Hc** Helicopters;
- **Mc** Multi-copters; and
- **As** Airships.

Piloting in BVLOS (beyond visual line of sight) is not allowed in Italy, because it has not been regulated yet.

To secure psychophysical fitness certification, it is necessary to pass a class-three medical examination and obtain the relative certificate issued by the ICAA Regulation, which will be valid for 24 months for pilots under 40 years of age. Over the age of 40, the certificate must be renewed annually.

The certification of aeronautical skills, also for the pilot license, is entrusted to the centers recognized by ICAA, after passing theoretical and practical exams. It is valid for 5 years. The regulation on drones was passed by the European Union in July 2019 and entered into force, replacing national regulations with simplified rules and higher safety standards for those who want to operate RPAS (remotely piloted aircraft systems). Following approval of the new basic regulation in June 2018 by the European Parliament, the EASA (European Union Aviation Safety Agency) voted in favor in July 2019—after the representatives of the Member States had examined the acts to be implemented, at the EASA Committee of the European Commission—and allowed passage of the regulation [16,18,20,21].

The rules contained therein will become applicable in July 2020 in all Member States, exactly one year after their approval. The use of UAS placed in the market before the new regulations, which had not been classified according to the new codes, will be permitted until July 2022 for low-risk operations (so-called open category), provided that certain criteria are met based on the weight range. Starting from July 2022, those who want to operate a drone in Italy will have to comply fully with the new European laws [8].

### 3. The Use of Drones to Search for Missing People

While we all know that there are many areas where drones are extremely useful, in this paper, we focus on their use for the search and rescue of missing persons in difficulty. This theme is particularly relevant in a country like Italy, where 61,036 people went missing from 1 January 1974 to 31 December 2019. For this reason, the post of Extraordinary Commissioner of the Government for missing persons at the Ministry of the Interior was established in Italy. From a perusal of the XXII report of the Extraordinary Commissioner of the Government for missing persons presented in February this year and containing the data of the year 2019, we can realize the enormity of the problem of missing persons: In 2019 alone, there were 15,044 such complaints made in Italy. Although this was a decrease compared to 2018, when the count was 18,393, the numbers remain significant [22].

The institution of the position of Extraordinary Commissioner of the Government for missing persons took place in July 2007 with a presidential decree, motivated by the need for specific coordination of research and monitoring of the phenomenon.

The Territorial Prefectures are responsible for adapting and updating the Provincial Plans for the search for missing persons, following the national and regional laws, the guidelines of the Office of the Extraordinary Commissioner, and the circulars of the Ministry of the Interior [23].

The Provincial Plans are aimed at defining the organizational structure, the operational roles, and the activities related to research to guarantee the maximum possible effectiveness of the rescue device.

This must be accomplished in consideration of the extreme morphological diversity of our country, which, depending on the case, requires the involvement of research teams specialized in different fields [24].

Worldwide, research systems are being increasingly refined, also with the use of technologies, such as aerial drones, marine drones, and robot drones, thanks to the new era of artificial intelligence. As early as 2016, the Riverside County Police Department in California began using drones equipped with a high-definition camera to record and transmit images in real time to a ground crew trained for search and rescue missions. The department has a fleet of helicopters, but these cannot always be used due to weather conditions, while the use of the RPA has proven to be much more effective and versatile. More specifically, they can be designed to be able to battle the bad weather (like, wind, rain, etc.) as well as being mentioned in [25–27]. It is able to respond immediately to requests for intervention and then rescue operations can be performed by a team that reaches the target overland after detection [28].

Between 2018 and 2019, some prefectures of the Italian territory signed “coordinated intervention plans for the search and rescue of people suffering from neurodegenerative diseases”, which provides for the use of geolocation devices, training for caregivers and recommendations, and useful information for citizens and operators in critical circumstances [29].

While, until a few years ago, private citizens were allowed to contribute their effort as research volunteers through the use of their drones, from 2019, the ICAA and the Prefectures have prohibited their use and support unless expressly authorized [14].

The new ICAA regulation on drones, in force from 15 December 2019, vide paragraph 7 of Article 7, has in fact prohibited pilots and RPAS operators from using a drone near or within areas where interventions are taking place in response to emergency situations. This article has been interpreted as a ban on the use of civil drones in daily rescue activities and for emergencies, provoking various reactions and numerous controversies; so much so that the rescue drones network, the first network of volunteers for the ready use of drones during emergencies, have initiated protest initiatives by launching petitions and demonstrating before the Ministry of Transport [30].

The phenomenon of missing persons has remained constant over time, but today, thanks to this technology, it is possible to operate search and rescue activities with reduced intervention times and a wider field of action, saving human resources and lowering costs, but above all limiting the risks for operators. However, most of all, they have obtained a greater success rate not only in finding people but in finding them alive [6,31–33].

Thanks to their small size and maneuverability, drones are able to fly at low altitudes (ca. 10 m.) and cover large areas. They offer the opportunity to coordinate a team through images and information transmitted remotely, and if equipped with thermographic tracking equipment and software, they can detect human presence even in the dark, without the search operations being interrupted at night.

Other implementations include SAR (synthetic aperture radar, i.e., a coherent, active, and microwave radar remote sensing system), the thermal imaging camera, the multispectral sensor (a multispectral sensor is an instrument capable of recording the amount of reflected energy of objects on the earth’s surface in the different wavelengths of the electromagnetic spectrum), the ALS, and the LiDAR (aerial laser scanner and light detection and ranging, respectively, or two types of scanning lasers) [3,5,34].

For the rescue teams’ activity to be guided by drones, the teams require constant training, a fair amount of flight hours, and the study of specific intervention techniques. Operators must also have adequate psycho-physical preparation to become a point of reference, and valid support from institutions involved in emergency management. This has started occurring more frequently, in recent times.

#### 4. An Integrated Case Study

A particularly significant case is the one in which a commercial drone (Quadcopter Goolsky ZERO TECH DOBBY Wifi FPV smart selfie Drone With 4K 13 MP HD 3-Axis camera) was used for



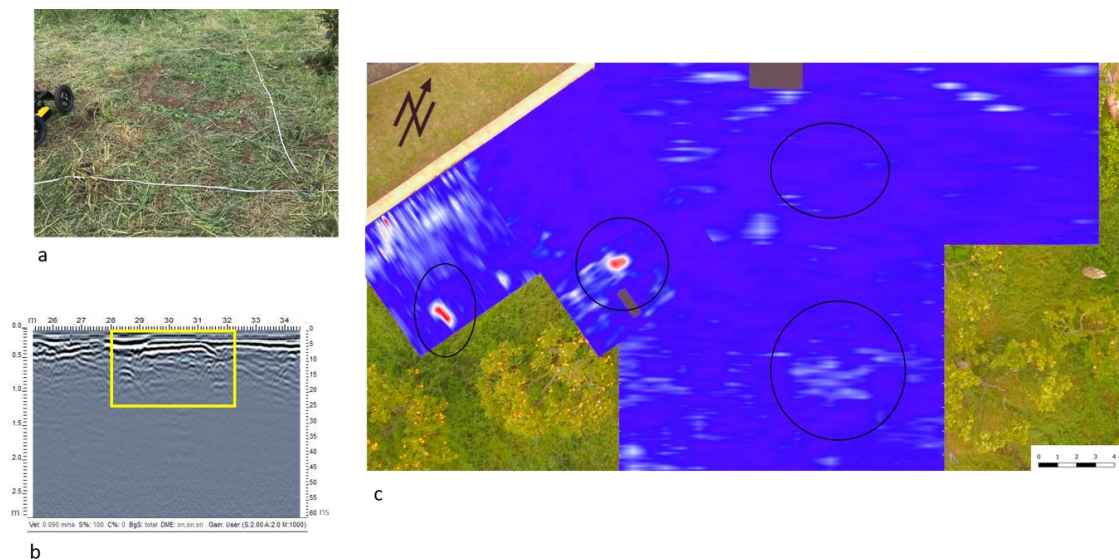
the identification and location of possible clandestine pits relative to two missing people who had disappeared and had been presumed murdered. The drone was used to investigate a private garden to which access had been denied, as the police had not yet obtained a search warrant from the proper authorities. As can be seen in Figure 1, these anomalies are particularly evident even without the use of particular filters or image processing. The problem that was immediately evident to law enforcement was the presence of four superficial anomalies, while there had been only two people declared as missing.



**Figure 1.** Drone photo acquired in the private garden of the suspect. Four ground anomalies are clearly visible.

The results from the drone were sufficient to authorize the search of the private property and the garden. Attempting to understand if there were more bodies buried in that garden than those sought or if the presence of these four anomalies were linked to other factors, we proceeded to use the GPR (ground penetrating radar)—a bistatic 500 MHz Noggin system, SSI—as a remote sensing tool [35,36]. The aim was to confirm in a non-destructive and real-time manner the presence underground of two more anomalies or not. The GPR results, in Figure 2, suggested the possibility of bodies lying buried at about 0.40 m only in two of the four ground anomalies previously detected by the drone, while the other two did not present any significant irregularities (Figure 2).

The subsequent use of the stratigraphic excavation appropriate to forensic archeology and the consequent collection of data and information confirmed the presence of the bodies of the two missing persons buried at the points confirmed by the GPR investigation, while the excavation of the other two alleged pits revealed no criminal activities [37,38]. The owner of the property, suspected of murder and concealment of a corpse, subsequently confirmed that he had created two other empty pits with the intention of misleading the investigators.



**Figure 2.** (a) shows the GPR acquisition on the top of one of the anomaly detected by the drone; (b) is a radargram showing clearly the presence of a dig backfilled with something inside (the yellow rectangle); (c) illustrates the depth slice (at 0.40 m) with the two clear anomalies related to the possible clandestine graves of the missing people (the black circles are the locations of the 4 anomalies detected by the drone, see Figure 1).

## 5. Conclusions

To deal with the proliferation of improvised and unrecognized drone pilots, it is hoped that companies and groups of volunteers specialized in the search and rescue of people will be accredited after careful verification of the requirements and officially included in the Provincial Plans of the Prefecture so that they can support search and rescue missions with their precious contributions.

The drone, now known and used mainly for photography and videography, becomes a fundamental and irreplaceable tool for the search and identification of people in difficulty, in the expert hands of a team who can intervene promptly for human rescue. The distances and especially the approach times are reduced, and the difficulties of rough terrain are canceled for those responsible for the rescue.

By flying over the ground with a drone and implementing it with the support of other remote sensing technologies, both on board, such as multispectral cameras, and on the ground, such as GPR, it will be possible to calibrate the type of intervention and adapt action strategies, no longer based on hypotheses arising from maps, but as targeted interventions based on the actual conditions of the moment (e.g., forensic archaeological investigation). Here, even a commercial drone, if properly equipped, can become a life-saving tool where human rescue might struggle to arrive [39,40].

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