
STATISTICAL ANALYSIS OF SIGNAL PROCESSING TECHNIQUES FOR DRONE COMMUNICATION SYSTEMS

Taqi Mohammed Khattab Al-Rubaye
Department of Medical Laboratory Technology,
College of Medical Technologies,
The Islamic University Najaf, Iraq
kaboos287@gmail.com

Abstract: The technology of unmanned aerial vehicles (UAVs), or drones, has witnessed tremendous advancements in recent years, making them indispensable tools across various applications, including transportation. These aircraft are characterized by their mobility and flexible deployment, making them an ideal choice for enhancing the efficiency and safety of transportation systems in Iraq. Importance of UAVs in Iraq Infrastructure Improvement: UAVs can be utilized for inspecting and maintaining infrastructure, such as roads and bridges, which helps reduce costs and improve safety. Disaster Management: UAVs can play a crucial role in disaster management, as they can provide accurate and rapid information about affected areas, aiding in directing rescue and relief efforts. UAVs can be employed for security surveillance of vital installations and border areas, contributing to enhanced security and crime prevention. Logistical Delivery: UAVs can be used for delivering goods and parcels in remote and distant areas, which helps improve logistical services and reduce costs. Challenges of UAV Utilization in Iraq: Infrastructure Iraq needs to develop advanced infrastructure to support the use of UAVs, including communication and air navigation systems. Iraq needs to establish clear legislation and laws that regulate the use of UAVs, including specifying permitted and prohibited areas, and setting safety and security rules. Iraq needs to train and qualify specialized personnel in operating and maintaining UAVs. Statistical Analysis of Signal Processing Techniques, Signal analysis is considered a fundamental element in UAV communication systems, as it helps improve communication quality and reduce noise and interference. This analysis aims to study and evaluate various signal processing techniques used in these systems, and determine the best ones for use in Iraq. Study Objectives, Identify Best Signal Processing Techniques: The study aims to identify the best signal processing techniques that can be used in UAV communication systems in Iraq, taking into account local conditions and existing challenges. The study aims to improve the quality of communication in UAV systems, and reduce noise and interference. The study aims to develop local capacities in the field of UAV technology, and qualify specialized personnel in this field.

Keyword: Unmanned Aerial Vehicle (UAV), Signal Processing Techniques, Communication Systems, Statistical Analysis, Iraq

1.1 Introduction

Unmanned Aerial Vehicle (UAV), also known as UAV, more commonly known as Drone, was originally used for military missions. Since 2010, the technology of UAV has developed rapidly. The successful integration of carbon fiber composite materials, brushless motors, lithium-polymer batteries (LiPo), power electronics, microelectronic components, communication navigation, flight control and other technologies has enabled UAVs to quickly enter the entertainment and livelihood uses, becoming more people-friendly and thus prospering the small and medium-sized UAV market. A fully functional drone, including the model, vehicle, power, avionics, control, The complete integration of the carrier and ground remote control systems is called an "Unmanned Aircraft System" (UAS). From the perspective of international aviation regulations, the International Civil Aviation Organization (ICAO) issued Notice No. 328 in March 2011, which is named Unmanned Aircraft System (UAS), and the notice also mentioned: The Remotely Piloted Aircraft System (RPAS)) specifications can also meet the conditions of the Chicago Convention and plan the flight management procedures for drones. Since then, in order to provide an international standard regulatory framework for drones, ICAO issued Document No. 10019 in 2015: "Remotely Piloted Aircraft Systems (RPAS)". The document aims to establish operational standards for drones around the world in a coordinated and seamless manner to support its Procedures for Air Navigation Services (PANS), and most importantly, to introduce drones into non-segregated airspace and reduce the safety risks of manned aircraft at airports. Therefore, according to ICAO Circular 328, Unmanned Aircraft Systems (UAS) are defined as "aircraft and related parts operating without a pilot on board the aircraft"). Unmanned aircraft system. An aircraft and its associated elements which are operated with no pilot on board According to ICAO document 10019, a remotely piloted unmanned aircraft system (RPAS) is defined as "a remotely piloted aircraft and its associated remote control station, including specified command and control links and other components of the design type." Remotely piloted aircraft system (RPAS). A remotely piloted aircraft, its associated remote pilot station(s), the required command and control links and any other components as specified in the type design. Supported by a legal framework, remotely piloted unmanned aerial systems (RPAS) are gradually creating a new industry with huge economic potential. RPAS provides a wide range of advanced features and applications. Driven by market demand, its related technologies, designs and operating concepts are developing rapidly. In this context, the challenge facing countries is to safely and effectively integrate remotely piloted UAV systems to the level of instrument flight rules (IFR) for manned aircraft, and to better enable them to coexist with manned aircraft in an operating environment (4).

The commercial application of drones is already very widespread around the world (5-6). According to the statistics released by Statista in 2017, the development of the global drone industry from 2015 to 2020 is predicted. The global investment in drone hardware is divided into

official investment of US\$8.35 billion, personal investment of US\$2.6 billion, and corporate global investment of US\$600 million, as shown in Figure 1.

Business Insider (3) used the 2017 statistics to predict and evaluate drone shipments starting in 2014, and observed a significant increase in drone shipments in recent years. As shown in Figure 2, 7 million drones were shipped in 2016, an increase of 1 million from 2015. In 2017, 10 million new drones were shipped, an increase of about 40% from the previous year. It is estimated that by 2021, drone shipments will increase fourfold, reaching 29 million worldwide. According to research data from Gartner, global unit sales of popular drone models climbed to 2.2 million units in 2016, with revenue growing 36% to \$4.5 billion. The U.S. Consumer Technology Association also pointed out that 2.4 billion personal drones were sold in the United States in 2016, more than double the 1.1 million units sold in 2015.

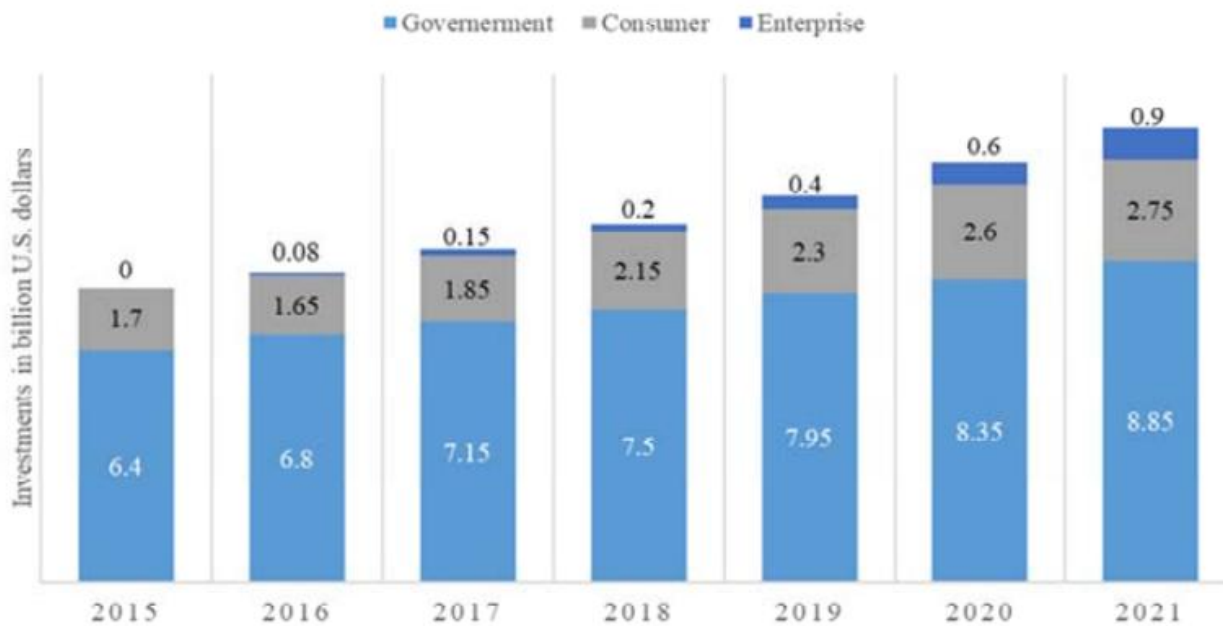


Figure 1: Global drone hardware investment from 2015 to 2021 (in billion US dollars) [7]

Estimated Consumer Drone Shipments *Global, Millions*

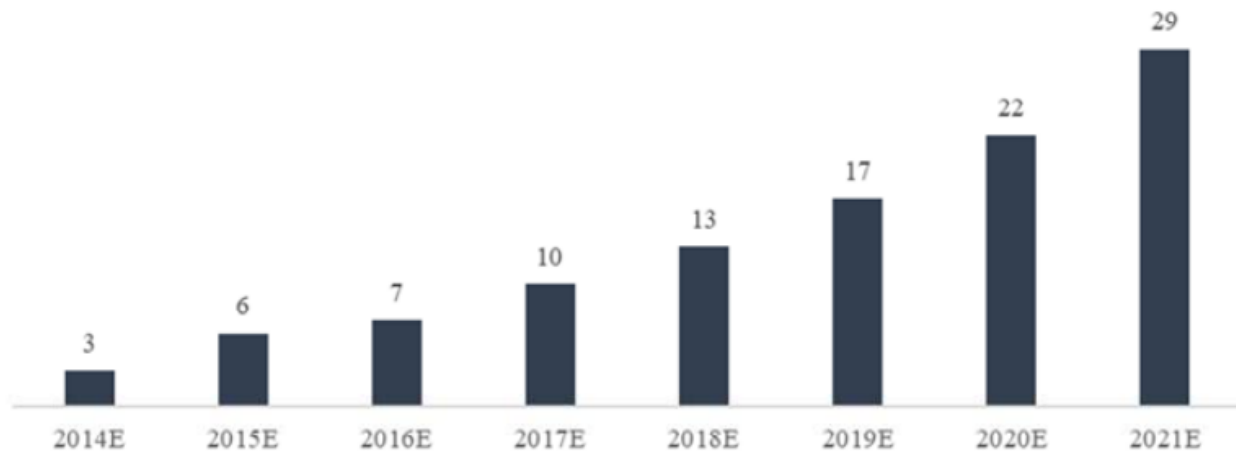


Figure 2 Forecast of drone cargo shipments from 2014 to 2021 (8)

The development of civilian remote-controlled drones in Taiwan began in the 1980s, mainly based on academic research, and the remote-controlled model aircraft industry was just starting out. At the time, the performance of remote-controlled communications and electronic technology was unsatisfactory, and technology research and development was full of bottlenecks. It was not until 2000 that, due to the rapid development of microelectronics, batteries, communications, control, photography, data processing and other technologies, remote-controlled drone research was implemented in the industry and gradually showed results. Since 2000, technological advances in many aspects have led to the development of the drone industry. According to the observations and contacts of this study, the overall technology of remote-controlled drones starts with the drone vehicle. Power, electricity and hybrid power are the core technologies, and flight control, sensing, payload and communication are integrated into one, allowing drones to demonstrate their ability to perform tasks (as shown in Figure 3). Since 2012, due to the rapid breakthroughs in brushless DC motors (BLDC), lithium polymer batteries (LiPo), electronic speed controllers (ESC), microcontroller units (MCU), and communication modules, multi-rotor drones with simple designs and easy controls have been transformed into communication electronic consumer products (3C) in a short period of time, and many drone applications have been extended.

For example: inspection of system facilities, aerial imaging operations, etc. The performance of multi-rotor aircraft varies greatly, and their ability to perform tasks is very different. The images and data obtained from aerial photography missions will need to be processed in depth to become valuable information. Therefore, remote control drone mission planning and post-

production of images and data captured from the air can greatly enhance the application value of drones.

This section mainly introduces the current status of the international and domestic drone industry, and combines the following five subsections to form a discussion on "Application of drones in the transportation field and policy promotion." When applying drones to the field of transportation, the first specific use is drone flight safety management. The second section of this article uses the drone flight management system establishment and civil aviation regulations of the International Civil Aviation Organization, the European Union, the United States and Taiwan to understand the system specifications and management mechanisms of the representative organizations or countries in drone flight safety management; the third section is the application of drones in the field of transportation in international or domestic practical literature, introducing application scenarios and specific operations in the fields of smart transportation, disaster prevention and relief, and logistics. The public sector of various countries has a demand for drone operations, both in China and abroad. Section 4 of this article uses the U.S. drone integration demonstration project as a benchmark to explain the cooperation mechanism between the U.S. public sector, national research and development departments, and industry. It then compares it with the current environment in Taiwan and explores the ways for the public sector and industry to cooperate through laws and regulations and actual operations. After understanding the domestic and international applications and regulatory management of the drone industry, Section 5 of this article will focus on the recommendations for Taiwan's drone industry development strategy, develop short-range and long-range policy recommendations from the perspectives of public sector demand, technology research and development, and flight operation management, and form the conclusion of Section 6 of this article.

2. UAV flight safety management

Since the safety management regulations of drones in various countries around the world are mainly based on the laws of each country, the maximum flight altitude of drones allowed by the laws of each country is an example: the drone flight altitude limit in Macau is 30 meters, the drone flight altitude limit in Singapore and Malaysia is 60 meters, the drone flight altitude limit in Hong Kong and Thailand is 90 meters; the drone flight altitude limit in Germany is 100 meters; the drone flight altitude limit in the United Kingdom, Spain, Australia and New Zealand is 120; Taiwan, the Philippines and the United States all have a maximum flight altitude of 400 feet (122 meters); the drone flight altitude limit in South Korea, Indonesia and Japan is 150 meters...etc. Although the management of drones varies from country to country, for the development of drone flight safety in low altitudes, advanced countries have made drone flight management a phased goal that must be achieved. This section will explain the drone safety regulations and unmanned aircraft systems traffic management (UTM) development of the International Civil Aviation Organization (ICAO), the Federal Aviation Administration (FAA) of

the United States, and the European Union Aviation Safety Agency (EASA), which formulates global flight operation regulations, as well as Taiwan's current industry-university research.

2.1 ICAO's Remote Control UAV Safety Management and UTM Development

ICAO established the Remotely Piloted Aircraft Systems Panel (RPASP) (4) to coordinate and develop ICAO Standards and Recommended Practices (SARPs), procedures and guidelines for Remotely Piloted Aircraft Systems (RPAS) to promote the safe, secure and efficient access of Remotely Piloted Aircraft (RPA) to non-segregated airspace and airport perimeters. In order to meet the needs of various countries for UTM, ICAO released the "UAV Flight Management" in 2019. UTM-A Common Framework with Core Principles for Global Harmonization

Core Principles for Global Harmonization), which defines UTM as follows:

Unmanned aircraft system traffic management (UTM). A specific aspect of air traffic management which manages UAS operations safely, economically and efficiently through the provision of facilities and a seamless set of services in collaboration with all parties and involving airborne and ground-based functions. ICAO defines UTM as the cooperation of all parties on the ground or in the air to provide facilities and ground functions to achieve safe, economical and effective management of drone flights. The "UAV Management (UTM) - Common Architecture of Core Principles for Global Coordination" published by ICAO mainly provides the architecture and core functions of a typical UTM system for countries that are considering implementing a UTM system. These countries need a common architecture to promote coordination among global UTM systems and enable related industries, including manufacturers, service providers and end users, to develop safely and efficiently without disrupting existing manned aviation systems. However, there are several components in the architecture of this document that have not yet been safely resolved, such as: the transition between UTM and ATM, the design and certification standards for UAVs, and the potential integration of UTM and ATM systems in high-altitude airspace.

2.1.1 UTM Implementation Architecture

In terms of the implementation principles of UTM, UTM is conceived as a subset of ATM. The operation of UTM aims to monitor and manage unmanned aerial systems (UAS) safely, economically and effectively, and provide facilities and seamless services of air and ground functions through cooperation with various units. The UTM system will deliver information through the synergy of integrated technologies, facilities and services, whether airborne, ground-based or space-based communications, navigation and surveillance functions. Therefore, the UTM system is envisioned to be interoperable and consistent with existing ATM systems to promote safe and efficient operations. A remotely piloted aircraft system (RPAS) is a subset of UAS. It consists of a remotely piloted aircraft (RPA), a remote pilot station (RPS), and a C2 link. These components must be interdependent to be approved as a system. In addition, RPAS must interoperate with ATC and airspace user systems. These three components are described as follows:

1. Remotely piloted unmanned aerial vehicle (RPA): Unlike traditional manned aircraft, the pilot is no longer in the aircraft, and the application of fuel and materials is different from traditional aircraft. The most obvious difference is the endurance. Other differences from traditional manned aircraft are: the launch and recovery system replaces the typical landing gear, wheels and brakes.
2. Remote Pilot Station (RPS): The RPS consists of equipment used to command, control and monitor the flight of the RPA
3. C2 Link (C2Link): Command and Control (C2) is the data link between the remotely piloted aircraft and the remote ground station. Used for flight management. There are multiple possible architectures and considerations for the design, security, and management of C2 links. The maintenance of C2 links can include two types: Radio Line-of-Sight (RLOS) and Beyond Radio Line-of-Sight (BRLOS), as shown in Figure 4. In order to facilitate international operations, the technical and performance requirements of RLOS and BRLOS C2 links need to be defined and agreed upon internationally, as follows:

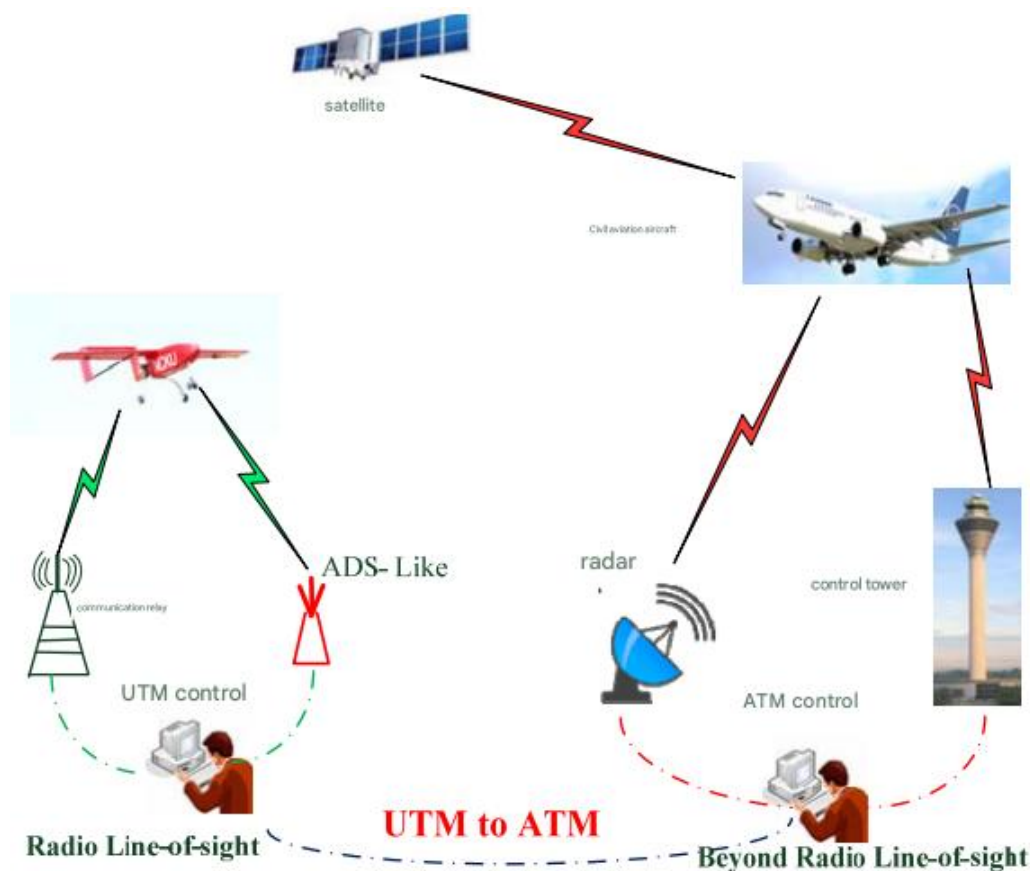


Figure 3 Controls covered by radio

(1) RLOS: refers to the situation where a radio transmitter and receiver are within the radio link coverage of each other and can therefore communicate directly or through a ground network, provided that the remote transmitter can complete transmissions and issue commands to the RPA via RLOS within a comparable time frame. UTM will be the primary link.

(2) BRLOS: refers to the transmitter and receiver not being in any configuration in RLOS. Thus, BRLOS includes all satellite systems, and possibly any system in which RPS communicates with one or more ground stations through a terrestrial network that is unable to complete the communication coverage capability within a time frame comparable to that of an RLOS system. ATM will be the primary link.

2.1.2 RPAS Operational Safety System

In addition to those components of the RPAS required to achieve physical flight, there are safety systems that are designed to meet operational needs, requirements and mitigate the chance of failure. The scope and complexity of an operational safety system will depend on the operational environment and its intended use. Items that are particularly important in instrument flight rules (IFR) operations include: sense and avoid warning systems, voice and data communications with ATC, and surveillance information provided to ATC, i.e. Pressure-Altitude Reporting Transponder (PART), Automatic Dependent Surveillances Broadcast (ADS-B) or Multilateration System (MLAT).

2.1.3 Detect and Avoid (DAA)

The RPAS sense and avoid (DAA) function is similar to the Traffic Alert and Collision Avoid System (TCAS) of manned aircraft and the requirement to remain alert to detect and avoid potential collision hazards. It is considered as a necessary basic function to realize the integration of RPAS system. RPAS DAA capabilities include the ability to detect and maneuver to avoid conflicts with manned and unmanned aircraft and other hazards such as obstacles, terrain and adverse weather, while maintaining alertness, determining effective avoidance maneuvers, executing the maneuvers and safely returning to the original path. These capabilities must be available to the remote flight operator so that appropriate decisions and actions can be made to ensure safe flight. However, if a failure occurs, for example if the C2 link is lost, the DAA system may need to respond automatically to ensure appropriate action is taken.

2.2 UAV regulations and UTM development in the United States

The Federal Aviation Administration (FAA) is the regulatory and safety management agency for drones in the United States. The regulations applicable to small drones under 25 kg (55 lb) are mainly 14 CFR PART 107-Small Unmanned Aircraft System (sUAS) [10] and advisory circular AC-107-2(11). With respect to the operating limitations of small unmanned aerial vehicles in section 107.51 of the regulation (§107.51), the operation of a small unmanned aerial vehicle system must comply with all of the following operating limitations (0);

1. The ground speed of small unmanned aircraft shall not exceed 87 nautical miles/hour (or 100 miles/hour, or 157 km/hour).
2. Small UAVs may not fly higher than 400 feet above ground level unless the small UAV: (i) is within a 400-foot radius of visual range of a building structure; and (ii) does not exceed the maximum height allowed by the building structure.
3. The minimum flight visibility observed from the control station shall not be less than or exceed 3 nautical miles. For purposes of regulation 107.51, flight visibility is the distance from a control station at which unilluminated flying objects can be seen and identified during the day and clearly illuminated flying objects can be seen and identified at night.
4. Minimum distance for small unmanned aircraft from clouds: (i) 500 feet below the cloud layer, (ii) 2,000 feet above the cloud layer.

Due to the diverse applications of remote-controlled drones, the airspace for operating drones in the United States is also regulated. In 2015, the National Air and Space Administration (NASA) proposed drone flight management.

The (UTM) concept of operation enables drones to operate in non-integrated airspace below 400 feet in the low altitude of civil aviation. Looking at the airspace classification in the United States, in order to safely accommodate manned aircraft and remote-controlled drones flying in different airspaces, ICAO currently divides airspace into six categories: A, B, C, D, E, and G. The uncontrolled airspace of Class G around airports ranges from the ground to an ultra-low altitude of 700 feet or 1,200 feet in other areas. Due to the high altitude close to the terrain, the radar coverage capability is limited, so aircraft flying in Class G airspace is not restricted. Aircraft operating in Class G airspace include commercial aircraft, light aircraft, helicopters, and hot air balloons. Remote-controlled drones can also operate in this airspace, and remote-controlled drones can also fly safely within visual line-of-sight (VLOS) and beyond visual line-of-sight (BVLOS) in Class G airspace. Based on its flight management and research and development experience, NASA is committed to low-altitude flight traffic safety. In 2015, it proposed the Concept of Operations (ConOps) of the UTM for the FAA. In this study, the goal is to achieve UTM that allows a large number of drones to fly in Class G airspace at the same time, avoiding and reducing the occurrence of flight safety accidents. NASA and FAA began working together in August 2015 to conduct UTM technical capability phase testing. As of the end of 2019, researchers have completed four phases of testing. As shown in Figure 5, the four technical energy phases of the planned research are: TCL1 for concepts and scenarios, TCL2 for information architecture for data exchange, TCL3 for location sensing and avoidance (DAA), and TCL4 for location tracking, communication and navigation (612). The following is an introduction to each phase:

UTM Technical Capability Level Progression



Figure 4 The four-stage planning and phased goals of the UTM UAV Technical Capability Level (TCL)[612]

1. Phase I Technical Capabilities TCL1: The UTM platform was built in August 2015 and as a starting point for the UTM platform, researchers conducted field tests to explore how drones can be used in agriculture, firefighting and infrastructure monitoring in the VLOS area. NASA researchers used different technologies to assist in safely flying drones, such as scheduling and the use of geo-fencing, and assigned safe flight areas to the drones used in this study.

2-operators operating the drones beyond visual line of sight (BVLOS). Initial validation, including: UAS service provider (e.g. Amazon and AirMap) technology and procedures, Geofencing Technology/Conformance Monitoring, Ground-Based Surveillance/DAA, Airborne Sense and Avoid, Communications, Navigation and Surveillance (CNS) and human factors associated with UTM data creation and display. In addition, performance indicators are defined and calculated based on flight data to establish a quantitative basis for comparison of flight test experiments and to provide potential indicators for routine monitoring in future UTM system operations.

3. Phase 3 Technical Capabilities TCL3: Spring 2018 focuses on building and testing drone avoidance technologies that will help drones fly at safe intervals within designated areas, allowing UAS to detect and avoid other drones in densely populated areas. This phase is beyond visual range flight, flying over areas with slightly higher population density, local interaction

with manned aircraft, and vehicle-to-vehicle position tracking through network connections. Limited package logistics delivery is allowed under public safety permission.

4. TCL4, the fourth phase of technical capabilities, is expected to begin in the spring of 2019 and will ultimately build on the results of TCL3. It will also test the integration of UTM systems to manage drone flights in more densely populated urban areas. Examples include testing package deliveries, infrastructure inspections, aerial photography, news gathering, public safety patrols and the study's first responder operations. This stage is still beyond visual range flight, and can fly in densely populated areas in urban environments, track locations, connect through the Internet and establish "vehicle to vehicle automation" (Vehicle to Vehicle), must have the ability to mitigate large-scale incidents, and can provide personal use for information collection and transmission.

2.3 European Drone Regulatory Management

In order to ensure the free flow of drones and a fair competition environment within the EU, the European Aviation Safety Agency (EASA) has formulated common European rules, applying the highest safety standards for manned aircraft in the air to drones. These rules are based on an assessment of operational risks and balance the obligations of drone manufacturers and operators in terms of safety, privacy, the environment, noise, etc. The new rules ensure that drone operators, both recreational and professional, will have a clear understanding of what is permitted and they will cover everything from those types of operations that do not require prior permission to those involving certified aircraft and operators, as well as minimum remote pilot training requirements. The EU's common rules are designed to foster investment and innovation in drones, and operators will be able to operate their drones seamlessly when travelling across the EU or conducting business involving drones in Europe. EASA published the revised version of the Acceptable Means of Compliance (AMC) and Guidance Material (GM) [13.14] of the General Rules for Unmanned Aerial Vehicles on October 9, 2019, which defined risk assessments for the first time. The explanation includes: the explanation of the assessment method called Specific Operation Risk Assessment (SORA) required in the revised version of the AMC and GM draft "Specific Categories" published in opinion 01/2018. EASA is using the first Pre-Defined Risk Assessments to assist operators in applying for specific types of operating authorizations (13). In the future EASA will publish other defined risk assessments to cover the most common operational risks occurring in the EU. The specific categories for this review include:

- Flying over sparsely populated areas;
- In uncontrolled airspace;
- In very low airspace;
- Beyond visual range flight with flight risk mitigation capabilities;
- The maximum characteristic size of the drone used is 3 meters.

In order to facilitate drone operations with lower risks, EASA also issued a declaration in October 2019 [15], proposing to amend the European Implementing Act to add two standard schemes. These two standard schemes will be amended by the European Commission through legislation and adopted after a vote by EU member states. Operators of drones will be allowed to send only a declaration to the relevant agency instead of applying for and waiting for authorization. The operating conditions are as follows:

1. Urban VLOS: Participants in the event will perform VLOS flights in densely populated areas, below 120 meters (about 400 feet), and the maximum characteristic size of the drone used is 3 meters.

2. Rural BVLOS: Use visual observation in sparsely populated areas, below 120 meters (about 400 feet), and the maximum characteristic size of the drone used is 3 meters.

In terms of airspace management, the Single European Sky ATM Research (SESAR) and the Joint Undertaking published the U-space blueprint in June 2017, which plans to implement highly complex drone operations in all types of environments in urban areas [16]. U-space emphasizes flexibility, encourages innovation to promote business growth in the European drone services market, appropriately addresses safety and security issues in the EU, respects citizens' privacy and minimizes the impact on the environment. Through the exchange of data and information, U-Space is highly automated and interacts with the environment (including the airspace environment and interface between manned and unmanned aircraft). The U-Space airspace blueprint is divided into 4 levels of service (see Figure 5):

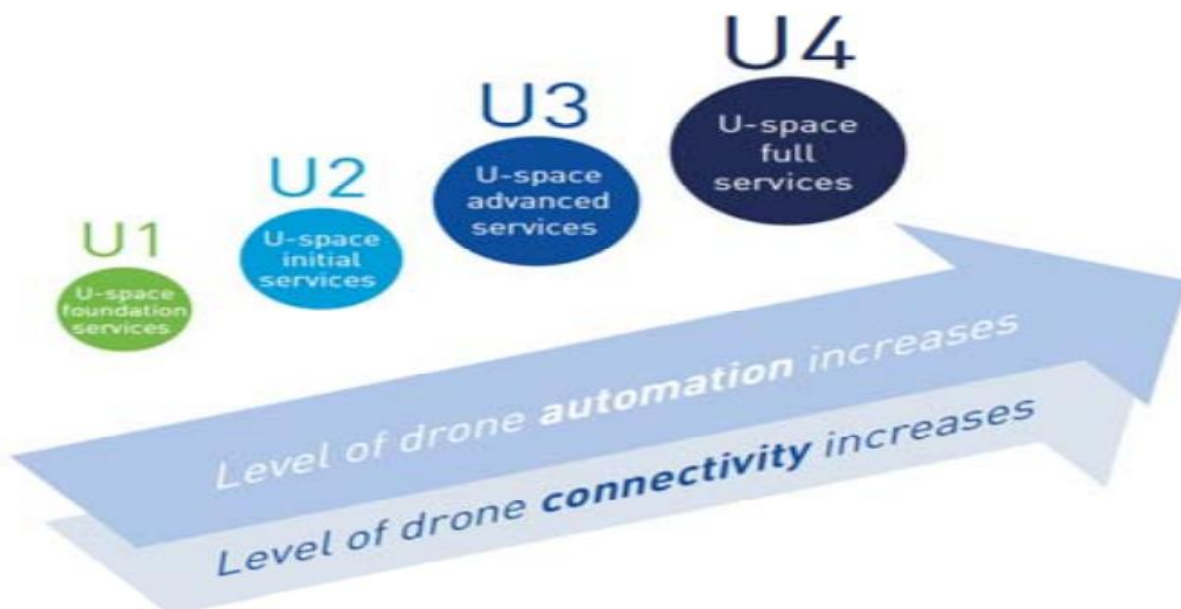


Figure 5: Four service levels of the European SESAR U-space blueprint (14)

1. U1: Foundation Services. Provide electronic registration, electronic identification and electronic fencing.

2. U2: Initial Services. Provide support for drone operations management, such as flight planning, flight permits.

3. U3: Advanced Services. Drone operations in densely populated areas include airspace capacity management, drone conflict detection services, and sense and avoid (DAA) services. 4. U4: Full Services. The drone airspace management service interface is fully connected with manned airspace. U4's services rely on high levels of automation, communication connectivity and digitization.

2.4 Taiwan's UAV Civil Aviation Regulations and the Development of Hierarchical UTM

The Civil Aeronautics Administration (CAA) of the Ministry of Transportation and Communications of Taiwan revised the civil aviation regulations and announced a special chapter on "remote-controlled drones" in the "Civil Aviation Act" on April 25, 2018. In 2019, it announced the "Remote-controlled Drone Management Rules" and implemented them on March 31, 2020. As a result, drones will be able to be used in more applications, such as logistics delivery, agricultural spraying, environmental monitoring, terrain monitoring and aerial patrols, power line inspections, bridge inspections, forest exploration, search and rescue, hurricane tracking, wildlife research and conservation, etc. [42] According to civil aviation regulations, small drones that may be used include multi-rotor aircraft, helicopters or fixed-wing aircraft, with a payload of several kilograms, a flight endurance of tens of minutes, and a range of several kilometers. The airspace below 400 feet is under the jurisdiction of local governments, and above 400 feet is under the jurisdiction of the Civil Aviation Administration. If the unit operating the drone is a legal person or public agency, it must hold a flight operator certificate and a drone inspection certificate before it can fly a remote-controlled drone with a maximum take-off weight that meets certain standards beyond visual line of sight (BVLOS). Therefore, opening up applications in the transportation field will inevitably face challenges in flight safety. It is necessary to establish a consensus among the general public and maintain the discipline and safety of remote-controlled drone flights. Regarding the examination institution for remote-controlled drone operator license, the Civil Aeronautics Administration of the Ministry of Transportation and Communications announced the draft "Regulations on the Entrustment of Remote-controlled Drone Inspection and Operator License Examination" on May 28, 2019. The Civil Aeronautics Administration began to conduct academic and practical examinations for civil servants' remote-controlled drone operator licenses at the entrusted institutions in August 2019, and officially implemented the remote-controlled drone operator license examination and drone inspection operations for the public on March 31, 2020.

2.4.1 Hierarchical UTM

From the aforementioned concepts of UTM in the United States and the European Union, it can be clearly seen that the international drone remote control and management are all focused on large, high-altitude, long-range mission drones, which may not only fly within their own national airspace, but may even cross over to connect with international routes. These studies focus

primarily on command and control (C2), establishing long-distance high-altitude command and control, such as the architecture shown in Figure 5. The investment cost required is extremely large, often tens of thousands of US dollars, which is not affordable for general small and medium-sized low-altitude flying drone service applications. These UTM systems built with command and control (C2) and the flight management technology of these drones are currently not as good as those of low-altitude drones. Drones in low-altitude areas are equivalent to flying blindly. Drone flights at lower altitudes will cover the largest number of drone flight operations. For example, the three major areas of transportation, namely mine protection and disaster relief, smart transportation, and logistics delivery, will provide medium and short-distance services in densely populated areas. Therefore, low-altitude flying drones will be the core mainstream of my country's development of the drone industry and applications.

Drones can be categorized by weight and thrust into multi-rotor or fixed-wing sizes. The command and control (C2) communications function is the primary means of flight operations within visual range (VLOS) and beyond visual range (BVLOS). Small unmanned aerial vehicles (sUAVs) are expected to be available in airspace below 400 feet outside urban or suburban areas to provide mission flights for various applications (17). The entry of drone systems into UTM will eventually threaten manned aircraft ATM. For large, high-performance, long-range fixed-wing drones, UTM will inevitably be integrated into the converged airspace and combined with ATM.

It adopted a system framework similar to manned aircraft ATM, and quoted communications, navigation, and surveillance (CNS) as the basis for the management of unmanned aerial vehicles and systems (UAV/UAS). In terms of the communication devices required for the monitoring of unmanned aerial vehicles, this UTM system proposed a communication infrastructure based on automatic data transmission surveillance (ADS-B Like) technology, and introduced mobile communication 4G/LTE (Long Term Evolution), XBee, LoRa (Long Range Wide Area Network) and the Automatic Packet Reporting System (APRS) used by amateur communication players and volunteer firefighters for small unmanned aerial vehicles [18]. In the development of UTM [2], airspace below 400 feet is under the jurisdiction of local governments, and airspace above 400 feet is under the jurisdiction of the Civil Aviation Administration. The hierarchical UTM will be developed into regional UTM (RUTM) and national UTM (NUTM) based on the same construction foundation, which are used in different procedures at the local and national levels to facilitate hierarchical management operations (20).

Among the many drone implementation plans, UTM's monitoring function is obviously the most important one. An effective reporting communications technology infrastructure and legally available frequencies are the most important keys to understanding UTM data reporting. The UAS DAA system in the UTM system will adopt the navigation situation warning and air collision avoidance (TCAS) in the "Automatic Reporting Surveillance-Broadcast" (ADS-B) system similar to that developed for manned ATM [21,22]. The development of DAA adopts a

concept similar to the TCAS separation bubble (23), which allows drones to have a protective circle as a protection mechanism. The hierarchical UTM system will demonstrate prototype capabilities for monitoring and managing unmanned aerial vehicle systems built on a “quasi-Automatic Reporting Monitoring” technology infrastructure, and will also demonstrate mid-air collision avoidance (18).

The Ministry of Science and Technology's industry-university cooperation project - "Hierarchical Remote Control UAV Flight Management (UTM) System Prototype Development Project" will carry out the design, development, construction, and testing and verification of hierarchical UTM operating system software and "Automatic Display Surveillance-B Like" communication hardware technology to provide complete monitoring and management of drone systems. Chunghwa Telecom Research Institute will support the development and integration of software technology. Table 1 is a functional comparison between UTM and ATM. According to the concept of their project, UTM and ATM are student systems.

2.4.2 Hierarchical system architecture

The hierarchical UTM system will be divided into regional UTM (Regional UTM, RUTM) under the jurisdiction of local governments at low altitudes, and national UTM (National UTM, NUTM) under the jurisdiction of the Civil Aviation Administration at high altitudes, according to the Civil Aviation Administration regulations. Each has its own responsibilities.

ATM/ATC	UTM
Aircraft Log-in	UAV Log-in
Pilot Log-in	Pilot Log-in
NAS flight plan	Waypoint path plan
Cruise altitude	<400 feet RUTM
5000feet~400FL	>400 feet NUTM
CPDLC VHF	Voice 4G/LTE
Communication HF/ VHF/UHF/SATCOM	No pilot-in-the-loop C2 from GCS
Navigation GPS/INS/VOR/Fix	Navigation GPS/INS/Autopilot
Surveillance SSR/ADS-B	Surveillance ADS-B Like
TCAS/GPWS	UTM-based DAA
ATC handoffs	No Handoff in RUTM Handoff to NUTM
Flight plan change to ATC by RQ	Not allow to change flight route

Table 1: Comparison of UTM and ATM functions

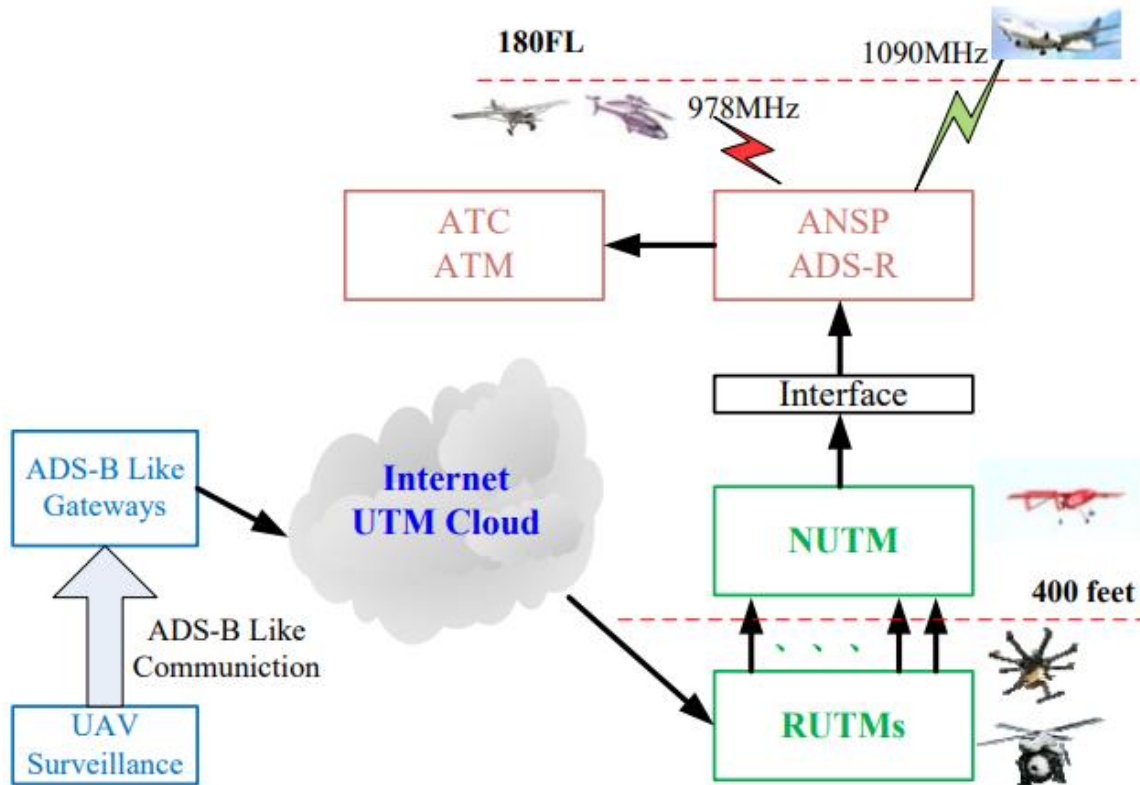


Figure 6:UTM hierarchy management into ATM architecture

The application of drones will be quickly and comprehensively introduced into society and will be close to people's daily lives. Therefore, in addition to actively developing safer and more mature drone manufacturing and flight control technologies, advanced countries are more prudently planning how to make drones fly safely. Therefore, UTM has become a necessary preparation before allowing legal drone flights. The research and development and implementation of UTM technology are important topics in aviation safety management. What worries civil aviation authorities the most is how to ensure sufficient coordination between the flights of UAVs and manned aircraft, and how to allow UAVs to enter the manned airspace NAS from UTM and be managed by ATM. It is a necessary architecture. The plan proposed in this paper is shown in Figure 7, which clearly draws a high degree of distinction. UTM adopts a system concept similar to ATM, designs a hierarchical UTM system, connects UTM to ATM, and enables the flight management of manned aircraft to achieve effective and transparent information flow and conflict resolution. For the transportation application of drones, the research and development of UTM technology is necessary to surpass various drone technologies.

3. Application of drones in the transportation field

The performance of drones lies in their vehicle performance from a commanding vantage point. In a good communication environment, they can achieve the monitoring function of fast

movement and image transmission when paired with photographic equipment. As long as the rocks fall and hit the protective net, a signal will be transmitted back and a warning will be issued. In addition to applying drone systems to risk prevention, the Highway Administration also uses drone aerial photography systems to transmit images of the collapse back to decision makers during post-disaster highway inspections, such as after earthquakes, wind disasters, and heavy rains. Compared with the method of personnel surveying disasters, this improves personal safety and work efficiency.

3.1 Smart Transportation Field

In recent years, the application of drones in the domestic transportation sector has become very common. For example, drones are used to collect traffic data on capacity and service levels at the confluence area of expressways or freeways, and to collect and analyze aerial images of the affected areas; or drones are used to take aerial images of the flow of people and vehicles at conflict intersections, and image analysis technology is used to identify high-risk accident areas and potential problems of human-vehicle conflicts. Drones are applied in traffic observation technology, specifically in the form of vehicle image recognition and tracking to provide judgment information for the traffic conflict analysis platform [2]. Prior to 2008, the drones used for traffic surveillance in the United States were primarily fixed-wing drones, which were developed primarily for military use and then converted to civilian applications as a tool for traffic surveillance (23). Fixed-wing UAVs have the advantages of high speed, high payload and longer cruising capability. Srinivasan et al. proposed the Airborne Traffic Surveillance System (ATSS), which is a framework for obtaining traffic information using drones. The Florida Department of Transportation (FDOT) subsequently conducted a Proof of Concept (POC) study on ATSS, under which drones were deployed to collect video data and transmit the data along the flight path to a ground station, which then distributed the real-time data to the appropriate traffic management center, where the information was analyzed for traffic management purposes.

As the number of drones has skyrocketed, the Drive Ohio Drone Center in Ohio, USA, invested \$5.9 million in a three-year study in June 2018 (2). It is collaborating with the College of Engineering at Ohio State University to study how to safely deploy and manage drones in the originally crowded low-altitude airspace. The low-altitude drones will be used together with the current fixed-position traffic camera system in the United States to monitor traffic and respond to traffic incidents along the 35-mile U.S. 33 Smart Mobility Corridor between Dublin and East Liberty. Sensors and communication equipment will provide UAS detection and tracking data to the Ohio Department of Transportation's Traffic Management Center for record and analysis. Unmanned aerial vehicle management (UTM) solutions will enable the Ohio Department of Transportation (ODOT) to respond to roadway conditions more quickly and effectively(2).

Small planes and helicopters using low-altitude airspace at the same time may come close to collisions, but the UTM system controlled by DriveOhio's Drone Center ensures that drones do

not collide with each other or get close to manned aircraft. The Federal Aviation Administration (FAA) estimates that commercial and hobbyist purchases of UAS will reach 7 million UAVs by 2020. Under the FAA's drone management plan, there are no pilots on drones, and an integrated surveillance system consisting of radar transceivers must be built, with powerful signal processing in the back end to track and filter all targets in the area of interest. With a proper dynamic UTM solution, the FAA can be provided with a safety reason to operate above personnel and beyond visual range. The UTM system needs to consider airspace planning, traffic flow management, determined flight corridors, UAS flight management around pop-up restricted areas, weather conditions or environmental hazards, congestion management, path planning and collision avoidance, etc.

3.2 Disaster prevention and relief

Natural disasters include four types: (1) Geophysical: such as earthquakes, tsunamis, volcanoes, landslides and avalanches; (2) Hydrological: such as flash floods, debris flows and floods; (3) Climatological: such as extreme temperatures, droughts and wildfires; (4) Meteorological: such as tropical storms, hurricanes and heavy rainfall. In terms of the application of drones in natural disasters, drones are combined with Wireless Sensor Network (WSN) technology to assist in disaster detection, assessment and response (Prediction, Assessment and Response). The application of drones in disaster management, according to Erdelj, et al. [33]

Six applications are summarized:

1. Monitoring, Forecasting, and Early Warnings: Using environmental and structural monitoring and analysis, drones can serve as Early Warning Systems (EWS).
2. Disaster Information Fusion and Sharing: Drones can combine different information sources or act as a bridge to provide different information technologies to support other application management during disasters. For example, when a building collapses after an earthquake, drones can be used to capture images from different angles to create a 3D perspective view, which can speed up the path planning of building rescue operations.
3. Situational Awareness and Logistics and Evacuation Support: When a disaster occurs, drones can help collect information about the disaster area, especially about the movement of people affected by the disaster and the deployment of rescue teams.
4. Standalone Communication System: When a disaster occurs, drones can replace and rebuild damaged or destroyed basic communication facilities.
5. Search and Rescue (SAR) Missions: Drones can search and rescue disaster victims or animals that are missing, injured or trapped in rubble.
6. Damage Assessment: Drones can be used for damage assessment in different ways, such as structural safety monitoring and drone video dynamic imaging inspection.

In addition, drones can also provide the following three disaster management applications, which can more effectively carry out related operations when disasters occur:

1. Media Coverage: Drones can provide timely reporting information to viewers, and conversely provide disaster area information to rescue teams.
2. Medical Application: When a disaster occurs, even if the transportation infrastructure is damaged or the roads are cut off, professional drones can provide necessary supplies to sustain the lives of victims within the limits of their effective weight capacity.
3. Infrastructure Reconstruction: Using drone networks can speed up inspections and improve efficiency and accuracy during infrastructure reconstruction.

· The latest developments in energy storage, computing power and drones Wireless Sensor Networks (WSN) and multi-drone systems play an important role in disaster management. During the critical moments when search and rescue personnel are saving lives in natural disasters, the most effective way to obtain the fastest situational awareness is through aerial observation and assessment, because drones can quickly reach the disaster area and take images and videos of the current situation in the disaster area. Among the applications of WSN and multi-rotor UAV systems in disaster management, WSN and multi-rotor UAV systems are divided into three categories in different application areas: monitoring, response and prediction. This classification is roughly completed after the disaster management stage. The application refers to prevention and preparation, the response refers to disaster response and recovery, and the monitoring scope includes the entire disaster cycle, because these applications provide disaster information, which is the main goal basis of disaster management at all stages. The applications of WSN and Multi-UAV technologies in disaster management are as follows:

1. Monitoring, forecasting and early warning systems
2. Disaster information integration and sharing
3. Situational awareness, logistics and evacuation
4. Independent communication system
5. Search and rescue missions
6. Damage Assessment

Chen, et al. described an early warning system for natural disasters that relies on currently available WSN technology (35) and focuses on providing reliable data transmission, significant data volume from heterogeneous sensors, and minimizing energy consumption. In addition to dynamic routing, network recovery and methods to manage mobility for reliable transmission, the system also uses a data fusion method to integrate all acquired data into a unified geohazard overview. Frigerio, et al. designed a web-based platform solution for automatic and continuous monitoring of the Rotolon landslide in the eastern Italian Alps [3]. The monitoring system integrated dual-field sensors to monitor the displacement of the landslide and trigger an alarm in the event of a debris flow.

Farfaglia, et al. introduced the Advanced System to Monitor the Territory (SMAT), a system that uses multiple drones for civilian surveillance operations. The project assumes the use of different types of drones for surveillance, ranging from micro-multirotor drones to light fixed-wing

aircraft. These drones in the SMAT system can be equipped with different sensors required to collect data for monitoring floods, earthquakes and volcanoes[37]. Feng, et al. proposed a flood monitoring system using data obtained from drones[*]. The high-resolution images obtained from drones need to be processed to detect areas that may be flooded. The system performs several stages to achieve this goal: (1) UAV data acquisition and preprocessing; (2) feature selection and texture analysis; (3) image classification; and (4) accuracy evaluation. The authors used a Random Forest Classifier to classify the regions and achieved a high accuracy rate (87.3%).

Information fusion during disasters is necessary and helpful in all aspects. Its most relevant impact is in the disaster management stage, and practical information can be obtained in the disaster response stage.

3.3 Logistics and transportation field

The “last mile” of delivering packages to customers’ doorsteps is the most expensive and inefficient part of the package delivery process (4). Many companies are exploring the use of drones to accelerate the last mile, smoothly deliver packages to customers, and reduce delivery costs. E-commerce companies hope to shorten delivery times and costs, improve customer satisfaction and loyalty, while traditional retailers seek the same advantages to increase online sales. Drone logistics companies are exploring two main types, such as domestic drone logistics transportation and supply chain transportation. As regulations are implemented and drone technology improves, drone logistics delivery will be carried out in stages and regions in the next few years. Currently, most tests are very limited in scope and take place in rural and suburban areas, and packages are not actually delivered to customers' doorsteps. As the tests progress, drone logistics will carry objects and packages to densely populated areas.

According to a survey conducted by BI Intelligence on the scope of drone logistics services for Walmart's potential customers in the first quarter of fiscal year 2017 (43), as shown in Figure 8, the maximum delivery distance of this business is within the range of 4-6 miles (approximately 6.44-9.66 kilometers), and the business volume accounts for 49% of the project (approximately US\$1.3916 million, with a total business volume of US\$2.84 million). The survey shows that the business volume with a delivery range of more than 20 miles (approximately 32.19 kilometers) is 22% (approximately US\$624,800), ranking first among the business volumes of many delivery distances, followed by 0.52-2 miles (approximately 0.84 kilometers to 3.22 kilometers), with a business volume of 18% (approximately US\$511,200), and the third-ranked delivery distance is 2-4 miles (3.22 kilometers to 6.44 kilometers), with a business volume of 17% (approximately US\$482,800).

Vlahovic, et al. proposed a conceptual model for implementing logistics delivery business processes using drones, which is a business-to-business logistics delivery operation based on the pharmaceutical supply chain. The business scenario uses a reasonable cost calculation structure to make drones economical.

This section reviews the domestic and foreign literature on the application of drones in the field of transportation, including smart transportation, disaster prevention and relief, and logistics. The supporting measures or technical support that help drones extend their functions and achieve their missions are listed below:

1. Information integration of advanced wireless communication technology and wireless sensor networks: used as a platform for information and image circulation, transmitted in normal times or disasters, and supported by multiple basic backup systems.
2. Unmanned aerial vehicle flight management system (UTM) reduces flight safety risks: In response to the increasing frequency of drone business, flight safety management in low-altitude areas is necessary. The regional flight management center of the local government is connected to the national flight management center through real-time messaging, and a full range of monitoring and avoidance isolation is formed with the national airspace system management unit to reduce the occurrence of flight safety risks. This is the function of the full combination of UTM and ATM.
3. Cooperation mechanism between the public sector and the industry: The public sector's demand for drone operations and the drone technology provided by the industry, the determination of the airworthiness of certificates and the suitability of operations, in addition to complying with the requirements of civil aviation regulations, the public sector's use of drones for overall operations should be reviewed by a third-party independent unit to conduct operation matching and qualification certification, such as complex transportation operations in logistics transportation, the suitability of complex transportation, the verification, registration and airworthiness of drones, and the validity of the operator's certificates. Use the needs of the public sector to promote the full implementation of drone applications, release administrative resources, and cooperate with the industry to achieve the expected goals.

4. Implementation and planning of drone integration demonstration

4.1 Integration Pilot Program (IPP) in the United States

Since 2017, the United States has launched the UAS Integration Pilot Program (IPP) (47), which brings together some state, county, and local governments in the United States and private sector entities such as UAS operators or manufacturers to accelerate the safe integration of drones. The program will help the U.S. Department of Transportation (USDOT) and the Federal Aviation Administration (FAA) develop new drone rules to support more complex low-altitude operations and achieve the following goals:

1. Define ways to balance local and national interests in the drone integration process;
2. Improve communications with local, state, and county jurisdictions;
3. Address the safety and privacy risks of drones;
4. Expedite approvals for drone operations that currently require special authorization.

With respect to the integration of drones, the program has balanced local and national interests, enabled meaningful dialogue, and provided the Department of Defense with actionable

information on the expansion and integration of drones into the National Airspace System (NAS). IPP lead participants are evaluating a range of drone operational concepts, including night operations, flights beyond the pilot's visual line of sight (BVLOS), logistics package delivery, drone sense and avoid (DAA) technology, and the reliability and safety of data links between pilots and drones. The project brings application opportunities to the drone industry.

The following is an IPP program implementation method to examine the application of drones in infrastructure inspection. Companies applying for IPP must have the following basic integration technology capabilities:

1. Develop and implement geo-fencing;
2. Alert drone manufacturers of hazards or flight restrictions (including prohibitions if necessary);
3. Detect and Avoid Ability (DAA);
4. Beyond visual line of sight (BVLOS);
5. Night work;
6. Flying above the crowd;
7. Simultaneous operation of multiple small drones;
8. Unmanned aerial vehicle management (UTM);
9. Use advanced UAS technology to improve or protect privacy.

An example of IPP application of drones in airport facility inspections is the Memphis Airport Integrated Demonstration Project (IPP) team in Tennessee, USA, which will use the Falcon 8+ drone to conduct research to inspect runways, taxiways and fences. The Tennessee IPP team is the only one conducting airport inspection testing. For fence inspection and runway foreign object inspection missions, including checking for damage and debris on runways and taxiways, it is critical that drone runway inspection and fence inspection functions are integrated into the airport control system center. Memphis Airport's partners include the City of Memphis, Memphis Fire Department, Memphis Police Department, FedEx, AgriCenter International, University of Memphis, Tennessee Department of Air Transportation, GE subsidiaries AirXOS and Avitas, Intel, Flirtey, 901Drones and ForeverReady Productions. Since August 2018 to February 2019, partners in the program have successfully conducted 127 drone flights. The flights were part of Phase 1 of the Low Risk Area Development and are designed to help develop operating procedures, assess potential impacts, develop airport and team member communication protocols, and determine the operational reliability of small drones that could be used at Memphis International Airport.

4.2 Taiwan Unmanned Vehicle Innovation Experiment Regulations

In order to promote the trend of unmanned vehicle experiments and promote the synchronous development of Taiwan's unmanned vehicle technology with international technology, the Ministry of Economic Affairs has introduced the spirit of "supervision sandbox" and formulated the "Unmanned Vehicle Technology Innovation Experiment Regulations" to allow experimenters

to conduct innovative unmanned vehicle experiments in an environment where risks can be controlled. This regulation has been announced in 2018 and applications will be accepted starting October 25, 2019. Applicants for unmanned vehicle experiments may include individuals, sole proprietorships, partnerships, or legal persons (including corporate entities). The types of unmanned vehicle experiments applied for include self-driving cars, drones, and self-driving boats. The review of experimental plans is conducted on a first-come, first-served basis, and the longest review period is 60 days from the date of acceptance, the day after the documents are confirmed to be complete, and a letter of review results must be sent. In principle, the implementation period of the innovation experiment plan is limited to one year, and it can be extended in accordance with Article 9 of the Unmanned Vehicle Technological Innovation Experiment Regulations, but the total innovation experiment period shall not exceed four years. Applicants should explain the innovativeness of the experimental content, the items excluded from the regulations, the description of the completed simulation analysis or closed field experiment, the safety of the vehicle/device, the response measures to the potential risks of the experiment, the relevant protection measures, and the insurance plan in the plan. After completing the application form and the plan and other related documents, the applicant can mail or personally deliver them to the Ministry of Economic Affairs' Technology and Engineering Department.

By focusing on the application of the Integrated Pilot Program (IPP) of UAVs in the United States, combining it with the application of the Unmanned Vehicle Innovation Experimentation Regulations in the industry in Taiwan, and comparing it with the cooperation between the public sector and the industry in Taiwan - "Using UAV operations in conjunction with the application of the IPP system", we can focus on the following directions:

1. IPP system establishment: The Ministry of Transportation's transportation think tank unit will undertake the establishment of the IPP system (such as the Ministry of Transportation's Transportation Research Institute) to facilitate the acceptance of UAV operation requirements, field testing, safety risk assessment, etc. proposed by the Ministry of Transportation's public departments.
2. IPP operation establishment: The Ministry of Transportation's Transportation Think Tank will work with professional certification agencies (such as technicians' associations, quality control associations, drone associations, etc.) to review drone contracting companies using a grading system. Companies that pass the professional qualification review will be awarded the bid, and then KPI (Key Performance Indicators) operating procedures will be established based on public sector needs.
3. IPP UAV Qualification Certification: The IPP mechanism established by the Ministry of Transportation's Transportation Think Tank will provide appropriate certification to companies that have achieved IPP integrated demonstration verification as supporting evidence for the most favorable bids used in bidding. The certification of IPP operations will be carried out in

conjunction with a public sector working group, which will include representatives of public sector demand units. In the drone qualification part of the contracting company, it is divided into three categories:

- (1) Basic qualification certification: personnel certification, technical equipment inspection, and the management of UAV verification, registration and operation license testing in accordance with civil aviation regulations.
- (2) Technical capability certification: The essential learning and ability level of the contractor's UAV professional field operations is graded, and then qualification certification and IPP subsequent KPI measurement are carried out.
- (3) Integrated Demonstration Effectiveness Certification: For the integrated demonstration project contracted, the performance and overall results of the project execution status evaluation, the potential ability of the technical content adopted in the implementation plan, the comprehensive evaluation of the technical personnel's capabilities, and the benefit evaluation of the use of drones will be given appropriate rating certificates.

5. Suggestions on the development strategy of the drone industry

The development of drones in my country should be guided by the needs of government departments, release the demand for the use of drones in government affairs across departments, and drive the domestic drone industry and applications. In terms of promotion strategy, it will be demand-oriented, using the "Integrated Demonstration Plan (IPP)" in the transportation field to promote the development of the drone industry, and actually promote high-level technical integration across ministries and scientific research and development, and can also be marketed internationally and look to the world. In terms of technical support, it is necessary to establish a national team (UAV Team) to combine industry, government, academia and research to establish a UAV R&D base to implement technological advancement, attract the attention of leading foreign manufacturers, and establish international cooperation and product marketing. In order to make the development of drones more perfect, improve the implementation and management of drone regulations, and further cultivate management talents to ensure flight safety.

5.1 Public sector demand-oriented policy formulation and investment

Government departments mainly focusing on transportation, economy, internal affairs and agriculture need to formulate a win-win strategy to promote the application of drones.

Entering the international market, as shown in Figure 9, innovating in application levels, introducing advanced technologies, and realizing that drones can save costs, improve operational efficiency, expand business scope, and ensure the safety of workers involved in high-risk activities. In the field of transportation, we will develop smart transportation, logistics delivery, unmanned transportation, etc.; in the field of internal security, we will develop drone application technologies such as disaster prevention and relief, police, firefighting, land, environmental protection, air search, and maritime patrol; in the field of smart agriculture, we will use drones to invest in precision agriculture, smart services, and plant species identification to increase

agricultural returns; in the field of economic industry, we will deepen drone manufacturing technology, invest more in service contracting, introduce artificial intelligence and big data analysis, and establish the economic output value of drones. How to achieve technological excellence? Academic research, technological development and industrial investment are all necessary infrastructure to achieve international standards and challenge higher technological achievements.

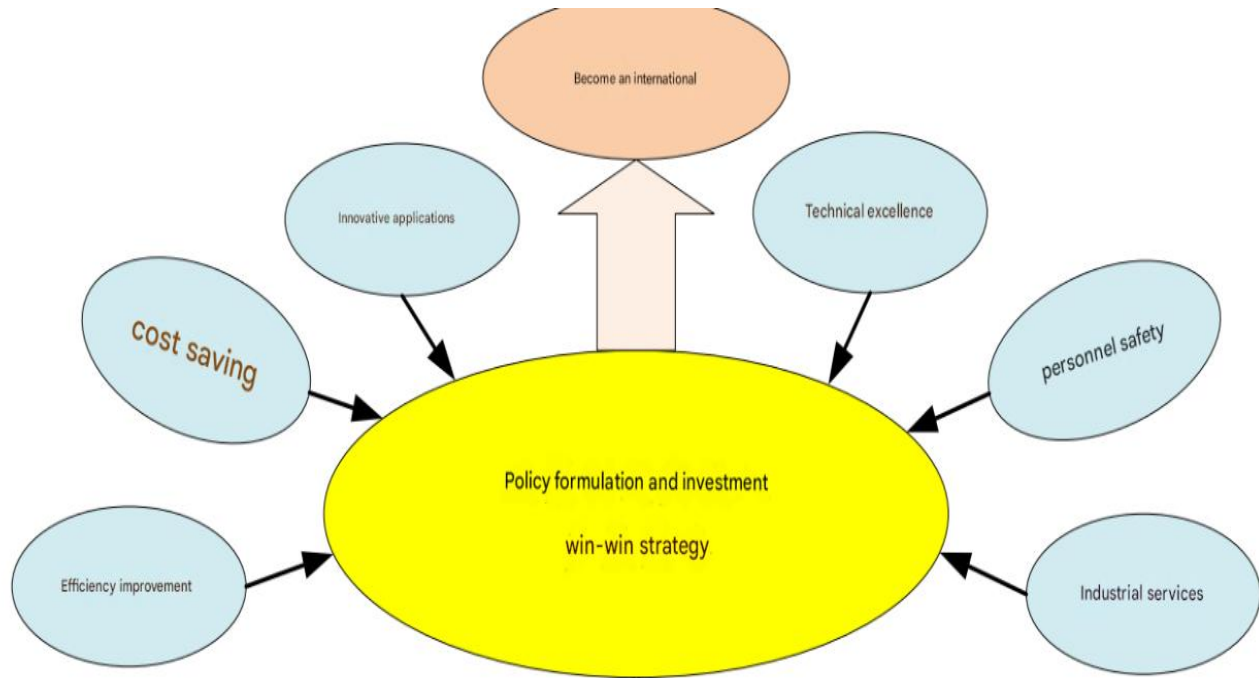


Figure 7 Policy formulation and investment in drones

5.2 Research and Development of UAV Micro-Components Technology

The development of the UAV industry focuses on the R&D and manufacturing capabilities of micro-component technology. As shown in Figure 10, we should cultivate cooperation among industry, government, academia and research to establish a complete national-level UAV technical team. In line with the policy direction and core suggested in Figure 9, we should complete the manufacturing of composite materials and mechanisms, the design and manufacturing of motor power and electronic transmission components, the design and construction of inertial and attitude sensing component technology, innovative high-performance batteries, broadband communication systems, and ground control stations. We should implement application systems that are suitable for the short- and medium-term planning goals of our country's 25kg-class UAV industry. The government should release the demand and promote the domestic UAV industry to achieve the "integrated demonstration plan" in various application fields, so that the application of UAVs can be popularized in the people's livelihood and social environment, bringing safety and convenience.

5.3 Research and Development of Passenger UAVs

The international research and development trend of drones is similar to that of self-driving cars. The idea of developing manned unmanned air taxis will be a revolutionary development plan for the whole world. Although aviation regulations and technologies are not yet in place, with the development of drone micro-technology and national civil aviation regulations, passenger drones will inevitably become a major challenge in the transportation sector of advanced countries. It is estimated that 2030 may be a breakthrough year. my country's drone research and development and industry should not lag behind the world's level, and must continue to move forward in the direction of research and development in multiple fields of drones. As shown in Figure 11, in order to achieve the technology of manned drones becoming air taxis, it is necessary to mature and use technologies such as high-performance micro components, high-efficiency batteries, hybrid power systems, high-payload drone systems, pilot-in-the-loop ground control systems, drone flight management (UTM), broadband communications, autonomous navigation and automatic driving, and the establishment of exclusive air corridors, as well as integration into the flight management system (ATM) of manned aircraft. These will be the necessary conditions for guiding manned unmanned aerial taxis to successfully take to the road and for civil aviation regulations to be successfully released.

5.4 Implementation of UAV Flight Management System

Looking at the safety management of drone flights in advanced countries, it has progressed to the point where drone flight operations are included in the drone flight management system (UTM) for unified monitoring and management, so that drone flights can meet safety standards. Drones entering the National Airspace System (NAS) where manned aircraft fly will have to be integrated with the flight management of manned aircraft in the future. Therefore, UTM entering ATM is an extremely demanding challenge. The prerequisite is that the construction of UTM must be mature and reliable, and have a fully functional monitoring and management mechanism. As shown in the schematic diagram of UTM entering ATM system in Figure 12, refer to the system architecture in Figure 7.

The application and development of drones requires the establishment of a national team's collective strength. The public sector should provide opportunities for integrated demonstration implementation, allowing the industry to engage in more appropriate practical experience to achieve substantial results in the application of drones in the transportation field. We will expand the advanced development of the entire drone industry structure from the results of people's livelihood applications, squeeze into the international competition with the status of a national-level team, establish higher technological achievements and stronger drone production capacity, and achieve the goal of safe and secure flight for both micro components required for drones and manned aircraft under effective and safe drone flight management operations.

6. Conclusion

The development of drones has entered a mature and usable stage. my country's drone production, government, academia and research are all actively participating in the race to catch

up with this wave of industrial technology. However, the development of the entire drone industry requires the support of policies from relevant government departments, as well as pragmatic actions to promote the implementation of drones. In terms of the research, development and application of drones, there are many very advanced and forward-looking ideas internationally, such as manned unmanned aerial taxis, which will break through the constraints of regulations and are the goals pursued by many international leading companies. In any case, safety is a universal value, and the reliability and safety of drones remain the basis for civil aviation regulations and the first line of defense to protect stakeholders. In terms of the industrial development of drones, to establish a complete economic scale for drones, we must first plan a roadmap plan for our country, backed by the needs of government departments and develop step by step, so that we can have the concrete energy to build successfully.

With the Ministry of Transportation as the core, in 2020, we will integrate industry, government, academia, and research to form a national drone team to carry out advanced planning for technology and industry. In a cross-departmental manner, we will combine the core technology research supported by the Ministry of Science and Technology and the development and construction of the leading industry of the Ministry of Economic Affairs to enable users to move towards a safe and stable drone application environment.

The application of drones in transportation must respond to the needs of relevant public departments, starting from the fields of smart transportation, disaster prevention and relief, and logistics, and then with the assistance of the Ministry of Economic Affairs, establish industry supply, and start from 2020 to carry out "integrated demonstration plans" in various fields, complete technical verification and application field operation certification, so as to promote a complete drone industry system integrating production, sales and services.

We will establish R&D and supply capabilities for micro-components, match the market size of domestic drone application demand, establish a completely independent industrial economic system by 2025, and take 2030 as the goal to participate in the international development of manned unmanned aerial taxis, enter the international competition arena, and demonstrate the technical capabilities of the national team. Taiwan should

Starting from the innovative experimental regulations, with the specific action of solving the needs of the public sector, we will develop high-end drone industry and technology from the aspects of technology research and development and civil aviation regulations.

In the future, drone flight activities will be integrated with the National Airspace System (NAS) interface of manned aircraft and will operate together. It is expected that a more active UTM development role will be played, so that drone flight management (UTM) and manned aircraft flight management (ATM) can be integrated into one to ensure flight safety, maintain the ecological system order of low, medium and high airspace, and reduce flight risks.

Reference

1. Amorim, R., Nguyen, H., Mogensen, P., Kovács, I. Z., Wigard, J., Sørensen, T. B., "Modelado de canales de radio para comunicaciones UAV a través de redes celulares", IEEE Wireless communications letters, vol. 6, n.º 4, 2017, págs. 514-517.
2. Organización de Aviación Civil Internacional (OACI), Manual sobre sistemas de aeronaves pilotadas a distancia (RPAS), Doc 10019, AN/507, 1.ª ED, Canadá, 2015.
3. OACI, Sistemas de aeronaves no tripuladas (UAS), Circular 328, AN/190, Canadá, 2011.
4. OACI, "Concepto de operaciones del sistema de aeronave pilotada a distancia (RPAS) para operaciones IFR internacionales", 2017.
5. Aweiss, A. S., Owens, B. D., Rios, J. L., Homola, J. R., Mohlenbrink, C. P., "Campaña formativa II sobre gestión del tráfico de sistemas de aeronaves no tripuladas (UAS)", Instituto Americano de Aeronáutica y Astronáutica, Kissimmee, Florida, 2018.
6. Kopardekar, P., Rios, J., Prevot, T., Johnson, M., Jung, J., Robinson, J. E., "Concepto de operación del sistema de gestión del tráfico aéreo no tripulado (UTM)", 16.ª Conferencia sobre tecnología, integración y operaciones de aviación (ATIO) de la AIAA, Washington, DC, 2016.
7. Statista, "Inversión en hardware para drones en todo el mundo por segmento de 2015 a 2021 (en miles de millones de dólares estadounidenses)", <https://www.statista.com/statistics/689143/investment-in-drone-hardware-worldwide/>, 2017.
8. Media, A., "El mercado de drones muestra una perspectiva positiva con un fuerte crecimiento y tendencias en la industria", Business Insider Intelligence, 13 de julio de 2017, <https://www.businessinsider.com/drone-industry-analysis-market-trends-growth-forecasts-2017-7>.
9. OACI, "UTM: Un marco común con principios básicos para la armonización mundial", A40-WP/2091, 2019.
10. Administración Federal de Aviación (FAA), "14 CFR PART 107 Sistemas de aeronaves no tripuladas pequeñas (sUAS)", 27 de septiembre de 2018, https://www.faa.gov/about/office_org/headquarters
11. FAA, 2016, "Circulación de asesoramiento: sistemas de aeronaves no tripuladas pequeñas (sUAS) (AC-107-2), Administración Federal de Aviación, 2016.
12. Marcus, J., Jaewoo, J., Joseph, R., Joey, M., Jeffrey, H., Thomas, P., Daniel, M., Parimal, K., "Evaluación de prueba de vuelo de un concepto de gestión de tráfico de sistemas de aeronaves no tripuladas (UTM) para múltiples operaciones más allá de la línea de visión", 12.º Seminario de investigación y desarrollo de gestión de tráfico aéreo de EE UU./Europa (ATM2017), Centro de investigación Ames de la NASA, EE. UU., 2017.
13. Agencia de Seguridad Aérea de la Unión Europea (AESA), "Medios aceptables de cumplimiento (AMC) y material de orientación (GM) para la aplicación del Reglamento (UE) 947/2019, Anexo I de la Decisión ED 2019/021/R, núm. 1, 2019, págs. 1-130.

14. EASA, "AMC y GM de la Parte-UAS Operaciones de UAS en las categorías 'abierta' y 'específica'", Anexo II de la Decisión ED 2019/021/R, Iss. 1, 2019.pp.1-61.
15. EASA, "Drones civiles (aeronaves no tripuladas)", <https://www.casa.europa.eu/easa-and-you/civil-drones-rpas,2019>.
16. Empresa Común SESAR, "Blueprint U-Space", Empresa Común SESAR, Oficina de Publicaciones de la Unión Europea, Luxemburgo, 2017.
17. Kerczewski, R. J., Apaza, R. D., Downey, A. N., Wang, J., Matheou, K. J., "Evaluación de las comunicaciones C2 para la gestión del tráfico de UAS", Conferencia sobre comunicaciones, navegación y vigilancia integradas (ICNS) IEEE/AIAA, Aeropuerto Dulles, Herndon, VA, EE. UU., del 10 al 12 de abril de 2018.
18. Lin, C. E., Hsieh, C. S., Li, C. C., Shao, P. C., Lin, Y. H., Yeh, Y. C., "Una comunicación similar a ADS-B para UTM", Comunicación, navegación y vigilancia integradas (ICNS), Aeropuerto Dulles, Washington DC, EE. UU., 9-11 de abril, IEEE, 2019.
19. Administración de Aeronáutica Civil (CAA), "Civil Aviation Act", Capítulo UAS, 25 de abril de 2018. <https://www.caa.gov.tw/en/content/index.asp?sno=325>.
20. Lin, C. E., Chen, T. P., Shao, P. C., Lai, Y. C., Chen, T. C., Yeh, Y. C., "Prototipo de sistema de gestión de tráfico de vehículos aéreos no tripulados jerárquico en Taiwán", Conferencia sobre comunicación, navegación y vigilancia integradas (ICNS), Aeropuerto Dulles, Washington DC, EE. UU., Institute of Electrical and Electronics Engineers Inc., 9-11 de abril de 2019.
21. FAA, "Introducción al TCAS II V7.1", Departamento de Transporte de EE. UU., 2011.
22. Lin, C. E., Hung, T. W., Chen, H. Y., "Algoritmo TCAS para la aviación de generación en ADS-B", Actas de la Institución de Ingenieros Mecánicos, Parte G, Revista de Ingeniería Aeroespacial, Vol. 230, N.º 9, IMechE 2016, págs. 1569-1591, DOI: 10.1177/0954410016631974.
23. Instituto de Investigación de Transporte, Ministerio de Transporte y Comunicaciones, "Investigación sobre análisis de capacidad y nivel de servicio de áreas de fusión de rampas de autopistas (1/3) - Entrada independiente y áreas de fusión de entradas", 2019.