Computer and Telecommunication Engineering 2024, 2(2), 2620.
https://doi.org/10.54517/cte.v2i2.2620

Article

An analytical view on Unmanned Aircraft Systems

Arunima Sharma

Department of Electronics and Communication Engineering, Shri Mata Vaishno Devi University, Katra, J&K 182320, India; Arunimasharma7893@gmail.com

CITATION

Sharma A. An analytical view on Unmanned Aircraft Systems. Computer and Telecommunication Engineering. 2024; 2(2): 2620. https://doi.org/10.54517/cte.v2i2.2620

ARTICLE INFO

Received: 13 March 2024
Accepted: 10 April 2024
Available online: 20 April 2024

Abstract: Unmanned Aircraft Systems (UAS) is a booming technology with a future perspective and does have a huge potential to transfigure warfare and enable up-to-date civilian applications. It furthermore matures in a technological way as to be impinged into the civil society. In 2010, the importance of scientific applications in the respective field was demonstrated by DOD in the contemporary years. In recent years, UAS has played an integral role in a number of missions that are public, like law enforcement, which is local, board surveillance, weather monitoring, wildlife surveys, and military training. UAS do force some challenges that are numbered as lacking a pilot who is on-board in order to see and hence avoid supplemental aircraft, and furthermore, the extensive discrepancy in the missions related to UAS, and in order to implement the operations in the NextGen time frame impinged in NAS, the capabilities of the respective topic must be communicated. The applications of UAS are numbered as Ariel Mapping and Meteorology, intelligence, remote sensing, surveillance and reconnaissance, environmental monitoring and agriculture, border security, security applications and law enforcement, counter insurgency, electronic attacks, attack strikes, communication relays, target identification, and designation. Via this survey paper, it can be concluded that UAS is emerging as a valuable and helpful technology having tremendous potential for revolting warfare and enabling new applications w.r.t the UAS field.

Keywords: UAS; reconnaissance; NAS; NextGen; time frame; security; payload

1. Establishment of unmanned aircraft

1.1. Introduction

An overly unambiguous view of unmanned aircraft is a type of aircraft in which the crew of the respective aircraft is removed and hence replaced by a system managed by a computer and radio link. Knowing the importance of UA, which is a wholesome system, furthermore including the stations that are groundly operated and launch mechanisms, a term was coined, i.e., Unmanned Aircraft Systems (UAS) [1]. Unmanned Aircraft Systems are also named Unmanned Aerial Systems [2]. This type of system comprises air vehicles and equipment that are associated with it [3]. No human operator is carried by this class of system [4]. UAS flies automatically or is remotely piloted [5]. UAS is implemented in those systems, which include command, control, and communication (C3) systems and personnel that control the UA [6].

As **Figure 1** depicts the different components like flight control and operating system, which furthermore comprise different control stations, data terminals, communicating links, launching and recovering elements, and so on [3]. UAS serves itself in different fields like aerial means, photography, air traffic, weathering, military, navy, and airforce missions, agriculture, forestry, and many more. Basically, the three main features that sum up to be an UAS are the aircraft, ground control stations, and the main operator [4].

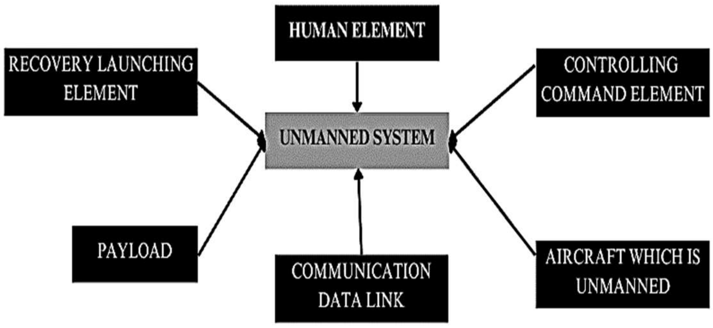

Figure 1. Corresponding elements of an UAS [5].

1.1.1. What does make an unmanned aircraft system

UAS in the civilian sector mainly consists of an aircraft remotely piloted or unmanned, an element of the human species, a payload, elements for controlling factors, and architecture w.r.t data link communication. But in the case of the military sector, UAS also consists of a platform for the weapon system and the supported soldiers. **Figure 1** depicts the various elements joining together to form a UAS.

Aircraft that is remotely piloted

Various classes of UAS that fly with no human on board are: i) Fixed-wing. ii) a rotor-wing or a vehicle that is lighter than air.

(1) Fixed-wing

A number of applications are served via a fixed-wing UAS, like gathering intelligent information, surveillance, and reconnaissance, or ISR. By the joint mission combination of ISR and delivery of weapons adopted via UAS fixed-wing used in the military sector, e.g., General Atomics Predator series of aircraft. The advantage of this type is to offer operators long flight duration via minimized station time or maximized range. Another advantage of this type is that it provides the ability for conducting flight at higher altitudes, which are not easily visible to naked eyes. The logistics that are required for launching and recovery are very substantial, which is a disadvantage w.r.t fixed-wing UAS.

(2) Vertical takeoff and landing

VTOL serves a huge contribution in the application field of UAS. A VTOL platform is formed like a helicopter—an aircraft that is fixed-wing, which can hover, or can be a tilt-rotor. Some examples of VTOL UAS are the Bell Eagle Eye Tilt Rotor. The need for roads for runways or land for takeoff is high; this is the main reason for launching small L&R footprints, which is advantageous.

Command and control element

(1) Autopilot

Without any intervention by the operator, an execution of a mission via UAS is done, which has a preprogrammed set of instructions, and hence this explains the definition of autonomy. From takeoff to landing, the fully autonomous UAS flies without any intrusion of the operator. The two aspects that are important are: external pilot and remotely controlled program, responsible for the operations regarding aircraft that are on the other end of the spectrum. The landing and taking-off are controlled via autopilot without any pilot intrusion. But a command known as Pilot-in-Command can intrude in between in the case of any emergency. For guidance of a designated path w.r.t a vehicle via predetermined waypoints, autopilots play a vital role in these types of vehicles. For small UASs, autopilot has been made available in recent years. Autopilot systems are programmed with a technology that is redundant in nature. If the communication between the control station and ground and air vehicles is disrupted, a procedure is performed named "lost link".

(2) Ground control station

The control center w.r.t GCS is either land/sea-based. It provides the facilities regarding human control w.r.t to UAS in either air or space. GCSs do vary in size and can be the size of a handheld transmitter or as large as a facility that is self-contained with various workstations. It mainly consists of a pilot station and a station for sensors.

Communication data link

It describes how commands from UAS and controlled information are sent and hence received from GCS and respective autopilots. The categorization is i) radio frequency LOS and ii) beyond LOS.

Payload

For accomplishing a mission, it is usually required, which should be onboard. Payload is related to surveillance, application, delivery of weapons, communication skills, aerial sensing, and cargo.

Launch and recovery

One of the most important aspects related to the UAS operation is the L&R element. The runway length is up to 10,000 feet, and equipment like ground tugs, trucks, etc. are important for large UASs.

Human element

This is the most important element in UAS. The operations are executed by this element in UAS. The different elements contained within this field are pilots, sensors, and ground crew. In commercial airlines, automation requires fewer human elements.

1.2. Evaluation of unmanned aircraft systems

In 180–234 A.D., a Chinese general named Zhuge Liang used UAS for the first time. By using balloons made up of paper impined with oil-burning lamps in order to heat the air. The main motive for doing such a thing was to make the enemy believe that there is a divine force present at work when they flew over them. In July 1849, warfighting occurred by using UAS via balloon carrier [7]. In 1903, a Spanish engineer named Leonardo Torres Yquevdo introduced "Telekino". which is a control system working on radio-based terms, in Paris. Academy of Science, aiming at the testing of an airship without risking human life [8]. In 1915, an uncrewed aerial combat vehicle fleet was discovered by Dempsey [9]. In 1916, Low attempted "Ariel Target", which was first powered by UAS [10].

On 21 March 1917, Taylor and John, using a radio system, flew the first monoplane [11]. In 1918, an aircraft-controlled fast motor was developed by the Low and Royal Navy, which aimed at attacking ships and the installation of ports. A pilotless aerial torpedo was developed by the Dayton-Wright Airplane Company during World War I [12]. The first scaled piloted vehicle was developed by enthusiast Reginald Denny in 1935 [9]. In the late 1930s, Tupolev TB-1 bombers were experimented with and controlled by Soviet researchers remotely [13]. The radioplane company was started by Denny in 1940, and many more models emerged during World War II, which were further used in training aircraft gunners and to fly attack missions [14]. In 1951, after WWII, the development work of vehicles such as the TB-4 continued for civilian use, and in 1955, the Model 1001 was developed by Beechcraft for the US Navy [9]. The US Air Force in 1959 was concerned in case of losing the pilots over a hostile territory, and hence the force started to plan the usage of uncrewed force [15]. In 1960, after the Soviet Union shot down a U-2, the planning intensified. During this phase, a program ran under the title "Red Wagon" [16]. During the years 1967–1970, the War of Attrition took place in which the intelligence field of Israel tested the UAS, in which a reconnaissance camera was installed. The main task of these UAS was to return from the Suez Canal after taking pictures. UASs were used in the Yom Kippur War, Israel, as decoys in 1973, serving the main purpose of spurring the enemies into the wastage process of expensive anti-aircraft missiles [17].

In 1987, the UASs were used by Israel for many purposes, for example, jet steering, proof-of-concept of super-agility, 3D thrust vectoring flight control, post-stall-controlled flight in combat-flight simulations that involved tailless, and stealth technology-based [18]. A large number of UASs found their active role in the 1991 Gulf War. From 1 May 2002–31 December 2005, a European Union project, CAPECON, developed UASs [19]. In 2012, the United States Air Force (USAF) did employ UASs, which were 7494 in number [20]. A drone named Kargu2 was hunted down in 2020 for attacking a human target in Libya. This was the pioneer killer robot [21]. The 2020 Nagorno-Karabakh was successfully won by Azerbaijan against Armenia by using the superior drone name Bayraktar TB2 [22]. NASA developed dragonfly spacecraft in order to reach and study Saturn's moon, named Titan.

1.3. Contributions

This paper briefly discusses the concept of unmanned aircraft systems. This paper describes the basic introductory concept of UAS and its history. The author successfully describes different classes of UAS, its design, and many more concepts related to the respective topic distributed in different sections. In this paper, the author has briefly explained classes of UAS in Section 2. In Section 3, the building design of UAS has been explained by the author. Section 4 explains the accord of UAS. Implementation of UAS in different sectors has been noted down in Section 5. Section 6 jots down the difficulties faced via UAS. Section 7 describes the futuristic approach of UAS. The gist of the study is stated in Section 8, and a list of abbreviations is shown in Abbreviations.

2. Classes of unmanned aircraft systems

Categorization of UAS

A non-carrying human vehicle, which is powerful in nature and can be remotely operated via automatic ways, is recovered and expanded, and so hence carries a payload that can be lethal or non-lethal. There are different types of vehicles that are not considered to be unmanned, e.g., mines, satellites, ballistics or non-ballistics vehicles, unattended sensors, cruise missiles, torpedoes, projectiles which are artificial in nature, and many more [23]. There has been a noticeable increment in the usage of the respective technology in many fields, such as military, civil, and a few more areas, serving some special purposes. The different types of UAS are based on size, endurance levels, capabilities, etc. is the effort that goes in for the increment of payload and flight endurance [19]. In **Table 1**, historical development of UAS is mentioned w.r.t technological development and sources related to the respective year, which helps in understanding the developmental course of action and how the UAS evolved over the years. The categorization into four classes is numbered as follows [19,21,24]:

A. Fixed-wing UAS

This type of UAS does require a runway from which it takes off and lands too. The characteristics that they inhibit are long endurance and high cruising speed while flying. This class is heavier in comparison to an airplane; examples like kits, hang gliders, aircraft, and many more using wing morphing do come under the category of fixed-wing aircraft. Different types are:

- Airplane

An airplane is propelled in a forward direction via thrust via a jet engine. Planes do come in various sizes, shapes, and configurations of wings.

- Seaplane

It is a type of fixed-wing aircraft that can take off and land on the water as well, sometimes on dry land too. These are sometimes termed hydroplanes.

- Powered gliders

By adding small power plants, various forms are mentioned as: motor glider, powered hang glider, powered parachute, power paraglider.

- Ground effect vehicle

It is a type of vehicle that attains a flight level that is near the earth's surface by using the ground effect.

- Glider

These are supported via dynamic reaction w.r.t air in flight against the lifting surfaces.

Table 1. Historical development of UAS.

S.No.	Year of development	Technological development	Technological sources
1	1900	Radio and autopilot	Wright Brothers, Nicola Tesla
2	1915–1920	Aerial torpedo	U.S. Navy, World War I
3	1920–1930	First helicopter uass	World War I
4	1930–1940	Target drone	After Wwi, U.S. Army
5	1935	World war ii	Wwii, U.S Navy
6	1940	V-1 buzz bomb	Nazis
7	1940–1950	Wwii german	U.S. Military
8	1950–1960	Unmanned reconnaissance aircraft	North Vietnamese

Table 1. (*Continued*).

S.No.	Year of development	Technological development	Technological sources
9	1950–1960	Radar decoys	U.S. Air Force
10	1960–1970	Long range reconnaissance UAS	U.S. Air Force

B. Rotary-wing UAS

It is also called out by two names, which are Rotorcraft UAS and the second one is Vertical Take-off and Landing (VTOL) UAS. The advantages of the specific class are as follows: hovering capability and high maneuverability. These characteristics are important in civilian applications, especially in robotics missions. The configuration of the respective class includes tail rotors, coaxial rotors, tandem rotors, multi rotors, etc.

This kind of aircraft is heavier than aircraft having rotary wings and generates lift via the rotation around a mast, which is vertical. The classes are:

- Helicopter

In this type of class, which is driven via rotors in the engine through the whole flight, for allowing vertical takeoff and landing and hovering, flying backwards and forward.

- Autogyro

The usage of an unpowered rotor is possible in this type; driven via forces that are aerodynamic in the state of autorotation in order to develop lift, which is powered through a propeller engine.

- Gyrodyne

The engine used for takeoff and landing has anti-torque property and propulsion for the forward flight.

An increase in the propeller's power results in a lower power requirement via the rotor in order to provide thrust in a forward direction, which reduces the pitch angle and flapping in the rotor blade.

C. Blimps

These are lighter than air. They have characteristics like long endurance, low-speed flying, and are of large size.

D. Flapping-wing UAS

They have wings like birds or insects that fly flexibly and are morphing small in nature. They have a convertible configuration in which they can tilt their body/rotor vertically while taking off and hence fly like an airplane, just like the Bell Eagle Eye UAS. The differentiation of this class from the rest can be done on the basis of the size and endurance of an aircraft [19,25,26].

Because of different aspects like capabilities, the size, and characteristics of operating systems, UAS has been classified. Most UAS are classified in terms of maximum gross takeoff weight (UA with payload), endurance and altitude, operational areas of radio-link, usage, and tasks performed by UAS (dull, dirty, dangerous). Classification is done by the operational requirement.

- High altitude

The range in this type within which the flight operates over 60,000 ft varies between different systems, there are Unix, Linux, and QNX.

- QNX

Usage is in QUAV group. Usually used in desktop and computing requirements in embedded fields. The advantage of QNX is evident in the process of porting applications from Linux to QNX, which are straightforward in nature [27].

- Medium altitude

Flying of aircraft with varying range is 18,000–60,000 ft.

- Low altitude

Flying of aircraft is possible within a range of 18,000 ft and below.

- Very low altitude

Flight is possible below 1000 ft.

- Endurance

In this factor, the vehicle operates in the range above 500 km or stays in flight for more than 20 h in the air. These factors, which are mentioned above, are considered to be sophisticated due to the high capabilities of these UAS classes. The classification of the UAS from other systems is done by their large dimensions and capabilities [23].

UAS classes are divided on the basis of applications they serve in a particular field.

- Target and decoy

Stimulating the target of an enemy aircraft or any missile by providing ground and analyzing video.

- Reconnaissance

Intelligence about the battlefield is provided.

- Combat

Provision of attack capabilities regarding high risks, which do have missions.

- Research and development

Further UAS technological development is a priority as it is impinged into the deployed field of a UAS aircraft.

- Civil and commercial UASs

Designed specifically for applications in civil and commercial fields.

The classes of UASs are classified further on the basis of altitudes, which are described as:

- Hale

It is an acronym for high-altitude long endurance. The altitude ranges over 15,000 m and the endurance levels are above 24 h. This class of UAS always has increasing arm length. This class is used for long range reconnaissance and so for long-range surveillance. This class finds its application in the Air Force, which operates on fixed bases.

- Male

The full form is medium-altitude long endurance. Its altitude ranges from 5000–15,000 m and the endurance levels to 24 h. The operation of this class is similar to that of HALE, but somewhat it does operate on a shorter range, which values over 500 km, still working from the fixed bases.

- TUAS

It stands for tactical UAS ranging between 100–300 km. These are operated by either land, naval, or both. This type of air vehicle is comparatively smaller in size, and the operation is similar to male/hare.

- Close-range UAS

The main three applications of this type of class can be summarized as: i) battle groups for mobile army; ii) some operations related to military or naval; and iii) for different civilian purposes. The operating range of these classes is about 100 km.

- Mini UAS (MUAS)

The main ranges are below 20 kg, and the operational range is about 300 km. The usage of this class is mobile battle groups and different purposes for civilians.

- Micro UAS (MAS)

This class does have the using span with a value no greater than 150 nm. The application of this class is mostly found in urban environments, most usually within buildings. It is usually launched via land. Because of this reason, the loading in the winged versions is low, which is furthermore vulnerable to atmospheric turbulence.

- Nano Air Systems (NAS)

It is the size of a Sycamore seed. Usually used in radar confusion, camera, propulsion, and controlling sub-systems, and for surveillance ranging in ultra-short range.

3. Building design of UAS

3.1. Architectural design of UAS

The basic architectural design of UAS comprises fewer elements which are depicted as in the **Figure 2** below.

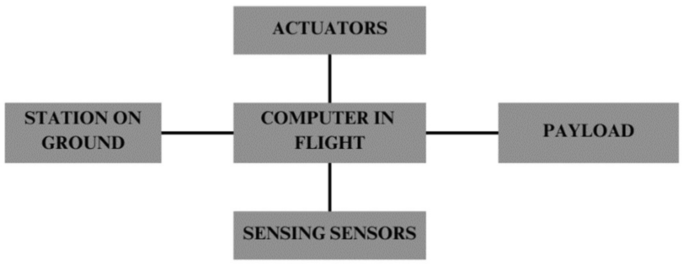

Figure 2. Basic architectural design of UAS [27].

The descriptional points and definition of different elements of UAS are:

- Computer in flight

This element describes the flying phase of UAS. It is an element in which there are two ways described. The first one is for remotely controlling data link radio, which is two-way, and the second is the computer, which is onboard and generally connected to aircraft control systems [28]. The system controlling flight and operating systems includes many factors like station(s) that control UAS, communication links, terminal(s) used for data exchange, launching and recovering system equipment that supports ground systems, and interfaces for air-traffic control.

Actuators:

- Payload

Payloads are generally high- and low-resolution camera/video cameras, day and night reconnaissance equipment, high-power radar, gyro-stabilizer, electro-optical signal, meteorological, chem-bio relay, welfare machinery, and generally any equipment required for the mission; the UAS is designed [29]. High fuel fraction is demanded by UAS with the desire for endurance. It results in a low payload fraction having a typical value of 10%–20% of gross weight [30].

- Sensors

It provides the basic function for maintaining the flight in the absence of humans: pictorial elements, radar elements, cameras for video recording, and IR scanners, which are very common. For providing a guided path in concern with missiles and sheets that are targeted by a laser, i.e., target designation is included in sensors. There are different benefits of sensing payload in a UAS, as follows:

a. Collecting intelligence data.
b. Reconnaissance surveillance.
c. Supporting operations by providing target acquisition.
d. Delivering weapons.
e. Identification and detection of the target.
f. Improvement in aim point accuracy [30].

- Navigation sensors and microprocessors

Sensors are the costliest item in UAS. The main aim of sensors is to navigate and achieve missions. With little or no human element, the processors do allow UAS to fly the entire mission and that autonomously [19].

- Aircraft onboard intelligence

The basic intelligence of UAS is basically related to the two phenomena:

a. Directly proportional to the handling power of a UAS in a tedious task.
b. Inversely proportional to the oversight required by a human element.

It includes guidance, navigation, and control [11].

- Communication systems

It is also known as the Air data terminal. The main issues with communication systems are:

a. Flexible capability.
b. Security and cognitive controllability of data flow.
c. Bandwidth on which it works.
d. Frequency of the system [19].

The building elements of a UAS data link are a transmitter and receiver of RF, an antenna, and connecting modems with sensor systems. There are three main functions served by UAS:

a. Ground station uplinks and/or control data sends to UAS via a satellite.
b. UAS downlinks, which are used to send data to ground stations via sensors that are onboard and telemetry systems.
c. To allow means for measuring azimuth and range from a ground station and satellite to UAS in maintaining a good communicative relation between them.

Standardizing efforts in concern to data links did result in the usage of common data link (CDL), which has the following characteristics: it is fully duplex and does work on wide-band data link while using UAS, which is usually secure and jam-resistant. These types of data links are used in connecting the ground station via UAS, which is direct and point-to-point/usage of satellite communication (SATCOM) [31].

Control types:

The central idea of a UAS is the removal of the operator from the cockpit and then controlling the aircraft via other means. There are three main types of controls that are exerted over the aircraft, as follows:

a. Ground control

The other name for this type is Remotely Piloted Vehicles (RPVs). The main requirement of this type is the operator's constant input. RPVs are a kind of sophisticated radio-controlled aircraft with the usage of a few basic techniques that are familiar to R/C hobbyists [32]. There are fewer moderation UAS that are remotely piloted.

b. Semi-autonomous

These types of UAS are defined as the input from the ground in case of critical portions of some flight, which are mentioned as takeoff, landing, unemployment of weapons, and some evasive maneuver. During different operations w.r.t. the flights, like during pre-flight, take-off, landing, and operating near base, the operator should have full control. The aircraft will follow a different set of pre-programmed waypoints once an autopilot function is engaged. Throughout the operation, the operator takes full responsibility for UAS [27,28].

c. Fully-autonomous

Within the end of the spectrum of the other side, capability of this type lies. For carrying an objective followed by the decision for taking off, this type does not need any human element. The health status and configuration of this type of UAS are monitored itself. The command and controlling assets onboard the vehicle are inbuilt within the programmed limitations [27,28].

Station on the ground:

It's also known as a Ground Control Station (GCS) or C3. There are different fields in which UAS has its own technology, like telecommunications, guidance, and control technology. The platform has been more reliable in case of flight control after the introduction of solid-state gyros and sensors. The flight is linked via modern technology in the field of telecommunications. Over a long distance and at a very long rate, the mission is commanded to an aircraft [18,20,21].

Ground station command, control, and communications (C3):

Several important points are addressed on the off-board infrastructure, like man-machine interfaces, multi-aerial C3, target identification, downsizing ground equipment, noise control, etc. A single person can control multiple aircraft with the help of advancement of the state w.r.t. the points mentioned above. By combining planning, personnel, equipment, communications, navigation, and technological functions and procedures, command and control functions are accompanied [20,33].

3.2. C3 system model

A system model of C3 is shown in **Figure 3.** Within the RF LOS or beyond this LOS, the operator of an aircraft operates w.r.t. YAS operations. UAS are divided into categories and subcategories on the basis of C3 in relation to technologies and operating procedures. The loss procedures related to the current link are described as follows:

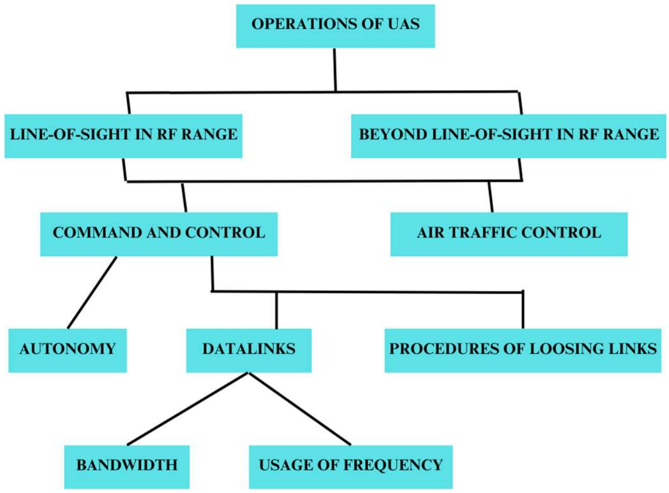

Figure 3. System model of C3 [33].

A. Blos operations

This figure above illustrates the overlapping operating conditions and different UAS classes that operate within these respective areas. **Figure 4** describes the following:

- All the aircraft are included in the LOS section
- High and medium endurance is included in the BIOS section [33].

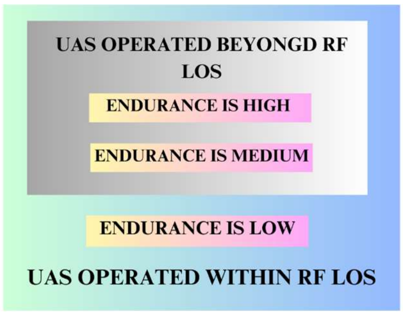

Figure 4. BIOS operation [33].

B. RF LOS C3 technologies and operations

The LOS operation is majorly divided amongst three categories, which are: High, medium and low UAS endurance. First class mostly operates in LOS [33].

C. BLOS C3 technologies and operations

BLOS majorly covers the high-endurance UAS and a smaller part of medium-endurance UAS that does operate beyond LOS [33]. Satellite-based communications (SATCOM) is a used element for beyond LOS commands and controls the communication with UAS.

3.3. Mostly commonly used frequency bands for UAS

Links of satellite communication in UAS are used both in LOS and BLOS mode. These types of communications are usually used for RF applications. **Table 2** mentioned below depicts the frequency band w.r.t working of UAS. The commonly used frequency bands for these types of links are [34]:

a. KU band

High speed links found application in this band. Propagation losses are suffered in this band due to the high frequency and short wavelengths. But beyond this disadvantage, this band has an advantage, like enabling the data to trespass many obstacles.

b. K band

A large amount of data works in this band, which possesses a large frequency range. There are mainly two disadvantages related to this band:

- Requirement of powerful transmitters
- Environmental interferences sensitivity

c. S, L bands

The data exchange is not possible with transmission speeds, which are above 500 kbps. The advantage of this band:

- Penetration into terrestrial infrastructure is easily done by using large wavelength signals.
- Requirement of less power by transmitter.

d. C band

Requirement of large transmitting and receiving antennas in this type of band.

e. X band

This band is always received for military applications.

Table 2. Frequency band [35].

S.No.	Band	Frequency
1	HF	3–30 MHz
2	VHF	30–300 MHz
3	UHF	300–1000 MHz
4	L	1–2 GHz (general) 950–1450 MHz (IEEE)
5	S	2–4 GHz
6	C	4–8 GHZ
7	X	8–12 GHz
8	Ku	12–18 GHz
9	K	18–26.5 GHz
10	Ka	26.5–40 GHz

4. UAS autonomy

UASs can be the three: automated, autonomous, and semi-autonomous. UAS can be accessed remotely and may be mixtures of the above-mentioned capabilities [36]. The minimum element in an autopilot system comprises altitude sensors and an onboard processor. There are a number of non-linearities in airplane dynamics, like 1) PID control, 2) neural networks, 3) fuzzy logic, 4) sliding mode control, and 5) H∞ logic. These are used for a smooth desired trajectory navigation in an autopilot system. Microelectromechanical Systems (MEMS) are a new technological advancement that is easy to use.

Manet:

It is a wireless network that is flexible in nature. It applies to the heterogeneous

UAS fleet whose separations are possible without any infrastructure. This type of network orients to collaborate, which is commonly known as Mobile Ad-hoc Networks (MANET). MANETs have a nature of self-organized networks. In this type of network, the connectivity is provided by a different wireless node. In this network, every wireless node does act as a repeater or a relay. The main purpose of this infrastructure is to forward data to the destined node. In the future, this network will find its application in civilian and military fields [37,38].

Security issues of UAS C3 technology and operation:

There are many challenges faced by UAS C2 and ATC communications, which are numbered as:

a. Jamming
b. Hijacking
c. Spoofing of data link

W.r.t the factor of “immediate control” of the aircraft, UAS is different from the rest of the aircraft, which are used conventionally. This term explains that the aircraft, which is in the immediate vicinity and at risk of collision, can be flown by the pilot of the aircraft. The difference between UAS and conventional aircraft is that UAS as a medium is present between the pilot present in the ground control station and the respective aircraft. The medium present is a data link, which is easily prone to threats. To take full control of UA, the hacker can do the following activities:

a. he/she can hack the data link
b. can jam the data link network
c. can create a fake UAS signal

Data links are very important for wireless communication; therefore, a precautionary measure should be taken while selecting the data link.

Advances in autonomous UAS technologies:

Some technologies amongst these that are applied to UAS like the airframe, propulsion system, structure of aircraft, etc. For enabling the autonomous behavior and flight of UAS, other technologies are specified, e.g., observe, orient, decide, act [36]. Some of the included technologies are sensors used for navigation and avionics, systems for communication, C3 infrastructure, and onboard autonomous capabilities.

- Automated system

In this type of system, an outcome is achieved by following the pre-defined set of rules w.r.t. response from the sensor(s). The output seems to be predictable if the pre-defined set of rules is known.

- Autonomous system

Higher-level intent and direction are the two factors that can be understood by an autonomous system. By this kind of understanding, any system can have the desired outcome by taking appropriate steps in a particular state without the dependency on human oversight and control. This system decides the course of action by using a number of alternatives.

- Navigation

There should be a number of ways in which the location/position of a UAS can be found out, and performing the above process in a navigating system that is robust in nature with a high level of accuracy and integrity is needed. The solution is GPS.

- Guidance and flight control

To fly along with the chosen flight, UAS generates steering commands and control deflections that are subsequent in nature.

- Sense-and-avoid

In civilian airspace, one of the major limitations regarding UAS is sense-and-avoid [18]. For avoiding the collision of piloted aircraft with each other, this sense-and-avoid is the primary mechanism. The active solution includes the usage of radar for detecting collision threats. The basic requirement of this is high power backup.

- Fault monitoring

For ensuring the integrity of the UAS system, there should be a conduct of fault monitoring on the flight and the system for critical missions. This system ensures that the system should not lead to failure, which is catastrophic in nature by system faults and hence undetected.

- Intelligent flight planning

For planning and re-planning, the flight of UAS aircraft should be capable enough, which results in the requirement of an environment with a high-level computing process system in which algorithms can be run down for planning the flight. The operation related to flight requires planning, which includes the surroundings of the UAS, like airspace, terrain, weather, restricted areas, and different obstacles.

- Payload

The two requirements of UAS in civilian applications for designing an infrastructure for performing a mission are:

a. Lower cost
b. Impact on UAS equivalent

A specific task is performed by equipment installed in an UAS called Payload. The payload requires three factors, which are space, weight, and allocation of power. A certain type of payload requires access to data from a UAS system, e.g., position, speed of air, or altitude.

5. Implementation of UAS in different sectors

The main investment in the future in the field of applications of UAS serves in military and defense scenarios. The prime usage of UAS for intelligence, surveillance, and reconnaissance (ISR) patrols and strikes. Another usage is in the detection of chemical, biological, radiological, and nuclear (CBRN). The advantages of UAS are: better and sustained alter nature in comparison to humans through dull operations. The operations related to UAS are in concern with the scope regarding the Japanese Ministry of Agriculture, Forestry, and Fisheries and are related associations that are affiliated with the Japanese agricultural aviation association [19,20,22,23,25,27,29,30,34].

Applications of UAS

There are number of applications in different fields which are numbered as:

a. Military applications
    - Reconnaissance Surveillance and Target Acquisition (RSTA).
    - Surveillance for peacetime and combat Synthetic Aperture Radar (SAR).

- Deception operations.
- Maritime operations (Naval fire support, over the horizon targeting, anti-ship missile defence, ship classification).
- Electronic Warfare (EW) and SIGINT (SIGnals INTelligence).
- Special and psyops.
- Meteorology missions.
- Route and landing reconnaissance support.
- Adjustment of indirect fire and Close Air Support (CAS).
- Battle Damage Assessment (BDA).
- Radio and data relay
- Nuclear cloud surveillance Military roles according to arm and forces [39].

b. Navy applications
- Shadowing enemy fleets
- Decoying missiles by the emission of artificial signatures
- Electronic intelligence
- Relaying radio signals
- Protection of ports from offshore attack
- Placement and monitoring of sonar buoys and possibly other forms of anti-submarine
- warfare Army
- Reconnaissance
- Surveillance of enemy activity
- Monitoring of nuclear, biological or chemical (NBC) contamination
- Electronic intelligence
- Target designation and monitoring
- Location and destruction of land mines Air Force
- Long-range, high-altitude surveillance
- Radar system jamming and destruction
- Electronic intelligence
- Airfield base security
- Airfield damage assessment
- Elimination of unexploded bombs

c. Civilian applications
- Policing duties (civil)
- Traffic spotting (civil)
- Fisheries protection (civil)
- Pipeline survey (civil)
- Sports events film coverage (civil)
- Agricultural operations (civil)
- Power line survey (civil)
- Aerial photography (civil)
- Border patrol (civil)
- Surveillance of coastal borders, road traffic, etc. (civil)
- Disaster and crisis management search and rescue (civil)
- Environmental monitoring (civil)
- Agriculture and forestry (civil)

- Firefighting (civil)
- Communications relay and remote sensing
- Aerial mapping and meteorology.
- Research by university laboratories (civil)
- Communications relay (civil)
- Law enforcement

Security is the main aim for the applications of UAS in every field [40].

6. Difficulties faced via UAS

The below-mentioned challenges are just numbered due to the census gained in the respective field, so hence the challenges are numbered as:

a. Sense and avoid technology

The important factor for the civilian application in a shared airspace is to "see and avoid". For the pilots is to use the sensors and different other tools that are used to find and maintain awareness of a situation w.r.t. the traffic [30].

b. Regulation of bandwidth

c. Procedures for lost link

In all the fields that are UAS-related, it must be provided with a number of recovery means in case of a lost link. The aim is to make sure that airborne operations are predictable in case of lost links [3].

d. Flight termination system

For ensuring overall safety and a system, the desired characteristics are redundancies and an independent functioning nature. If the above point is not satisfied, the pilot manually activates the termination system, in which the command of a UAS pilot is required for safeguarding the public.

e. On-board intelligence challenges

On-board intelligence, teaming/swarming [35], health management, collision avoidance, affordability, sensing.

f. Interoperability

The UAS should be compatible enough in order to serve in the domains of air, ground, and marine fields seamlessly. The robust implementation process of interoperability tents enables UAS to perform the above tasks smoothly.

g. Autonomy

The introduction of incremented UAS autonomy must include affordability, utilities that are operational, developments related to technology, policies, opinions related to the public phase, and the respective associated constraints with it.

h. Airspace integration

DoD with integration with the Federal Aviation Administration (FAA) ensuring the access routine of the UAS with meeting the training process impinged with the National Airspace System (NAS). The main purpose is to meet the training and operational requirements.

i. Training

A continued and joint training process is assessed in UAS for fruitful work. Improvement in basing decisions and standardizing the training and operational training process improves effectiveness and efficiency.

j. Propulsion and power

Increased demand for efficiency and logical sources of propulsion and power results in rapid development of UAS deployment.

Table 3 shows the main differences between manned and unmanned aircraft systems.

Table 3. Difference between manned and unmanned aircraft.

S.No.	Manned aircraft	Unmanned aircraft
1	Suitable for both projects which are large and small in size.	The operations that are executed via their aircrafts are low-cost.
2	Capable of carrying sensors that are used for high end-mapping.	This type of aircrafts has high resolution power.
3	Suitability for operations which are airspace-friendly.	These aircrafts are suitable for very small projects.
4	Aviation is safer.	Aviation is at high risk.
5	Operations are high-costed.	Aircrafts are not able to carry sensors for high-end mapping.
6	Not suitable for very small size projects.	Are not suitable for large projects.
7	Low resolution power.	Flying UAS over people is restricted via the FAA.

7. Futuristic approach

The next generation of UASs will need more execution of difficult missions like air combat, target detection, recognition, and destruction, strikes on an enemy's defense related to an electronic attack, etc. [24]. The respective technology of autonomy that will be important in the future for UAS development falls under the numbered classes: sensor fusion, communications, motion planning, trajectory generation, task allocation, and scheduling cooperative tactics. For the development of UAS intelligent mission management is important. For future generations, intelligent autonomous architecture plays an important role, which combines the onboard and ground-band systems for controlling vehicles and their payload.

8. Conclusion

This paper is all about the phenomena related to unmanned aircraft systems, i.e., what is UAS, how it works, what are its applications, drawbacks, and how it will affect the future or what developments will be there in relation to the respective subject.

Conflict of interest: The author declares no conflict of interest.

Abbreviations

e.g.,	For example
UAS	Unmanned Aircraft System
i.e.,	That is

References

1. Tarık AK, Gökhan SARI. Decision-making mechanisms in the use of armed unmanned aerial vehicles, the new actor of security (Turkish). Journal of International Scientific Researches. 2018: 623-628. doi: 10.21733/ibad.474608
2. Dahiya S, Garg M. Proceedings of UASG 2019. 2020. p. 201.
3. Changoluisa I, Barzallo J, Pantoja J, et al. A Portable UAV Tracking System for Communications and Video Transmission. In: Proceedings of the 2019 IEEE 4th Colombian Conference on Automatic Control (CCAC); 15-18 October 2019; Medellin, Colombia. pp. 1-6. doi: 10.1109/ccac.2019.8921053
4. Gómez-López JM, Pérez-García JL, Mozas-Calvache AT, et al. Mission Flight Planning of RPAS for Photogrammetric Studies in Complex Scenes. ISPRS International Journal of Geo-Information. 2020; 9(6): 392. doi: 10.3390/ijgi9060392
5. Jyoti, Batth RS. Classification of Unmanned Aerial vehicles: A Mirror Review. In: Proceedings of the 2020 International Conference on Intelligent Engineering and Management (ICIEM); 17-19 June 2020; London, UK. pp. 408-413. doi: 10.1109/iciem48762.2020.9160179
6. Guimarães N, Pádua L, Marques P, et al. Forestry Remote Sensing from Unmanned Aerial Vehicles: A Review Focusing on the Data, Processing and Potentialities. Remote Sensing. 2020; 12(6): 1046. doi: 10.3390/rs12061046
7. Kaplan P. Naval Aviation in the Second World War. Available online: https://en.wikipedia.org/wiki/ISBN (accessed on 9 March 2024).
8. Everett HR. Unmanned Systems of World Wars I and II. The MIT Press; 2015. pp. 91-99. doi: 10.7551/mitpress/10095.001.0001
9. Dempsey ME. Eyes of the Army—U.S. Army Roadmap for Unmanned Aircraft Systems 2010–2035. Available online: https://irp.fas.org/program/collect/uas-army.pdf (accessed on 6 March 2024).
10. Professor AM. The First Guided Missile. In: Low FLIGHT. 1952.
11. Taylor JWR, Munson K. Jane's Pocket Book of Remotely Piloted Vehicles. Collier Books; 1977.
12. Kanyike R. History of U.S. Drones. Available online: http://understandingempire.wordpress.com/2-0-a-brief-history-of-u-s-drones/ (accessed on 17 February 2024).
13. Andersson L. Soviet Aircraft and Aviation, 1917–1941. Naval Institute Press; 1994. p. 249.
14. Everett HR. Unmanned Systems of World Wars I and II. MIT Press; 2015. p. 318.
15. Dunstan S. The War of Attrition was also notable for the first use of UAVs, or unmanned aerial vehicles, carrying reconnaissance cameras in combat. In: Israeli Fortifications of the October War 1973. Osprey Publishing; 2013. p. 16.
16. Walker SW. Integrating Department of Defense Unmanned Aerial Systems into the National Airspace Structure. Biblioscholar; 2010.
17. Ehrhard T. Air Force UAVs—The Secret History. Mitchell Institute; 2010.
18. Gal-Or B. Vectored Propulsion, Supermaneuverability and Robot Aircraft. Springer New York; 1990. doi: 10.1007/978-1-4613-8961-3
19. Goraj Z, Frydrychewicz A, Świtkiewicz R, et al. High altitude long endurance unmanned aerial vehicle of a new generation—A design challenge for a low cost, reliable and high performance aircraft. Bulletin of the Polish Academy of Sciences, Technical Sciences. 2004; 52(3): 173-194.
20. Ackerman S, Shachtman N. Almost 1 in 3 U.S. Warplanes is a Robot. Available online: https://www.californiaskywatch.com/warcosts/wp-content/uploads/drones/517AN_1_2012_Almost_1_in_3_U.S._Warplanes_is_a_Robot_January_9_2012_Wired_News_http_www.wired.pdf (accessed on 8 January 2024).
21. Hambling D. Drones may have attacked humans fully autonomously for the first time. Available online: https://www.newscientist.com/article/2278852-drones-may-have-attacked-humans-fully-autonomously-for-the-first-time/ (accessed on 9 March 2024).
22. Forestier-Walker R. Nagorno-Karabakh: New weapons for an old conflict spell danger. Available online: https://www.aljazeera.com/features/2020/10/13/nagorno-karabakh-new-weapons-for-an-old-conflict-spell-danger (accessed on 9 March 2024).
23. Tsouros DC, Bibi S, Sarigiannidis PG. A Review on UAV-Based Applications for Precision Agriculture. Information. 2019; 10(11): 349. doi: 10.3390/info10110349
24. Sumardi, Afrisal H, Rahmadani T, et al. Inertial Navigation System of Quadrotor Based on IMU and GPS Sensors. In:

Proceedings of the 2019 6th International Conference on Information Technology, Computer and Electrical Engineering (ICITACEE); 26-27 September 2019; Semarang, Indonesia. pp. 1-6. doi: 10.1109/icitacee.2019.8904198
25. Zhou Z, Su Q, Fu W, et al. A Summary of the Development of Cooperative and Intelligent Technology for Multi-UAV Systems. In: Proceeding of 2019 IEEE International Conference on Unmanned Systems and Artificial Intelligence (ICUSAI); 22-24 November 2019; Xi'an, China. pp. 80-84. doi: 10.1109/ICUSAI47366.2019.9124899
26. Latte N, Gaucher P, Bolyn C, et al. Upscaling UAS Paradigm to UltraLight Aircrafts: A Low-Cost Multi-Sensors System for Large Scale Aerial Photogrammetry. Remote Sensing. 2020; 12(8): 1265. doi: 10.3390/rs12081265
27. Akdeniz HY. A Study on Aerodynamic Behavior of Subsonic UAVs' Wing Sections with Flaps. 2020; 2(1): 22-27. doi: 10.23890/ijast.vm02is01.0103
28. Xu Z, Petrunin I, Tsourdos A, et al. Cognitive Communication Scheme for Unmanned Aerial Vehicle Operation. In: Proceeding of 2019 Workshop on Research, Education and Development of Unmanned Aerial Systems (RED UAS); 25-27 November 2019; Cranfield, UK. pp. 271-277. doi: 10.1109/REDUAS47371.2019.8999707
29. Zahran M, Abdelwahab M. Crash Analysis of UAV Hybrid Composite Fuselage Structure under Different Impact Conditions. Materials Science Forum. 2019; 953: 88-94. doi: 10.4028/www.scientific.net/msf.953.88
30. Motwani S. Tactical Drone for Point-to-Point data delivery using Laser-Visible Light Communication (L-VLC). In: Proceedings of the 2020 3rd International Conference on Advanced Communication Technologies and Networking (CommNet); 4-6 September 2020; Marrakech, Morocco. pp.1-8. doi: 10.1109/commnet49926.2020.9199639
31. Tamer A. Aeroelastic Response of Aircraft Wings to External Store Separation Using Flexible Multibody Dynamics. Machines. 2021; 9(3): 61. doi: 10.3390/machines9030061
32. Digman KL. Unmanned Aircraft Systems in a Forward Air Controller (Airborne) Role. USMC; 2009.
33. Jasim MA, Shakhatreh H, Siasi N, et al. A Survey on Spectrum Management for Unmanned Aerial Vehicles (UAVs). IEEE Access. 2022; 10: 11443-11499. doi: 10.1109/access.2021.3138048
34. Neupane K, Baysal-Gurel F. Automatic Identification and Monitoring of Plant Diseases Using Unmanned Aerial Vehicles: A Review. Remote Sensing. 2021; 13(19): 3841. doi: 10.3390/rs13193841
35. Du Y, Zhang X, Gu Q. Adaptive Separation Thresholds for Self-Separation of Unmanned Aircraft System in Dynamic Airspace. IEEE Access. 2019; 7: 141817-141825. doi: 10.1109/access.2019.2941220
36. Sigala A, Langhals B. Applications of Unmanned Aerial Systems (UAS): A Delphi Study Projecting Future UAS Missions and Relevant Challenges. Drones. 2020; 4(1): 8. doi: 10.3390/drones4010008
37. Ariante G, Ponte S, Papa U, et al. Ground Control System for UAS Safe Landing Area Determination (SLAD) in Urban Air Mobility Operations. Sensors. 2022; 22(9): 3226. doi: 10.3390/s22093226
38. Ueda T, Mitsuhata Y, Okuma S. Review of geophysical exploration methods using unmanned aerial vehicles (UAV). BUTSURI-TANSA (Geophysical Exploration). 2021; 74(0): 93-114. doi: 10.3124/segj.74.93
39. Kurdel P, Češkovič M, Gecejová N, et al. Local Control of Unmanned Air Vehicles in the Mountain Area. Drones. 2022; 6(2): 54. doi: 10.3390/drones6020054
40. Sharma A, Jha RK. A Comprehensive Survey on Security Issues in 5G Wireless Communication Network using Beamforming Approach. Wireless Personal Communications. 2021; 119(4): 3447-3501. doi: 10.1007/s11277-021-08416-0