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Features to Consider When Purchasing a Small Unmanned Aircraft System (sUAS)

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The use of small unmanned aircraft systems (sUAS) is expected to expand rapidly. The Federal Aviation Administration (FAA) forecasts[1] that the combined total for hobby and commercial sUAS sales will increase from $2.5 million in 2016 to $7 million in 2020 (180% increase in 4 years). Purchasers of sUAS are overwhelmed with a diversity of types of aircraft and aircraft features. Non-military aircraft can range in price from $13 to over $55,000. To reduce financial risk, purchasers need to be well informed. This fact sheet is designed to help purchasers make improved purchasing decisions by highlighting some of the common hardware and software options.

Example of a small unmanned aircraft system (sUAS).

Aircraft typically fall into two broad categories, rotary and fixed-wing, and each has their strengths and limitations. The number of blades on a rotary aircraft may vary from one to eight, with four- (quadcopter), six- (hexacopter) and eight-bladed (octocopter) being the most common for collection of imagery. In general, increasing the number of blades from one to eight increases the stability of the aircraft which may prove useful when acquiring high-resolution images. The majority of sUAS rotary aircraft are powered by lithium ion batteries which is one current limitation to long duration flights. Advantages of rotary aircraft over fixed-wing are (1) the ability to hover in place/stationary image collection, (2) vertical takeoff (no need for airstrips, launchers), (3) lower flight altitudes, (4) multi-directional flight paths and (5) more complex flight patterns. Currently, the main advantages of fixed-wing aircraft over small rotary aircraft are that they can cover larger areas and achieve longer flying times. While this fact sheet will emphasize issues related to rotary aircraft, the website https://www.heliguy.com/blog/2016/03/01/choosing-fixed-wing-drone/ (Heliguy, March 1, 2016) does a good job of describing different types of wing configurations for fixed-wing aircraft and has a good list of 'requirements for a good fixed-wing drone.'

A critical decision before purchasing an sUAS (aircraft and sensor) is to clearly establish what you plan to use the system for (i.e., clearly establish your needs). Some questions that you need to ask include (1) is your use recreational or professional, (2) is the sensor included adequate for your needs or will you need the flexibility to interchange sensors down the road, (3) what duration of flight times do you need, (4) how large is your typical flight area, (5) can I easily upgrade software or apps and (6) will there be much post-image processing.

Other issues that you need to consider during the purchase process are (1) type of warranty, (2) any available information about customer service and (3) any available information about spare parts (e.g., IF the unit is manufactured in a foreign country, does the company have a distributor in your country?). As indicated earlier, the sUAS industry is in an expansion mode and you want to know if your company will be around in the future to provide parts and service.

Similar to purchasing a car, one approach to selecting an sUAS is to develop a spreadsheet with features or issues related to the purchase. An example of a feature comparison table is shown in Table 1.

In the following, we will go through some of the terms used in Table 1 to describe navigational software and aircraft features.

Table 1. sUAS Feature Comparison

	Rotary sUAS #1	Rotary sUAS #2
Flight Navigation Features		
Return to Home	Yes	Yes
Follow Me	Yes	No
Geofencing	Yes	Yes
Position Hold	Yes	Yes
Altitude Hold	Yes	Yes
Carefree/Headless Mode	Yes	Yes
Auto Takeoff/Landing	Yes	Yes
Waypoint Navigation/ Autonomous Flight	Yes	Yes
Object/Collision Avoidance	No	No
Aircraft Features		
Navigational Features		
Accelerometer	Yes	Yes
Gyroscope	Yes	Yes
Magnetic Compass/ Magnetometer	Yes	Yes
Inertial Measurement Unit (IMU)	Yes	Yes
GPS	Yes	Yes
Barometer	No	No
Rangefinder	No	No
Object/Collision Avoidance Sensor	Yes	No
Airspeed Sensor (fixed-wing only)	-	-
Data Logger	8GB micro SD card	16GB micro SD card
Max. Transmission Distance	FCC: 3.1 miles (5km) (outdoors)	FCC: 3.1 miles (5km) (outdoors)
Fuel	electric	electric
Battery Capacity	1500mAh	2600mAh
Battery Detachable	Yes	Yes
Number of Engines	4	8
Frame Material (e.g., plastic, aluminum, foam)	Plastic	Carbon fiber
Gimbal (none, manual or gyro-compensated)	Manual	Gyro-compensated
Sensor included (NIR, camera, none)	Camera	None
Camera video quality	4K	-
Camera image quality	12 MP	-
Remote Control (RC) included	Yes	Yes
Flight Time	13 min	25 min
Weight (as sold)	2.8 lb	5.5 lb
Payload Capacity	1 lb	2.5 lb
Dimension (unfolded)	15 x 14 x 8.2 inches	31 x 31 x 13 inches
Price	$399	$3,500

Flight Navigation Features[2,3]

Return to Home (RTH)[4,5]

Return to Home is a very good safety feature. It is meant for circumstances where you lose the communication signal or don't have enough battery power and you need the aircraft to return to the home position quickly. The emergency flight path may involve an auto landing, but it is primarily a safety feature to bring the aircraft back to the general launch area. Remember that when this feature is engaged, the aircraft flight path will be the shortest route back to the launch area and there may be obstacles (e.g., trees) in the way that may cause an unplanned collision. RTH may also be referred to as Failsafe Mode, Coming Home or One Key Return.

Follow Me[6,7] (Rotary only)

This feature is especially useful for videography allowing the pilot to lock the direction and movement of the sUAS on a specific moving target. This intelligent flight mode is very popular with athletes, cyclists, climbers or anyone wanting to capture self-moving scenes. This feature may also be called Auto Follow, Tracking Mode or Selfie Mode.

Geofencing[8]

Geofencing is a safety feature that uses autopilot software and a reliable navigation system (e.g., GPS) to create a 'virtual' fence around restricted areas of flight. Certain units allow the pilot to code in a specific distance (e.g., do not fly past 700 feet from home) that the aircraft should not exceed which provides an additional layer of safety.

Position Hold (PH)[3] (Rotary only)

As the name suggests, this navigational feature allows the aircraft to stay in relatively the same position (x,y,z) in the air allowing the pilot to perform other tasks such as triggering a sensor. PH is a useful feature in that it allows the pilot the flexibility to operate a sensor trigger and yet hold the aircraft in the desired position even under strong winds.

Altitude Hold (AH)[3,9]

Altitude Hold is different from PH. With AH the aircraft simply holds a specific flight altitude but the aircraft could still move horizontally within that plane (altitude), whereas PH would mean that the aircraft can maintain its single fixed position as previously described.

Carefree (CF)[10] (Rotary only)

To understand this feature a user must understand that even a rotary aircraft has a 'nose' and 'tail.' The pitch and roll stick positions on a remote control (RC) are linked to the orientation of the 'nose' and 'tail.' IF at takeoff the 'nose' (possibly indicated by a red mark, red LED light or red propeller) is pointed away from you, pushing the pitch/roll stick to pitch forward causes the aircraft to fly FORWARD away from you. On the other hand, during the flight with the same aircraft nose orientation, pulling the pitch/roll stick causes the aircraft to fly BACKWARD toward the operator. Imagine during flight you used the throttle/yaw stick to 'yaw' or rotate the aircraft counter-clockwise 90 degrees so the 'nose' is now facing to your left and your flight software does not have CF. In this case, when the pitch/roll stick is pushed forward the aircraft will still pitch forward but now the aircraft will head further to your left. Aircraft orientation (nose/tail) can be a problem when you cannot easily identify the in-flight orientation of the aircraft due to light conditions or aircraft distance. Carefree eliminates the need for the pilot to keep track of aircraft alignment as it relates to RC throttle position. Once CF is engaged, pitch/roll is linked relative to the controller. When CF is active, pushing the pitch/roll stick forward will result in a flight path away from the controller and pulling the pitch/roll stick will result in a flight path toward the controller. CF may also be referred to as Headless Mode.

Mode II RC: Pushing pitch/roll stick forward.

Mode II RC: Pushing throttle/yaw stick to left.

Auto Takeoff/Landing

Auto Takeoff/Landing is a useful autopilot feature, especially for beginners, to assist with the start and end of a flight. Some sUAS may use an ultrasonic sensor to assist in this task. When this feature is working well, it allows for a smoother takeoff and landing. This feature is also very useful for testing payload stability before deploying an autonomous flight when 'hover' is included as a part of the autonomous takeoff and landing. Users should also consider that the aircraft will land near, but not always in the exact, launch position.

Waypoint Navigation[11] (Rotary and fixed-wing)

This feature allows the user to plan and save a flight path including information such as waypoint altitude, orientation, wait time at a specific waypoint and speed between waypoints. For most sUAS users this autopilot feature is extremely valuable allowing planned and repeatable flight paths. This feature requires GPS. Waypoint Navigation may also be referred to as Autonomous Flight.

Waypoints (red dots) noted on the flight dashboard.

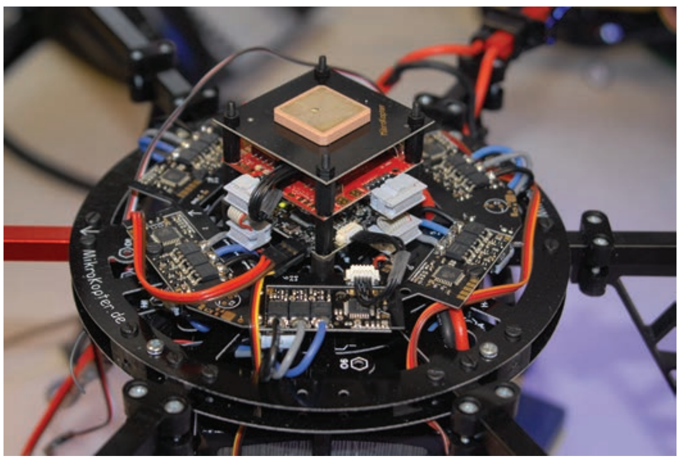
Collision Avoidance[12]

Collision Avoidance is a useful safety feature that reduces, but does not eliminate, the likelihood of a collision of your aircraft with an object. Collision Avoidance uses some type of sensor (LiDAR, optical, ultrasonic, microwave radar) to ‘sense’ an object. An important question to ask with this feature is the expected working distance (e.g., detect objects up to 25 feet) of the system. This feature may also be called Object Avoidance or Sense & Avoid.

Aircraft Features

Navigational Hardware[13,14,15,16,17]

One of the marvels of this emerging technology is the miniaturization and falling cost of the complex electronic components that make precision flight available to the masses. The following are some of the critical components of the navigational system.

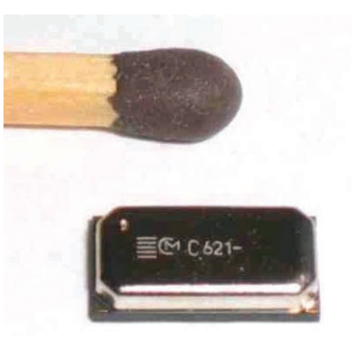


Miniaturization of electronics makes sUAS possible.

Accelerometer

An accelerometer measures ‘acceleration forces’ and is used to determine the position and orientation (x,y,z) of the aircraft in space. It plays a critical role in maintaining and stabilizing flight control. An accelerometer by itself cannot be used to maintain an aircraft in a particular orientation and thus must be integrated with other components such as a gyroscope.

Gyroscope



SMD gyroscope
(Authorized source: Mikrokopter.de)

A gyroscope measures the rate of rotation around a particular axis. A three-axis gyroscope measures rotation around three axes for roll, pitch and yaw. While a gyroscope by itself can provide stable flight, it is most often integrated with an accelerometer.

Magnetic Compass/Magnetometer

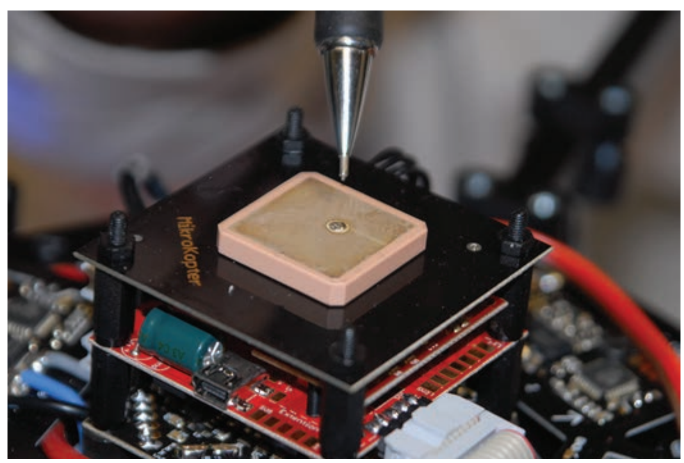
The compass/magnetometer provides ‘directional’ information which is more critical with rotary aircraft than fixed-wing since rotary aircraft can fly multi-directionally. It is the workhorse of all GPS-assisted flight modes. A magnetic compass (magnetometer) works with the accelerometer and gyroscope to let the flight controller know what direction the rotary aircraft is flying. Since a magnetic compass is sensitive to magnetic interference from wires, motors, etc., it is often mounted away from these various sources of interference. Your compass may require calibration, and the frequency and calibration process will vary by manufacturer.

Inertial Measurement Unit (IMU)

An IMU is an electronic device that combines (‘fuses’) information about the force, angular rate and sometimes magnetic field imposed on the aircraft in coordination with accelerometers and gyroscopes. Some IMU include a magnetometer to assist in calibration against orientation drift. An IMU works with GPS to maintain aircraft direction and flight path.

Global Positioning System (GPS)[18]

The GPS provides geographic location as well as aircraft speed and absolute altitude. Horizontal position is more accurate than vertical. The GPS receiver is often mounted on the top of the aircraft to get an unobstructed signal. Almost any autonomous flight mode such as Waypoint Navigation, Return to Home and Position Hold requires GPS.



GPS receiver

Barometer

A barometer measures air pressure. Since air pressure decreases with altitude, a barometer can be used to measure altitude, but this requires calibration and is susceptible to rapid air movement or localized pressure changes. A barometer would be used for ‘altitude hold’ positioning.

Rangefinder

A rangefinder is a device (sonar, laser) used to measure the altitude above ground level (AGL). While a sonar rangefinder is less expensive than a laser-based sensor, it has a more limited range and the signal is affected by the surface type. A rangefinder serves a similar function to a barometer (altitude) but has several advantages in that it is typically more accurate, not affected by drift and can measure the distance to the ground so terrain-following modes can be used. Disadvantages for establishing AGL distance using a rangefinder compared to a barometer include the fact that ground has to be within sensing range of the sensor and the sensor must be pointed toward the ground. If you modify your aircraft (e.g., add a sensor), you need to be mindful of how your sensor placement may block the rangefinder sensor. When flying indoors, or in thick tree cover, it's not always possible to obtain a reliable GPS signal. An optic flow sensor, facing downward, may help maintain position if flying over a suitable textured environment.

Object/Collision Avoidance Sensor

Sense-and-avoid technology is beginning to enter the sUAS market and may become a requirement on aircraft in the future. There are currently a variety of sensors (e.g., optical, LiDAR, ultrasonic, microwave radar) being used to accomplish this task. Users need to be aware of the position of the payload so it does not block or hinder the signal from the sensor(s).

Data Logger

A data logger is essentially the 'black box' for your aircraft and can store critical flight information (e.g., altitude, speed, direction) that can be extremely useful post-flight to diagnose flight problems or the data may be synchronized with sensor data. Most data loggers will use a removable micro memory card for easy data transfer to a computer.

Airspeed Sensor *(Fixed-wing only)*

Similar to full-sized aircraft, an airspeed sensor uses a Pitot Tube to measure airspeed by comparing the dynamic and static air pressure.

Battery[19]

Lithium Ion Polymer (LiPo or LIB) batteries are the most common battery type used for both fixed-wing and rotary types of sUAS. LiPo is a rechargeable battery. The main benefit of using this type of battery is its high energy density compared to other batteries [nickel-cadmium (NiCad) and nickel-metal hydride (NiMH)]. However, there are some important issues that users of LiPo batteries need to be aware of: (1) LiPo batteries require a specific charger, (2) most LiPo chargers come with a safety feature that stops charging at a certain set time as overcharging/overheating the battery is a great concern and (3) any deformation of the packaging of the battery is an indication that the battery is unsafe to use.

Miscellaneous terminology that you may discover during your purchasing process are as follows:

RTF: Ready-to-fly

BNF: Bind-and-fly; the drone needs to be bound to a controller that is not included in the package. Binding is a critical process that the sUAS user needs to understand. Most hobby sUAS include a remote control (RC) that was already 'bound' to the aircraft at the factory. However, there are circumstances when you need to bind your RC and aircraft; for instance, (1) many high-end and professional aircraft require you to purchase a separate RC, (2) you need to replace your current RC or (3) your current receiver requires you to 're-bind' your aircraft receiver to your RC. You are essentially matching, or binding, the signal from your RC to the receiver on your aircraft. 'Binding' an aircraft with a specific RC requires a unique series of steps provided by the RC or aircraft manufacturer.

ARF: Almost-ready-to-fly

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