White Paper

maxon

# How to develop a drone successfully?

## The importance of having a reliable, dedicated, and powerful motorized solution for drones.

# How to develop a drone successfully. The importance of having a reliable, dedicated, and powerful motorized solution for drones

The use of drones has unquestionably increased over the last ten years among many players in the B2B market. As is the case for autonomous warehouse robots – known as automated guided vehicles (AGVs) – the B2B market for unmanned aerial vehicles (UAVs), commonly known as drones, is growing exponentially and has great potential. It is still far from reaching full maturity, involving deliveries of groceries and prepared meals, building inspections, rescue services, etc. **Application and development opportunities are almost infinite** for the use of these flying robots. An increasing number of start-ups, major corporations, and professional drone pilots are taking advantage of these technologies to offer their services to all kinds of private individuals and businesses.

While the market matured about five years ago on the B2C side, the B2B market remains more open, with almost as many potential possibilities as there are industrial sectors. Drone manufacturers are thus able to develop specific technologies that differentiate their products and address the specific issues that their target markets encounter. **When it comes to UAVs, innovation is crucial:** an innovative product tailored to a specific need is far more likely to succeed than a generic drone.

There is another essential element at the international level that could play a major role in the development of this market: **UAV regulations are currently being defined.** The conditions for certification of drones to fly over cities should be ready by 2025. This would speed up the development of a new area of application for drones which could one day help save lives, such as: transporting organs quickly and safely.

The aim of this white paper is to provide a concrete analysis of the challenges and technologies involved in a successful drone design project.

# UAVs : a booming market

# Drone/UAV: what is it all about?

A drone, also known by the acronym UAV, which stands for Unmanned Aerial Vehicle, is an aircraft without any passengers, which can be piloted from a remote location.

**Different types of drones**

There are three main types of drones, each with different technical characteristics and areas of application.

**Multicopters: short-range drones**

Multicopters or multirotor UAVs are drones equipped with multiple motor and propeller sets whose thrust is directed mainly towards the ground. The ability to control each motor individually provides these drones with great flexibility in movement. They are very agile drones as they can stay stable in a fixed position, just like helicopters. They can move up and down very quickly and change orientation easily. As these drones have no wings, their flight relies entirely on the thrust from their propellers, and their autonomy is limited to less than one hour, (typically), largely due to battery capacity.

Areas of application: The multicopter's stability makes it particularly suitable for building inspection and surveillance, for capturing images, and for surveillance of factories and restricted areas. With its ability to take off and land quickly without a long landing strip, it can also be an excellent tool for all kinds of deliveries. A multicopter would be ideal for retrieving a sample (blood or organs) from the roof of a hospital and taking it to another hospital or a medical laboratory.

**Fixed-wing drones: maximum range drones**

Unlike multicopters, which are like helicopters, fixed-wing drones are more like airplanes: they have wings. They require long runways for take-off and landing, or the use of a catapult. However, they can fly long distances, up to several hundred kilometers, thanks to the lift generated by their wings.

Areas of application: Their long flight range make fixed-wing drones ideal for long-distance surveillance missions, e.g., over lakes, cities, or the sea. They are perfect allies for agriculture or surveillance. Fixed-wing drones can be equipped with multiple cameras and sensors to analyze the terrain over which they fly.

**Hybrid drones: drones for hybrid missions**

Hybrid drones are fixed-wing drones capable of vertical take-off and landing (VTOL) due to their directional propulsion systems (motor and blades) or additional systems. They have the dual advantage of being able to take off over short distances and being able to travel long distances because of their wings. A true compromise between the other two types of drones.

**Drone motors**

Most of these drones are equipped with battery-powered electric motors. However, some large-sized fixed-wing drones are equipped with a combustion engine. For example, the military uses even larger drones that run on combustion engines.

In the case of hybrid drones, the combustion engine is sometimes coupled to an electric drivetrain.

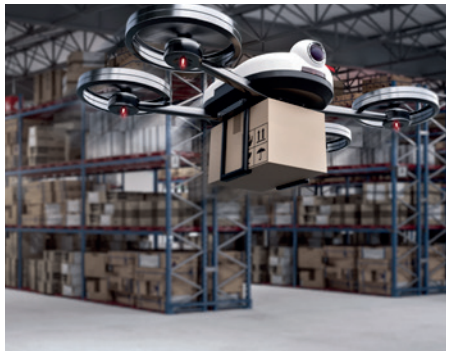

Like all robots, the main purpose of drones is to simplify the lives of their users. Their flying capacity and their variable characteristics – in terms of size, weight, power and motor type – along with the range of technologies with which they can be combined, offer a wide range of potential uses.

## Inspection

The use of drones greatly simplifies inspection work, whether you are inspecting the tank of an oil tanker, the blades of a wind turbine, power lines, or a construction site – in other words, any structure that is difficult to access for human beings. Either outdoors or indoors. Some drones are even capable of flying inside buildings, tanks, or pipes. Let's take a bridge as an example, this type of structure requires regular inspection to check for possible cracks or other anomalies. In the absence of drones, this work is carried out by a technician hanging in the air who must visually inspect the structure. It is a risky and time-consuming job. A drone equipped with a high-resolution camera and sensors can be flown very close to the bridge to inspect each pillar and gather precise data. The images are then safely analyzed by software or by a person looking at a screen.

Drone type: For inspection purposes, multicopter drones prove to be the most efficient solution, due to their high stability. The only exception is the inspection of power lines or railways, where a fixed-wing drone is more suitable, given the distance to be covered.

## Delivery



The delivery sector is similar to the inspection sector, with one major difference: The risk of a crash is not tolerable for deliveries. Since deliveries are made to people, delivery drones must fly over areas with major safety concerns, such as a city. The drone's reliability is of utmost importance to prevent accidents. The drone's lifting capacity, its package transport system, and propulsion systems are critical and will vary depending on the weight of the load. Delivery drones are generally equipped with a parachute, so if a failure is detected, the drone will open its parachute to land as smoothly and as safely as possible.

Drone type: Multicopter drones are the best fit for deliveries. Long-distance deliveries are an exception and require fixed-wing drones.

## Mapping and surveillance

Be it mining, nuclear power plants, police and fire departments, rescue at sea, etc., the use of a drone for mapping and surveillance can be useful in various areas.

In mines, where there is a flot amount of material to extract and requires considerable organization to transport the materials to the right locations, the data collected by mapping the entire mining area with a drone can help identify appropriate loading routes. Trucks can then be in the right places when the material is ready to be collected.

At a nuclear power plant fitted with motion sensors, an automatic surveillance drone can be sent out as soon as the presence of intruders is detected. The drone is parked in a box, ready to take off as soon as the alert is sounded. This avoids having to deploy staff to investigate a possible intrusion.

This type of application is also very useful for firefighters. When there is a fire, a drone equipped with thermal sensors can be sent to take pictures in and around the building, to determine where the heat is coming from, where the smoke is going, and which areas are affected or unaffected. You can choose a wired system for this type of application. The drone is then connected to a cable which supplies it with power, so that it can fly continuously 24 hours a day.

As a final example, police could also use drones to track down a fugitive.

Drone type: Either drone type could be suitable for mapping and surveillance, depending on the size of the area to cover. According to the type of application, the drone must be more or less resistant to heat, water, salt spray, and dust.

## Agriculture

Agriculture is a sector that is similar to mapping. Drones can be used to map agricultural fields, inspect production, or apply pesticides. By flying over fields, surveillance drones flying at a slow speed can also identify areas that need watering or treatment. Using the data that the drone collects, you can apply pesticides or water to only those areas that need it, saving money. Note: Unlike all other sectors, drones in agriculture will only fly over private properties, those of the farmers where the restrictions are less significant.

Drone type: Fixed-wing drones are very effective in accomplishing this type of mission. Long flights by drones equipped with powerful sensors and high-definition cameras will provide valuable crop condition data. Multicopters are still important for certain types of inspection and for highly localized treatment, such as with pesticides.

## Emergency services

On the border between surveillance and delivery, is the emergency services sector which covers several applications, such as: the transport of organs, delivery of blood bags or lab samples, and also all aspects of emergency response (firefighters and police). Applications in emergency services clearly show the positive impact that drones have on society. For example, if a person suffers a cardiac arrest on the street, a drone can make an emergency delivery of a defibrillator to resuscitate the person. Similarly, drones simplify and speed up the transfer of organs or drugs between hospitals in a city with lots of traffic.

Drone type: Multicopter.

Drones: six challenges to be addressed

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## 1. The challenge of regulations

Meeting regulatory requirements for the drone's design and use is necessary to obtain a flight permit.

In Europe, it is the European Aviation Safety Agency (EASA) that defines the regulations governing the design and use of drones, while in the United States it is the Federal Aviation Administration (FAA). The rules are currently being defined and harmonized between the administrations. Please visit regularly : https://www.easa.europa.eu/domains/civil-drones
See here an abstract - It divides drones into the following three categories:

→ 'open' category is a category of UAS operation that, considering the risks involved, does not require a prior authorisation by the competent authority nor a declaration by the UAS operator before the operation takes place;

→ 'specific' category is a category that, considering the risks involved, requires an authorisation by the competent authority before the operation takes place, taking into account the mitigation measures identified in an operational risk assessment, except for certain standard scenarios where a declaration by the operator is sufficient or when the operator holds a light UAS operator certificate (LUC) with the appropriate privileges;

→ 'certified' category, the safety risk is considerably high; therefore, the certification of the drone operator and its drone, as well as the licensing of the remote pilot(s), is always required to ensure safety.

The second most determining criterion for regulation aspects is the travel distance that the drone will be able to achieve, with or without the pilot presence.

While the rules resulting from these requirements have not yet been announced, one thing is certain: The heavier the drone and/or the farther it flies, the stricter the regulations will be. This risk-based approach means paying particular attention to the equipment and materials used as well as to the planned safety measures. In other words, slightly modifying a recreational drone to provide B2B services will no longer be enough to obtain certification. To ensure compliance with future regulations on the design and use of drones, the best strategy remains to apply the best safety protocols and use the most reliable and highest-quality components available. We also recommend doing tests to prove the safety of your drones, which will make it easier to get a certificate of airworthiness.

## 2. The challenge of reliability

Ensuring the reliability of a drone is essential. This is achieved with a combination of high-quality components, such as the following:

→ Effective **propellers** of appropriate size and good build

→ A reliable and well-designed **motor** to avoid crashes

→ Repeatable motor performance characteristics from one production batch to another

→ A **controller** that monitors many motor parameters, for greater safety

→ Powerful batteries and an effective battery management system **(BMS)** to prevent sudden discharge in mid-flight

→ An **onboard computer** that can make the various systems of the drone work together

→ Possible **additional safety features,** such as an emergency parachute

## 3. The challenge of cost

The choice of components that will make up your drone depends on the stage of your project. If you are in the prototype testing stage, you can settle for cheap and quickly available components.

However, when selecting components for your final drone, **it is essential to focus on the total cost of ownership (TCO).** When choosing the key components, namely the motor and ESC, you are better off investing in quality rather than going for cheaper models which you will have to replace far more often, or which might not consistently comply with specifications from one product to the next (repetability).As an expert in motion, maxon offers motors that have outstanding performance repeatability and a lifetime up to five times longer than low-cost models. Each part is tested before it is shipped and, in the event of an incident during delivery, customer service is at your disposal to replace the motor as quickly as possible.

The search for quality must be just as rigorous for the remaining components of your drone. **Some components may seem more expensive, but bear in mind that this is precisely because they meet strict regulatory requirements, and also high quality standards in design and production.** When the TCO and the total lifetime of the product are considered, they are profitable, because they last longer and do not require maintenance.

## 4. The challenge of weight

Weight directly influences the flight time and performance of drones. Drones are usually powered by batteries, which provide a limited supply of energy. However, the lighter the drone (including its load), the longer or further it will fly.

Regulations govern the flight certifications of a drone, this affects, among other things, their weight and flight duration. As a result, most drone manufacturers strive to ensure that their drones have a controlled weight (25 kg, or even less) in order to also increase energy efficiency. Indeed, it is the total weight of the flight system that is taken into account. The delta between the weight of the unloaded drone and the authorized limit can be used to carry more payload, such as cameras, or larger packages.

Therefore, the weight of every component counts. When choosing between motors with the same power, you should choose the lighter one. The structure of your drone will be lighter, and that will allow you to carry heavier objects. **To achieve the lightest weight possible, you will need intelligent component design and engineering.** The design of the various components must aim to optimize the drone's weight as much as possible. This is called weight-saving design. For example, to make the motor as light as possible, you should choose lightweight components and favor aluminum or composite materials whenever possible.

**The weight, performance, and robustness of drones form a triad that must be balanced.** The challenge is to design a lightweight motor that remains powerful and robust. This is what maxon has been working on in recent decades, with success. Since 1997, NASA has trusted maxon to contribute to its Mars missions, notably in the design of Ingenuity, the first drone to fly on Mars. It has been pursuing its mission on Mars since February 2021.

## 5. The challenge of flight time

Be it for inspection, surveillance, or delivery, flight time is important since it enables the drone to perform longer-lasting inspections and surveillance tasks, and to cover longer distances. **Flight time is fundamental to the value of the service that the drone provides.**

If your drone is intended for bridge inspection, but has a flight time of only 20 minutes, you will need to land it approximately every 18 minutes to change its batteries. On the other hand, if it provides a flight capacity of 40 minutes, you will be able to make best use of its presence at the site. The inspection will take less time, and you will inevitably end up saving money.

Drones can fly for 20 minutes at a time on average, but maximum flight time varies from one drone to another. Depending on their size, multicopters can generally fly from a few minutes to about 40 minutes, whereas fixed-wing drones, whose wings provide lift, can fly for several hours.

To improve the flight time of your drone, **you need to reduce its weight and use the available battery capacity in the most efficient way possible.** To achieve this, you need the perfect combination of components in the system must be optimal. In other words, the controller, the motor, and the propeller must be adjusted to work together, to achieve maximum efficiency.

## 6. The challenge of data management

The drone's mission is to collect data. This information may include the following:

→ **Recorded data:** as part of an inspection. It is either recorded by the drone or transmitted immediately. Higher-performance cameras and sensors require more robust drones. If the drone is intended to shoot 4K video footage, it needs to be equipped with a more powerful onboard computer to save or transmit data.

→ **Flight data:** used to manage the drone's position in relation to other drones, buildings, or aircrafts. This will become increasingly important when drones are allowed to fly over cities.

→ **The drone's own data:** performance data management can help to identify malfunctions by performing predictive maintenance. You can also add thermal sensors to monitor motor performance more effectively. These sensors allow you to regularly monitor the temperature in the windings and preventing the motors from overheating, making them safer.

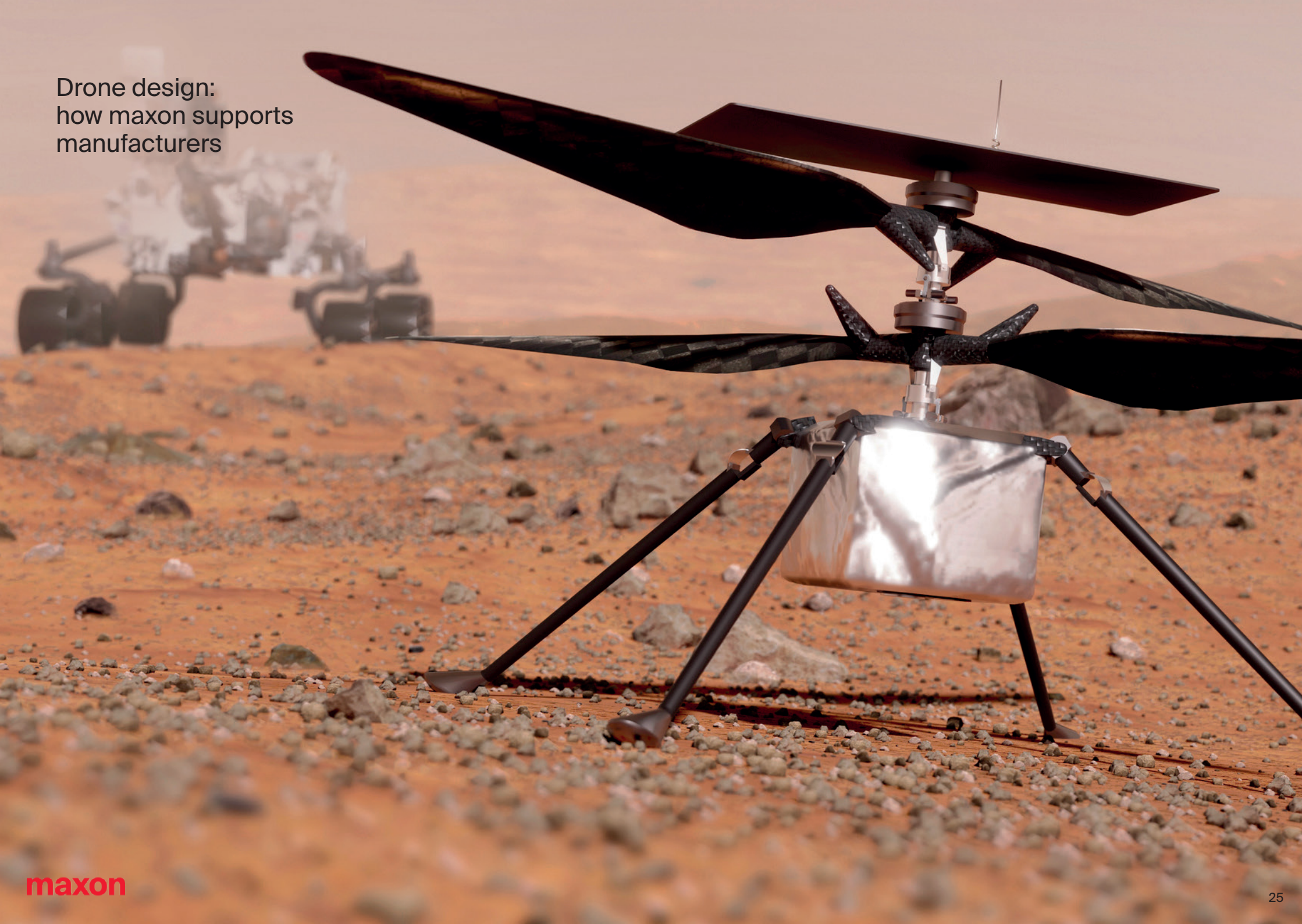
Bear in mind that the trend is towards comprehensive drone solutions, because it is not the drones themselves that add value to businesses, but the data they collect and its potential applications.

# Drones: the role of each element in the design

# Essential drones components.

| Element | Description | Main Variables |
|---|---|---|
| **Drone Design** | Drones can be fixed-wing (maximum range), multicopter (short range), or hybrid (mixed missions with VTOL capability).<br>Their maximum take-off weight (MTOW) and dynamic requirements determine their total thrust [N]. Drones generally require a maximum thrust capacity which is 2.5 times the MTOW. | Mission profile<br>Dimensional footprint<br>MTOW [kg]<br>Total thrust [N]<br>Thrust to weight ratio<br># Propellers |
| **Propeller** | Dimensional and aerodynamic requirements determine the number of propellers and their characteristics. Propellers can provide lift and thrust, but they also generate drag during linear flight. VTOL drone designs often need the lift-generating propellers to be locked at a given angle to limit drag during flight in aircraft mode. The efficiency of a propulsion system is defined by the thrust provided by the power supplied. | Thrust [N]<br>Performance [N/W]<br>Dia. [inches]<br>Pitch [inches] |
| **Motor** | The nominal and maximum thrust determines the required motor speed and torque.<br>Motor and winding size are selected to achieve optimal power, dimensions, weight, battery voltage and current, as well as an efficient and operational service life.<br>Mechanical strength requirements are determined by the aerodynamic and gyroscopic forces as well as the required operational service life. | maxon standard |
| **Electronic Speed Controller (ESC)** | The ESC controls the motor based on values determined by the flight computer, and is powered by the battery. The control interfaces used are PWM, multi-shot, and UAV CAN (CAN bus systems).<br>Good air convection at the ESC improves the nominal power. The ESC regulation must be configured by maxon taking into account various variables, such as the propeller's inertia, acceleration/decceleration, and more for highest possible efficiency. | maxon standard |
| **Flight Computer** | The drone's flight computer is the main control system for flight control, gyroscopic measurement, communications, payload control, etc. Most flight computers are based on open-source hardware and software (e.g. PX4). | There are many available. |
| **Battery** | Most drone manufacturers use lithium-polymer batteries rather than lithium-ion batteries due to higher discharge rates (higher discharge current). | Energy [Wh]<br>Capacity [mAh]<br>Weight [g]<br>Nom. voltage [V]<br>Min. voltage [V]<br>C rating [xC] |

# Drone design: how maxon supports manufacturers



When it comes to drones, there are very few standard ready-to-use products. Every customer needs a specific solution in terms of weight, flight time, or electronics management. To meet these needs, maxon has developed a range of products dedicated to drones that can be adapted upon request.

maxon actively supports professional drone manufacturers in obtaining drone certification and in operating their drone fleet safely. maxon's optimized propulsion systems are designed to provide optimum efficiency, to maximize range and flight time.

The maxon UAV product portfolio includes optimized propulsion motor assemblies, ESCs, and propellers from recommended manufacturers. **maxon is expanding its portfolio and customizations to offer customers a wider range of solutions**.

All the solutions maxon offers are based around standardized designs and processes of manufacturing and testing, with the aim of providing minimal variation in performance and quality.

Drone manufacturers benefit from maxon's quality system and its extensive experience in motion control projects for the aerospace industry. maxon has dedicated equipment in Switzerland for conducting commissioning tests on drone motors assembled with propellers. This equipment is used to optimize ESC control parameters, characterize propellers, and carry out destructive life tests.


## 3 good reasons to trust maxon for your drones

### 1. Safety

UAV manufacturers benefit from maxon's mature quality system, proven and certified in the medical (ISO13485) and aerospace (EN9100) industries, among others.
We offer sustainability and stability, combined with efficient configuration management and traceability of parts. All maxon products rely on standardized designs, manufacturing processes and testing, to assure top repeatability between parts. Best-in-class product documentation is available for each product, with reliable and verified performance data based on real tests.

maxon ensures the safety of your drones with high-quality design featuring several elements:

→ **Aerospace-quality materials**

→ **Significant safety margins** in the sizing of bearings and windings

→ **Rigorous testing and 100% end of line testing.**

→ And more

The materials and design methods maxon uses allow it to offer its customers products that can be used in demanding industries such as: aerospace and medicine. Beyond materials, maxon also relies on robust processes. maxon performs functional tests on all its motors before they are delivered to you. maxon has developed in-house facilities for these tests: temperature, impact resistance, service life, etc., and the results may be provided upon request.

**Repeatability has been a cornerstone of maxon's success for 60 years.** Whether you order a maxon motor today or in ten years, their performances will be the same. maxon relies on internal processes to manage and anticipate the risks of obsolescence in electronics.

This perfect combination of quality materials and processes has made maxon a major player in its field. **Thousands of maxon motors are already flying around the world,** on board various aircrafts. maxon motors meet very demanding manufacturing standards, which boost your chances of certifying your drones for flight over sensitive areas. Although the procedures for certifying drones are not yet clearly established, it is very likely that the quality standards required will be like those of the most demanding industries, such as aerospace.

## 2. Flight time

maxon guarantees flight time through optimal efficiency gained by the following:

→ Optimized design of active parts: magnetic elements and windings

→ Best motor control algorithms (FOC - Field Oriented Control)

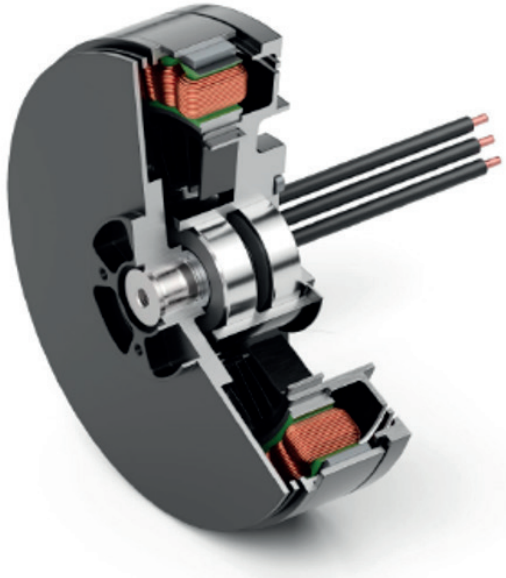
→ Lowest possible weight

→ Excellent propeller aerodynamics

**Propulsion system efficiency is crucial for flight time.** The components that make up the drone must be optimized with respect to each other. A team of 50 engineers specifically dedicated to aerospace and UAV engineering, plus a partnership with propeller design specialists, enable maxon to provide a comprehensive range. We are able to ensure that the system is optimized precisely for your needs, and that the components are perfectly suitable.

The maxon electronic speed controller (ESC) uses a sensorless closed-loop control algorithm that is still unrivaled on the UAV market. Individual calibration and advanced parameter settings ensure optimal field-oriented control (FOC) for each motor, with minimum power losses.

The hardware is supported by the intuitive studio software, allowing the operator to commission and monitor relevant parameters and data to find the best setup. A complete set of documentation including validation data is provided.



## 3. A team dedicated to drones

At maxon, precision is fundamental. To achieve it, the company relies on an experienced team of engineers and technicians who support customers from the specification phase, through prototype testing, to the start of production and beyond.

**Complete understanding of all aspects of drones.** What is most important in the drone industry is complete knowledge of the perfect interaction at the system level between brushless motors, controllers, and the matching propellers. We have that knowledge, and we understand it.

Solid partnerships ensure that maxon products are not an isolated solution but operate seamlessly within drone systems. maxon **is also developing partnerships with data management experts** to develop a communication system that will further improve the retrieval of motor-related data.

**Reliable international support in engineering and production.** The maxon Group and its 3,000+ employees, including 350 engineers in our 40 subsidiaries around the world, have developed an efficient supply chain and transparent configuration management to support our customers' innovation.

Transparency and traceability are essential to us. For each product, documentation and traceability of its top-quality components is available. Each product is thoroughly tested in our in-house testing center, resulting in reliable and verified performance data.

maxon also provides **complete and detailed datasheets for in-depth information about the performance of our motors.** You don't just buy a product, you receive true support.

At maxon, you will be **guided by highly qualified sales engineers, who speak the same language as your engineers.** Our electronics and mechanical engineers and our managers are easy to contact. You can come and meet them in person at our locations. They can also travel to you, to work with you to find the best technical solutions and to provide you with the necessary information and documentations to get your drones certified.

As a **European manufacturer and supplier headquartered in Switzerland,** maxon is the ideal partner for the certification of your drones.

## Standard or custom?

When the product specifications or drive combination in our standard products are not sufficient, we develop custom drive systems with a complete set of components, for the design of high-tech drones adapted to the needs of each project.

Explore maxon's standard products for drones on uav.maxongroup.com

**Are you working on a drone project that you would like to discuss with our experts?**

**Contact us!**

NOTES

Precision Drive Systems

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