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THE ULTIMATE GUIDE FOR DRONE CONNECTIVITY 2021

Technology, BVLOS, Regulation, Scale, Time to market

1. Executive Summary

Drone technology is set to play an important role in the near-term future of our connected society. Popular images of tireless drones criss-crossing our skies while performing precise and repetitive tasks are well-founded. Drones hold the key ability to help human civilization get to the next level of mass automation and convenience.

There are many benefits of using unmanned aerial systems to carry out endless tasks in cheaper and more efficient ways. It is a question of when, not if, unmanned, beyond visual line of sight drone activity at commercial scale will become a reality.

Today's global population is more interconnected than ever before. Super Cities are home to millions of people whose everyday lives intersect. Traditional supply chains that serve these communities are straining to keep up with population growth. Drone technology is poised to bring a quantum leap in efficiency to help this and other problems.

The COVID-19 pandemic has brought the medium-term arrival of beyond visual line of sight drone operations onto our doorsteps today. It's clear how a comprehensive drone network could have helped crowd tracking, symptom monitoring, and medicine delivery.

The regulation remains a last barrier to effective mass drone rollout. It is not enough to simply own a drone with comprehensive flying, planning, and situational awareness capabilities. The ecosystem has to convince regulators that these features can work in unity over a prolonged period to ensure that operation is consistently safe.

This guide will lay out the technologies that are in operation today. It will cover the barriers that are stopping us from achieving commercial scale drone rollouts. It will cover existing communication types and lay out a pathway for commercial expansion. Finally, the guide will attempt to map out what the drone landscape could look like in a few short years.

2. Introduction

2.1 Drone technology is on the verge of an evolutionary leap

The applications of drone technology are endless. Common use cases include law enforcement, public safety, and precision operations in industries like agriculture and mining.

The enormous potential of commercial drones is hampered by weaknesses in the technology required to make them reliably safe to operate. The future of drone technology is already here, it just needs to be unlocked by innovative first movers who can harness the best combination of existing technologies to satisfy regulators.

2.2 What to expect in the short to medium term

The drone industry has matured slowly. One necessary handbrake has been the element of safety. Naturally, the idea of unmanned drones accidentally causing significant loss of human life or infrastructure damage is enough to make regulators hesitant.

The short to medium term future of drone use is very exciting. Already some industry players have received FAA waivers to operate their drones beyond visual line of sight under certain conditions. There is a shared understanding from many players within the industry that a full regulatory certification is not far away, as long as they can satisfy the regulators.

2.3 The most promising technologies

The major barrier to widespread use of drones is finding a solution that can safely allow drones to operate over extensive areas. BVLOS is where commercialism, scale and business expansion lay.

There is no single technology in pole position to win the race to regulation. Rather, it will be a combination of technologies that best shows the failsafe connectivity and unbroken uptime that regulators demand. We will go into more detail on the most promising technologies later in the guide.

2.4 What is the state of competitive play?

Currently, the drone technology ecosystem features a range of companies that each has a noted speciality that will be a key component in the final BVLOS approved flight system. These companies are drawn from the following component sectors:

- Drone manufacturers.
- Analytics companies.
- Data storage and processing companies.
- IaaS Service providers.
- Flight planning and management companies.
- Hardware manufacturers.
- Connectivity Solution companies.

In order to get approval for BVLOS, businesses will have to collaborate to create the best platform that answers all the common concerns of regulators.

3. The fundamentals of communication

3.1 Introduction to Wireless broadband

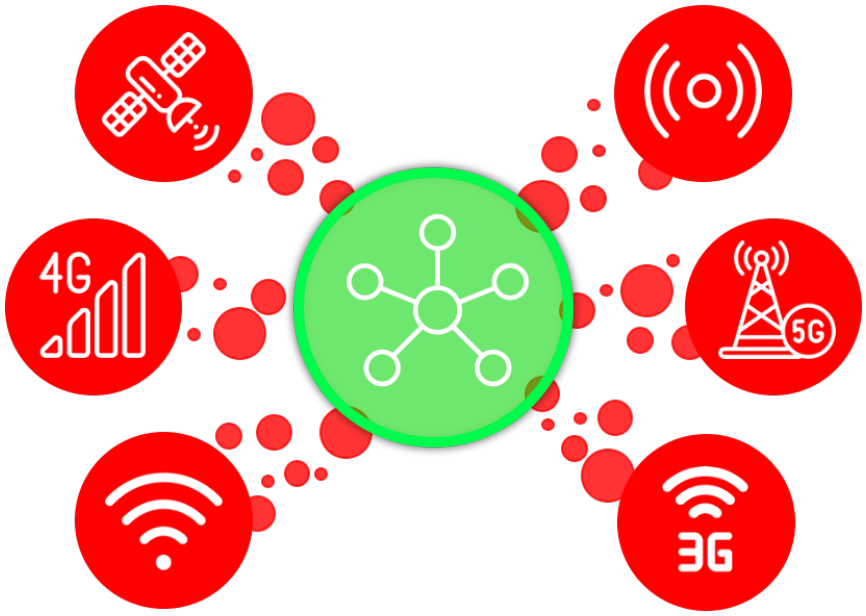
Wireless broadband is the fundamental technology that enables drones to take to the skies safely. Wireless communications can be fixed or mobile. With a fixed solution, these can often be found in homes and company buildings.

Drone technology relies on the mobile version of wireless broadband that supplies connectivity to unmanned drones as they move through different locations. Wireless broadband services emanate from a collection of towers / antennas that are most commonly found in more populated areas.

These towers / antennas provide an overlapping service that allows a moving drone to connect and reconnect to them on the “fly”. It’s no exaggeration to say that wireless broadband has been the bedrock technology that early drone use has been based upon.

3.2 Common communication technologies

For a drone to remain in the sky, it needs unbroken connectivity. So, drone operators have relied on a combination of established and emerging communication methods. Drones have used the best combination of communication technologies to maintain drone uptime, while searching for greater communication survivability , reliability, and higher data transmission capabilities.



3.2.1. Radio Frequency

This trusted and traditional technology has been used in many industries for decades. Radio frequency waves offer an unlimited range of distinct patterns that can be used between transmitters and receivers to communicate a message. Many types of drones use this technology.

Benefits

- RF signatures are reliable even in crowded urban operating environments. This reliability is perfect for drone use.
- It is a well-known technology that can be scaled up easily.
- When used correctly, it is largely safe.

Disadvantages

- Radio frequency waves are prone to interruption by other frequencies or by malicious actors.
- It is the ultimate limited range technology, as it must be used within line of sight.
- RF is unlicensed, meaning that there is no oversight of applications and usage.

3.2.2 LTE / 4G

Mobile Network Operators Licensed use developing versions of wireless broadband such as LTE and 4G. As large, licensed, and reputable operators, these two types of technology are available over wide ranges and with excellent quality.

Benefits

- These newer generation communication technologies bring faster and more stable data transfers at higher volumes.
- Coverage depends on the number of cell towers. In urban areas, there is an abundance of cellular infrastructure, making drone operation in cities easier.

Disadvantages

- The age-old challenge of LTE/4G technologies is coverage. Many drone use cases such as monitoring and data gathering require large operating ranges. With limited tower coverage, this becomes a challenge.

- LTE/4G technologies are vulnerable to system failures such as power interruptions and software failures, creating gaps in coverage.
- Transition between different LTE/4G cells causes short term loss of communication.

3.2.3 Satellite

Satellite technology depends on a global network of satellites that are often government-owned and used for military applications. The technology can be expensive and has not been accessible to commercial players meaningfully.

Benefits

- Satellite technology offers global always-on communication and control with reliably high uptime.
- Coverage is very high, and the technology comes to life in remote areas that are traditionally where wireless broadband fails.

Disadvantages

- This technology requires a visual line of sight – meaning if there is no sky clearance connection will be lost.
- Can be prohibitively costly.
- Is hampered by latency which affects real-time control.
- The current existing Satellite solutions are heavy power consuming, with a large form factor and payload, meaning they are not viable for most commercial UAVs.

3.2.4 5G

There is a lot of excitement around this technology, with good reason. 5G offers throughput and latency which are many times faster than its predecessor 4G. This means it can accommodate higher volumes of data transfer during flights.

Benefits

- It comes alive with demanding tasks such as quality real-time data transfer. With superior latency and data speeds than previous technologies, it serves the needs of drone operators.

Disadvantages

- Coverage is still not widespread as it is an emerging technology. This makes relying on 5G alone makes it dangerously vulnerable to coverage gaps.
- This coverage challenge makes long range operation of drones using 5G almost impossible.

3.3. A word on mesh technology

For a drone to remain in the sky, it needs unbroken connectivity. So, drone operators have relied on a combination of established and emerging communication methods. Drones have used the best combination of communication technologies to maintain drone uptime, while searching for greater communication survivability , reliability, and higher data transmission capabilities.

Mesh technology refers to networks made up of different communication options that create a coverage web, or mesh. This rich interconnectedness is exactly the type of technology option that a drone operator concerned about coverage gaps can use.

3.4 Introduction to bonding technology

It's in the nature of transmission channels to fail. Regardless of the communication technology, they each have a weakness. Channel failure is very dangerous in drone operations, especially when operating beyond a visual line of sight. Therefore, any technology that can aggregate multiple transmission channels into one connectivity pipe, diagnose each channels' quality in flight, locate other suitable channels ,aggregate them as well as part of the main connectivity pipe, and seamlessly transition between the different available channels automatically , is called bonding technology.

Using existing network infrastructure, bonding technology is the best way to ensure a high uptime solution to the problem of unstable connectivity. The technology is usually more secure, with higher throughput, and supports operations in real-time. Bonding technology creates a more strongly interconnected communication pathway by fusing together multiple IP links to reduce latency, increase bandwidth, create redundancy and support secure transmission of data.

4. Drone communication and connectivity methodologies

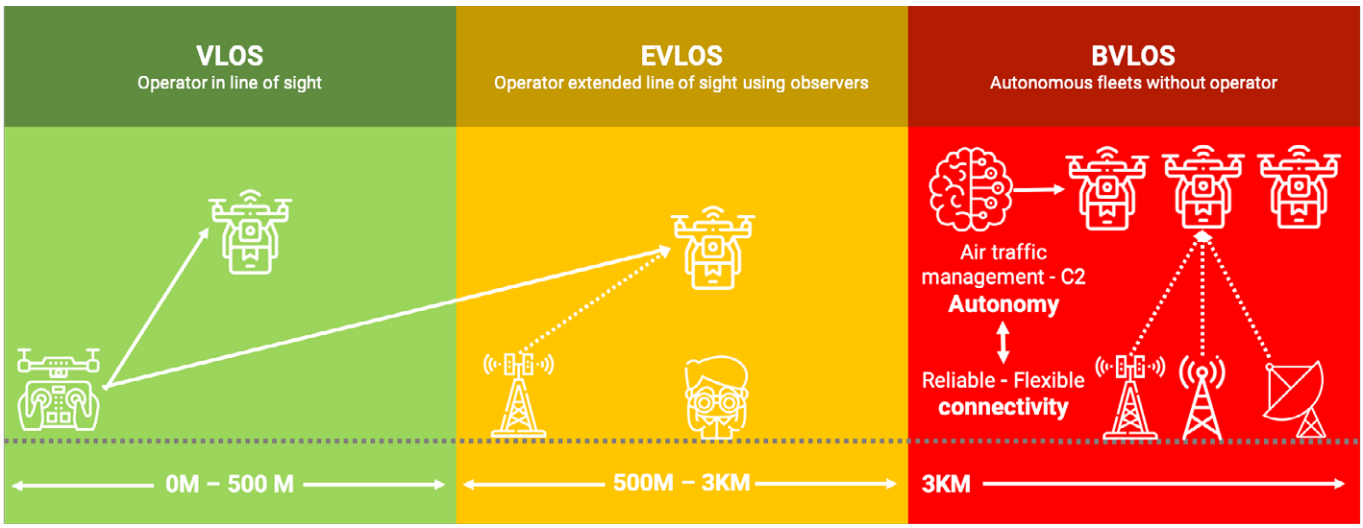
4.1 From VLOS to BVLOS: The transition to unlimited distance

Operating within Visual Line of Sight (VLOS) was the original operating method for drones. It's lightly regulated and is largely safe, if performed responsibly. Drone operators monitor their drones to avoid mid-air collisions with other objects. If there is a forced landing because of a communications failure, the drone operator can see where the drone fell, or the drone can return back to the operator as part of its security systems.

Naturally, there are limits to the usefulness of VLOS. It is simply not scalable because having a pilot operate every drone to the limits of their eyesight is expensive and impractical. Also, the range of operation is comparatively tiny when compared to the potential of BVLOS.

If the industry is to develop into something truly useful, BVLOS is the only logical way forward. The difficulty facing BVLOS is that as a maturing industry, there are still significant performance weak spots. These involve connectivity survivability, failsafe systems, durable platforms, and evidence of safe performance.

It won't be easy to get regulatory approval, but it will be worth it when vast commercial markets embrace BVLOS. Here are some points on how BVLOS can develop.



4.2 How drones use connectivity methods

Different drone manufacturers have their own approach to creating a solid communication and connectivity solution. But what is stopping them from developing to an acceptable BVLOS platform?

The FAA's part 107 waiver is a highly desirable first step towards attaining BVLOS operating permission. To achieve the part 107 waiver, operators would need to show that they have the plans and technology to operate a drone within VLOS. To achieve BVLOS, the operator would have to answer the same questions as the VLOS operator, only that their solution would be unmanned. The regulator stipulates that achieve a waiver to operate BVLOS, a drone system should:

- Know the unmanned aircraft's location.
- Determine the unmanned aircraft's attitude, altitude, and direction of flight.
- Observe the airspace for other air traffic or hazards.
- Determine that the unmanned aircraft does not endanger life or property.
- Unmanned aircraft ongoing status report like battery health.

At the centre of fulfilling these requirements is the crucial element of connectivity. When operating BVLOS, access to high-volume data transmission services would cater for every requirement.

Naturally, a drone operator using the best combination of RF, LTE, 4G, 5G, 3G (at times) and satellite technology could provide a viable answer to each of these requirements.

4.3 Bonding technology, the most flexible communication platform

Bonding technology can help provide a solution to some regulator's requests. The best bonding solutions help create an unlimited operating area by removing range-limited, single communication types and replacing them with a platform based on widespread network infrastructure, like cellular networks.

Bonding technology combines multiple connectivity types to form vast operating ranges. Using hybrid and modular technology, it can solve the problem of limited bandwidth connectivity over extensive ranges.

By fusing together multiple IP links, bonding technology keeps a network pathway that guarantees the continued transmission of data. With best-in-class fail-over protection, intelligent technologies can isolate unsuitable transmission channels and re-route transmission to working channels.

4.4 How can drones use bonding technology for reliable connectivity in any terrain?

Different terrains bring unique challenges. Drones working in remote areas face the problem of limited connectivity, while harsh terrains often contain communication channels that have been damaged by the elements.

Any solution has to be robust enough to allow drones to fly dynamically in different environments. Creating a long-range operating reach with failsafe communications is the answer to limited or compromised connectivity.

Not all communication infrastructure is the same in every area. A reliable platform with great connectivity and no downtime that can work in different environments is a must.

4.5 The benefits of multiple link usage

There are many reasons to adopt a multi-link solution. Here are some of them:

- It creates more stable connectivity by reducing dependency on one link
- It increases the capacity for high-volume data transfer
- It safely increases operating range
- It creates a durable platform that can operate in any terrain
- It overcomes infrastructure shortfalls and guarantees that drones keep working
- It can reduce cost by controlling the networks used

4.6 Multi-sensor data over long distances

Sensors are a crucial part of drone construction. The use case of drone operations is often related to monitoring and information gathering. Sensors are also key to UAV navigation. Having a solution that supports the functions of sensors that can rapidly process information and transmit their data-rich findings is essential.

Common sensors found on drones include GPS, attitude sensors, navigation sensors, video cameras, LiDAR, and more. All these functions require unbroken connectivity links that can support high amounts of data transmission in real-time and over extensive ranges.

4.7 Balancing connectivity and data management

How do you prioritise between connectivity and data management? When performing their functions, drones must dynamically decide whether to maintain connectivity or to transmit data. These parameters are programmed into key drone functions. So, it is essential to have superior

component quality and build efficiency that ensures that data prioritisation is done seamlessly and in real-time.

Data management is a vital part of drone operation. Therefore, it's critical for operators to choose connectivity partners that facilitate superior transmission of video, audio, and telemetry. Only by deploying robust fail-over protection, can connectivity partners offer solutions to problems such as secure and reliable in-flight data transmission.

With industrial drones in particular, multi-source data analytics creates a stream of resource-heavy, real-time information. Platform reliability is vital, as high uptime and high levels of operating capacity are non negotiable. When choosing partners for their drone platform build, manufacturers are encouraged to give priority consideration to partners who can:

- Provide platform capacity to prioritise data management vs `transmission mid-flight.
- Provide high-capacity solutions to seamlessly enable resource-rich functions such as live video transmission.

4.8 The importance of latency in BVLOS operations and real time control

To achieve BVLOS approval, drone operators must show that their systems have low latency. Drone operation at high speed and in populated areas means that communication systems will have to be responsive and always-on to activate evasive mid-flight actions when necessary.

Each connectivity method had its advantages and drawbacks. Terrestrial wireless broadband networks have high coverage and low latency. Satellite communications cover enormous ranges but have latency problems.

The best solution will be to find a connectivity partner that combines the best of all available technologies to optimize latency, bandwidth and networks used in real-time.

4.9 UAV reliability and redundancy. One communication channel or multiple?

Safety is a fundamental concern for BVLOS drone operations. It will come as no surprise that using multiple communication channels is best practice to maintain high uptime and responsiveness. Recreational drones still utilise RF as their only communication method, which is why they will forever be required to operate within VLOS.

The burden of safety is much higher with BVLOS. Regulators need to be satisfied by the robustness of any solution that would allow drones to fly dynamically in different environments.
The best solutions in the market solve the problem of connectivity survivability by offering connectivity through multiple links to improve vital command-and-control robustness.

4.10 Cost effectiveness of managed networks in relation to BVLOS

As with the connectivity solution, the cost solution involves a hybrid approach. Terrestrial networks are already well-established, have high throughput and relatively low costs. This remains the most cost-efficient option for drone operations.

However, terrestrial networks will not always be available in BVLOS operations, particularly in low-coverage areas. This is where a hybrid system could seamlessly default to another communication method, such as satellite communication, even if the cost of operation is momentarily higher, and switch back to a lower cost network once available again.

5. Regulation and Certification

5.1 What are regulators looking for?

Safety is the top priority with BVLOS certification. Regulators have split their primary concerns into distinct sections. Here is a list to understand what they are looking for:

5.1.1. Connectivity

Finding a high uptime connectivity solution is an enormous challenge. A lapse in network coverage could be disastrous. Regulators want to see that drone manufacturers have paid some thought to creating a robust communication platform that uses the best available technology.

5.1.2. Flight Management System

It is sometimes said that regulators are managing a system of systems. Creating failsafe communications that can command and control autonomous UAVs takes consideration and detailed planning.

Regulators are interested in systems that have accumulated many hours of testing and application. Have you partnered with best-in-class vendors? Is your system robust, requiring little customization? These are questions that the regulator will ask.

5.1.3. Failsafe Systems

If a drone fails in mid-air, what is the contingency plan? A failsafe system could involve an on-board computer that deploys a parachute in the worst-case scenario. Regulators are interested in seeing solutions that have taken care to minimise damage to people and property.

5.1.4. Detect and Avoid

Sensors provide important situational awareness to BVLOS flights. Having an intelligent and responsive detect and avoid system could avert a disaster. Current solutions involve sensors on a drone bumper that can scan the space around the aircraft for obstacles.

There is no silver bullet. Regulators are open to a convincing solution that has undergone rigorous testing. Situational awareness and collision avoidance are key parts of the BVLOS toolkit.

5.1.5. Platform Structure Durability

Sensors provide important situational awareness to BVLOS flights. Having Most drones, except for recreational drones, face testing environments of extreme temperature, moisture, and shock. If the drone construction is not durable, it will fail during operation.

Regulators will look kindly upon drone platforms with a proven record of durability in the face of harsh conditions. This is why choosing quality component partners is essential. Even minor components can fail in flight, which is why it's important to always look for the best quality.

5.2 Airspace management: How UAVs join civilian airspace

Regulators are concerned about matters like aircraft visibility and drone unit identification. They are also worried about safe, robust communication links for BVLOS operations. Establishing standards for all players is vital to the long-term success of UAV.

For UAVs to join civilian airspace, important foundations around roles and responsibilities, common information language, data exchange methods, and performance requirements need to be agreed upon.

Several different organisations and role players will contribute to the process. These will be drawn from drone operators, connectivity companies, mobile network operators, and regulators.

This is the function of bodies like NASA and the FAA in the US, the European Aviation Safety Agency (EASA), and Australia Civil Aviation Safety Authority, to name a few.

5.3 Drone location and identification

Steps are being taken to consistently and thoroughly log and manage the identifying information of all drones for the safety of the UAV ecosystem. The FAA recently proposed regulations around the Remote Identification of Drones. The proposal mentions two major categories: standard remote identification and limited remote identification.

Within standard remote identification rules, drone operators must broadcast identification and location information from the drone itself. They should also send the same identifiers over the internet to a Remote management company that keeps these records in real-time. This section of the regulation pertains to BVLOS flights.

Limited remote identification refers to VLOS flights that travel no further than 400 feet from the pilot. Identifying information must be sent to the Remote management company over the internet. They do not require it to be broadcast in flight.

5.4 How commercial UAVs combine with other airborne platforms

Commercial drones undertake several use cases such as aerial mapping, inspections, delivery, surveys, construction, filming, and emergency services. In the past, outdated commercial drone laws required even VLOS pilots to undergo a lengthy training and exemption process.

One significant barrier to entry to this market was that not only were pilots required to undergo this training, but they were only approved to undergo the process if they were already certified helicopter or airplane pilots.

With the new commercial drone laws, any person over the age of 13 can undergo the training. The drone must be clearly marked with its unique identifiers and must be in good working condition. An appointed vendor can confirm airworthiness.

Besides clearly physical incapacities, anyone who can see clearly and is in good physical health can pilot a commercial drone within VLOS. They should learn some key rules, such as not operating at night, but in general the requirements for operation are much smaller.

However, VLOS will never be as effective and scalable as BVLOS, which is why unmanned, large scale BVLOS commercial operation regulatory approval is in such high demand and short supply.

5.5 The role of platform reliability for regulator certifications

Fully autonomous flights over populated areas face stringent rules from the FAA. Regulators needed to be satisfied by the robustness of any solution that would allow drones to fly close to people and property.

The FAA will not grant a waiver and / or Type Certificate for limitless operations over busy civilian areas to just anyone. Operators need to prove that they have a robust and durable platform that has undergone stringent testing. In particular, regulators are looking for solutions to the problem of reliable connectivity and fail-over protection for almost every component in the UAV systems.

5.6 Getting ahead of the regulation – What should I be looking out for?

As a maturing industry, there is no established route to certification. Innovations are in constant development, and new ones will replace existing ones in time. To satisfy regulators, operators need to show that they have carefully designed their platforms and rigorously tested them. Here are some other things to keep in mind:

- Pay close attention to platform design and execution
- Put a premium on safety, including connectivity survivability, and failsafe protections
- Don't be afraid to work with component partners who are leaders in their area
- Work on proving the platform durability
- Keep a log of testing under dynamic conditions

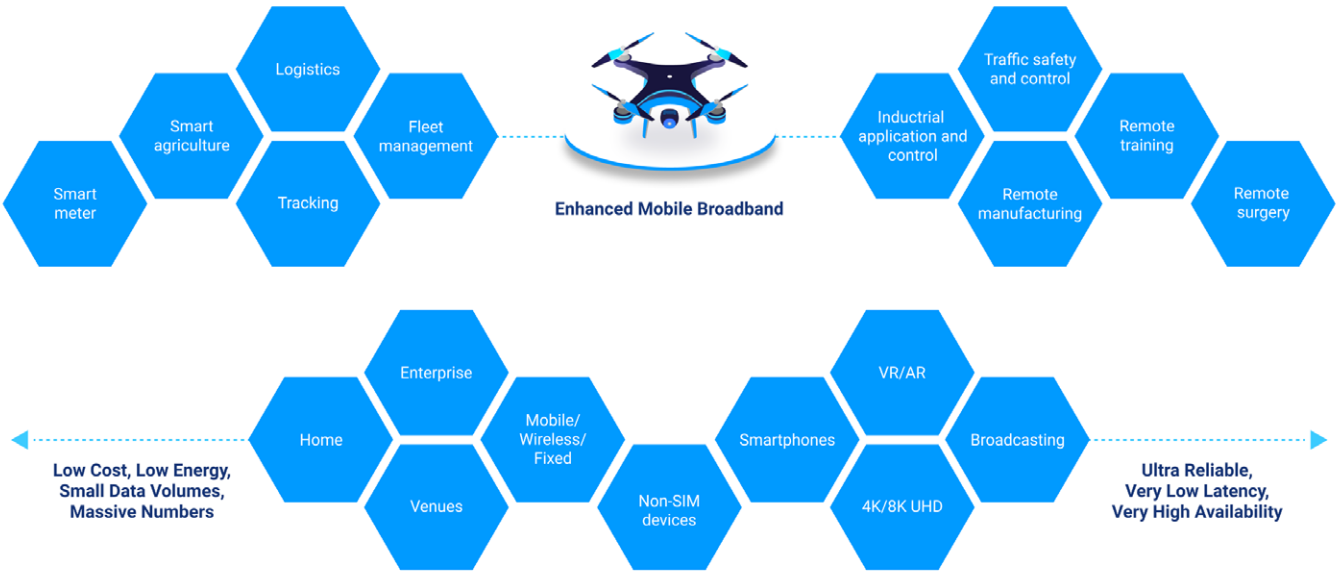
6. Going commercial

6.1 What are the key elements to look out for when trying to go commercial?

The major barrier to commercial scale UAVs on BVLOS missions is securing a robust and scalable solution for autonomous and semi-autonomous operations. Collaboration with other partners could be the key to getting over this.

Many sectors of the drone industry are in a heated race to get regulatory approval. Companies are trying to get approval from different angles. Outsourcing can be a real timesaving way to advance platform development. Here are some key things to consider when trying to craft a commercial solution:

- Focus on companies with experience and certifiable solutions.
- Trust OEM partners to complement the service offerings that will help achieve BVLOS commercialisation.
- Planning is crucial. Today's vendor decisions will be an irreversible part of your system in the future – Make sure you choose flexible solutions with a solid roadmap.
- The right partner can help scale your business.



Ericsson. Drones and networks: Ensuring safe and secure operations.

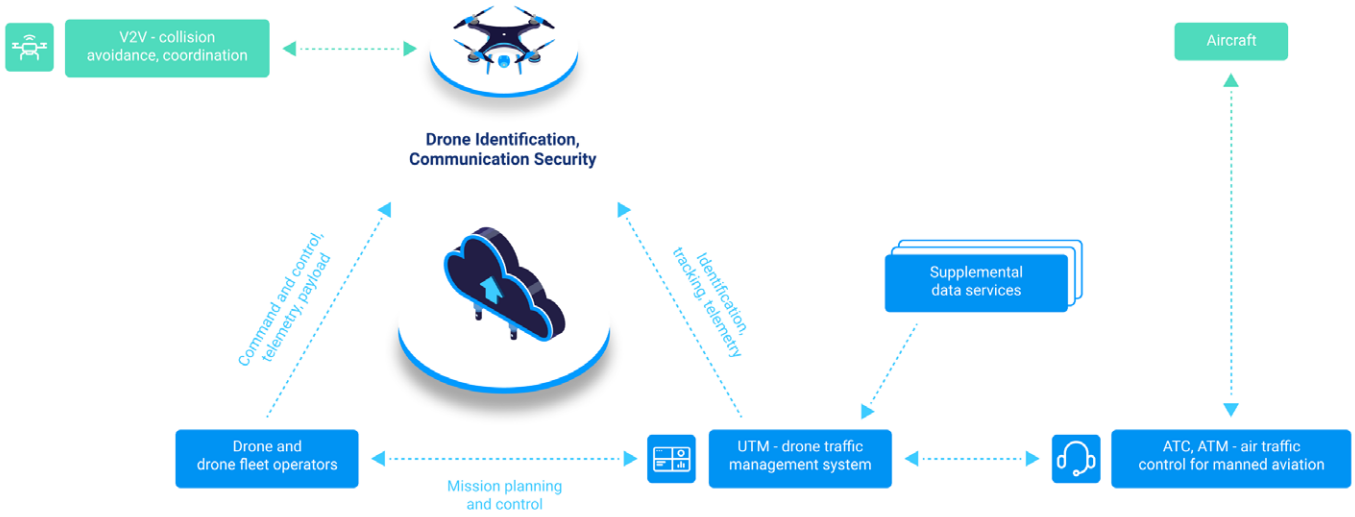
6.2 How can you prepare for business expansion?

You should strive towards finding experienced, professional partners who can help you create a reliable, scalable business soon, so you can reach your market share in time.

There are still several working methodologies of commercial BVLOS operations, and many combinations can successfully lead to commercialisation, scalability and regulation. Who will get there first?

It can be easy to integrate and cooperate with other solution manufacturers. The value of combining your products with a complementary partner is very rewarding. Platforms must be well-designed from the outset, as altering them after regulation is virtually impossible.

Each unmanned aerial platform can be constructed from several different component products. Manufacturers, operators, component manufacturers, maintenance companies, and technology partners all have a part to play in an excellent system. There are many decisions to make.



Ericsson. Drones and networks: Ensuring safe and secure operations.

6.3 The growth estimation of the industry and use cases

The UAV industry continues on a high growth path. Driven mainly by consumer innovations like food delivery, it shows no sign on stopping. Below is a key statistic to show this growth:
The drone market is likely to grow to USD 21 Billion by 2035 from less than USD 1 Billion today.

UAV use cases are already established. Radically new use cases are not expected to appear in the near term, but established use cases will grow. Here are the main ones:

Commercial use cases

- Food delivery
- Package delivery
- Inspections
- Agriculture
- Mapping

Government use cases

- Fire fighting
- Search and rescue
- Border patrol
- Crowd monitoring
- Law enforcement
- Conservation
- Infrastructure protection

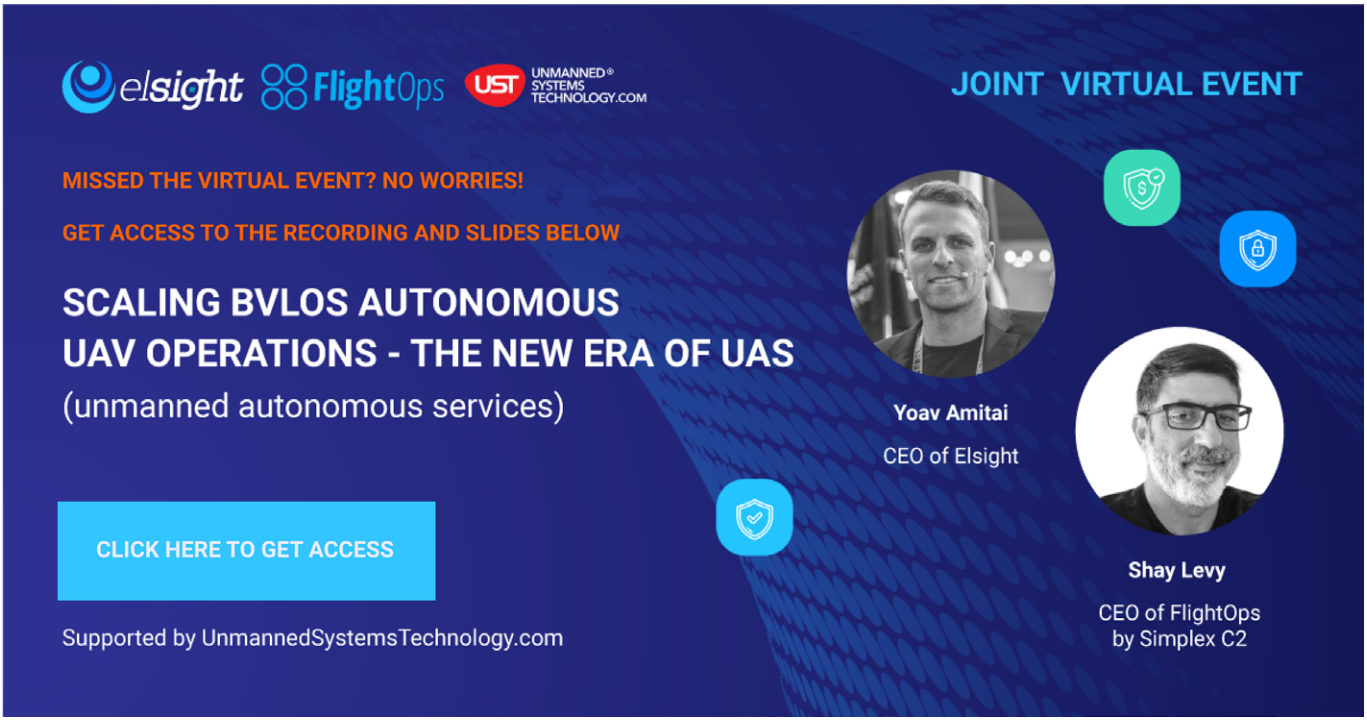
7. How COVID-19 impacted the drone industry

With human movement heavily reduced during the pandemic, several drone food delivery start-ups in countries like the US could make crosstown commercial deliveries.

Some countries used drones for exceptional use cases, such as spraying disinfectants on outdoor stadiums. In parts of Asia, thermal imaging drones successfully scanned crowds of people for elevated temperatures.

Although the pandemic was a once-in-a-lifetime event, it did not speed up regulatory approval in any meaningful way. What it did, however, was brought to life the potential of drones for a variety of use cases. Developers sped up such projects as apps to monitor critical infrastructure and people.

Law enforcement agencies could deploy their drones to monitor if crowds were successfully socially distancing. The pandemic coincided with social unrest and elections in the US in particular, leading to increased uses of drone monitoring by law enforcement.



8. Future Outlook

8.1 How will drones change the world in the next 10 years

We envision that commercial UAV use will continue to rise steeply in the next decade. The use cases are already known, and others could yet come to the forefront of our rapidly changing world. Each sector will experience this growth in their own way:

8.1.1 Drone manufacturers:

They can expect to come to the forefront of commercial and government usage as regulations are passed. Drone manufacturers are already collaborating with a range of different industries as each industry pre-emptively tries to use drone technology for their own purpose.

8.1.2 Drone operators:

Commercial package deliveries will spike, as will other use cases like inspections, research, and entertainment. Once BVLOS approval becomes mainstream, drone operators will feel the vast commercial boost immediately.

8.1.3 Communication companies:

Without wireless communication services, there is no drone industry. Communication companies will take a prominent role in shaping traffic management systems as they already have proprietary tracking and connection technology.

9. Resources

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