Opportunities in the drone sector with the adoption of AI and blockchain

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Foreword

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Drones, AI, and blockchain technology have the potential to completely change a wide range of businesses as we approach the dawn of a technological revolution. While the convergence of these revolutionary technologies offers hitherto unseen growth prospects, it also brings with it special difficulties that need careful manoeuvring.

Future growth prospects of the drone industry using blockchain technology and AI, handling related risks and cybersecurity issues, and investigating environmentally friendly technical solutions are the main subjects touched upon.

It is a privilege for ASSOCHAM to collaborate with PwC for this report on 'Opportunities in the drone sector with the adoption of AI and blockchain'. We hope that the report will strengthen our efforts to support innovation and technical growth in India.

Foreword

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The convergence of drones, AI, and blockchain technology is set to revolutionise numerous industries, offering unprecedented opportunities.

The integration of AI with drone technology represents a significant leap in autonomous systems. AI empowers drones with enhanced autonomy, intelligence and decision-making abilities. The future of AI-powered drones holds promising prospects, this also calls for ethical frameworks and responsible deployment.

In India, drones have a key role to play in the agriculture, disaster management, public services, mining and defence sectors. The report in partnership with PwC addresses key topics like managing cybersecurity risks, exploring sustainable tech solutions, and integrating drone technology with blockchain and AI.

Foreword

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Once a specialised technology, drones are now indispensable in many fields. Drones equipped with AI have access to sophisticated data processing capabilities that allow them to adjust to changing conditions and make judgements in real time. For instance, drones with AI capabilities are transforming crop management in agriculture by evaluating enormous volumes of data to optimise growing conditions and yield forecasts. These smart drones are also enhancing response times and efficacy in disaster response by offering vital real-time information for search and rescue operations.

AI-powered drones are also improving security and surveillance systems. Drones can monitor large areas for possible threats or environmental changes by utilising picture recognition and pattern analysis. This opens up new possibilities for infrastructure management, security and wildlife protection.

Though promising, technological breakthroughs also raise significant ethical and regulatory questions. Therefore, it is important to address potential data security issues and ensure that AI-enabled drones can be used ethically. Maximising the advantages and minimising the negative impacts of this technology will require a balance between innovation and ethical issues.

This paper offers a comprehensive analysis of the present uses of AI-enabled drones and potential future developments in drone technology. It seeks to provide insights into how the technological synergy between AI and drone technology can transform numerous sectors and open up new development options by showcasing noteworthy use cases and real-world applications.

Foreword

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The combination of blockchain, drone technology, AI and geospatial analytics is a significant development in aerial vehicles. Important insights into spatial patterns are provided by geospatial analytics which can be enhanced with AI's real-time and predictive capabilities. Blockchain safeguards the integrity of the data by introducing a crucial layer of security and transparency. Drones with sophisticated sensors provide unmatched capabilities for data collection and monitoring and help in enhancing the efficacy of AI and geospatial analytics. The adoption of blockchain technology can open up new options like catastrophe management, urban planning and environmental monitoring.

In a world where combining geospatial analytics, AI, blockchain and drones is important for innovation, this paper discusses the applications of these technologies with drones to demonstrate how drone technology can solve various problems such as public safety and traffic management.

Foreword

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Drones are important tool in bridging the divide between digital and physical systems, aligning with the principles of Industry 4.0, which emphasises the integration of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data.

Today, drones have become indispensable across various sectors. Those equipped with AI capabilities possess advanced data processing skills, allowing them to adapt to dynamic environments and make real-time decisions. The integration of AI with drone technology signifies a significant advancement in autonomous systems, enhancing drones' intelligence, autonomy and decision-making capabilities. While AI-enabled drones hold great potential for the future, their responsible deployment and adherence to ethical guidelines are essential.

This paper offers a comprehensive analysis of current applications of AI-enabled drones and explores potential advancements in drone technology. It aims to illuminate how the synergy between drone and artificial intelligence technologies can transform multiple industries and create new opportunities for growth.

Foreword

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In the age of Industry 4.0, drone technology is an essential tool for transforming various processes across industries to enhance automation, operational efficiency and data collection. Drones are essential for connecting digital and physical systems since Industry 4.0 stresses the integration of cutting edge technologies such as the internet of things (IoT), AI and big data.

Drones can also improve the operations of the logistics and supply chain sector by improving inventory management and enabling real-time tracking of shipments. They can also expedite operations and shorten delivery periods by making quick deliveries, particularly in difficult-to-reach locations. Drones are also used in the energy sector to maintain and check vital infrastructure such as pipelines and power lines to ensure safety and reduce downtime.

By offering precise overhead views and gathering data in dangerous or difficult situations, drones also help in improving the safety and efficiency of the people and processes in mining and environmental monitoring sectors.

Drones: An overview of the market

In an ever-evolving tech landscape, various industries like construction, real estate, e-commerce, agriculture, utilities and energy, financial services, and media and entertainment are seeking ways of implementing drone technology in their operations.

Due to the merging and quick advancement of two entirely distinct technologies – radio communication and smartphones – both consumer and commercial drones can collect data which can be leveraged for various purposes in different industries.

Drones

Drones or unmanned aerial vehicles (UAVs) can either be operated autonomously using pre-programmed instructions or controlled by human operators. UAVs are available in various shapes and sizes and are equipped with a variety of equipment that allows them to function well. Based on maximum all-up weight (including payloads), as per India's Drone Rule, 2021, drones can be classified as follows:

Nano UAS: Weighs ≤ 250 grams

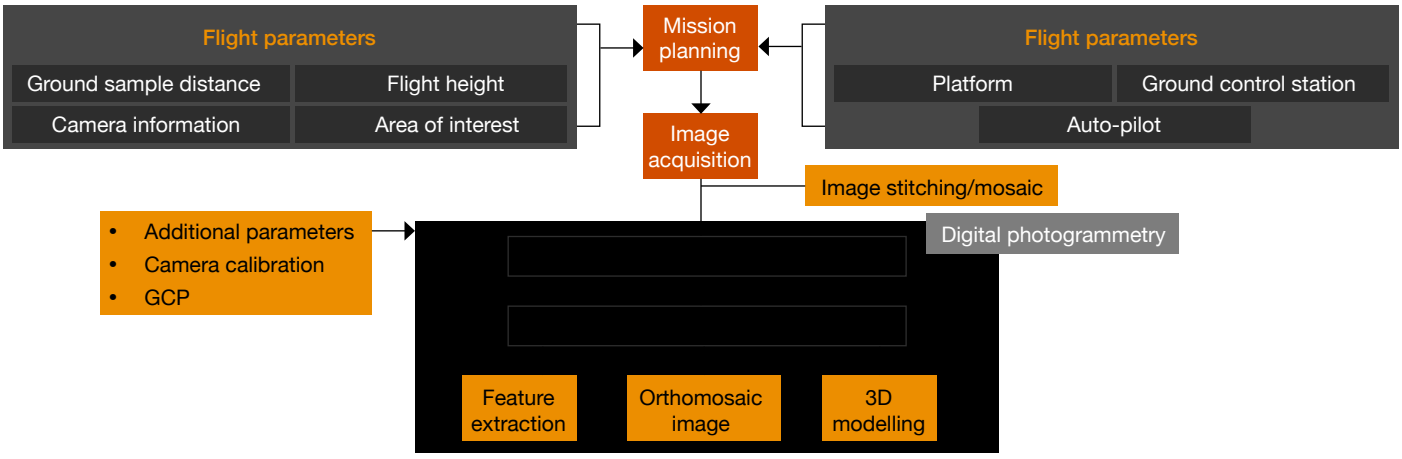
Small UAS: Weighs > 2 kilograms and ≤ 25 kilograms

Micro UAS: Weighs > 250 grams and ≤ 2 kilograms

Medium UAS: Weighs > 25 kilograms and ≤ 150 kilograms

Drones are commonly used for image acquisition and processing which helps in surveillance activities in the defence, agriculture and construction sectors. An overview of the workflow for image acquisition using UAV is given in Figure 1 below.

Figure 1: A general workflow for image acquisition from UAV



Source: PwC analysis

Since drones are a flexible and affordable alternative to traditional piloted aircraft for aerial view, their use as remote sensing platforms has acquired widespread acceptance. For example, drone data maps can be leveraged to develop active communication tools. Furthermore, drones can monitor sector-wise, real-time data and offer contextual insights, which enables businesses to make better decisions.

1 https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/mar/doc202232932501.pdf

Global drone market: An overview

The increasing adoption of drones in various sectors has been a major driver of the growth of the global drone market as drones are predominantly being used for various applications such as delivery services, surveying, inspection and monitoring. The integration of drones with e-commerce delivery platforms is also evolving rapidly since many companies are developing drones which are specifically meant for commercial use related to agriculture, defence and asset monitoring.

According to a PwC report, the global commercial drone market has grown and will continue to grow at a CAGR between 16% and 17%.[2] The percentage distribution of the total revenue from each industry segment is depicted in Table 1.

Table 1: Percentage share of each industry in the total drone market

Industry segment	% share of total drone market
Infrastructure	36%
Agriculture	25%
Transport	10%
Security	8%
Media and entertainment	7%
Insurance	5%
Telecommunication	5%
Mining	3%

Source: PwC analysis

The global drone market is segmented into two categories:

1. **Rotary wing drones:** Also referred to as a quadcopter or multicopter, a rotary wings drone generates lift and stability through the use of several spinning blades, which enables hovering and vertical takeoff and landing.
2. **Fixed wing drones:** Using its fixed wings for lift and forward drive, a fixed wing drone mimics a regular aeroplane. Though this allows for higher speeds and longer flying times, it also necessitates the use of runways or other launching devices for takeoff and landing.

The growth of each segment in the global drone market is driven by the unique capabilities of drones along with their potential to perform agile manoeuvres while maintaining continuous visual contact with specific targets. According to a study conducted by PwC, 72%[3] of the organisations today feel positive about commercial drones. There is a strong positive sentiment around the expected benefits that can be derived from the adoption of drones for performing various functions (represented in table 2).

2 https://www.pwc.in/assets/pdfs/publications/2018/flying-high.pdf

3 https://www.pwc.co.uk/issues/technology/drones/building-trust-commercial-drones.html

Table 2: Possible areas where organisations can benefit by using drones

Benefits	% of survey participants agree
Time savings	88%
Carbon reduction	87%
Safety	86%
Cost reduction	86%
Productivity	84%

Source: https://www.pwc.co.uk/issues/technology/drones/building-trust-commercial-drones.html

However, only 43%[4] of the organisations think that the industry is using commercial drones effectively and its use can be improved by focusing on the factors given in Table 3.

Table 3: Focus areas to improve the effective implementation of drones

Benefits	% of survey participants agree
Credible drone service providers	63%
Clarity of use case benefit	59%
Industry specific qualification	56%
Reviewing the regulations	44%

Source: https://www.pwc.co.uk/issues/technology/drones/building-trust-commercial-drones.html

The Indian drone market

The drone market in India continues to expand and this expansion is driven by advancements in technology and changing consumer preference. As the market and the global tourism sector recovered gradually after the COVID-19 pandemic, the growing popularity of drones for recreational use and aerial photography also created a wide range of opportunities in various sector such as agriculture, defence and mining.

India has set a target to become a major global drone manufacturing hub by 2030, and this ambition is expected to boost the country's gross domestic product (GDP) by 1–1.5% and create at least five lakh jobs in the coming years.[5] Drones have been identified as a crucial part of the industry 4.0 ecosystem as the adoption of drones can enhance data accuracy and efficiency since it can automate tasks related to inspection, monitoring and provide real-time data. These unique features of drone technology allow predictive maintenance by detecting early sign of any possible malfunction and facilitate immediate decision-making and operational adjustment. Its ability to swiftly gather and analyse information blends seamlessly with other industry 4.0 technologies like AI and the internet of things (IoT) to enhance industrial processes, reduce expenses, improve safety and ensure smooth resource allocation.

4 https://economictimes.indiatimes.com/industry/transportation/airlines-/-aviation/what-will-it-take-for-indias-drone-industry-to-fly-higher/articleshow/107729412.cms?from=mdr

5 Ibid

Key drivers of drone industry in India

The rise of the drone industry in India began with the government's introduction of liberalised drone regulation in August 2021, which was expected to propel India into 'an era of supernormal growth'.[6] These regulations simplified the bureaucratic process by reducing the number of required forms and permissions from 25 to five and removed the need for security clearances during registration and licensing.

The Ministry of Civil Aviation identified five key pillars[7] to establish India to be a drone hub in coming years:

1 ease of doing business (Drone Rules 2021)

2 financial incentives (production-linked incentive scheme)

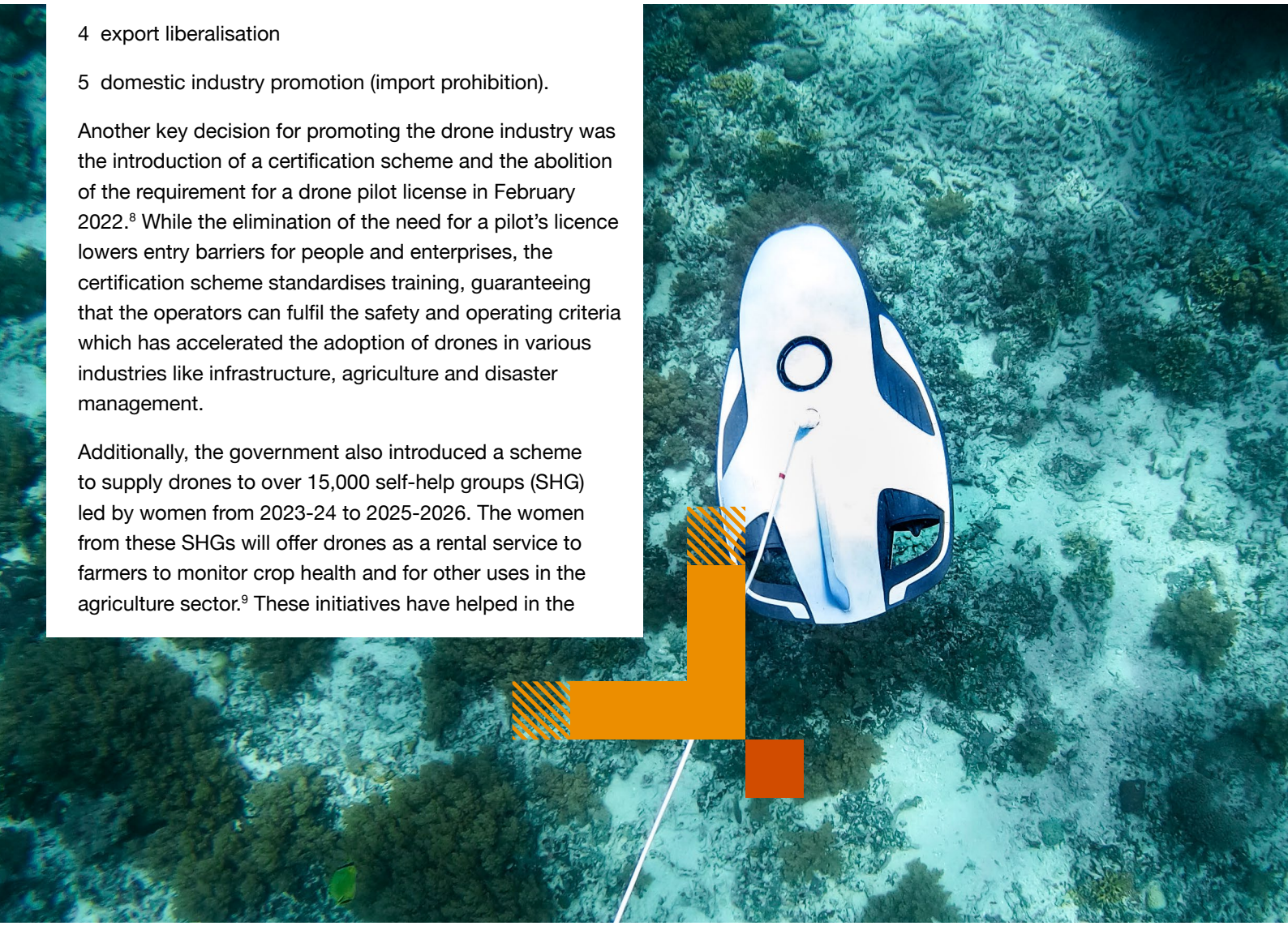
3 government as market maker (procurement by government)

4 export liberalisation

5 domestic industry promotion (import prohibition).

Another key decision for promoting the drone industry was the introduction of a certification scheme and the abolition of the requirement for a drone pilot license in February 2022.[8] While the elimination of the need for a pilot's licence lowers entry barriers for people and enterprises, the certification scheme standardises training, guaranteeing that the operators can fulfil the safety and operating criteria which has accelerated the adoption of drones in various industries like infrastructure, agriculture and disaster management.

Additionally, the government also introduced a scheme to supply drones to over 15,000 self-help groups (SHG) led by women from 2023-24 to 2025-2026. The women from these SHGs will offer drones as a rental service to farmers to monitor crop health and for other uses in the agriculture sector.[9] These initiatives have helped in the expansion of drones across all sectors. The government has facilitated the use of drones by businesses and people by removing the requirement for security clearances and pilot licenses, expediting the regulatory procedure and lowering bureaucratic barriers. Liberalisation of exports and prohibitions on the purchase of foreign drones encourage innovation and home manufacturing. Drone training institutes and certification programmes are also enabling the development of a trained workforce. These developments have led to the adoption of drones in various industries including agriculture (drones are used for precision farming and crop monitoring), construction and infrastructure (aerial surveys and inspections are beneficial), mining (better data collection), disaster management (search and rescue operations are improved), and healthcare (medical supplies are delivered to remote areas by drones).



6 Ibid

7 Ibid

8 https://sansad.in/getFile/loksabhaquestions/annex/179/AU3021.pdf?source=pqals#:~:text=The%20Drone%20(Amendment)%20Rules%2C,remote%20pilot%20to%20operate%20drones.

9 https://legalaffairs.gov.in/sites/default/files/Civil%20Aviation%20Regulatory%20Landscape%20of%20Indian%20Drone%20Ecosystem%20red.pdf

Blockchain technology, geospatial AI and drones

This section explains how companies are attempting to integrate drone technology with other technologies such as AI and blockchain.

Enabling drones with blockchain

Many organisations are working towards developing an integrated solution for drones and blockchain technology. While blockchain technology can improve operational efficiency, transparency and data security, drones can provide large volumes of data which comes from real-time sensor readings and aerial imagery which is vital for many industries including logistics, agriculture and defence.

Given below are some of the advantages of integrating drones with blockchain:

1. Every drone can have an unchangeable, safe digital identity with the help of blockchain technology. This avoids impersonation and guarantees that only authorised drones are identified. For example, every drone involved in a relief mission has its identity documented on the blockchain. This keeps unauthorised or fraudulent drones from interfering with the task by guaranteeing that only verified drones can function inside the system.

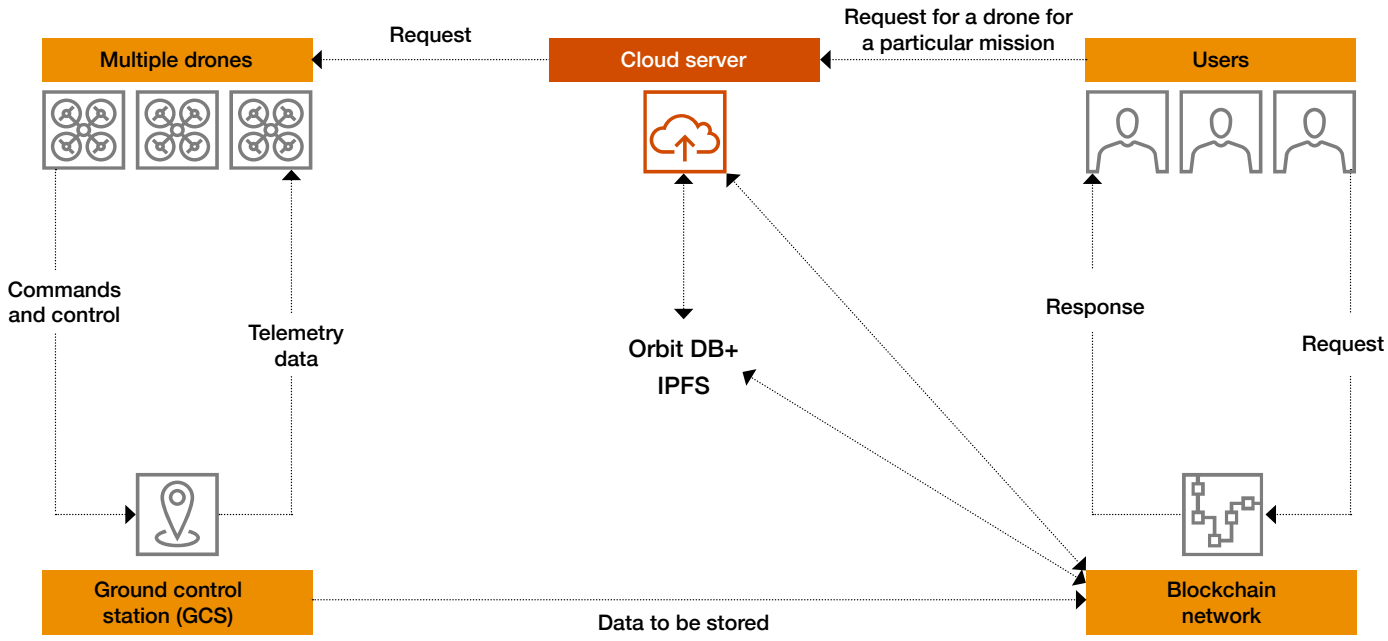
2. Blockchain's decentralised ledger facilitates the separation of authentic drones from counterfeit ones. It is harder for fake drones to enter the network when a safe register of all drones is kept up to date. For example, in an environment monitoring project, blockchain technology ensures the authenticity of each drone through its secure ledger. Unauthorised drones are detected and prevented from contributing to data collection, ensuring that only genuine drones are utilised.

3. The security of drone communications is strengthened by blockchain's cryptographic and decentralised features, making it less vulnerable to hacking and other cyber threats. Drone communications in security surveillance tasks are protected and encrypted using blockchain technology. This stops any unauthorised entry or interference with the data being sent between drones.

Next, to scale the implementation of drone technology effectively, organisations can consider the internet of drones (IoD) technology which combines blockchain with drone networks to improve data integrity, security and transparency. Through IoD, drones can safely exchange and record flight data, transactions and operational records in an immutable ledger by utilising blockchain technology.

This connection enhances regulatory compliance, streamlines drone operations across many applications and fosters trust and collaboration among multiple stakeholders. The major components that goes into the making of IoD comprises drones, users, ground control station, blockchain network, cloud-based servers and an orbit database. A high level solution architecture which provides an overview of implementing IoD is given below (Figure 2).

Figure 2: A high level solution architecture for blockchain-enabled IoD



Source: PwC analysis

The architecture for blockchain-enabled IoD consists of six components:

- **Multiple drones** and UAVs equipped with sensors to gather a wide range of data.
- **Ground control station (GCS)** which plays a crucial role in the operation and management of UAVs along with receiving data and sending command.
- **Users** often access data of drones and GCSs along with other parameters for certain purposes.
- **Blockchain** network to maintain a distributed immutable database for UAV operations and data management. In a blockchain network, the recorded transactions are shared among all nodes in the network. In a blockchain-enabled architecture, where users, UAVs, and GCSs act as nodes within a blockchain network, each component plays a crucial role in maintaining the blockchain and participating in the consensus protocol.
- **Cloud server** is used to offload computation from the drone offers several advantages, particularly in terms of optimising mission execution and extending the drone's flying time.
- **Orbit** DB along with inter-planetary file system (IPFS) is used as an off-chain database for UAV data to overcome the limitations of blockchain in handling large datasets.

DroneChain – blockchain-based drone communication

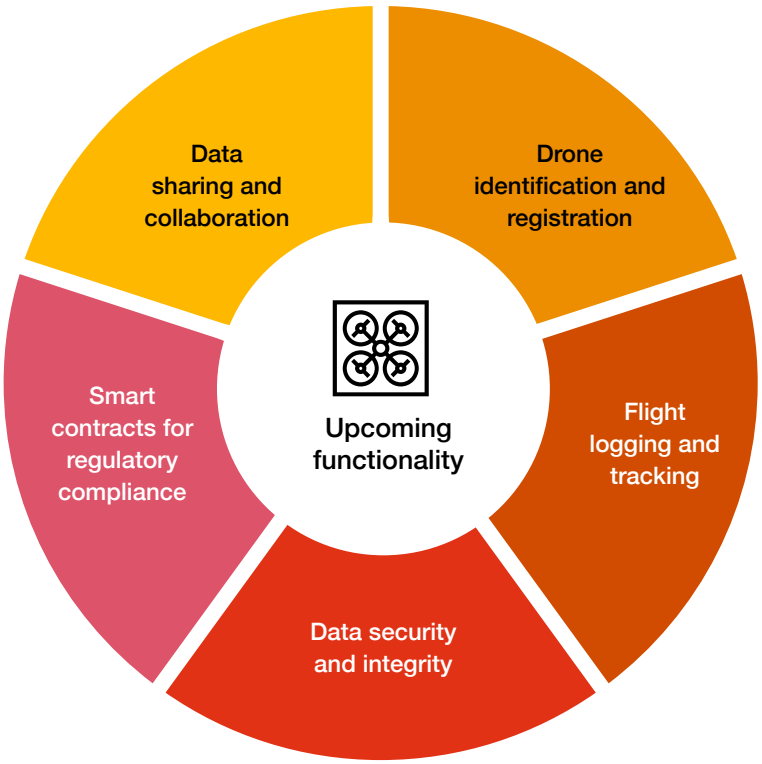
With the widespread adoption of drones in various domains such as military, agriculture and logistics, effective solutions to protect data integrity and communication between drones and the control system have become important to avoid potential vulnerabilities which may lead to data breaches and losses. For secure drone communication during data collection and transmission and to maintain the integrity of the collected data, a decentralised solution that uses blockchain technology in addition to the traditional cloud server can be a viable solution.

DroneChain is a blockchain based solution that enables communication between multiple drones. Some of the primary features of DroneChain are consensus techniques, self-amendment and simple verification.

Some of the key measures which organisations must take into account before deploying DroneChain (represented in Figure 3) are:

1. **Drone identification and registration:** This gives each drone a unique digital id and keeps track of the registration information to ensure compliance of the drones' processes.
2. **Flight logging and tracking:** It provides real-time tracking and employs geofencing to implement and enforcement of no-fly areas.
3. **Data security and integrity:** It gives safe storage of data collected by drone on the blockchain along with data integrity and authenticity verification ensures that the data has not been altered.
4. **Smart contracts for regulatory compliance:** Smart contracts provide automate regulatory reporting including pre-defined flight height and demarcated restricted areas, and compliance checks in real time.
5. **Data sharing and collaboration:** DroneChain allows safe data exchange between parties with blockchain technology. It also supports collaborative drone operation and mission and assures interoperability across various system.

Figure 3: The five essential functionalities to implement DroneChain



Source: PwC analysis

Drones with AI and geospatial AI

AI-enabled drones are capable of carrying out tasks like object/picture identification and pattern analysis. This enables them to conduct difficult operations with little assistance from humans. For instance, AI-enabled drones use airborne photos to detect insect infestations or disease symptoms in order to assess crop health. Similarly, in urban planning, these drones can analyse high-resolution photos and data to evaluate the state of the infrastructure and identify maintenance needs.

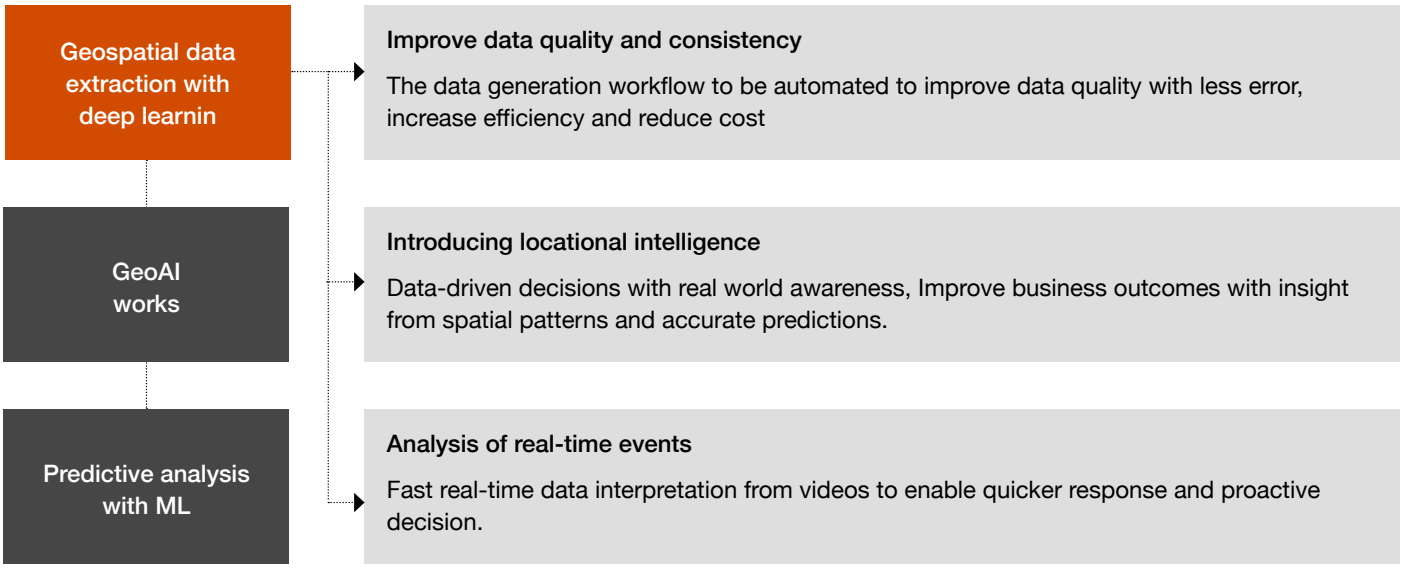
With AI, drones can now process data in real-time which significantly increases their efficiency. They can be trained to recognise particular traits or anomalies using machine learning (ML) algorithms which can improve their capacity to conduct activities like environmental monitoring, search and rescue, and surveillance.

Geospatial AI (GeoAI) is the application of AI on geospatial data. GeoAI can help organisations by:

a) reducing the time taken to extract geospatial data from high resolution imagery captured by drones.

b) since data collected by drones has large volumes of geospatial data sets, it can be analysed more precisely and accurately by GeoAI algorithms rather than by conventional techniques.

Figure 4: GeoAI – an illustration



Source: PwC analysis

GeoAI uses cutting-edge techniques and algorithms to extract valuable information from spatial data which is important to the geographic information systems (GIS) sector to enhance decision-making and improve resource management. GeoAI uses ML algorithms to identify intricate patterns, correlations and anomalies in geographic datasets to improve the interpretation of geographical data. This analytical expertise fosters a thorough comprehension of spatial dynamics, empowering decision-makers in a variety of fields, including urban planning, environmental monitoring, disaster management, agriculture and transportation.

Since GeoAI uses automation to simplify GIS data processing and analytic processes, GIS specialists may focus on drafting plans based on the information provided by automated devices and ML and AI-based algorithms. With the use of historical geographical data, GeoAI can improve forecasting and predictive modelling by identifying patterns and trends. It can also provide real-time monitoring of these devices which can be beneficial for monitoring air quality, traffic patterns and infrastructure health to maximise resource utilisation and improve public safety.

Drone technology – areas of implementation

Drones are gaining popularity in several industries, including public safety, construction, urban planning and agriculture since this technology offer enhanced efficiency and precision. UAV or drone sectors are expanding quickly, particularly in business sector. Some of the sectors which are adopting drone technology are discussed in the next section.

Areas of implementation

From mining to real estate and from telecom to urban planning, drone technology is being adopted and implemented in various sectors due to its ability to automate tasks, provide cost–effective solutions and ensure precision in data monitoring. Figure 5 gives an overview of some of the industries where drones can be implemented for various purposes.

Figure 5: Use cases of drones in various sectors

Potential use cases of drones

Mining

- Stockpile management
- Monitoring and operation planning
- Haul road optimisation
- Hazard identification and mitigation

Disaster management

- Hazard and exposure mapping and risk assessment
- Mapping and monitoring the extent of disaster

Infrastructure planning

- Site analysis
- Asset mapping and monitoring
- Construction management and monitoring

Real estate

- Better property marketing
- Cost-effective
- Increased efficiency

Telecom

- Tower inspection and maintenance
- Improved safety

Agriculture

- Monitor plant health
- Precision farming
- Perform plant count

Environmental monitoring

- Population monitoring
- Monitor land changes
- Classify areas

Urban planning

- City modelling
- Corridor mapping
- Urban landscape planning
- Land record management
- Traffic management

Source: PwC analysis

The integration of drones with blockchain further enhances the use of drones. While drones can enhance crop monitoring and improve transparency in the supply chain in agriculture, blockchain guarantees data accuracy and traceability with data encryption and verification, which also makes it ideal for use in the defence sector for their drone operations. Effective asset tracking and maintenance is beneficial for both manufacturing and infrastructure. Some of the sectors which can leverage drone technology are:

Agriculture: AI-powered drones can be used for automating tasks such as precision crop monitoring, field mapping and automated spraying. Integrating blockchain, AI and drone technology can facilitate data sharing with farmers, agronomists and regulatory bodies.

Defence: In the defence sector, drones are used primarily for surveillance and combat operations. However, a multipurpose GeoAI model can help in identifying objects based on key inputs while blockchain can ensure a secure platform for storing and transmitting surveillance data and the results of GeoAI models.

Disaster management: High resolution images captured by drones can be used to detect which houses are more prone to damage due to natural disasters such as landslides, hurricanes and cyclones. The addition of blockchain verifies the authenticity of these deep learning models and their predictions based on reliable and unaltered data.

Manufacturing: Improving quality control using high resolution sensors along with AI-powered identification of anomalies can help detect potential defects or deviations from set standards. Smart contracts along with blockchain technology sends alerts and reports based on the anomalies detected and ensures timely action for addressing the anomalies and helps in maintaining a centralised record of quality control processes.

Infrastructure development: Drones equipped with light detection and ranging (LiDAR) sensors and AI-driven high-resolution cameras can be used to examine important structures such as electricity lines and bridges. These drones can autonomously scan the various components of infrastructure for possible defects and produce detailed reports which can be used to derive actionable insights. A comprehensive audit trail can also be ensured by integrating drone technology with blockchain which can track the inspection and repair.

Mining: Drones have revolutionised the mining industry by coupling AI with drone technology. The technology is used at large mine sites for quarry management and to gain information related to the site's condition. Blockchain can further track and record all data collected during the mining operations.

Road traffic: Drones can also help the police in monitoring traffic by providing live data on traffic congestion. By recording traffic data on blockchain, law enforcement officials can create a log of events which can facilitate transparency and accuracy of large volumes of data.

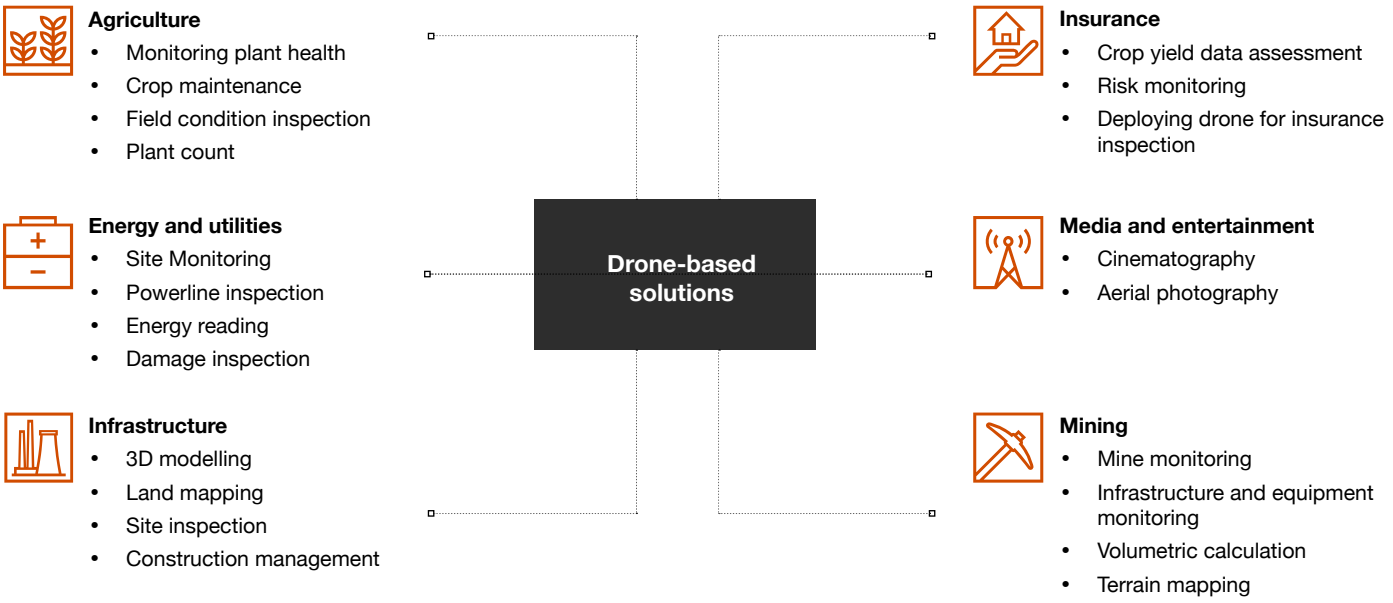
Healthcare: Delivering medical supplies to isolated or underdeveloped areas is a compelling use case for drones in healthcare services. Essential supplies like immunisation, drugs and blood products can be delivered by drones to areas which are inaccessible by conventional means of transportation. Drones, for example, can make timely deliveries in remote or rural regions, guaranteeing that vital medical supplies are available when needed. This capacity not only increases the effectiveness of healthcare logistics but also ensures timely access to supplies in emergency cases by cutting down on the time taken to deliver the medical supplies expands access to treatments in emergency cases by cutting down on delays. Furthermore, integrating blockchain can improve supply chain transparency as it can track the entire delivery process. This would allow healthcare providers to verify the authenticity and integrity of the supplies, thereby reducing cases of fraud or counterfeit medicines.

Telecom: By using high-resolution photography and video to audit and check communications assets, including towers and wireless infrastructure, drones can enable the telecom industry to monitor telecommunication assets to reduce the risk associated with manual operations which involve climbing communication towers and high buildings. Embedded with blockchain, these solutions can create detailed records of inspections and findings and can facilitate audits and maintenance while minimising the need for manual inspection.

Drone-based solutions for various sectors

Drone technology is transforming various industries by providing innovative solutions which enhance efficiency, precision and overall effectiveness of the operations. After the identification of the use cases in each sector/segment, the right technology needs to be identified for the specific requirements of each sector. Figure 6 illustrates some of the examples of some of the drone-based solutions in various sectors.

Figure 6: Drone-based solutions across various sectors



Source: PwC analysis

Drones and sustainable development

Besides automating tasks related to surveillance and distribution, drones can also help organisations in achieving their sustainable development goals. Drones can be an energy-efficient alternative for other methods of transportation, and inspection and monitoring. Some of the ways in which drone technology can help various sectors achieve some of the UN's Sustainable Development Goals are:

Good health and well-being: Drone technology can provide access to vital healthcare services, including vaccine distribution in remote or rural areas.

Decent work and economic growth: Drones contribute to economic sustainability by creating new business opportunities and increasing efficiency in various sectors. Drones can streamline operations in labour-intensive sectors such as site monitoring and inspection work by automating the tasks using drone technology which are traditionally done manually. The automation of these tasks can also lead to cost savings and improve the overall productivity of the processes.

Industry, innovation and infrastructure: Drones offer sustainable and energy-efficient solutions for creating and evaluating infrastructure or performing duties that require the use of other modes of transportation. For example, drones can be used for transporting medicine or other medical accessories to remote locations which are inaccessible by road or air.

Sustainable cities and communities: Drones can help improve emergency response in cities by monitoring and controlling natural disasters and taking immediate measures to save lives. Drones can also be used as a sustainable solution to provide smart crowd management, traffic management, etc.

Climate action: Drones can be used for monitoring the changes in ecosystems due to climate change. It can monitor and provide data related to areas that need immediate care and sensitive ecosystems in order to plan remedial and preventive actions.

Life of land: Drones can monitor vast expanse of land and provide data related to deforestation, land degradation and agricultural land. This data can be used to plan and implement sustainable management practices. Drones can also provide high-resolution imagery which can be integrated with data from other sources (e.g. satellites) to enable the agriculture industry in planning the spraying of herbicides, irrigation and other uses.

PwC's suggested framework and recommendations

While managing infrastructural challenges and cybersecurity risks is a top priority for adopting drone technology, having the right framework to mitigate these risks is important before the technology is implemented.

Managing cyber security risks

The integration of drones into various sectors also makes the operations vulnerable to significant cybersecurity challenges which need to be addressed to ensure data integrity, operational safety, and data privacy. Some of the challenges in adopting drone technology are:

Security concerns: Drones are vulnerable to several cybersecurity threats which can jeopardise data security and operational integrity. If not properly encrypted, the data captured during transmission can be misused. Furthermore, the security and operations of drone software can be jeopardised by malware or hacking if there are no adequate data security protection measures in place. Reducing these dangers and protecting drone operations from cyberattacks requires strong encryption, frequent software updates and secure communication protocols.

Public perception and acceptance: Negative perceptions around drones can significantly impact their adoption and integration into various industries. Building trust through transparency and training the workforce about drones and its use is essential for overcoming these hurdles.

Drones are susceptible to cyberattacks due to their reliance on wireless connections. As a result, bad actors can intercept, spoof and hijack these devices. Furthermore, critical data or networks may be accessed by intercepting the data sent between drone operators and their vehicles. Drone-based cyberattacks can interrupt operations which can lead to financial and reputational losses. As a result, both commercial and military applications are becoming increasingly concerned about cybersecurity. To detect and address cybersecurity issues related to drones, a multilayered, comprehensive framework is necessary. This framework, which combines operational, technological and regulatory elements, provides a robust approach to manage cybersecurity threats.

Given below is a proposed multi-layered cybersecurity framework which can be used for securing drone operations.

1. **Detection layer:** The detection layer is responsible for spotting possible drone threats using cutting-edge sensors and monitoring tools to guarantee prompt and precise identification of breaches. Some of the technological tools and strategies for detecting drone movement are:

a) **Radar system:** Radar is a key technology for detecting and tracking drones, particularly due to its ability to monitor their size, speed and movement patterns.

b) **Infra-red sensors:** In low visibility conditions, infrared camera can help to detect drones.

c) **Control centres:** Integrated command and control centres are crucial for effectively monitoring and managing threats.

2. **Identification layer:** Using detailed images of drones along with complex algorithms and data processing techniques, this step segregates possible threats from genuine drone activities by:

a) **Decoding control signals:** Decoding control signals to gather information about a drone and its operator

involves intercepting and analysing the communication between the drone and its remote controller. This process can provide valuable insights, such as the drone's operational status, its position and the identity or location of its operator.

b) **Suspicious activity detection:** This process can provide valuable insights such as identify unusual or abnormal behaviour in drones, includes sensor attack, Communication network attack, which is very crucial for detecting potential threats.

3. **The mitigation layer:** The mitigation layer entails developing policies and leveraging technology to control and eliminate threats which have been identified while ensuring that efficient countermeasures are in place.

a) **Spoofing:** GPS spoofing involves sending fake GPS signals to a drone. The objective is to mislead the drone's navigation system by injecting false GPS data, potentially neutralising its threat or redirecting it away from sensitive areas.

b) **No fly zone:** Implementing geofencing is an effective strategy for controlling drone operations and ensuring that drones stay out of restricted or no fly zones.

4. **Legal and ethical considerations:** This layer ensures that the responses to drone threats adhere to legal requirements and data regulations

a) **Regulatory compliances:** In order to ensure that counter-drone measures are effective, both legally and operationally, organisations must adhere to national regulations.

b) **Community No-fly zone:** Educating the people about recognizing and reporting suspicious drone activity is essential for enhancing community safety and ensuring timely intervention when potential threats arise.

PwC's proposed framework for mitigating drone-based cyberattacks

PwC's proposed framework can be adopted by organisations who have adopted drone technology for their operations. This comprehensive framework combines cybersecurity strategies, physical security measures and regulatory compliance. The key components of the framework are:

1. **Risk assessment and threat identification:** A cybersecurity risk assessment involves a thorough examination of an IT infrastructure to pinpoint weak areas and potential threats. The assessment includes:

- **Vulnerability assessment:** Conducting a thorough analysis of potential vulnerabilities in both physical and digital infrastructure.
- **Evaluating threats:** The cyber risk assessment method needs to be conducted regularly with well-defined criteria (based on organisation policy) in order to evaluate and mitigate risk.
- **Potential impact analysis:** Drone-based cyberattacks pose significant risks to critical systems and operational continuity. To understand the potential impact, it's important to assess various scenarios where drones can be misused for malicious purposes.
- **Hypothetical scenario planning:** It is necessary to create comprehensive hypothetical attack scenarios which include physical incursions and data breaches to help the drone operators understand the different kinds of threats the drones can encounter.
- **Red team exercises:** These exercises can be conducted by the organisation to find vulnerabilities and replicate drone-based cyberattacks.

2. **Cyber security measures:** Cybersecurity measures are essential for safeguarding digital assets and sensitive information. Some of the measures which are used to enhance cybersecurity are given below:

- **Network segmentation:** This can help isolate important systems and lessen the possible impact of a security attack.
- **Intrusion detection systems (IDS):** An IDS can monitor network traffic for suspicious activity related to drone-based cyberattacks.
- **Encryption protocols:** Using strong encryption protocols is essential for protecting sensitive information from interception and unauthorised access. Encryption ensures that data remains confidential and secure.
- **Secure communication channels:** Ensuring that all communication between drones and control stations is encrypted and authenticated is essential for preventing unauthorised access and control.
- **Updates:** Regularly updating drone firmware and software is crucial for maintaining the security and functionality of drones.
- **Anti-malware solutions:** Deploying anti-malware solutions on all endpoints is essential for detecting and

preventing malicious activities that can compromise system integrity and data security.

- **Multi-factor authentication (MFA):** Implementing MFA for accessing drone control systems and sensitive data is a critical step to enhance security and protect against unauthorised access.
- **Initiating role-based access control (RBAC):** Initiating RBAC is an effective way to manage and restrict access to critical systems and data based on user roles.

3. **Physical security measures:** Limiting access to specific locations can discourage intruders and help in reducing the number of cyber-attacks. This measure includes:

- **Geofencing:** Implementing geofencing to set up a virtual boundary which can block unauthorised drones from entering restricted areas.
- **Real-time alerts:** Setting up real-time alerts by deploying radar and sensors (radio frequency) which can detect, analyse and respond to unauthorised drone incursions promptly.

4. **Regulatory compliance:** This step highlights the need to adhere to established standards, regulations and guidelines which are designed to protect data and systems. Some of the key aspects of this regulatory compliance are:

- **Proper understanding of regulations and data protection:** Staying updated about local and international regulations governing drone operations and cybersecurity is crucial for ensuring compliance, maintaining security and adapting to the evolving global regulatory landscape. Maintaining drone operations which are compliant with data privacy laws is essential to avoid legal repercussions.

5. **Incident response and recovery:** Creating and maintaining an effective incident response plan along with establishing a dedicated response team for handling drone-related cyber incidents is essential to mitigate the risk.

6. **Training and awareness:** Training the employees regularly on cybersecurity's best practices is important for handling major risks.

7. **Continuous improvement:** Continual improvement in information security is vital for ensuring that an information security management system (ISMS) remains effective in the face of evolving threats. The process of continuous improvement includes regular upgradation of technology as per the new developments in UAV and cyber security technologies. It is also essential to deploy resources in cutting edge innovations for improved security.

Besides mitigating cyber threats, organisations need a step-wise approach for the smooth adoption and implementation of drone technology in various sectors. Some of the key steps to follow in this approach are:

Establishing processes: To lower the risks associated with drone-based cybersecurity threats, organisations should implement processes for recognising and managing drone activity, utilise counter-UAS technologies and establish comprehensive cybersecurity solutions.

Adopting technologies: Drones can quickly swap frequencies thanks to frequency hopping spread spectrum (FHSS) technology, which makes persistent jamming operations more difficult. Id a communication route is interrupted, continuity is ensured by implementing redundant channels, such as satellite, cellular networks and radio. Modern signal processing techniques and anti-jamming devices are able to identify and reduce interference. Secure authentication and robust encryption guard data integrity from unwanted access. While adaptive algorithms modify communication parameters to counteract interference, increasing the overall resilience and reliability of drone operations, integrating radar and detecting devices aids in the identification of jamming sources.

Implementing cybersecurity solutions: Businesses should implement complete cybersecurity solutions which can identify harmful behaviour for their networks and curb it before it reaches their drones or infects their computer systems. Malicious behaviour on edge computers can be identified by AI-powered cybersecurity solutions which enables enterprises to promptly identify any possible dangers and take action to neutralise them before they disrupt their operations.

Ensuring efficiency in drone operations

In order to maximise the efficiency of their operations while using drones, organisations must consider the following factors:[10]

a) **Application capabilities:** Drone solutions combined with blockchain, and AI should effectively cover the entire value chain of the business including project management and monitoring.

b) **Industry sector diversification:** The platform or suite of applications supporting drone solutions which leverages blockchain and AI should be able to assist the organisation in the diversification of their operations. For example, By utilising multispectral cameras and sensors, these drones along with GeoAI algorithm provide detailed insights into crop health and environmental conditions.

c) **Integration capabilities:** Integration with capital project tools such as building information modelling (BIM) is an essential part of the planning in product roadmap. For example, the transfer of drone data files to mining software should follow standard industry process. Furthermore, blockchain and AI can offer enhanced data security, real-time insights and efficient workflows leading to better outcomes.

d) **Compatibility with third-party hardware:** Cloud platforms which support all the essential ingredients of the implementation of blockchain, AI and drones should be able to process the images and analyse them irrespective of the drone type. The image from third party drones must conform to certain specifications (mandatory fields) to get it processed via cloud computing for analysis.

Organisations should also consider the following points while conducting the technical assessment of drone technologies before they are implemented:

- **Architecture:** The supporting platform should have a tiered architecture which is divided across its user interface, application and data.
- **Technology:** Ensure conformity with industry standard tools and technologies used for the platform development.
- **Data and analytics:** Ensure robust image processing capabilities to build high-end analytics with highly scalable architecture for the analytical engine.
- **Infrastructure:** Develop a robust and scalable infrastructure using cloud components.
- **Code review performance:** Tool-based code review to suggest and improve the overall quality of codes implemented.
- **Performance stability:** Overall performance of the application should be stable and no major performance issues should arise in the production process to support the uptime of 100%.
- **Product roadmap planning:** High-level plan should be broken into small/micro level releases.

Organisations also need to consider the following factors as a part of the drone adoption process:

a) **Identification of appropriate use cases for the implementation of drones:** While choosing a drone technology for an organisation's individual needs, companies should focus on identifying appropriate use cases for the implementation of drones.[11] For example, inspecting or examining assets and infrastructure such as oil and gas pipelines and power plants.

Despite significant advancements over the years, drone technology and its implementation is still at a nascent stage. As a result, it is challenging to use the technology in domains that require sophisticated GPS for last-mile delivery, an obstacle avoidance system and the ability to detect changes beneath the surface.

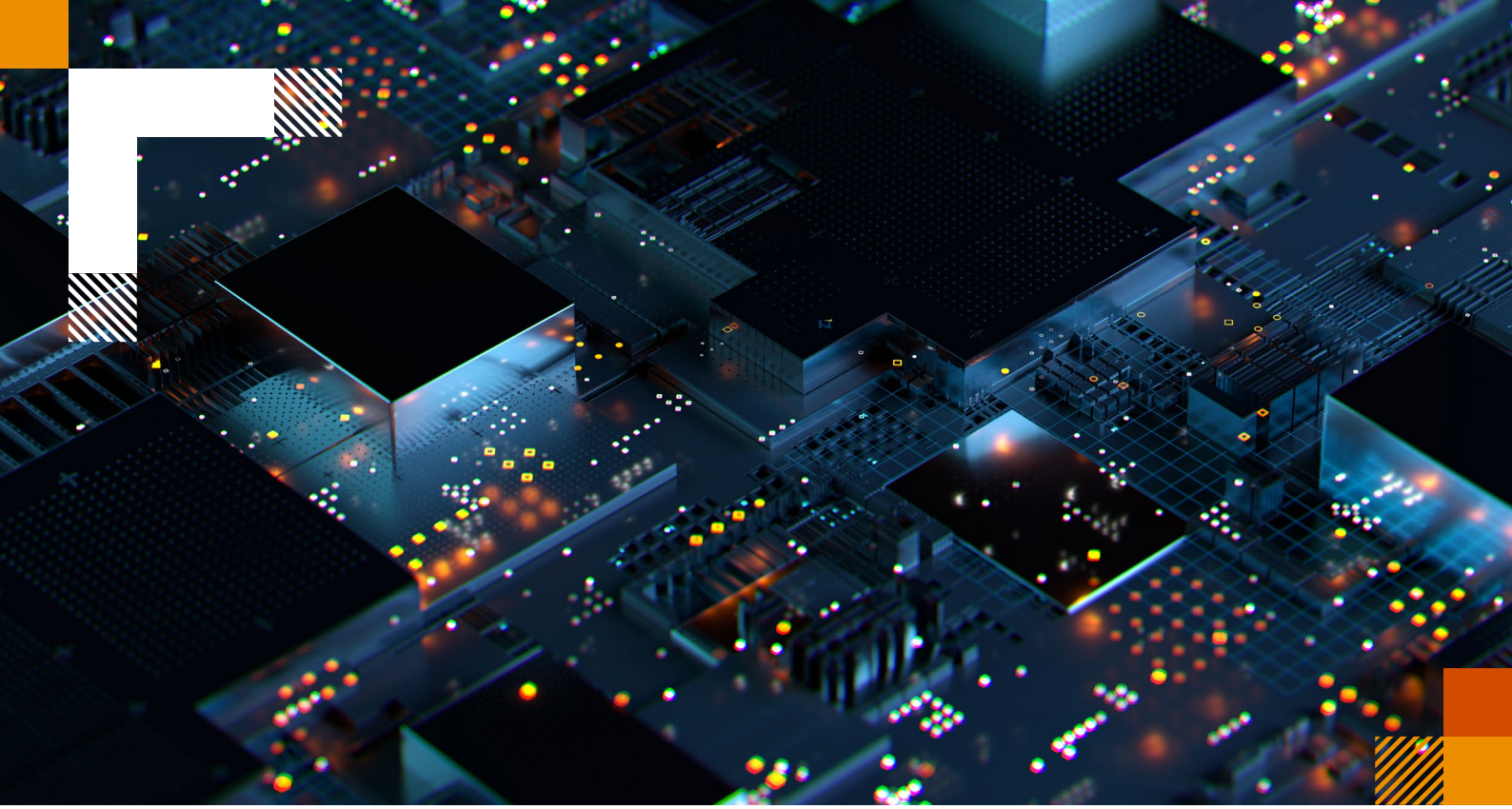
b) **Commercial aspects:**[12] Deciding to adopt drone technology integrated with blockchain and AI is cost intensive and therefore organisations need to choose an operating model which can best serve their purpose. There are three aspects – procurement, operations and data analysis – which organisations should assess before adopting drone technology. Some of the options which are available to businesses which are seeking drone technologies for their operations are:

- **Drone-as-a-service:** This is beneficial for organisations which require aerial data gathering and analysis, but prefer not to purchase their own drone fleet.
- **Leasing or purchasing:** Leasing requires less investment at the initial stage and provides better maintenance assistance while purchasing provides more autonomy. The decision to lease or purchase

10 PwC analysis

11 Ibid

12 Ibid



drones is primarily be influenced by the frequency of its use – routine, periodically or on a need basis. If the drones are rented, the payment method could be a one-time upfront payment for a set time period or paying per use or per hour. Organisations also need to employ licensed drone pilots to operate drones. Furthermore, the responsibility for repairs, maintenance and upgrades of the drones can be held by either the lessor or the lessee. Using drones in challenging geographical and weather conditions can be a significant factor to take into account, as they might experience damage.

c) **Types of output from drone-enabled aerial data collection:**[13] It is imperative to select the type of output and level of accuracy required from the aerial data collection and analysis depending on the nature of application. The following are some of the available output types:

2D output

Images: High-resolution images or raw images

Orthomosaic/orthophoto/orthorectification: Images that are captured will be combined with ground control points for geo-rectification in order to create one image.

Contour lines show the same height levels from a specific point. It is created in the vector file format and consists of lines instead of pixels.

Videos: Superior quality videos captured by drones.

3D output

Digital surface model represents the elevation of bare earth terrain considering natural and man-made features.

Digital terrain model represents the elevation of the bare earth without considering any over-ground features.

Digital elevation model represents the elevation of the earth's surface above a certain datum.

Point cloud model which is a 3D visualisation model made up of geo-referenced points and provides high resolution data without any distortion.

Multidimensional data refers to data that is captured and analysed across multiple dimensions or aspects, providing a more comprehensive view of the information.

13 Ibid.

Future growth opportunities for the drone sector

Though drone technology has numerous benefits and applications, organisations need to start weighing the potential advantages of drone operations against the challenges as they formulate their strategy to create a competitive advantage for themselves by tapping on the possible opportunities in the drone sector. While assessing the strategic alignment and understanding the cost-benefit rational, working on the following questions can be helpful:

1. Which products are feasible for drone delivery, and how open will consumers be to this idea?
2. In which areas would drone delivery be most beneficial?
3. Can drone deliveries be made to already-existing stores and warehouses, and will new facilities or infrastructure be needed?
4. How successfully can drone operations be combined with more general ways of delivery?
5. Do drone delivery businesses have any natural partners?
6. What role may drones play in the organisation's sustainability objectives?

In the Indian context, certain areas of potential opportunities for the growth of drone technology are given in Figure 7.

Figure 7: Opportunities for drone sector in the Indian market

01 Urban development

- Monitor and control the development activities or projects through drone-based outputs.
- As a pilot project, the Karnataka Government is using drones for property tax estimation and creation of base maps of a city/town for detailed planning and sustainable governance. Other state governments can follow the same.

02 Transport

- Monitor railway operations to proactively identify cases where there can be collisions and these collisions can be avoided.
- Drones can ensure accuracy with respect to the extent of land required for roadways land projects.
- As a pilot project, the Government of Maharashtra is looking to leverage two drones to monitor weekend rush hour traffic and accidents on the 95-km stretch between the Lonavala Exit and Khalapur Toll Plaza and on the six-lane Mumbai-Pune Expressway. Other state governments can do the same.

03 Disaster Management

- Scan areas where search and rescue teams could not access in flood-hit areas.
- Search and rescue operations and to map toppled monuments, ruined heritage sites and homes destroyed during earthquakes.

04 Agriculture

- A general insurance company can deploy drones in a particular zones for assessment of crop damage due to natural calamities such as floods.
- Crop loss assessment due to deficit rainfall.
- Drones to monitor and assist with spraying crop pesticide/ fertiliser in limited crop areas.

05 Mining

- Monitoring of stockpile storage, 3D mapping and volumetric analysis of limestone over a period of time.
- Drones equipped with 18.2 MP cameras and night vision capability which fly at an altitude of 1 km for about 30 minutes to detect illegal sand mining from miles away.
- Drones deployed for boundary and safety zone inspection of coal and iron mines, counting of vegetation in reclaimed areas, and profiling of quarry and dump for volume calculations
- A general insurance company deployed drones in a particular district in Maharashtra for assessment of crop damage due to floods in 2016.
- The Maharashtra Government has used drones over fields in the Marathwada region for carrying out crop loss assessment due to deficit rainfall.
- Individual farmers of Andhra Pradesh's capital region are deploying drones to spray crop pesticide/fertiliser in limited crop areas.

Source: https://www.pwc.in/industries/government-and-public-services/preparing-for-takeoff.html

Way forward

Though there are numerous benefits of drone technology, challenges related to operations, regulatory compliance and other aspects need to be considered before the technology is adopted and implemented. Figure 8 illustrates the five key stages for developing high quality solutions using drone technology:

Figure 8: The five key stages for developing high quality drone based solutions

Source: PwC analysis

1. **Vision setting:** It's important to set up a clear vison by identifying the key concerns and aligning organisational goals to the purpose of using drone technology for various tasks.
2. **Assessment of industry best practices:** The assessment requires collaboration with multiple stakeholders, and the identification and incorporation of industry best practices.
3. **Project planning:** The project planning phase defines the roadmap, resources and risk assessment along with the timelines for achieving the organisational goals.
4. **Implementation:** Once the use cases or problem area has been identified, drones can be implemented to complete the various tasks within the organisation.
5. **Project management:** Project expectations and timelines need to be assessed and drafted to ensure that the project objectives can be met according to timelines while solving the key problems.

Organisations should also focus on investments for infrastructure development to support drone solutions and launch awareness and training programmes which can promote the adoption of drone technology.

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About ASSOCHAM

The Associated Chambers of Commerce & Industry of India (ASSOCHAM) is the country's oldest apex chamber. It brings in actionable insights to strengthen the Indian ecosystem, leveraging its network of more than 4,50,000 members, of which MSMEs represent a large segment. With a strong presence in states, and key cities globally, ASSOCHAM also has more than 400 associations, federations and regional chambers in its fold.

Aligned with the vision of creating a New India, ASSOCHAM works as a conduit between the industry and the Government. The Chamber is an agile and forward looking institution, leading various initiatives to enhance the global competitiveness of the Indian industry, while strengthening the domestic ecosystem.

With more than 100 national and regional sector councils, ASSOCHAM is an impactful representative of the Indian industry. These Councils are led by well known industry leaders, academicians, economists and independent professionals. The Chamber focuses on aligning critical needs and interests of the industry with the growth aspirations of the nation.

ASSOCHAM is driving four strategic priorities - Sustainability, Empowerment, Entrepreneurship and Digitisation. The Chamber believes that affirmative action in these areas would help drive an inclusive and sustainable socio-economic growth for the country.

ASSOCHAM is working hand in hand with the government, regulators and national and international think tanks to contribute to the policy making process and share vital feedback on implementation of decisions of far-reaching consequences. In line with its focus on being future-ready, the Chamber is building a strong network of knowledge architects. Thus, ASSOCHAM is all set to redefine the dynamics of growth and development in the technology-driven 'Knowledge-Based Economy. The Chamber aims to empower stakeholders in the Indian economy by inculcating knowledge that will be the catalyst of growth in the dynamic global environment.

The Chamber also supports civil society through citizenship programmes, to drive inclusive development. ASSOCHAM's member network leads initiatives in various segments such as empowerment, healthcare, education and skilling, hygiene, affirmative action, road safety, livelihood, life skills, sustainability, to name a few.

About PwC

At PwC, our purpose is to build trust in society and solve important problems. We're a network of firms in 151 countries with over 360,000 people who are committed to delivering quality in assurance, advisory and tax services. Find out more and tell us what matters to you by visiting us at www.pwc.com.

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