IT WILL BE BUSINESS AS USUAL FOR DRONES BY 2030

DRONEPORT FRAMEWORK
GUIDANCE DOCUMENT

FEBRUARY 2022

CATAPULT Connected Places

Met Office

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LETS GET STARTED

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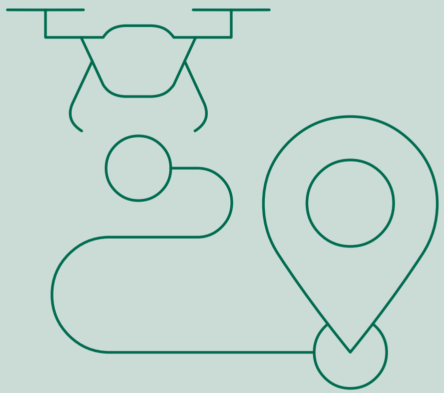
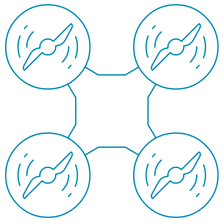


GLOSSARY OF TERMS

Term	Description
ACERT	Airport Carbon and Emissions Reporting Tool
ACRP	Airport Cooperative Research Program
ADS-B	Automatic Dependent Surveillance – Broadcast
ANSP	Air Navigation Service Providers
ATC	Air Traffic Controlled
BER	Bit Error Rate
BREEAM	Building Research Establishment Environmental Assessment Method
BVLOS	Beyond Visual Line Of Sight
C2	Command-and-Control
CAA	Civil Aviation Authority
CAV	Connected Autonomous Vehicle
CFD	Computational Fluid Dynamics
CFIT	Control Flight Into Terrain
CNSI	Communication, Navigation, Surveillance, Information
CTR	Controlled Traffic Region
EASA	The European Aviation Safety Agency
EIA	Environmental Impact Assessment
EMI	Electromagnetic Interference
EP	Effective Precipitation
FAA	Federal Aviation Administration
FOD	Foreign Object Debris
FRZ	Flight Restriction Zone
FPV	First Person View
FSI	Floor Space Index
GHG	Greenhouse Gas
GHz	Giga Hertz
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HVAC	Heating, Ventilation, and Air Conditioning
ICAO	International Civil Aviation Organization
IEEE	Institute of Electrical and Electronics Engineers
ISM	Industrial, Scientific and Medical
LEED	Leadership in Energy and Environmental Design
LiDAR	Light Detection and Ranging
MaaS	Mobility-as-a-Service
MAC	Mid-Air Collision
Mb/s	Mega bit per second
MTOW	Maximum Take Off Weight
NATS	National Air Traffic Services
NPL	National Physical Laboratory
ODD	Operational Design Domain
OE	Operating Environment
PIC	Pilot In Command
PINS	Planning Inspectorate
OSC	Operational Safety Cases
RFI	Radio Frequency Interference
RP	Remote Pilots
RTH	Return To Home
SDSP	Supplemental Data Service Provider
SMS	Safety Management Systems
SNR	Signal-to-Noise Ratio
SOP	Standard Operating Procedures
STOL	Short Take-Off and Landing
TFR	Temporary Flight Restrictions
UAM	Urban Air Mobility
UAS	Unmanned Aerial Vehicle
UTM	Uncrewed Traffic Management
VLOS	Visual Line of Sight
VTOL	Electric Vertical Take-off and Landing

INTRODUCTION



76,000

drones operate in the UK's skies[1]

"The 2018 PwC report Drones Impact on the UK Economy[1] noted that 'Delivery drones could become business as usual by 2030. Large retail and logistics companies are investing in delivery drones with the aim of achieving increased efficiency, lower costs, and increased customer satisfaction. The scope of delivery drones could also be beyond dropping off parcels in the 'last mile' of client logistics'.

In order for this to be realised, Connected Places Catapult identified a need for guidance - particularly from Local Authorities - on where these 'last mile' Droneports may be located, and the design and planning requirements for such sites, particularly for those providing a service for a variety of users. Globally, there is currently no known guidance for the design and development of Droneports."

Andrew Chadwick, *Aviation Technology Innovation Lead*

The aim of this document is to provide a top-level framework for the design and development of Droneports in a variety of locations. The Droneport Design and Development Framework provides guidance to designers, engineers, investors, Local Authorities, and all stakeholders on best practice in developing Droneport solutions and is an essential guide to the development of infrastructure for commercially viable drone services across the UK. The Framework has been developed in collaboration with industry and a number of Local Authorities drawing upon their experience.

This document is not legally binding and is not intended to be an exhaustive framework, but to provide guidance to the reader on those aspects that need to be considered, and identifying where possible the necessary regulators, policy makers, and planning authorities, that Droneport operators, *et al,* should engage with when planning the design and development of a Droneport.

Connected Places Catapult would like to thank Urban Air Port Ltd for their contributions to the Operational Concept, Stakeholder Management, Emergency Management, Construction and Droneport Access sections and the Met Office for their contributions to the Weather Considerations section.

1 https://www.pwc.co.uk/intelligent-digital/drones/Drones-impact-on-the-UK-economy-FINAL.pdf

OPERATIONAL CONCEPT

WHAT IS A DRONEPORT?

A Droneport is defined as an infrastructure with a capability of operating and hosting drones, whether that is Electric Vertical Take-off and Landing (VTOL) or Short Take-Off and Landing (STOL) aircraft and is guided by six constructs:

1. An Infrastructure – which employs Standard Operating Procedures (SOPs) to enable aircraft and payload turnaround, including charging/fuelling and a maintenance capability;
2. A unique regulated and certified localised controlled airspace for safe aircraft management;
3. Uncrewed Traffic Management (UTM) system to monitor aircraft entering a Droneport-controlled traffic region, enabling essential situational awareness;
4. Aviation Regulation – Civil aviation regulation adaptions are constantly being developed to match the accelerating changes in the EVTOL operational and UTM sector. Flight safety is paramount;
5. Planning – Interaction with landowners, planning and governmental bodies is critical to determine Droneport integration, not only from a dimensional footprint perspective but how air corridor networks pass over other land users and how end to end Droneport interlink with other existing infrastructures; and
6. Public acceptability.

There are unlimited Droneport structural configurations, ranging from a confined ground construction or integrated into, or an extension to, an existing building or a maritime platform, depending on the need and location. As with current airports they employ a set of systems to ensure safety of flight and are used for the purposes of aiding an efficient operational turnaround, incorporating a command-and-control (C2) capability, charging facility, payload transition and maintenance activities.

DRONEPORT AIRSPACE

Droneport airspace is a volume of atmosphere directly above and expanding out into the local surroundings. The airspace will have a set of dimensions, in shape, size and altitude, with its own specific rules and regulations. The airspace must be agreed upon by the Civil Aviation Authority (CAA), including other aviation bodies such as National Air Traffic Services (NATS), other air users, and potential intersecting classes of airspace etc. Once established the airspace is controlled by the Droneport Command and Control, where drone operators must seek permission to enter or leave such control zones.

A Droneport Operating Environment (OE) substantially influences airspace design, management, procedures, and roles. Drones within the OE largely operate in urban areas extending into the urban periphery below exciting and actively controlled Class B, C, D, or E to lower-level airspace around Droneports, or with Class F and G in more outer urban and/or rural locations. The OE in this area is established through rulemaking, within existing airspace classes that has specific payload requirements necessary to ensure safe operations of diverse aircraft configurations, it is established through a collaborative design process used by the CAA with input from local government due to the increased impact on local stakeholders given drone low altitude operations.

The area of the Operating Environment that is available at any given time is based on traffic demand and criteria.

The airspace associated with a Droneport is defined as a controlled traffic region (CTR), which extends from the surface to a specified upper limit and should laterally mesh safely with the surrounding location. The CTR is overseen by the Droneport C2 centre (which may not be co-located with the site), governing and sharing the following applicable flight information to operators:

- Airspace boundaries (shape and size) within the CTR – limited by the surrounding area, flight restriction zones, plus other aviation, and infrastructure facilities;
- Airspace operational roles, rules, and procedures, which must be established and defined within the OE by the drone operator;
- The operational class of airspace above the Droneport
  - Consider altitude limits – currently lower bands of Class G airspace (see CAA CAP722 for details);
  - Boundary area (Control zone limits);
  - Type and call sign of aircraft operating in that space (Identification information); and
  - Flight Rules and Regulations (dictated by interacting flight traffic, individual flight performance capabilities, surrounding obstacles, and the environment).
- Flight restriction zones – impacts to flight profiles
  - Proximity to other Droneports and airports;
  - Proximity to other infrastructure, for example railways, nuclear power stations etc.; and
  - Proximity to military establishments.
- CTR open airspace timelines;
- CTR flight profiles:
  - Approach/departure vectors;
  - Altitude limits; and
  - Speed limits.
- Environmental impacts on local areas – noise and visual context.

The OE has a fixed maximal size that is tailored upon the unique characteristics and needs of specific metropolitan areas (structural restrictions, environmental limitations, no fly zones) and a collaborative Air Traffic Controlled (ATC) airspace design process. The area of the OE that is available at any given time is based on traffic demand and criteria. This means that although there is a fixed maximum size of the OE, the area that is available is based on factors such as traffic demand, temporary flight restrictions (TFR's), needs of non-Droneport airspace users, etc. Hence within the OE the CTR shape may change dynamically both laterally and in elevation.

FLIGHT OPERATIONAL CONSIDERATIONS

Flight operational considerations revolve around the safe and efficient management of Droneport aircraft movements, taking into account – aircraft dispatch, flight planning, flight watch, weather data provision, operations control, ground to air communications and integration with crew, schedules, and maintenance planning.

From an operational flight perspective, the following are key attributes to employ:

- Ensuring airspace, Droneport hosting and turnaround capability can cope with various density of air traffic.
  - Consider safe location of holding patterns based on drone flight performance capabilities in line with CAA CAP722 restrictions;
  - Consider alterative landing zones for both emergency and depleted battery conditions;
  - Ensure safe drone segregation can be always maintained; and
  - Ensure full situational awareness can be maintained by both C2 and drone Remote Pilots (RP).
- Ensure permission to fly within CTR for all drone types from the aviation regulator (CAA).
  - Dialogue with an aviation regulator should cover:
    - CTR boundaries – air corridor intersections;
    - Proposed CTR and Droneport operator rules and regulations;
    - Dissemination of operational responsibility between drone operators, Droneport C2 and associated ground crews;
    - Operational safety cases (OSC) for both flight and if applicable those linked to ground activities;
    - Communication strategies between all stakeholders;
    - Hazard Identification; and
    - Risk management and mitigation strategies.
- CAA UTM CAP1868 *(Innovation Hub: A Unified Approach to the Introduction of UAS Traffic Management)* – Traffic management around a Droneport OE is a function of automated communication between UTM's and onboard drone navigational systems – all of which can be supervised via a C2 centre. UTM allows traffic management services to understand and track the location and intent of aircraft for safe traffic management services. Of note,
  - Ensure the Droneport and CTR can host either 4G or 5G signal capability – to ensure C2 can be maintained with the drone and joint links with associated UTM;
  - UTM can provide Communication, Navigation, Surveillance, Information (CNSI) infrastructure. CNSI are the main functions that form the infrastructure for air traffic management. Where Communication refers to the exchange of data or information between an aircraft and Command and Control; Navigation (Air NAV) refers to the process of planning, recording, and controlling the movement of an aircraft from one place to another by providing accurate, reliable and seamless position determination capability; Surveillance systems are used by command and control to determine the position of aircraft; finally Information such as Supplemental Data Service Providers, refers to the actual Droneport specific data required by the pilot or autonomous system to approach and land safely at the Droneport (see – CAP1868);
  - OE operations and UTM's seamlessly operate concurrent with controlled airspace managed by traditional human-operated ATC in specific areas of the terminal environment where it has been pre-authorised that safe operations can occur;
  - UTM's provide a dynamic, common operating holistic view of the OE through information-sharing and exchange between fleet operators, all types of aircraft, and the CAA to achieve safe operations; and
  - The UTM framework ensures the safe conduct of aircraft operations through the assurance of performance authorisations that ensure operational and performance requirements are met, the sharing of flight plan and airspace constraint information amongst operators, and the use of service and systems to deconflict flight paths.

- Supplemental Data Service Provider (SDSPs) may provide safety-critical services and provide enhanced services for safe operations to fleet operators (e.g., a, specialised weather data, surveillance, and constraint information). SDSPs may also provide information directly to UTMs or fleet operators and can be further supplement through ground navigational systems such as radar for example.

AIRCRAFT TYPES

Aircraft types are governed by CAP722. Aircraft type, including dimensions, performance, and handling qualities, dictate flight profiles associated with the approach and departure profiles to and from Droneports. These include:

- Maximum Take Off Weight (MTOW) – impacts performance capabilities.
- Aircraft dimension's including – influences landing and take-off areas:
  - Lateral dimensions – wingspan or rotor spread or hybrid of both; and
  - Vertical dimensions – undercarriage, rotor blade tilt (if applicable).
- Performance capability
  - Stall speed – influences drone approach and departure speeds;
  - Hover mode performance and duration – influences in air holding times;
  - Departure time, distance, and height to reach forward speed velocity; and
  - Approach time, distance, and height to reach deceleration speed to enter hover mode.
- Turbulence characteristics that could lead to Control Flight Into Terrain (CFIT) or Mid-Air Collision (MAC).
- Ensure aircraft entering the Droneport CTR has the applicable navigational limitations in place and has the ability for autonomous collision avoidance
- Hydrogen and electrical power are fast growing sectors with numerous hybrid variants being tested – however battery technology is considered the most current viable energy resource – employing various methods of recharging:
  - Removed battery to be placed in a charging station – allowing a higher frequency turnaround utilising battery replacement; and
  - Plug in from battery charger – may require longer re-charge requirements.

Each method will impact upon operational turnaround and maintenance procedures, including wear and tear on battery systems. Battery swapping offers the quickest turnaround as replacement batteries can be separately charged via ground charging stations, however the replacement method may have the potential to distort battery housing structures and associated connectors due to the high substitution frequency needed to maintain flight status. Plug-in chargers have less potential for battery damage however the aircraft requires to remain in the hanger charging area and thus creates longer down time in order to replenish its battery charge. It should be noted that battery technology is developing at a significant rate, ranging from more efficient batteries providing longer charge capacity, to hybrid energy resources that only require the battery to be used at specific flight periods, therefore extending its duration time, and reducing the frequency rate for recharging.

- Ascertain what type of category each drone is when entering the CTR as this will influence operational procedures. Ascertain its capabilities:
  - Does the drone have full autonomous capability from take-off to landing allowing remote supervision Beyond Visual Line Of Sight (BVLOS) flights; and
  - Or does it require Visual Line Of Sight (VLOS) during take-off and landing, which would require a handover procedure from Remote Pilot to Droneport C2.

SAFETY CONSIDERATIONS

Droneport safety refers to the efforts that are taken to ensure aircraft and associated ground operations are free from factors that may lead to injury or loss. The subject of airside safety is of great importance to Droneport operators who need to prevent or reduce as low as reasonably practicable all foreseeable risks of accidents especially when operating within the close confines of an urban environment. In addition to personal injuries, material damage, the possible impact on Droneport operations and a possible negative perception by the public, there are also important liability issues in case of an accident. This ethos forms part of a coordinated approach to Safety Management Systems (SMS), which all Droneports should develop and adhere to.

Safety Management Systems represent a systematic, explicit, and comprehensive process for managing risks to safety. Each system is based on the Droneport operator's in-depth knowledge of its organisation, and integrates safety into policies, management, and employee practices, as well as operating practices throughout the organisation.

As each organisation integrates safety into daily operations, management and employees can continuously work to identify and overcome potential safety hazards that could cause accidents.

Droneport safety management systems are very specific to their particular industry segment and must allow all the Droneport stakeholders to interact in a joint effort to improve safety. A SMS has to be modular and commensurate with the Droneport size and operations. It has to be practical and efficient so as to ensure a high level of safety and not become counter-productive.

The responsibility for the implementation of a SMS lies with the Droneport line managers and employees. Organisations may also have a specifically designated Safety Manager who monitors and assists in SMS implementation and audits compliance. Depending on the size and complexity of the organisation, the Safety Manager function can either be a dedicated position or include other responsibilities. Some organisations may also create a Safety Office that will be responsible for the implementation and development of the SMS.

Flight safety considerations centre on the operational attributes which link Droneport C2 with ground personnel and UTM capabilities. These include:

- Ability to conduct drone pre-flight visual checks for payload secure connection, identify any damage, mounted warning lights, etc.;
- Conduct landing pad foreign object observations and clearance, etc.;
- Urban environment influences:
  - Operations from obstacle-challenged urban Droneports in low-visibility conditions – these may lead to drone Controlled Flight Into Terrain (CFIT);
  - Operations in wind fields that may approach aircraft operational limits and in proximity to areas where winds may exceed these limits; and
  - External influences that could impact flight safety, for example interference that could include electronic signals that disrupt navigation and communication between the Droneport and aircraft; off-Droneport high-intensity lighting that make it difficult for Remote Pilot operators to distinguish the landing site at night or in reduced visibility. Also, of concern are situations that create bird strike hazards (such as landfills).
- Ensure GPS signal availability (if required) to ensure drone navigation can be engaged and maintained. This reduces the potential for C2 loss and drone "runaway" (the term runaway portrays an uncontrolled drone, which has an unknown projected trajectory that could create a catastrophic event);
- Ensure good constant communication is maintained with any surrounding airports or airfields. Engagement will be required if a drone un-planned and unexpectedly goes beyond its pre-set navigational boundaries, to ensure deconfliction procedures can be employed to prevent potential mid-air collisions with other aircraft;

- In the case where a fleet operator experiences an "off-nominal" event, redundant emergency landing locations must exist to allow for safe landing. These may be in the form of en-route emergency Droneport locations which may be identified by automated systems;
- Droneport structural integrity, i.e. the ability of a Droneport to absorb landing impacts from drones;
- First Responder accessibility to all Droneport areas, especially landing zones;
- Droneport evacuation capabilities and strategies under emergency situations;
- Although a Droneport maybe in a network with similar infrastructures, each should be considered as a standalone facility which can endure micro-environmental atmospheric activity that could be detrimental to drone's operational performance. Therefore, to ensure flight safety, individual Droneports require a primary surface weather observing system, designed to support aviation operations and weather forecast activities.
- Drone charging should consider the following:
  - Ability to monitor battery thermal "run-away" to prevent battery fires;
  - Have an adequate in-house fire suppression system that can effectively deal with battery and electrical fires; and
  - Have a First Responder fire strategy in place if in-house suppression is not fit for purpose.
- Supporting ground infrastructure activities include the following:
  - Hangar location and size;
  - Manoeuvring space;
  - Schedule management:
    - Resource scheduling;
    - Flight Planning;
    - Charging periods and frequency; and
    - Drone maintenance frequency.
  - Landing reservations;
  - Drone maintenance facilities:
    - C2 – ground-related communications; and
    - Drone tug movements.

These aspects are explored further in the remainder of the document.

PLANNING

INTRODUCTION

It should be noted that before any work commences on the development of a Droneport, the site owner/operator (applicant) should seek planning permission from the relevant local authority. It is advisable for the applicant to obtain pre-application advice as it can result in the resolution of difficult issues prior to submission of a planning application. Development outcomes are generally better if applicants engage with the local authority early on as it avoids applications being refused unnecessarily.

The sections below outline the main considerations for successfully navigating the planning process and securing necessary planning consents for Droneport development. Upcoming planning reforms may change aspects of the approval process and is worth monitoring should there be other considerations in the future planning landscape.

LEGISLATION & POLICY

The planning application for a Droneport will need to demonstrate alignment with local and regional planning policies. These are laid out in key strategic documents, such as:

- The Local Plan: this is the key statutory document used by the local planning authority to determine planning applications;
- Supplementary Planning Documents (SPDs): this supports the Local Plan and its policies (for example: Air Quality, Tall Buildings, Trees, Health Impact);
- Site specific policy guidance: policy matters that may relate to a specific site (for example: Area Action Plans, Neighbourhood Plans); and
- Other policy guidance: such as Climate Action Plans and/or Transport Strategies that are politically significant and can be consequential to a proposal being approved.

USE CLASS

The planning system puts uses of land and buildings into various categories known as 'Use Classes'. Therefore, a key aspect to keep in mind is the use class that the Droneport development will fall into. This depends on what the primary and secondary uses of the development site will be. For example, a drone cargo/delivery operation is likely to fall into Class B (B8 Storage or distribution – including open air storage) because of the storage requirements for goods.

The other applicable class covers those uses that are specifically defined and excluded from classification by legislation, and therefore become *'sui generis'* – where they fall outside the defined limits of any other use class (for example: fuel stations, taxi businesses). The use class for the Droneport operation as a transport mode for goods would fall under this category.

CONSULTATION

After a local planning authority has received a planning application, it will undertake a period of consultation where views on the proposed development can be expressed. The formal consultation period will normally last for 21 days, and the local planning authority will identify and consult a variety of different stakeholder groups.

- **Public consultation:** including consultation with neighbouring residents and community groups;
- **Statutory consultees:** where there is a requirement set out in law to consult a specific body (e.g. Health & Safety Executive, Historic England, Environmental Health, Environment Agency, Highways England, Civil Aviation Authority, Local Planning Authority – specific departments, e.g. Highways);
- **Any consultation required by a direction** – where there are further, specific, statutory consultation requirements as set out in a consultation direction; and
- **Non statutory consultees:** where there are planning policy reasons to engage other consultees who – whilst not designated in law – are likely to have an interest in a proposed development (e.g. local police force).

It is strongly advised that applicants discuss their proposals with neighbours, landowners or other parties interested in the relevant site before submitting a formal planning application. Experience has shown that planning applications have been refused in cases where the local community have not been engaged.

DESIGN & SITE SELECTION

The application will need to address how design principles and concepts have been applied to the site development, in turn demonstrating how the proposed development's context has influenced the design. It will also need to consider how specific issues might affect access to the proposed development.

Design considerations:

SITE SELECTION CRITERIA

- **Location:** It is crucial to assess where the potential site for a Droneport can be based on the use case – which would vary if the Droneport is at ground level, vertical, mobile, or elevated. Similarly, the function of the Droneport becomes a key consideration for determining its location, such as whether it is serving as a Droneport for medical supplies (in which case, proximity to hospitals, ease of access for emergency vehicles etc.) or commercial goods (in which case, proximity to high demand areas, goods storage facilities etc.);
- **Access:** Ensuring that there are no heavy freight vehicles or traffic running along key access roads adjacent to the landing site in the case of ground-based Droneports. This is to mitigate the risk of collision during landing. Further consideration needs to be made for goods delivery, facilitating easier access to storage facilities on site;
- **Physical Landscape:** Vegetation, fauna, topography, and stormwater drainage must be taken into consideration when selecting a site. Vegetation and fauna could be potential live hazards to day-today operations, whereas topography and drainage systems on site could dictate how resource intensive it would be to construct operable Droneports. Man-made entities such as existing infrastructure, agricultural land and future land-use scenarios also play a major role in site selection. Adhering to government guidelines for minimum clear space between buildings and drones is critical for community safety; and
- **Potential future development:** Factoring in potential changes to the surrounding landscape help determine the longevity and efficiency of Droneport operation. This includes potential high height obstructions, avoiding high FSI regions, and areas where services (overhead powerlines etc.) could be potentially constructed.

CONSTRUCTION

- **Component Assembly & Delivery:** Assessing how the components of the Droneport would be constructed is critical to determining site location. If construction involves large, prefabricated components, larger and multiple existing road access networks would be required. If the port is to be constructed in-situ, there must be ample provision for trucks etc. to enter as well.
- **Use-Case based specifics:** The type of Droneport determines the requirements for on-site construction and site characteristics. Vertical Droneports would require multiple access points surrounding them, as they would most likely be situated in dense urban environments, whereas flat Droneports would require relatively fewer.

BACK-OF-HOUSE INFRASTRUCTURE

- **Cargo Storage & Loading:** The design of cargo storage is essential for Droneports as it varies based on the type of cargo being stored. The thermal and water insulation levels, ease of access, quantum of storage and ease of loading/unloading would differ between medical and commercial goods. These structures must be well designed, suitably ventilated, insulated, secure, and accessible to ensure smooth day-to-day operations;
- **Collection & Distribution:** It is important to consider how supplies are transferred from storage to the drones (and vice-versa). Proximity of landing pads to storage facilities is critical to minimise operational costs of transport and cargo handling; and
- **Ancillary Functions:** Apart from cargo, other back-of-house functions such as waiting areas, electrical/HVAC rooms, user services (toilets, etc.) must be carefully zoned in order to ensure efficient operations and non-interference with port operations. Another set of key ancillary functions includes drone support – facilities for maintenance and repair, technical support and medical emergency treatment are critical for Droneports – this degree of provision would depend on the scale of operations (whether the port is a hub or decentralised).

LANDING BASE/SLOTS (BASED ON USE CASE):

Clear Area and Relevant regulations: Droneports must comply with existing Civil Aviation Authority regulations for drone operations. Basing this upon personal drone requirements – landing areas must have at least a 50m clear radius from people or properties/objects not in the drone operators' control. Similarly, the drones must not operate within a 150m radius of a congested area or organised open air assembly. Such regulations would inform how the Droneport is sited and constructed as well

MATERIALS

The materials used for constructing Droneports are of high importance. Many considerations must be made during material selection, across a variety of factors:

- **Outdoor Landing Ports:** Landing areas that are exposed to natural elements must use materials that can deal with changing weather conditions, so they must have the suitable thermal properties, as well as water resistance properties to continue to operate under harsh conditions. For example, materials that retain large amounts of heat would be detrimental to the drones on a hot day and could damage the aircraft;
- **Vertical Port Slots:** If vertical Droneports are being considered, materials that can withstand the vertical load of the structures must be used. Or lightweight materials that are durable must be considered. Either way, the structural and environmental factors that could potentially affect a vertical Droneport must be factored in during material selection; and
- **Cargo loading:** Loading and unloading of cargo, especially heavy cargo, can potentially damage storage spaces. Flooring, storage racks and other spatial elements of cargo spaces must use materials that can withstand the potential impact and stress over time. In the case of Droneports where the drones have direct interaction with cargo, the materials must also have sufficient cushioning and protective layers to ensure the drones aren't damaged.

DRONEPORT ERGONOMICS

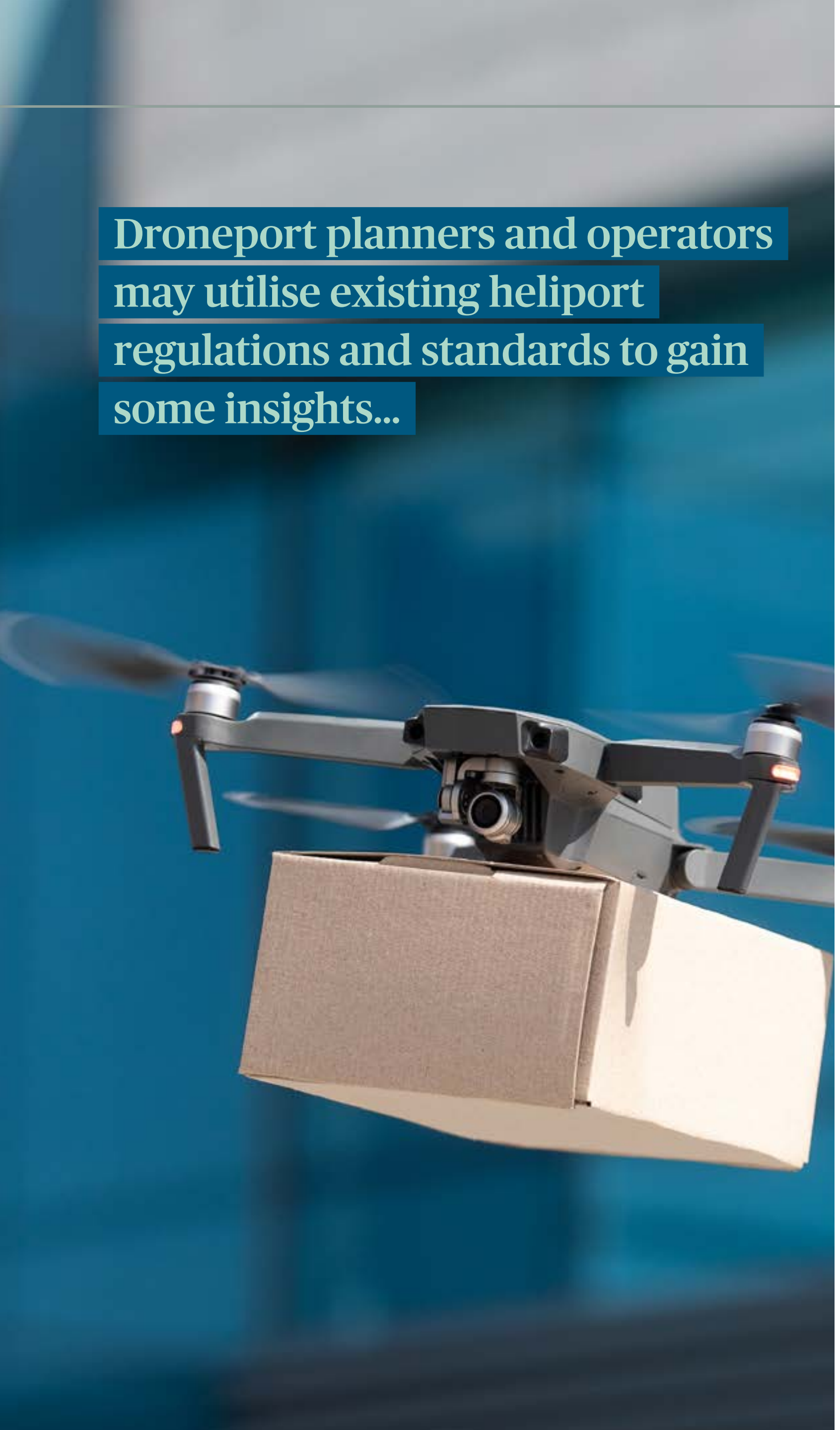
Droneport Ergonomics refers to the ergonomic design considerations to be taken when designing the spatial proportions of Droneports. Several areas must be considered when doing so:

- **Cargo Handlers access to drones:** Ensure there is sufficient space for loading and unloading, as well as aisles with sufficient width for trolleys etc. to comfortably pass through;
- **Technician access to Back-of-House and drones:** Ensure that there are ample access doors for technicians and back-of-house operators, and that the door dimensions adhere to building regulations (fire etc.) and also accommodate for drones to be brought in for maintenance;
- **Waiting Areas:** In the scenario where the Droneports would have people in waiting areas (medical or commercial personnel awaiting a delivery), the waiting areas must be designed to accommodate anticipated foot fall, per person – as per relevant building regulations;
- **Universal Accessibility:** Document "M" of UK building regulations highlights the requirements for accessibility for all building types. The design must accommodate ramps, exits, UA toilet and service facilities, etc.; and
- **Walking Distance:** Landing zone to loading zone distances must be designed to a reasonable threshold to ensure smooth operation – long walking distances for the same must be avoided to minimise additional requirements such as on-site vehicles to transport goods and supplies.

KEY PLANNING ISSUES

The following is a summary of key factors that are likely to affect Droneport development approval from a planning perspective:

- **Environmental Impact:** (e.g. traffic generation and emissions, biodiversity impact, Environmental Impact Assessment (EIA));
- **Transport and Highways:** how will it affect the local and wider strategic transport network? (connectivity and integration);
- **Public realm:** how will it have an impact on the public realm?
- **Heritage Impact:** does it fall into a conservation area?
- **Safety:** safety of the general public and local infrastructure;
- **Noise:** impact on local area (e.g. Noise Impact Assessment);
- **Privacy and security concerns:** how will neighbourhood concerns on potential surveillance, cybersecurity breaches, and noise be addressed;
- **Line of sight:** will drone operation and flight affect key views? How will landing, recharging, and taking off affect visual amenity?
- **Flood risk:** does it fall into a flood risk zone and how is this mitigated?
- **Fire risk:** does it pose a fire risk and how is this mitigated?



AVIATION REGULATION

Currently there are no standards nor recommendations published by regulatory organisations or government for the infrastructure development specifically for the operations of drones. It can be assumed the standards and regulations for the infrastructure development needed for operations of drones could reuse some of the already existing regulations. Although drones are quite dissimilar compared to current aircraft technology in terms of propulsion, size and shape, the associated ground infrastructure for drone operations can leverage ground infrastructure design requirements of current aircraft technology, particularly heliports. Droneport planners and operators may utilise existing heliport regulations and standards to gain some insights as to some of the design considerations which could be applicable to Droneport infrastructure. Current regulations that may serve as an initial guidance material for Droneport planners and operators are internationally ICAO's Annex 14 Volume II Heliports and the UK's CAP 1264 Standards for helicopter landing areas for hospitals. Nevertheless, there are fundamental gaps existing in current regulations in relation to landing and take-off of drones, electric charging facilities, and the management of battery related fires, amongst other aspects.

Other sectors where Droneport operators may obtain guidance on regulations for Droneports are the ongoing efforts by national and international regulatory and standards bodies on the design of vertiports and associated ground systems. Vertiports are take-off and landing areas for VTOL (Vertical Take-off and Landing) aircraft and associated ground infrastructure for the transportation of goods and passengers. The European Aviation Safety Agency (EASA) and US Federal Aviation Administration (FAA) are in the process of developing vertiport design standards, having set up working groups and task forces for developing industry-led standards.

It is important that before any work commences on the development of a Droneport, the site owner/operator (applicant) should speak with the national aviation regulator (for example the CAA in the UK) to understand the regulatory requirements for the site, then maintain a dialogue with the regulator during the planning and development process.

STAKEHOLDER MANAGEMENT

OVERVIEW

Stakeholder engagement and consultation is a key component of any successful scheme which contributes towards a consensus on Droneport development plans, encompassing a variety of interested parties, including those with direct business interests, and boarder groups which may include the local community, local authorities, and regulatory bodies.

In order to achieve a successful outcome to the planning, design, and delivery process of a Droneport, continuous and close engagement with all stakeholders will be essential to help communicate the key objectives of the Droneport. These include the drivers that lie behind those objectives, the benefits to be delivered, and how both success and benefits can be targeted and measured.

Developing a Stakeholder Engagement Plan will be fundamental in realising the desired outcomes – from initial Brief Development and benefits mapping process through to the selection of preferred design options. Maintaining visibility of the design development, capturing and responding to feedback and ensuring that Stakeholders are given adequate opportunity to influence the progression and direction of the Droneport development are all key elements in ensuring endorsement.

KEY CONSIDERATIONS

To ensure stakeholder buy-in/support/endorsement:

- Maintaining visibility of the design development;
- Capturing and responding to feedback; and
- Ensuring all Stakeholders have the opportunity to influence the project.

Aim for the process to be:

- Open and transparent;
- Impartial and objective; and
- Responsive and reciprocal.

Desired outcomes include:

- Benefits mapping;
- Initial Brief Development;
- Generation of options;
- Selection of preferred solutions; and
- Converting stakeholders into active supporters and champions of the scheme.

STAKEHOLDER ENGAGEMENT PLAN

Stakeholder input, engagement and feedback is critical to the success of the project. Different Droneports and their developers will employ a diverse range of development processes, and some may have specific stakeholder engagement processes already established. However, there are some basic common principles that are essential to ensuring that stakeholder engagement is planned and executed with desired outcomes.

BASIC PRINCIPLES

- Identify all key stakeholders who have an interest in or influence on development;
- Map stakeholder interest, importance, and influence;
- Define appropriate communication and engagement method within the context of a communications plan;
- Capture and understand stakeholder aspirations, translate into brief requirements, and design objectives;
- Seek regular engagement and feedback;
- Validate decisions at milestone reviews with stakeholders;
- Ensure information flow via regular communication updates;

- Issues and complaint/grievance management;
- Keep records of progress and decisions made – ensuring stakeholder accountability; and
- Measure success through feedback and milestone achievement.

A Stakeholder Engagement Plan needs to be defined and implemented to facilitate and engage with the stakeholder groups early in the project to ensure stakeholders are fully aware of the process, how they will be engaged and communicated with, and most importantly, that they understand what objectives of the project are, and what is expected from them as Stakeholders and when.

The Stakeholder Engagement Plan should encompass a wider programme of publicity, and communications and engagement needed to promote the project to decision makers, influencers, and the media to ensure the project is seen as a credible proposal.

STAKEHOLDER CONSULTATION PROCESS

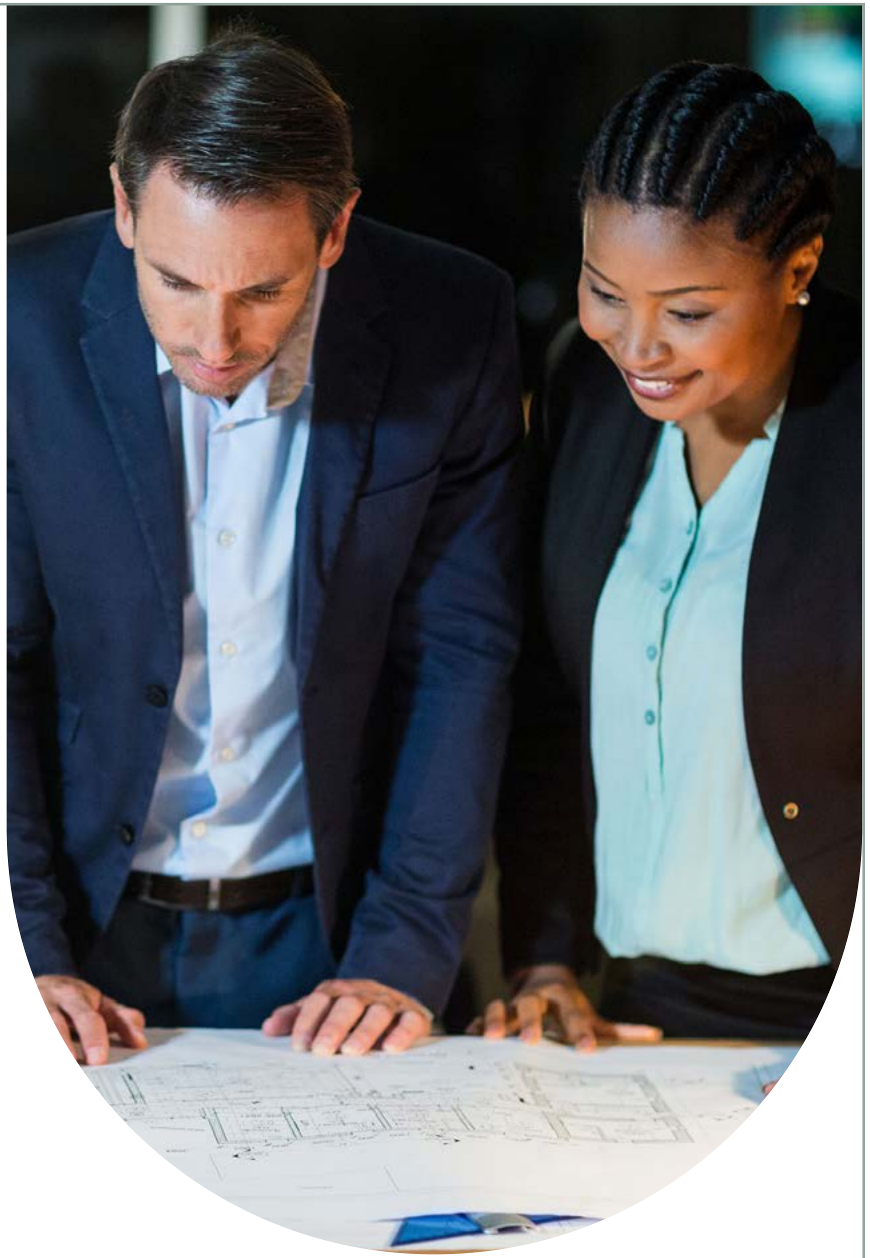
Consultation implies an open discussion before any decisions are made in order to take stakeholder feedback into account. This is an integral part of the design process, ensuring that a proposed design has been fully explored, all concerns identified, and alternatives considered. Ideally, the consultation process will result in a balanced outcome that meets the needs of all groups.

In order to achieve this, a well-considered consultation plan ensuring that project messaging and actions are carefully formulated, communicated, and received. The benefits of this process include:

- Platform for information exchange between all stakeholders;
- Informed understanding regarding the impacts of the proposed development;
- Sharing of different ideas, perspectives, and viewpoints;
- Identify specific areas of misunderstanding, disparity, agreement, and synergy;
- Sense of ownership in the design process; and
- Commitment to transparency and accountability.

A Stakeholder engagement framework consists of three main components:

- Briefing – understanding and capturing business objectives and detailed brief;
- Concept Design – testing and building the design solutions with all stakeholder groups; and
- Overall support and information transfer.



STAKEHOLDER GROUPS

Stakeholders include a wide-range of individuals and organisations that are linked to the proposed Droneport site by proximity, interest, and influence. They include those who perceive any type of relationship with the planning, development, construction, and operation of Droneports. Key stakeholder groupings may include, but not necessarily limited to:

REGULATORY BODIES

International standards and national regulations are under development, however, influential stakeholders critical to gaining consent may include the following amongst others:

- Department for Transport;
- Planning Inspectorate (PINS);
- Civil Aviation Authority (CAA);
- National Air Traffic Services (NATS);
- Other Air Navigation Service Providers (ANSPs);
- Local airports, airfields, centres of national infrastructure; and
- Local Authorities, Boroughs, and Parish Councils

STATUTORY UNDERTAKERS

Authorities are encouraged to provide active support for new aviation systems plus their enabling ground infrastructure. It is anticipated there will be changes to planning policy, laws and production of guidance following the introduction of a regulatory framework. Collaboration with municipalities during Droneport regulation development ensures community concerns are addressed from the outset.

Statutory Authorities to be considered include:

- Regional and local authorities (host local authority & neighbouring authorities);
- Government bodies, for example the Environment Agency;
- Asset owners;
- Police & emergency services, including the fire & rescue service;
- Utility companies; and
- Transport/surface access agencies.

PILS AND OTHER IMPACTED PARTIES

Persons with an Interest in the Land (PILS) and other impacted parties include landowners and occupiers of land which is necessary to implement the proposed development site as well as others with an interest in the land and parties with a compensable interest. This includes local businesses and residents affected by the proposals and may cover a wide catchment area (to be defined) impacted by amendments to surface access, and potential noise/environmental effects both during construction and operation.

END USERS

This includes current and future users of the Droneport and ancillary uses:

- Logistics carriers;
- Customers/Consumer groups;
- Local community groups;
- Employee groups including unions/trade associations;
- Droneport ground and flight operations;
- Asset management;
- Commercial property; and
- Commercial retail and media.

MPS, MEDIA, AND OTHER INFLUENCERS:

Whilst not prescribed consultees, it is recognised that there is a wider group that could potentially influence the Droneport development and operation. These should also be identified and consulted.

PROPOSED STRATEGY FOR INFORMATION DISCLOSURE

The tools utilised to disseminate information relating to the Droneport is equally as significant as the issued statements. Over a period, the media can be a key tool to reach stakeholders and the public. Channels that should be considered to distribute content include, but are not limited to, the following:

- Press releases;
- Web sites;
- Facilitation Meetings, workshops, walk-in information sessions;
- Social media;
- Local publications;
- Locally distributed leaflets; and
- Press conferences.

ENVIRONMENTAL FACTORS

Environmental factors are an important aspect to be considered for the operation of drones and Droneports. Some of the key environmental factors that can affect the operations of drones and droneports include noise, prevailing weather conditions, Greenhouse Gas emissions, Air Quality and Electromagnetic Interference.

Droneport operators need to consider these factors from an early stage of Droneport planning and development right up to the design, build and operation of the Droneport. A few environment factors, such as weather and electromagnetic interference, may affect the operation of drones and a complete risk assessment of their impact needs to be considered before operations commence. Other environmental factors such as noise, Greenhouse Emissions and Air Quality are impacted by the operations of drones. Hence a thorough impact assessment must be carried out before selection of a Droneport location. As it is likely that increased drone operations will take place in urban environments and the majority of Droneports may be in urban environments, it becomes more imperative that environmental factors are considered at an early planning stage by the Droneport developers and operators, as urban environments have an increased set of regulations relating to them.

NOISE

Noise is considered to be one of the potential major barriers to public acceptance of drone operations in urban environments. According to research conducted in the City of Southampton on the effects of a hovering drone on urban soundscapes perception[2], in soundscapes highly impacted by road traffic noise, the presence of drone noise led to minimal changes in the perceived loudness, annoyance and pleasantness of drone flights. However, in soundscapes with reduced road traffic noise, the participants reported a significantly higher perceived loudness and annoyance and a lower pleasantness with the presence of the same drone noise. Therefore, based on these results, the concentration of drone operations along flight paths through busy roads might aid in the mitigation of the overall community noise impact caused by drones.

WEATHER CONSIDERATIONS

EFFECTS OF WEATHER ON DRONES AND DRONEPORT OPERATION

The following information and guidance is, by necessity, a simplification of complex meteorological topics including climatology, observations, and forecasting.

Additionally, the drone/unmanned aircraft domain is rapidly developing and there will be new challenges to identify and address. Readers are encouraged to engage with the meteorological community at the earliest opportunity in order that a full mutual understanding of the needs, challenges, and solutions necessary to support safe, and efficient Droneport operations is developed.

The weather and prevailing meteorological conditions can pose risks that affect the operation of drones and Droneports in a similar way to that of traditional onboard-piloted aircraft and airports. Adverse weather conditions such as strong wind and turbulence, extremely high/low temperature, precipitation (rain, drizzle, snow, hail), poor visibility due to fog, cloud cover, in-flight icing conditions, thunderstorms and other extreme weather hazards can have a negative effect on the performance of drones, remote pilots' situational awareness, and Droneport operations. Appendix I (below) lists a range of weather parameters and the (non-exhaustive) risks that need to be considered.

2 Effects of a Hovering Unmanned Aerial Vehicle on Urban Soundscapes Perception at https://arxiv.org/pdf/1912.00087.pdf

Drones can be of various shapes and sizes, with most of the drones expected to be substantially lighter than some common general aviation aircraft. The smaller size of drones, a reliance on non-human perception systems and the use of power, propulsion and aerodynamics that are different from traditional onboard-piloted aircraft are likely to introduce different challenges and possibly greater sensitivity to weather. Small drones (less than 25kg) are likely to be susceptible to certain weather hazards due to their size and lower weather operating tolerances, as compared to larger drones. Flying drones in adverse weather conditions can result in loss of situational awareness through reduced visibility (where vision or other electro-optic systems are used), degradation of other sensor suites (active or passive), loss of communication or loss of control; all of which can lead to loss of aircraft.

In Visual Line of Sight (VLOS) operations, visual observers and operators flying the drones need to observe the local prevailing conditions on the ground and determine the weather conditions are not affecting their health and do not impair their ability to see and control the aircraft. Beyond Visual Line Of Sight (BVLOS) operations are at higher risk than VLOS operations from a weather perspective, as the operator is not present at the site and able to make observation-based decisions themselves. Local measurements of weather parameters and real-time sharing of those measurements to the extent possible at take-off, landing and at locations en-route can mitigate the challenges caused through the absence of a human observer.

The take-off, approach, and landing phases of drone flight account for a large proportion of drone accidents and incidents. Hence, the weather and meteorological hazards in and around Droneports is an important factor to consider for ensuring safe operation of drones. Droneports and flight paths of drones located in/around populated urban areas must consider the weather hazards related to turbulence near to and downwind of surface features – whether natural or artificial.

RISK MITIGATION OF WEATHER HAZARDS IMPACT ON DRONEPORT DESIGN AND OPERATION

At every stage of Droneport development considerations need to be made to mitigate risks of weather hazards on the Droneport and drone operations in and around the Droneport. Some of these key considerations are:

- The primary concern for operating drones within urban environments is small-scale turbulence and localised wind flows generated by surface features such as trees and buildings. The wind effects near buildings can generate complex wind flows and very localised turbulence that can have an adverse impact on the operation of drones. Considerations around Droneport architectural design, to minimise localised adverse phenomena (such as turbulence), would need to be made. Solutions such as investing in a digital twin of the build site could help with modelling the effects of different weather scenarios on the Droneport. Computational Fluid Dynamics (CFD) modelling would assist in identifying small scale phenomena that may occur at the location and affect drone operations.

Including a larger area around the proposed Droneport site for such an analysis would help identify any local effects, with consideration made to potential new structures that may be built within the vicinity in the future.

- During planning, design, and construction phase of a Droneport, it is important to ensure that the site is not particularly prone to the weather hazards that affect drones. It would be pertinent that a thorough site assessment is carried out, including obtaining a detailed climatology (seasonal and diurnal) of the location. Additionally, it may be appropriate to install weather monitoring equipment at the site prior to build, if possible, for a sustained period, to establish a more detailed picture should a suitable climatology not be available or to supplement the existing climatological record. Seeking a climate projection type analysis would also help identify if the site would likely become prone to adverse weather on a more frequent basis in the future. These processes will provide a better understanding of the weather challenges that may affect the proposed site but should be assessed carefully since the Droneport structure itself will have some modifying effect on the site's subsequent climatology.
- Any prevalent local weather phenomena that exist on the approach to the Droneport landing site is also worth investigating. A safe corridor for missed approach in the event of unexpected hazardous weather is also an important consideration to be made in the planning of Droneport siting.

...it must be recognised that drone operations are likely to be affected by weather...

- In the case of understanding complex wind flows a robust approach would be to install a small network of low-cost sensors in the vicinity of the proposed Droneport. Comparison of measurements from those sensors with values derived from a digital twin/computational fluid dynamics (CFD) model without the Droneport would enable validation of the performance of the CFD model and subsequently enhance confidence in the outputs of the digital twin/CFD analysis with the Droneport included.
- The impact of winter hazards such as ice and snow (including the loading implications of heavy snow on the Droneport structure itself) would be prudent to consider. In such cases, appropriate building regulations would need to be adhered to.
- Ensuring suitable drainage for precipitation and adherence to appropriate building and environmental regulations.
- The operator of the Droneport can attach appropriate weather sensing equipment on-site and in the neighbouring area to assess meteorological conditions in real-time at a local level
- Safer and more efficient operating environment for users of the Droneport would be expected if the data from these instruments is made available to the users and the wider community, including meteorological service providers. Droneport operators can also supplement measurements from surface-based instruments by requiring drone operators to share meteorological measurements from drones operating from/to the Droneport.
- Drone corridors, and the location of Droneports below those corridors, should be positioned to maximise safety and efficiency and minimise energy usage.
- Wind direction is an important criterion to consider for Droneport design and defining the drone corridors for approach and departures. Fixed-wing drones, which prefer take-off and land into the wind, and multirotor drones, which prefer take-off and land with 'tail winds', benefit from prevailing wind direction differently. Understanding the prevailing wind conditions can minimise time for drones to take-off and land thereby minimising time over objects thereby mitigating risks.
- Drone corridors and Droneports should be positioned to minimise turbulence caused by upwind topography and/or buildings/structures.
- Where coasts/lakes/marshes may tend to generate mist and fog, the drone corridors and Droneports should be positioned as far as possible away from such features.
- Terrain, even minor undulations, can affect whether the Droneport may be above where fog tends to form (i.e., the Droneport is on a hill or ridge); or a location where fog is likely (i.e. the bottom of a valley or hollow).

WEATHER INFORMATION SERVICE

When considering weather services for Droneport operations, and the users of Droneports, it must be recognised that drone operations are likely to be affected by weather that traditional onboard-piloted aircraft are not, and at scales that would not otherwise significantly affect traditional onboard-piloted aircraft. Sensors (lidar, radar, ultrasound, etc.) and communications essential for drones may be affected by different weather types. Historically, there may be no observations of such weather, and this makes it particularly challenging to understand the climatological frequency of such events.

In this context, experience from the development of Connected Autonomous Vehicles (CAV) shows relevant climatologies of frozen precipitation share several challenges associated with other weather parameters, such as rainfall or visibility, namely:

- In many cases, the meteorological measurement was designed to mirror the human observer experience of the weather. This may limit its appropriateness for use for drone (as it did with CAV) sensors, which may work at different wavelengths.
- A recent report by the Met Office and National Physical Laboratory (NPL)3 for Connected Places Catapult in the CAV domain highlights the need to create a rigorous taxonomy of weather-related degradation pathways.
- The relationship between measurable weather parameter and drone system impact (as per CAV system impact) may be complex (non-linear) and not fully-explainable by a single simple weather parameter.

Recognising the above, a meteorological service provider can provide meteorological information including climatological, observed, or forecast. Climatology can provide statistics, particularly frequency of events, that allow an assessment of the number of occasions that a given weather parameter may exceed the capabilities of the drone(s). This is critical for assessing the viability of the business case for the Droneport. The granularity of the meteorological information available will depend upon the parameters required.

It must always be remembered that climatology is historical and does not guarantee that, for example, a given month in the future will not be wetter, drier, windier, less windy, colder or warmer that the climatological average, nor that events may occur more or less frequently than climatology might suggest. However, it does provide a guide to anticipated weather conditions across a year and longer timescales.

On a day-to-day operational perspective, probabilistic forecasts can provide an assessment of how likely – in the next several hours, or days – a given weather parameter may exceed the operational design domain (ODD) of the drone.

There are various weather information sources used by meteorological service providers to provide meteorological data. The weather parameters generally captured by the various weather observation sites are as follows:

- Surface Weather Observations;
  - Daily rainfall measurement.
  - Daily maximum and minimum temperatures, rainfall, and often other elements such as sunshine, snow depth are measured.
  - Hourly observing sites where temperature, rainfall, humidity, wind speed and direction (mean and gust speeds), pressure, visibility, cloud type, height and amount, 'weather type (mist, rain, snow, fog etc) are measured.
  - In addition, there are anemometer sites (that do not observe other elements) which have hourly mean speeds and direction and the maximum gust speed each hour and its direction.
- Above the surface meteorological information is typically available from radiosondes (weather balloons) or aircraft reports (typically from commercial airliners) although this may not be available at some proposed Droneport sites, especially in urban areas;
- Information from remote observation systems (radar, satellite etc.) provide very valuable data although there are restrictions on usefulness in some circumstances (for example rainfall radar beams may be several thousand feet above ground level and not detect light precipitation from cloud layers below the beam). In order to exploit such information for safety and efficiency, it is necessary to combine information from a range of data sources and careful attention must be paid to the correct application of the data to the drone task;
- Wind and temperature information can be derived from Mode-S/ADS-B (Automatic Dependent Surveillance – Broadcast) transmissions in recent years. However, except for locations very close to existing airports there is a sparsity of such information below 1000 ft currently. Drones themselves could, in principle, make observations below 1000 ft to fill this gap in data and this has the advantage of measuring the weather and impacts where the drone is operating around Droneports; and

- It is possible to retrospectively calculate Effective Precipitation (EP) in an area and this gives a more realistic picture of the likely run-off, i.e., how much rainwater will run-off the land and end up in drains, rivers etc. Historical flooding information can be available from Environmental Agency and/or the Centre for Ecology and Hydrology. Individual water companies will also keep records of floods.

Since all meteorological information (observed or forecast) has some degree of uncertainty then it is necessary to take account of such uncertainties when formulating the risk. Therefore, a requirement is that any meteorological information used in such processes must also express the uncertainty (or error bars) appropriate to that information. Uncertainties regarding climatological data can be reduced with on-site observations of weather.

WEATHER RISK ASSESSMENT AND PLANNING FOR DRONEPORT OPERATIONS

The Droneport service providers should engage with the regulatory authorities in understanding the safety aspects that need to be considered for the Droneport design and location. It is critical that for a successful design, build and operation of a Droneport engagement at the earliest opportunity with meteorological service providers, regulators, drone service providers as well as the Droneport operators in order to identify the challenges and capabilities relating to weather. In these early, pioneering, days of the drone industry a holistic approach to measuring and making available as much observed meteorological information as possible is a fundamental foundation to safe and efficient operations.

The risk assessment of weather hazards on Droneport design and drone operations involves each of the Droneport operational stakeholders specifying relevant weather information and assessing the impact of weather hazards on their operations. At every stage effective risk mitigation needs to be considered to minimise impact of adverse weather conditions on Droneport and drone operations. Droneport operators, drone service providers, meteorological service providers, and regulatory authorities should work together to assess risk posed due to weather hazards and ensure the safe operation of drones.

Meteorological service providers can provide input on understanding the uncertainties of meteorological information but are not the determiner of risk assessment methodologies. The meteorological information is an input into the risk assessment and, from probabilistic forecasts, can provide probabilities of specific conditions occurring. The other inputs provided are the sensitivity of the drone to weather parameters and the impact (collateral damage/human injury) that would lead to if a loss of control of drone occurs. The calculation of the risk, considering the capabilities of the drone, should be undertaken by the Droneport operator.

Whilst it falls to the drone manufacturers, drone service providers, Droneport operators and regulators to determine and define weather limits; and it falls to drone manufacturers/operators to identify to what degree their drone sensors and communications systems are (or are not) affected by/sensitive to the weather; it is nonetheless essential to engage early with the meteorological community to ensure that the precise definition and correct interpretation of that limit, if it is expressed as a weather variable, is done so correctly.

Likewise, Droneport ancillary operations (opening/closing of cargo doors during strong winds; systems to move drones into/out of the building that might be affected by the wind, snow/ice removal etc) can only be determined by the Droneport operator but early engagement with the meteorological community will help identify the most correct and relevant weather information services to support operations. Building and environmental regulations will also apply in such instances.

APPENDIX I

The non-exhaustive list of weather parameters and possible effects on drones and Droneport operations below should be further developed through a comprehensive consultation with meteorological service providers, drone manufacturers, operators and Droneport designers.

Weather Parameter	Anticipated Impact on Drone
Horizontal Wind	• Sensitivities of drones to wind will vary dependent on design, mass and the capability of the propulsion unit(s) and control surfaces. This requires that careful definition of the time scale over which the wind is calculated (e.g. the averaging time) is essential. • Particular challenges regarding eddies and vortices around and downwind of buildings and structures. • Wind gusts and turbulence can decrease flight endurance of small drones due to the additional flight control power required to maintain a steady flight. • Wind shear is also an important consideration, especially strong outflows from thunderstorms. • An extra consideration for BVLOS operations is that turbulence and wind gusts can interfere with the satellite control and communications links. • Specifically, in the case of drones, vortices and flow reversals generated by buildings and structures may result in loss of control of drones.
Vertical Wind	• Downdraughts from deep cumulus and cumulonimbus cloud may cause severe turbulence resulting in lack of control of drones. • Specifically, in the case of drones, downdraughts/updraughts and flow reversals generated by buildings and structures may result in loss of control of drones.
Visibility (e.g., mist, fog, haze, smoke)	• The meteorological use of the term *visibility* strictly relates to a human observer, and careful consideration must be given to its application to other electro-optical sensors. That noted, where visibility (or other electromagnetic wavelength used by electro-optical sensors) is compromised, it follows that there is a likely detrimental impact on any sensor (such as on-board First Person View (FPV) cameras and LiDARs) operating near the region of the electromagnetic spectrum used by the sensor. • On-board sensors can be affected by obscuration, such as LiDAR, and fail to function correctly. Presence of cloud can also affect communications links between the pilot and drone.
Temperature	• High temperatures can have a negative effect on engine performance and can affect on-board electronics and sensors. • Low temperatures can affect battery performance (affecting range/endurance). • Low temperatures are an important factor for icing (see below).

Weather Parameter	Anticipated Impact on Drone
Icing	• Risk of inflight icing when flying in temperatures between 0˚C and -20˚C where moisture is present (i.e. in cloud or precipitation). • Important to consider temperature changes with height (e.g. height of 0˚C isotherm) to determine icing risk areas. • Ice accretion on the airframe and propeller decreases aerodynamic efficiency, thrust capability, and increases vehicle weight, possibly resulting in loss of control. • Small drones are especially susceptible as icing can build faster on a small airframe and over blade surfaces of propellers.
Rain	• Small drones are often not sealed to water, so any precipitation can cause electrical failure. Potential attenuation of sensors (passive/active) and/or communications links. • Reduction of visibility (other electro-optical sensors), especially in drizzle (if using on-board cameras as a means of navigation/orientation). • Striking action of precipitation on the aircraft can affect control and aerodynamics.
Snow	• Fouling of propellors/rotors. • Fouling of control surfaces. • Obstruction of vents. • Obstruction of optics. • Obstruction of other sensors. • Water ingress (if melting on contact). • Potential attenuation of sensors (passive/active) and/or communications links. • Increase in weight. • Marked reduction of visibility (if using onboard cameras as a means of navigation/orientation). • Melting snow may intensify some effects, such as water ingress.
Changes in precipitation states (solid or liquid)	• Liquid precipitation at the surface of the ground may be solid (snow) or melting (sleet) a short distance above the surface, with effects listed in snow/melting-snow above. • Sub-zero, liquid precipitation (super-cooled) may result in extreme icing where airframe itself is sub-zero (including through aerodynamic cooling).
Humidity	• Moisture in the air condensing on electronics on UAS not sealed to water can have similar effects as precipitation, causing electrical failure. • High humidity can also cause misting/fogging of optics.

Weather Parameter	Anticipated Impact on Drone
Hail	• Damage to airframe/external structures (aerials etc) and sensors. • Fouling of propellors/rotors. • Fouling of control surfaces. • Obstruction of vents. • Obstruction of optics.
Lightning	• Catastrophic failure of on-board electronics. • Catastrophic failure of aircraft structure.
Solar Storms	• Solar storms, such as solar flares and coronal mass ejections, can disrupt GPS transmissions and cause degradation of communication signals

GHG EMISSIONS/CARBON FOOTPRINT

Aviation is one of the fastest-growing sources of greenhouse gas emissions. The international and national aviation organisations are committed to take action to reduce global aviation greenhouse gas emissions. Drones are usually powered by electricity, thereby release much less greenhouse gas emissions as compared to jet fuel powered aircraft. Drones are likely to be charged using the electricity from the grid where they locally operate. Thus Droneports – take-off and landing areas for drones – should be the locations which consist of the electric charging infrastructure for drone operations. Drone operations could be considered environmentally friendly than its alternative crewed aircrafts, depending primarily on the means of producing electricity locally. Other means of greenhouse gas emissions due to drone operations are the ground-based Droneport emissions caused by diesel and fuel for ground support equipment.

To reduce Greenhouse Gas (GHG) Emissions at Droneports, Droneport operators need to begin by estimating the amount of GHGs from Droneport sources. Similar to the approach used by airports for calculating GHGs inventories, Droneport GHG inventories can be divided into three categories. These categories are based on the amount of control Droneport has in reducing GHG emissions. These categories are as follows:

- **Scope 1** – Emissions from Droneport-owned and controlled sources. Examples include Droneport-owned powerplants, conventional fuel-based ground support equipment.
- **Scope 2** – Indirect emissions from consumption of purchased energy.
- **Scope 3** – Indirect emissions that the Droneport does not control but can influence. Examples include emissions from commuter vehicles or cargo vehicles arriving or departing the Droneport, commercial tenant emissions and emissions from waste disposal and processing.

There are several easy-to-use GHG emission inventory tools. One example is Airport Council International's Airport Carbon and Emissions Reporting Tool (ACERT). Other examples are included in research by the Airport Cooperative Research Program (ACRP).

Once the GHGs sources have been identified, Droneport operators can develop strategy for reducing GHG emissions. Some of these measures include purchase of renewable energy or/and installation of renewable energy systems at Droneports.

AIR QUALITY

The operation of drones in/around Droneports should cause no impact to the air quality in the surrounding areas. The ground infrastructure design of Droneports is also not envisaged to cause any detrimental impact to the quality of air. However, where the Droneport designers/operators need to be mindful of is that the location of Droneports may lead to some minimal impact on the air quality due to increased community activity. Droneports are also designed to act as a community hub of activity and thereby more movement of cargo vehicles and people commuting to/from Droneports by other ground transportation means is likely to occur. If the access to Droneports for people and cargo is not provided by clean and efficient transportation means, this may have detrimental impact on the air quality of areas in/around the Droneport.

ELECTROMAGNETIC INTERFERENCE

In general, electromagnetic interference can be categorised into three main groups:

01

Narrowband EMI (Electromagnetic Interference) is also called RFI (Radio Frequency Interference), which typically originates from intended transmissions such as radio and TV stations or mobile phones;

02

Broadband EMI or RFI, which is unintentional radiation from sources such as electric power transmission lines; and

03

Natural electromagnetic phenomenon (high altitude) such as atmospheric noise or cosmic radiation.

It is evident the first two groups have more impact on drone operations. High voltage power converter stations generate high-intensity, wide-spectrum electromagnetic emissions which can have an impact on the communication circuits of drones and consequently on the command and control (C2) and data transmission links. Drones usually use Wi-Fi technology for communications which is based on IEEE 802.11 protocols in ISM (Industrial, Scientific and Medical) band (mainly 2.4GHz). The data rate automatically adjusts based on a factor called Signal-to-Noise ratio (SNR) and when the interference is too large and the SNR is lower than a certain threshold, the transmission rate can be automatically reduced dramatically, e.g., from 54 Mb/s to 6 Mb/s, or it can be reduced to 2 Mb/s or 1 Mb/s depending on the different spread spectrum technology.

In addition, Electromagnetic interference increases the bit error rate (BER) of the digital packet and reduces the reliability of the signal and even may cause data loss/errors.

Interference may impact the navigation and positioning systems of the drone and cause the drone to lose connection or even crash out of control. More information about the impact of interference on drone systems is available in reference.[3]

To this end, the Droneports should be positioned in locations with less influence from interreference sources (powerlines, mobile masts, etc.).

3 A Survey of Electromagnetic Influence on UAVs from an EHV Power Converter Stations and Possible Countermeasures https://www.mdpi.com/2079-9292/10/6/701/pdf

WILDLIFE HAZARD MANAGEMENT

Collisions between aircraft and wildlife, particularly birds, are common occurrences across the developed world. Wildlife strikes are numerous and costly.

59%
below
100
feet (30 m)

92%
below
3,000
feet (900 m)

Most wildlife strikes occur in the airport environment: Thus, management efforts to reduce wildlife hazards are generally focused on airports. Bird strike risks are particularly relevant for Droneport operations, as the majority of done operations are currently at low level, and Droneports are more likely to be situated in more populous areas.

Aviation safety agencies, regulators and associated stakeholders worldwide have produced guidance, standards, manuals, and policy documents to help aerodrome and aircraft operators in managing and mitigating bird and wildlife strike risks, these may all be referenced and adopted as applicable for Droneports. Indeed, in the UK, CAA publication CAP772: Wildlife hazard management at aerodromes forms a good basis for advice on wildlife management and the development of a Wildlife Hazard Management Plan for Droneports.

The first step of managing wildlife hazard is to assess the level of risk that each species of animal presents to drone operations at the Droneport. This risk assessment is more than simply surveying the species found in and around the Droneport; it involves assessing the likelihood of each species striking a drone and the probability and extent of damage that may result. This allows managers to prioritise their management actions to target the highest risk species. The Risk Assessment should also identify the biological factors that cause different wildlife species to present a risk to drone safety. Identification of these factors will greatly aid in the formulation of a Wildlife Hazard Management Plan.

This generally includes the entire Droneport, including take-off routes and landing approaches when significant wildlife hazards are present in these zones, particularly birds.

Land use and habitat management on areas near a Droneport are also an important consideration, particularly in urban areas, although a Droneport operator may have limited ability to control off-site land use and will need to work in partnership with local landowners and stakeholders. In principle, the habitats off-site should be more attractive to wildlife than the Droneport site itself. However extreme cases such as a land fill or recycling centres might attract so much wildlife that it may pose an increased hazard on Droneport land.

When addressing the hazard posed by both birds and wildlife, stakeholders must ensure their actions are lawful. Specific licences are required for some wildlife control activities in order to preserve air safety which would otherwise be illegal under the 1981 Wildlife and Countryside Act. The agencies responsible for them are: Natural England, Scottish National Heritage, Natural Resources Wales, and the Northern Ireland Department of Agriculture, Environment and Rural Affairs.

EMERGENCY MANAGEMENT

EMERGENCY CONDITIONS

Each Droneport requires a specific Emergency Plan that outlines the Droneport emergency strategy and procedures. The emergency plan is the process of preparing a Droneport to cope with an emergency occurring at the location or in its local vicinity.

The objective of the plan is to minimise the effects of an emergency, particularly in respect of saving lives, equipment, and surrounding infrastructure. The Emergency Plan sets forth the procedures for coordinating the response of different internal agencies (or services) and those agencies in the surrounding community that could be of assistance in responding to the emergency. The plan should reference out to specific emergency operating procedures, points of contact and other associated information.

Examples of emergencies include drone emergencies, sabotage including bomb threats, unlawfully seized drones, dangerous goods occurrences, building fires, natural disaster, and public health emergencies.

Currently there are no regulatory documents or procedures for Droneport emergencies however developers can look towards current ICAO documents which can provide background information e.g. Doc 9137-PART 7 Airport Emergency Planning; Doc 9859, Appendix 3 to Chapter 5 – Emergency Response Planning, etc.

The Emergency Plan should cover the following as a minimum:

- Types of emergency situation for which it is intended to deal with;
- Agencies involved in the plan;
- Responsibilities and the role of each agency, the director of the emergency operations centre and emergency command post, for each type of emergency;
- Names and telephone numbers of services or people to alert in the case of an emergency – air traffic control unit, rescue, and fire-fighting services;
- Aerodrome administration, medical and ambulance services, aircraft operators, security services, and police;
- Grid map of the aerodrome and its immediate surroundings.

The following are some key operational aspects to consider within the Emergency Plan:

- Drone C2 loss on approach or departure
  - Internal drone flight protocols can be engaged – hover, from hover position to land, return to last waypoint or base – or kill switch capability; and
  - Standard Air Traffic Control communications for combined emergency team to engage deconfliction procedures.
- Damaged battery leading to thermal runaway;
- Crash landing – inspection sequence and method, introduction of Accident Investigations procedures if required);
- Each drone type needs to have the ability to execute a forced landing safely at an unprepared site. The responsibility and capability of the different agents (e.g., automated systems, Pilot In Command (PIC), as a Remote Pilot (RP), etc.) could be different based on different aircraft variants in such scenarios;
- Fire
  - Extinguishing method – especially those linked to battery fires;
  - Emergency ingress (first responders)/egress – methods of escape; and
  - First responder interaction/strategies.
- Third party impacts;
  - Catastrophic injuries to people and property.
  - Insurance; and
  - Legal responsibilities.

CONSTRUCTION

INTRODUCTION

Given the potential number of Droneports envisioned to be developed in the near future and the volume of operations in conjunction with these, there is a sound business case for standardised design and construction, especially by companies already specialising in logistics design and engineering. Using standardised designs and components will help reduce the time needed for construction and could help streamline the permitting and application process by building out a set of precedent cases for local authorities and municipalities to reference when considering permitting requests.

The construction phase of a project includes all activities necessary to fulfil the requirements of a design specification, and may include but not necessarily limited to:

- Policies and regulations;
- Construction methods;
- Logistics;
- Equipment;
- Surface transportation;
- Re-use and recycling of materials; and
- Sustainable materials.

Construction activity may include but not necessarily limited to:

- New and expanded facilities – including enabling works;
- Maintenance;
- Demolition/replacement; and
- Upgrading to comply with new standards.

KEY CONSIDERATIONS

- Impact on Environment:
  - Natural resource/environmental; and
  - Social conditions of a Droneport, the surrounding community, or region.
- Impact on operations (also economic)
  - Maintain safety and operational continuity/efficiency; and
  - Managing operational/end-user stakeholders.

PLANNING STAGE

As local authority approvals may have a major impact on the construction process, practices should be considered and specified during the planning process to inform the design early.

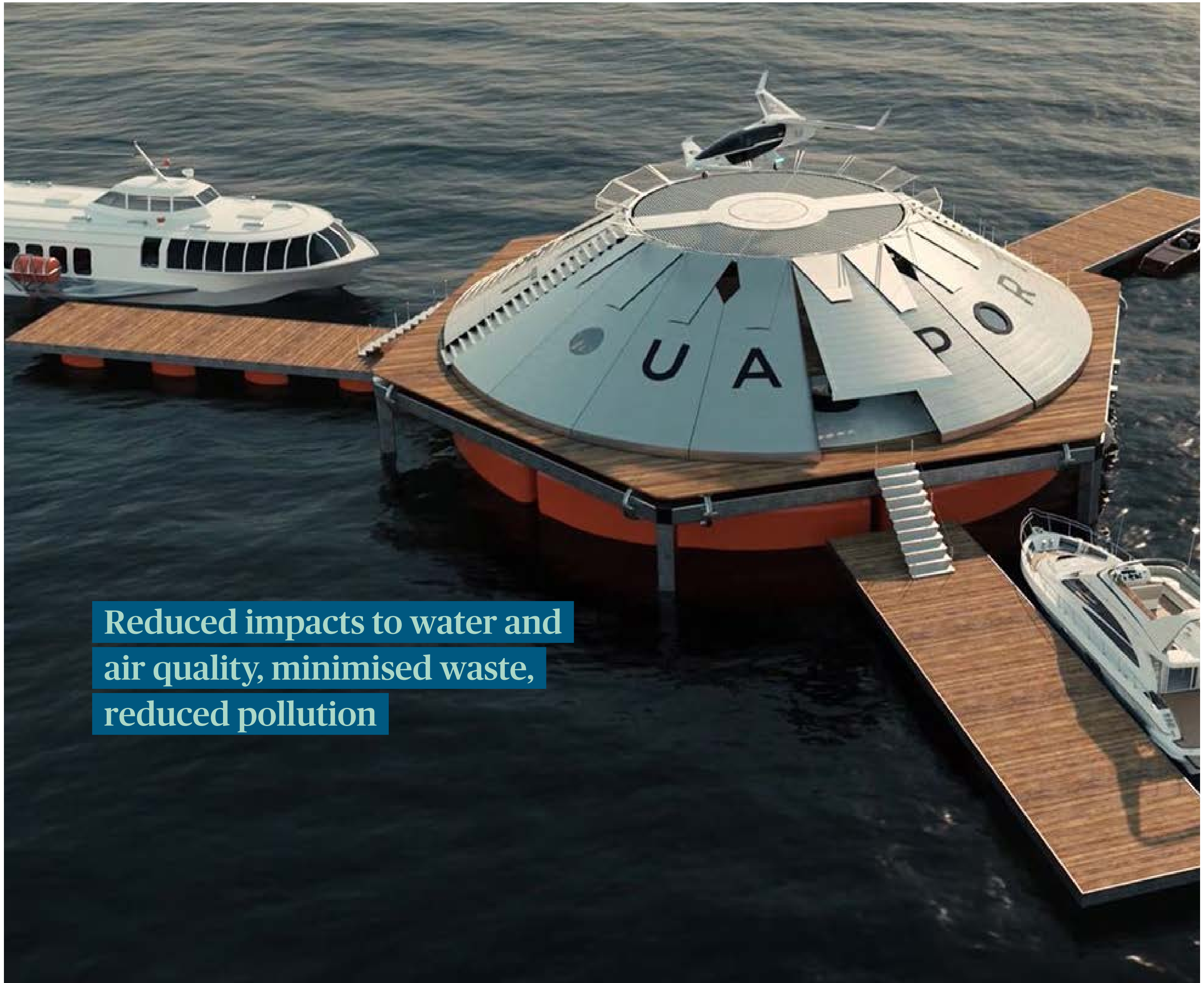
Pre-Construction considerations include but not necessarily limited to:

- **Constructability** – identify how to safely construct within project budget and programme;
- **Phase-ability** – sufficient allowances to cover multi-phase works delivery and temporary relocations, in order to minimise disruption;
- **Identify stakeholders and services affected** – the outcome of this shall inform the risk and operational impact assessments;
- **Health & Safety Risk assessment;** and
- **Operational impact assessment** – identifying mitigation measures and minimise extent of impact on operations: Project Management Plan – defining how a project will be executed, monitored, controlled, and completed.

DESIGN STAGE

It is important to understand the influence that design and material decisions have on construction for a Droneport development. There are potential sustainable construction practices to be considered upfront which may ultimately inform design solutions, also affecting budget and programme:

- Reduced embedded carbon footprint of the development;
- Energy efficiency and renewable energy;
- Reduced impacts to water and air quality, minimised waste, reduced pollution, and/or minimise other environmental impacts;
- Material conservation and resource efficiency;
- Sourcing material, labour/craftmanship locally (local supply chain procurement);
- Improved construction operations;
- Improved construction safety;
- Reduced construction impacts on Droneport operations;
- Benefit to the surrounding communities; and
- Reduced costs associated with construction.



IMPLEMENTATION STAGE – AREAS OF CONSIDERATION

Prior to commencement of construction, contractor(s) should complete all agreed pre-construction activity in keeping with the Project Management Plan to facilitate a smooth start on site. During construction, there needs to be physical control of the construction site to avoid incidents occurring due to compromised site area closure; control of worker, equipment, and vehicle movements – especially where these may interact with existing Droneport operations in the case of expansion or upgrade of existing projects.

DURING CONSTRUCTION

- Security;
- Construction area safety;
- Site access and construction traffic;
- Closure of areas – if an existing operational Droneport;
- Transportation of material, labour, and construction waste;
- FOD (Foreign Object Debris) control – critical if an existing operational Droneport;
- Environmental impact;
- Inspections and supervision – general construction safety audits and inspections in conjunction with Droneport operations safety audit if an existing facility; and
- Continuous improvements and application of the risk register – ongoing development during construction and commissioning phases.

HANDOVER AND COMMISSIONING

- Inspection and approval – confirm all construction deliverables have been met, inspecting the appearance, position, quantity, dimensions, quality, finishes, functionality, etc. – including drawings and documents of record;
- Inspections by CAA or local government/relevant authorities as required;
- Handover – confirm construction deliverables complies with design specifications;
- Dissemination of information - notification of commissioning to set target date for commissioning with relevant authorities/stakeholders such as CAA, NATS, flight and ground operators, etc.;
- Preparations - allowing sufficient time for commission date to be achieved, taking into account preparation works comprising:
  - Operation and maintenance plan – Implementing Standard Operating Procedures for flight and ground operations;
  - Training and staffing plans; and
  - Emergency response and operational contingency plans.
- Commissioning – preparation works as mentioned above to be checked again as a final check to ensure all actions and processes required for operations to commence have been undertaken properly.

SUSTAINABILITY

Sustainable construction practices are those practices that have sustainability embedded during the construction phase of a project, including those benefits that may result from decisions made during the planning or design phases of a project.

Many companies are increasingly committing to sustainable design and construction practices for all projects and along with their users, and will design, build, and deliver new construction and renovation projects in accordance with BREEAM or LEED (Leadership in Energy and Environmental Design) certification.

BREEAM (the Building Research Establishment Environmental Assessment Method), was created in the UK to guide the development of high performance, healthy, durable, affordable, and environmentally sound buildings. Refer BREEAM - Sustainability Assessment Method

RE-CYCLED/RE-PURPOSED BUILDINGS

It is often regarded that the most sustainable way forward is to avoid construction in the first instance, and not to build at all, for example, in the case of old inefficient, end-of-life facilities needing replacement or upgrading to comply with new standards.

The first solution to explore when planning new facilities is to consider existing build assets for opportunity to recycle or re-purpose old buildings as a way of revitalising otherwise under-used or un-used buildings.

DRONEPORT ACCESS

INTRODUCTION

Locations for Droneports will be strategic so that air logistics services can smoothly integrate with the broader local and regional area goods transportation system with ability to potentially reach international markets. They may be aligned to a local authority strategic transportation plan, and building on existing transport connections, Droneport access and movement strategy will be a key feature of its development planning which seeks to develop safer, more reliable, resilient, sustainable and efficient freight/logistics movements to support economic growth and reduce impacts on the community and environment.

A well-considered Droneport location creates potential to integrate Urban Air Mobility (UAM) into other modal systems such as public transportation, ride-sharing economy modes, or private modes; but also enable other infrastructure to provide mutual support for UAM and other transportation options, such as parking garages that can serve both a light rail station and co-located with a UAM Droneport.

A drone's ability for direct flight routes independent of topography and legacy mobility infrastructure means that Droneports may also be located in areas not well served by surface infrastructure. Drones with the capacity for heavier payloads for example, can assist in difficult-to-reach construction projects, or drone use cases beyond the urban setting which may include agriculture, offshore transport, humanitarian, and emergency aid for instance.

NEW OPPORTUNITIES

The advantages of Urban Air Mobility give rise to unique opportunities to place Droneports closer to the public than heliports and airports, for example:

- **Elevated above ground** – for example, on top of buildings when there is no suitable space at ground level;
- **On water** – offering greater diversity for inter-modal connectivity; and
- **Mobile** – innovation around portable infrastructure as a pop-up facility should be anticipated.

Minimising the first and last mile of travel time by optimising the proximity to and from a Droneport might be key to providing genuine time savings to customers, but the need to consult local transport planning authorities will be critical to site selection process. Some considerations which has been covered in the Planning section of this document may include the following amongst others:

Key influences of surface access

- Policy;
- Masterplan strategy;
- Local and regional connectivity; and
- Future growth & expansion.

- Modes of access.

NEW DEVELOPMENT INFLUENCES – SURFACE ACCESS MODES

A range of access modes and mode-sharing for consideration are presented here to encourage a modal shift towards increased walking, cycling, and use of public transport over private car journeys.

PUBLIC TRANSPORTATION

- **Buses** – important local and regional connections for customers and staff. An essential form of sustainable transport to be encouraged through appropriate routes, service frequencies and fare pricing.
- **Rail** – potential to integrate rail services in connection with other modes of transportation. Potential for rail freight integration especially with rail freight terminals but also passenger rail stations potentially in the future.
- **Metro and light rail** (Rapid Transit Systems) – the potential to open up areas currently difficult to reach within larger metropolitan city areas.

ROAD ACCESS

Road connectivity is critical to day-to-day operations of logistics companies, and any incidences, capacity/congestion issues on the major road network causes problems for their businesses.

Droneport developments should seek to improve the local road network within the greater strategic road network/surface access planning policy and support the delivery of proposed road improvement schemes to reduce congestion and minimise journey times.

Roadway elements should consider the coordination of existing conditions, structural foundations, impacts to existing and proposed utilities and potential transit systems, other elements include:

- Roadway and utility routing and phasing;
- On-grade and elevated pavement design;
- Pedestrian crossings;
- Storm water routing;
- Sanitary sewer routing;
- Car parking provision; and
- Signage and lighting.

PRIVATE CARS

Whilst Droneport developments will generally support sustainable transport practices to improve the public transport modal share, it is inevitable that some staff and customers will still need to travel to and from by car. In this instance, car share schemes can be introduced to encourage staff to use in order to reduce the number of car journeys. Refer to the Sustainable Travel section below for other initiatives for consideration.

ACTIVE TRAVEL

Walking – one of the most sustainable modes of travel and should be encouraged as a viable option for customers and staff who live locally. Pedestrian routes should be integrated with existing local routes to provide connectivity to surrounding communities, helping to ensure they mutually benefit with opportunities both economically and socially. Ensure routes are accessible, convenient, safe, and secure, providing effective signage, and appropriate crossing facilities. Also, consider enhancing the quality of road safety and wayfinding in the area in efforts to improve pedestrian routes.

Cycling – similar to walking, and also a viable option for local customers and staff to travel to and from the Droneport. Some considerations to encourage cycling:

- Showering facilities and lockers for staff, and cycle parking facilities for staff and customers;
- ‘Cycle to Work Scheme’;
- Provide pool bikes and electric bikes together with charging facilities; and
- Actively influence the provision of new cycle routes to surrounding areas/to improve connectivity between the Droneport and the surrounding area.

SURFACE ACCESS & ENVIRONMENTAL IMPACT

SUSTAINABLE TRAVEL

In addition to reducing the number of car trips generated to the Droneport, efforts should be made to minimise the carbon footprint of trips made, encouraging greater use of sustainable technologies including electric and low-emission vehicles and alternative fuels. Suitable charging infrastructure will need to be considered to support this.

Efforts should also be made to minimise the number of individual vehicle trips required to accommodate deliveries. Freight/logistics operators can consider new technologies as they become available to minimise vehicle emissions. This includes use of Smart Hybrid technology, zero emission vehicles, and autonomous/semi-autonomous vehicles.

To improve the efficiency of freight movements, operators should consider using more sophisticated distribution systems and fleet management to:

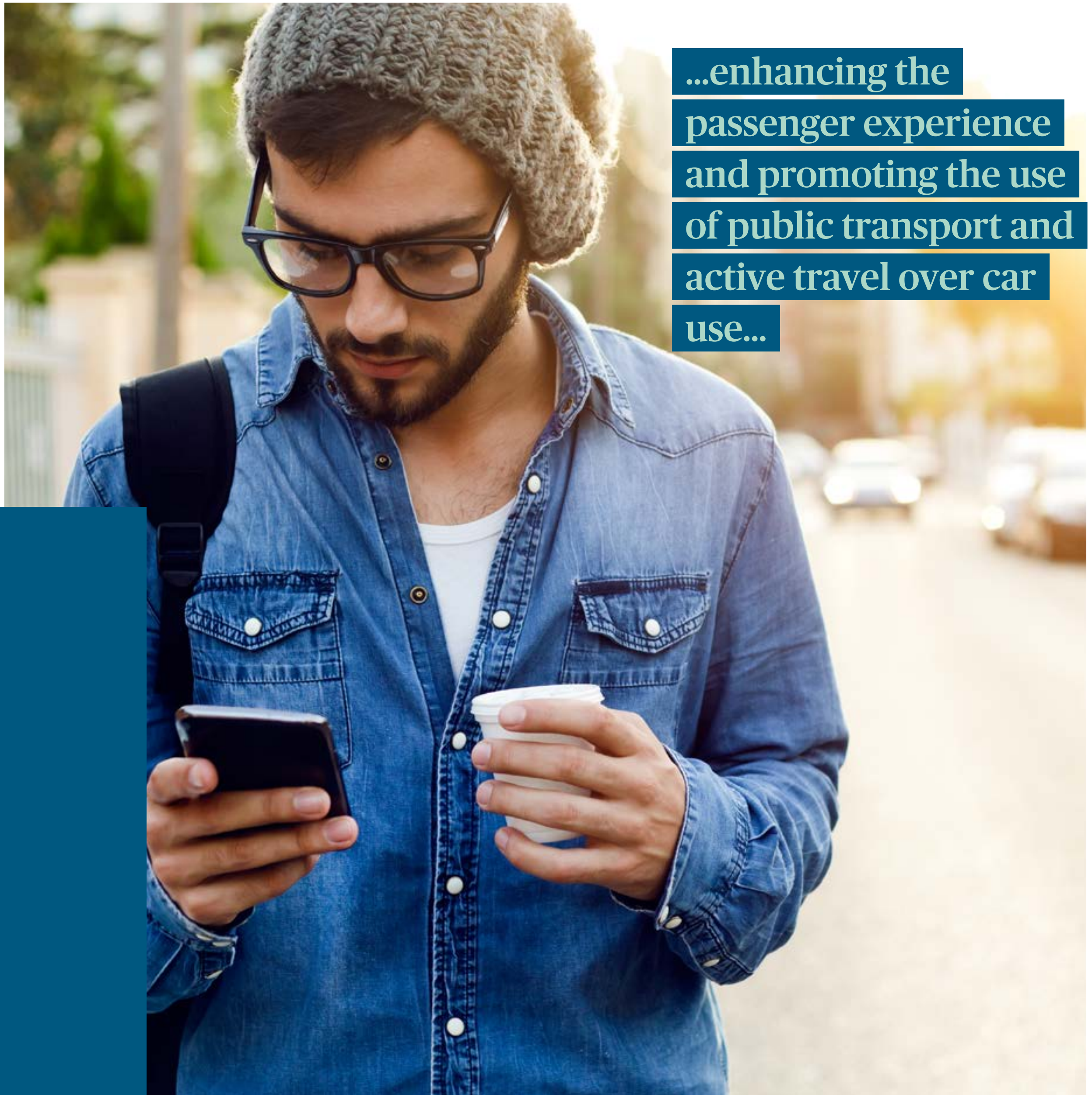
- Consolidate movements where possible – for example, off-site consolidated delivery centre to reduce the number of delivery vehicles accessing a Droneport in densely populated area; and
- Reduce empty space in vehicles – especially return journeys.

SMART TRAVEL

Increasingly, technology is playing a major role driving further improvements in surface access by minimising journey times, enhancing the passenger experience and promoting the use of public transport and active travel over car use (modal shift). Alignment to local/regional authorities and research organisations' initiatives, trials, pilot programmes should be considered.

Mobility-as-a-Service (MaaS) is a mobile platform which will enable users to establish the best option for their journey by considering a range of transport modes, including car, taxi, public transport and hire bicycles.

For journey planning, mobile app technology offers functionality to enable customers, staff, and delivery/freight operators to plan their journeys efficiently. Digital marketing of different public transport options should be utilised to promote customer and staff awareness of all transport modes available to them.



AIR ACCESS

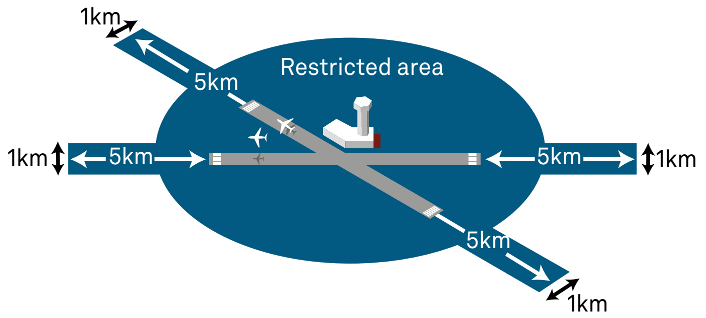
There needs to be consideration of the aviation access requirements as well as access requirements on the ground. Droneport and vertiports are different to normal ground infrastructure in that there is a need to ensure the surrounding airspace environment can safely and effectively accommodate flight operators and their aircraft performance characteristics. Refer to the Operational Concept chapter in this document, sub-sections: Droneport Airspace, Operational Considerations, and Safety Considerations.

SECURITY

PHYSICAL SECURITY

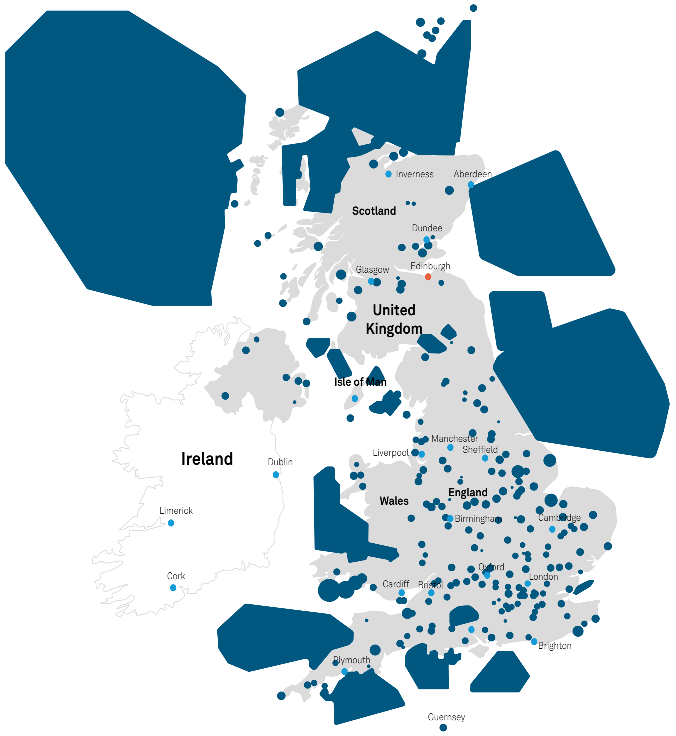
It is important to keep malicious persons and members of the public from intruding on the operating area and/or from tampering with Droneports. This should be applied to all three options for Droneports: either at surface (mounded Droneport specifically landscaped and constructed for the purpose), at elevated (rooftop) level; or a purpose-built raised structure[4]. One of the most important considerations in physical security is the location of the Droneport. It is recommended that drones do not to fly within 150m of residential, recreational, commercial, and industrial areas, in accordance with current regulations. This is the minimum distance therefore Droneports should be built to comply with this requirement. In addition, Droneports should not be built in Flight Restriction Zones (FRZs) near airports as illustrated in the following figure.

Figure 1: Flight restrictions around aerodromes[5]



Droneports are not to be built in permanent airspace restrictions areas. The map below shows all current permanent airspace restrictions that are applicable to drones, including Fly Restricted Zones'. The latest interactive version of this map can be found at[7].

Figure 2: UAS Airspace Restrictions Map in UK[6]



4 Standards for helicopter landing areas at hospitals, available at: http://publicapps.caa.co.uk/docs/33/CAP1264HelicopterlandingathospitalsAugust2019.pdf
5 https://register-drones.caa.co.uk/drone-code/where-you-can-fly
6 https://www.caa.co.uk/Consumers/Unmanned-aircraft/Our-role/Airspace-restrictions-for-unmanned-aircraft-and-drones/

Droneports should be kept secure and free of foreign object damage (FOD). Multiple layers of physical security need to be in place. Physical barriers such as fencing should be considered. A fencing system is a key part of overall physical security of Droneports. It should protect the Droneport from unauthorised access as well as not causing any collisions with the drones. Therefore, special design considerations (i.e., angle, height, etc.) need to be taken into design of the fencing.

Hangars can be used to protect drones from malicious activities. They can also be used as a shelter from environmental conditions (heavy rain, strong wind, very high/low temperature, etc.) Drone-in-a-box systems, as self-contained landing "boxes" have been recently introduced for autonomous drones that also functions as a landing pad and charging base.

The security fences and Droneport need to be regularly inspected for damage or intrusion. To automate this task cameras (or security drones) can be equipped with a machine learning software. The images taken by the camera could be analysed automatically and send alerts to the security centre.

CYBERSECURITY

Cyber security is an extensive technical area, and while this section covers key aspects of cybersecurity related to Droneports at a high level, there are recent reports such as RAND's "How to Analyse the Cyber Threat from Drones"[7] and NCBI's" Security analysis of drones systems: Attacks, limitations, and recommendations"[8] which go into far more detail about the cyber threats related to drones. Here are a few examples of cybersecurity threats that may cause air/ground collisions and should be considered when developing a Droneport:

REMOVING OBSTACLE DETECTION AND COLLISION AVOIDANCE

Some drones have obstacle detection and collision avoidance capabilities. Stereo Vision, Monocular Vision, Ultrasonic, Infrared, Time-of-Flight and Lidar sensors being used to detect and avoid obstacles. People have been able to disable this feature and there are many guides online that show how to do this, making the drone easily flyable into objects at the will of the controller. This feature can be turned off in the settings of the controller and there are some easily available online guides. As a result, the drones will not detect obstacles and may cause air or ground collisions.

CHANGING "RETURN TO HOME" (RTH) MODE

Usually there are three options to in-drone settings in case of RC Signal Loss: Hover, Landing and RTH. Hover can be useful when the drone is in a safe location, and not obstructing other air users. Landing may be the best option when the controller has line of sight to the drone. In other cases (urban area, over sea, etc.) RTH is recommended where possible.

WI-FI SPOOFING

Drone communications using unencrypted or weakly encrypted Wi-Fi (IEEE 802.11 protocol using 2.4 GHz and 5 GHz frequency) can potentially be attacked using spoofing techniques. Attackers can hack Wi-Fi connections using cracking tools, which de-authenticates the drone from the controller network and reconnects the drone to the hacker's Wi-Fi, therefore, giving control of the drone to the attacker.

SPOOFING/JAMMING GNSS DATA

Most drones use GNSS (Global Navigation Satellite System) for navigation and because civilian GNSS signals are not encrypted, they are easy to spoof. Spoofing or jamming GPS signals can be performed easily by low-cost GPS jammer that can be purchased online. As a result, this may cause air or ground collisions.

7 https://www.rand.org/content/dam/rand/pubs/research_reports/RR2900/RR2972/RAND_RR2972.pdf
8 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7206421/

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