Protecting airports against drones

How to protect airports against unauthorized use of drones
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Executive Summary

This white paper describes the issues with drones and airports, explains the impact on flight safety and financial losses and discusses drone detection and mitigation solutions.

The use of drones is rising worldwide. The US Federal Aviation Administration (FAA) predicts more than 2 million drones will be operated in the USA by 2020. Such an increase in usage raises questions about the unintentional risks of drones colliding with aircraft.

FAA concludes that airborne collisions between drones and airplanes could introduce "a significant economic burden" to aircraft operators, due to downtime and repairs - not to mention a potential loss of life, and additional legal liability to airlines and/or airport facilities.

It is recognized that defending airports against unwanted drone activity is a wide and deep problem set. Airports are large infrastructure with a lot of area to protect.

It is, however, possible to detect small drones. Technology exists and combining different sensors in a system is considered the ultimate drone detection solution. Therefore, utilizing a combination of radio frequency (RF) sensors with optical sensors (cameras) and/or radar would provide the most accurate overview, while also being a more expensive solution.

Mitigating the drone threat in an airport environment is a much bigger challenge than drone detection. Because of the large airport area, net capturing a drone is not realistic and jamming is illegal. When it comes to mitigating the threat the only realistic thing at present is to develop a set of procedures that separate departing and landing air traffic from the rouge drones entering the protected area.

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Introduction

The use of drones is rising worldwide. The US Federal Aviation Administration (FAA) predicts that more than 2 million drones will be operated in the USA by 2020\(^3\). With that increase in usage comes questions about the unintentional risks of drones colliding with, or disrupting, manned aircraft.

There have been seven confirmed cases of direct collisions between drones and civil or military manned aircraft worldwide\(^4\) as well as six suspected collision events. However, the number of occasions where pilots have reported suspected drones in proximity to their aircraft is increasing, and in the UK, there were 59 such occasions between April 2016 and March 2017\(^5\). Two of these involved large passenger aircraft near Heathrow airport and in December 2018 an object believed to be a drone was seen near Gatwick. This led to Gatwick airport being closed, flights being diverted and 140,000 passengers stranded.

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\(^3\) FAA Unmanned Aircraft Systems report (2018)
\(^4\) Aviation Safety Network drone database (Dec. 2017)
\(^5\) Drone safety risk – an assessment published by the UK Civilian Aviation Authority (CAA) (2018)
Drones and Airports - what is the problem?

The problem with drones operating near airports is of course the risk of collision between aircraft and drones and thus the fear of human and material losses, but also fear of terror attacks on airport infrastructure as well as financial losses due to periods of airport shutdown.

The Flight Safety Problem – Collision Hazard

In 2015 the United States Federal Aviation Administration (FAA) decided to test the potential damage to manned aircraft due to mid-air collisions with drones and how that compared to the more traditional airborne hazard: bird strikes.

Figure 1: Kinematic Comparison

The report concludes that drones which collide with manned aircraft can cause more structural damage than birds of the same weight for a given impact speed\(^6\). Because drones are constructed of heavy plastic or metal and often contain batteries and cameras, the researchers found that a collision with a drone could cause significantly more damage to the planes than an impact with the soft tissue of a bird.

Comparison of the kinematics of impact between a commercial transport jet vertical stabilizer and a 1.2 kg (2.7 lb.) Drone/Bird at 128.6 m/s (250 knots).

\(^6\) Report by the Alliance for System Safety of UAS through Research (ASSURE) (December 2017)
The Financial Problem – Airport Shutdown and Economic Losses

The FAA states that it receives more than 100 reports of unauthorized drone usage per month and concludes that airborne collisions could introduce “a significant economic burden” to aircraft operators, due to downtime and repairs\textsuperscript{7} - not to mention the potential resulting loss of life, and additional legal liability to airlines and/or airport facilities.

An airport shutdown can be extremely expensive. In 2016 the Dubai International Airport (DXB) was closed three times (an accumulated 115-minute closing) due to illegal drone activities near the airport. Emirates Authority for Standardization and Metrology (ESMA) estimates financial losses to be $95,368 per minute\textsuperscript{8} due to shutdowns caused by drones. The total loss of DXB in 2016 was estimated to be around 11 million US dollars due to drones.

Newark airport in New Jersey, was closed due to a drone spotted in the vicinity in January 2019 for 90 minutes at a price of 1 million US dollars per minute for the airport. Airplanes diverted to other airports therefore using extra fuel consumption and adding to the economic loss for the airlines.

Anti-Drone Solutions for Airports

Unknown\textsuperscript{9} drones do not go well hand in hand with air traffic near airports. Thus, some detection and mitigation system must be established at or near airports to detect and mitigate unwanted drones in order to keep traffic flowing and avoiding collisions between drones and aircraft.

Airport environments present a variety of design features ranging from a single runway layout to large international airports with several runways and terminals, some located in dense urban areas and others in rural desolate areas. Despite the different airport shapes, they have similar security requirements for detecting and countering drones, which can be implemented in different ways - either as a distributed system on the airport perimeter or as a single point detection capability. Early warning and breach of the perimeter are the two key elements in providing airport security authorities with drone detection and mitigation.

Detection Solutions

It is the combination of the small size drone and the very large search area that poses a challenge when it comes to detection. Airport areas are often very large, and the small drones are hard to detect, although some detection methods do exist.

\textsuperscript{7} Safetyandhealthmagazine.com (22. Dec. 2017)
\textsuperscript{8} Arabian Business.com, Sun 09. Jul 2017
\textsuperscript{9} Unknown is here defined as any drone that is not known and controlled by Air Traffic Control (ATC)
A comparison overview of the different sensor technologies are presented below.

**RF detection**
The drone and controller are connected by a radio link, which has a distinct signature that can be detected. RF detection provides early-warning through the fact that drone and controller transmit radio signals when turned on, allowing adequate detection time even before the drone takes off. This signal can also be corrupted by emitting a radio signal designed to prevent the drone and controller to link up and prepare for flight. This is referred to as jamming.

**Radar detection**
An exact position of the Drone can only be provided by radar capable of detecting drones from other moving (flying) objects e.g. birds or airplanes. The shape of a drone provides for a good detection element that can be recognized on radar and the rotating propellers provide a tool for classification. A radar system provides a detection solution that is independent and that cannot be tricked as easily by the drone and thus provides an excellent virtual perimeter for any application. The radar is also the most expensive sensor of all the available drone detection sensors.

**Acoustic detection**
The sound generated by the drone propellers or engines make it possible to detect a drone acoustically. Drone propellers transmit an audio pattern that can be detected and used for positioning and classifying the type of drone detected. Acoustic systems however, have limited range (in most cases less than 100 meters) and are subject to further range limitation with other audible noise, which is quite significant at an airport.

**Visual detection**
Imaging systems can be used both in the visual- and infra-red spectrum to detect and classify drones. A Pan-Tilt-Zoom (PTZ) camera can be used for daylight images. A thermal camera can be used to detect drones based on the heat signature originating from the drone batteries during limited visibility during the day, or at night. High performance camera systems are often equipped with a high zoom capability that is capable of showing small objects at a distance.
With regard to radar detection it can be added that depending on the airport size there can be several radars at the airport serving different purposes.

Some radars are surveillance radars, other radars are precision approach radars or bird detection radars. All radars are designed for a specific purpose and as such normal aircraft surveillance radar is unable to detect small drones. Some radar types, bird detection radar for instance, might be able to detect drones if new or extra detection software is added.

However, at present time an airport will typically have to install a suitable type of radar to locate and track drones. Radars are wildly different in design and price. Some radars will be able to detect a small drone out to a distance of perhaps 5 km, but such kind of radar is also very expensive. Other radar, which are designed to look for drones, might have a shorter detection range but are also less expensive.

Utilizing different sensors in a system is considered the ultimate drone detection solution. Therefore, utilizing a combination of radio frequency (RF) sensors with optical sensors (cameras) and/or radar would provide the most accurate solution, while also being more expensive.

<table>
<thead>
<tr>
<th>Method</th>
<th>Benefits</th>
<th>Limitations</th>
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<tbody>
<tr>
<td>RF detection</td>
<td>• Long range</td>
<td>• Requires RF signal</td>
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<tr>
<td></td>
<td>• Can locate controller and drone</td>
<td></td>
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<tr>
<td></td>
<td>• Lends itself to signal jamming and intercept</td>
<td></td>
</tr>
<tr>
<td>Radar</td>
<td>• Can detect drones without RF control signal</td>
<td>• Difficult to detect low flying drones</td>
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<tr>
<td></td>
<td>• Long range</td>
<td>• Problems distinguishing from other small objects</td>
</tr>
<tr>
<td>Acoustic</td>
<td>• Can detect drones without RF control signal</td>
<td>• Very limited range</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Interference-prone in noisy environments</td>
</tr>
<tr>
<td>Infra-red</td>
<td>• Can detect drones without RF control signal</td>
<td>• Most small drones produce very little heat</td>
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<tr>
<td></td>
<td></td>
<td>• Limited range</td>
</tr>
<tr>
<td>Visual - human</td>
<td>• Can detect drones without RF control signal</td>
<td>• Human(s) needed to observe skies</td>
</tr>
<tr>
<td></td>
<td>• Can easily tell whether it’s a drone or a bird at reasonable distance</td>
<td>• Limited visual range of humans</td>
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<td></td>
<td></td>
<td>• Not effective at night and in poor visibility conditions</td>
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<tr>
<td>Visual - automated</td>
<td>• Can detect drones without RF control signal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Limited range</td>
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Mitigation of Drone Threats

Signal Jamming
Jamming is a general term that relates to manipulation of radio or radar signals. There are many different forms of jamming. In an airport context, however, it is very important that the jamming does not interfere with other important radio signals at the airport (this can be Instrument Landing Systems, surveillance or precision approach radars, Wi-Fi, radio communications etc.). Jammers that transmit low power and are programmable will, despite the signal rich environment, be able to work in and near an airport without presenting a hazard to flight operations.

In the case where the drone is preprogrammed to fly via waypoints navigating on its build in satellite navigation, and thus not emitting any RF signature, the only robust detection method is radar. Mitigating a satellite navigated drone is a much larger challenge than jamming the RF controlled drone. It is possible to effectively jam a satellite navigation signal, but jamming GPS/GLONASS signals near an airport is considered dangerous because most airplanes rely heavily on satellite navigation.

In any case jamming is illegal in the Western World (EU, Canada, USA and Australia) and as such jamming is not a mitigation option at present time. It is believed, however, that authorities over time will be forced to change legislation because jamming in many cases is the most effective mitigation method.

With a detection and jamming system in place however, a drone can be denied entry to the airport maneuver area when it crosses a defined boundary.

Net Capturing
It is possible to physically capture a drone with a drone entangling net. Such system work on relatively short distances and is effective when the drone does not maneuver. The drone has to be visually detected and within a range of 100 meters to be effective.
Locating the Drone Operator
A key part of mitigating drone attacks is not only to remove the flying element, but also to locate and apprehend the drone operator because it is important to capture evidence for legal prosecution. Triangulation with RF sensors can provide the necessary capability to estimate the position of the drone pilot.

A rapid response drone equipped with both cameras and radiofinding payloads can be launched to search for the drone pilot, in an effort to obtain photographic evidence of the perpetrator, such as cars with license plates or other key elements pertaining to legal prosecution for unauthorized use of drone. The position of the rapid response drone can be integrated in the Air Traffic Management software, so the position of the rapid response drone is available to the Air Traffic Controller.

As presented above, the orange cones illustrate the triangulation of RF sensors, with the drone pilot being located at the intersection of the cones.
Detection Area of Interest

No matter what sensor or combination of sensors chosen, it is apparent that a significant number of sensors would be needed to create a protective bubble around an airport. But a protective bubble around an airport does not protect the aircraft from collision with drones when the aircraft are airborne. Inside the airport perimeter only a limited portion of the airport is used for flying aircraft. Why is that? That is because the aircraft touchdown approximately 1,000 feet down the landing runway during landing and leaves the runway approximately 5,000 feet down the runway during take off. In other words the most vulnerable part of the aircraft operation is not covered if only the airport perimeter is protected against drones.

But if the protective bubble around the airport perimeter is not sufficient when it comes to protecting approaching- and departing aircraft what shall the protective area look like and how far out shall the sensors reach? A small radio-controlled drone typically has a control radius of approximately 1,000 meters (equal to 3,000 feet) both horizontal and vertical distance. 3,000 feet also happen to be the typical final approach height. This means that the area of protection at an airport should include the movement area as well as the approach corridor extending on a standard 3-degree glide path from final descent to touchdown on the landing runway including a missed approach corridor up to 3,000 feet.

\[ \alpha = 3^\circ \]

\[ \text{Height 3000'} \]

\[ \text{Distance 9 Nautical Miles} \]

\[ \text{Runway} \]

\[ \text{Approach geometry} \]

\[ \text{Figure 2: Risk area} \]

10 A movement area, as defined by the International Civil Aviation Organization (ICAO) is "That part of an aerodrome to be used for the takeoff, landing and taxiing of aircraft, consisting of the maneuvering area and the apron(s)"

Source: ICAO Aerodrome standards, December 2016
An example could be a large international airport i.e. in the Middle East.

*Figure 3: The area of concern - an airport approach corridor*

In this scenario, the critical area is along the Runway centerline of Runway 31R. The assumption is that the aircraft will be protected at a height from touchdown up to 3,000 feet. The area of protection in this example is then defined as a corridor extending from the runway end and 9 nautical miles out. This will cover a sector up to 3,000 feet for airplanes approaching on a three-degree glide path to Runway 31R. The expected detection range for a small commercial drone is typically 1,000 meters. Thus, a number of sensors must be deployed with correct spacing ensuring correct detection.
Conclusion
In conclusion it is possible to detect and mitigate small drones. Technology exist and combining different sensors in a system is considered the ultimate drone detection solution. Therefore, utilizing a combination of radio frequency (RF) sensors with optical sensors (cameras) and/or radar would provide the most accurate overview, while also being a more expensive solution.

Mitigating the drone threat in an airport environment is a bigger challenge than drone detection. Because of the large airport area, net capturing a drone is not realistic and jamming is illegal. When it comes to mitigating the threat the only realistic thing at present is to develop a set of procedures that separate departing and landing air traffic from the rouge drones approaching or entering the protected area. But some kind of drone detection is imperative because without awareness of the drone no action can be taken.