UAS RISK ASSESMENT

Airport X

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY – RISK ASSESMENT

Drone activity in airport surroundings have been of growing concern over the last decade. Regulations are being put in place both for operators of drones and for the aviation industry. This document contains a risk assessment of the drone activity in the surroundings of Airport X.

1.1. RISK ASSESSMENT PROCESS

The drone hazard is continuously monitored, and the risk is reassessed. For the purpose of the risk assessment a drone detection sensor has been installed at the Airport X in January 2020. The sensor is providing an initial overview of the potential threat. Risk is assessed based on a combination of objective factors and a subsequent subjective analysis of the risk elements – time, cost, and life (see Figure 1).

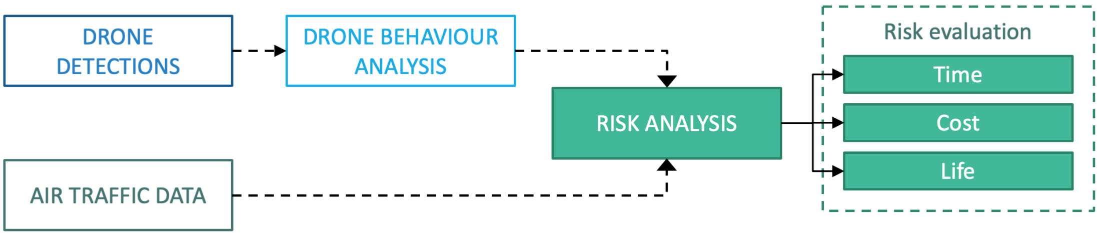

Figure 1 Risk assessment process

This Risk Assessment will support the airport management prior to selection of specific counter unmanned aerial system (C-UAS) technology (see Figure 2). Operational requirements (OR) are derived from this risk assessment and are presented in the Operational Requirement document. It is essential to monitor the risk over time, since the risk can change leading to new operational requirements in order to enable an appropriate level of protective safety measures. Additionally, a site-specific C-UAS strategy has been developed based on the findings in this risk assessment. This risk assessment outlines the UAS threats faced by the airport. A description of principles for mitigating these threats is presented in the Protective Safety Measures document.

Figure 2 Assurance of safe uninterupted aircraft operations in regards to drone operations

Please note, that this risk assessment analyzes the risk based on normal non-hostile use of drones in the airport surroundings. The risk of terrorism and/or eco-terrorism will be based on a day-to-day assessment in collaboration with appropriate authorities.

The use of drones for both commercial and recreational activities is becoming increasingly frequent. Expectations to the future use of drones are tremendous, therefore it is essential for the airport to have a well-defined and continuously updated mitigation plan in place.

1.2. CONCLUSION

Following elements have been risk assessed: time, cost, and life. The risk in Airport X ranges from medium to high (see Figure 3). Based on these findings, operational requirements and protective safety measures will be revisited. Additionally, the risk will be continuously monitored and adjusted accordingly.

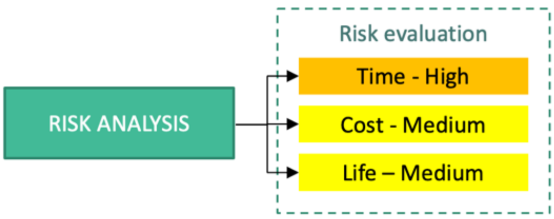

Figure 3 Risk levels for the three elements

2. LEGAL REFERENCES

Will be adapted to local regulations.

3. DESCRIPTION OF THE TECHNICAL SYSTEM(S)

INTENTIONALLY LEFT OUT.

4. AIR TRAFFIC INFORMATION

Air traffic information included in the risk analysis consists of number of movements and traffic patterns (see Figure 5). Based on the current traffic flow at Airport X the total number of aircraft operations in February 2020 was 10000. An analysis based on historical data has been performed in order to identify the hourly distribution of aircraft movements. The data used for the analysis is based on the actual aircraft movements including both arrivals and departures in August 2019. The numbers of movements for each hour of the day in August are presented in Figure 6, and the average movements for each hour of the day are presented in percentage in Table 1. The monthly aircraft movements during specific hour of the day in February are calculated from the total number of movements for February (10000) using the distribution calculated from the movements in August (see Table 2). For the purpose of the risk assessment this information is compared to the hour by hour drone operations in airport surroundings in order to identify peak risk periods. Runways in use in the same period has been 70% RWY 26 and 30% RWY 08.

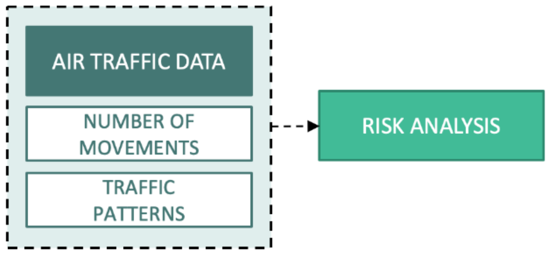

Figure 4 Air traffic data included in the risk analysis

Time of day	Movement percentage
00-01	1.9%
01-02	1.0%
02-03	0.4%
03-04	0.4%
04-05	0.2%
05-06	4.4%
06-07	8.0%
07-08	6.1%
08-09	4.6%
09-10	3.7%
10-11	4.5%
11-12	5.4%
12-13	6.4%
13-14	5.9%
14-15	4.7%
15-16	5.4%
16-17	5.6%
17-18	6.5%
18-19	6.3%
19-20	4.6%
20-21	4.4%
21-22	4.1%
22-23	3.5%
23-24	2.2%

Table 1 Movements for each hour of the day as percentage of the total for August

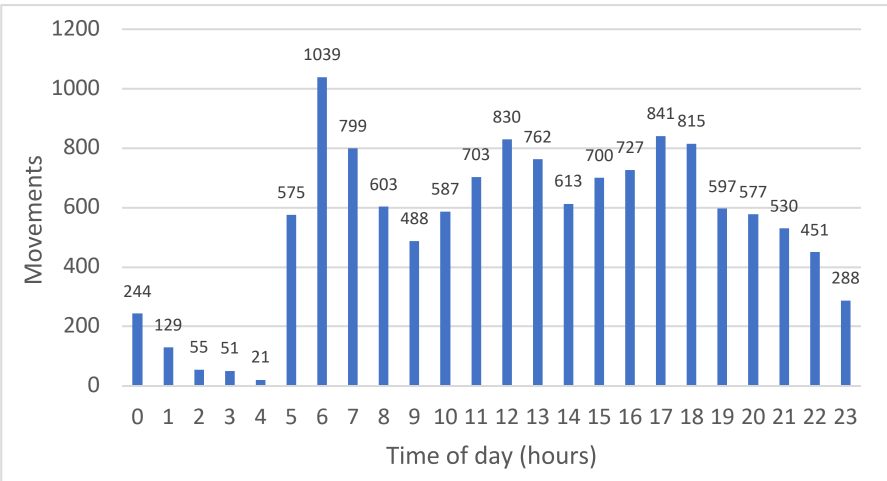

Figure 5 The movements over the time of day for August

Time of day	Monthly movements	Hourly movements per day
00-01	177	6.1
01-02	94	3.2
02-03	40	1.4
03-04	37	1.3
04-05	15	0.5
05-06	418	14.4
06-07	755	26.0
07-08	580	20.0
08-09	438	15.1
09-10	355	12.2
10-11	426	14.7
11-12	511	17.6
12-13	603	20.8
13-14	554	19.1
14-15	445	15.4
15-16	509	17.5
16-17	528	18.2
17-18	611	21.1
18-19	592	20.4
19-20	434	15.0
20-21	419	14.5
21-22	385	13.3
22-23	328	11.3
23-24	209	7.2

Table 2 The movements each hour of the day. The movement values are calculated from the total number of movements for February (10000) using the distribution calculated from the movements in August. The last column represents the number of movements per day in February.

5. DRONE DETECTION

5.1. DRONE OPERATIONS DATA SOURCES

Data about drones detected by sensors is used in this risk assessment in combination with pilot reports, ATC observations, and records about approved drone operations (see Figure 7). Approved drone operations are risk assessed separately and therefore subtracted from the total number of drone operations in this risk assessment. Once the information about approved drone operations is provided, it will be included in this risk assessment. In Figure 8 you can see all drones detected in February 2020.

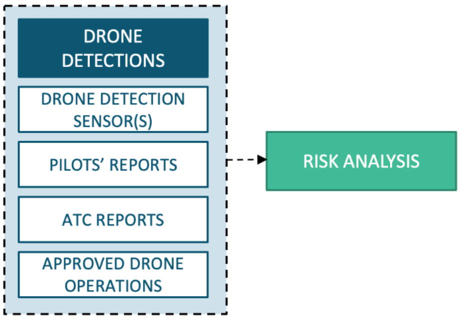

Figure 6 Drone detection data in the risk analysis

5.2. ALL DETECTED DRONES

This report is based on the data from **February 2020** from a single drone sensor at Airport X and includes data recorded within a 20 km radius from the Airport Reference Point (ARP). Drone tracks that have at least one detected position within the 20 km radius are included in this report.
During the month of February **149** drone flights have been detected by the sensor with **55** unique drone IDs. The detected drone tracks are shown in Figure 8. Each detected drone track is marked with a line

and the starting point is indicated by a dot. This is done to make the short tracks visible. In order to assure anonymity of the original airport, drone detection data has been transferred onto a map of a random area in Spain with a road chosen to be perceived as a runway for this particular analysis. The map under the drone detection data from Airport X is for illustration purposes. Airport X sees the actual map of the airport in their report.

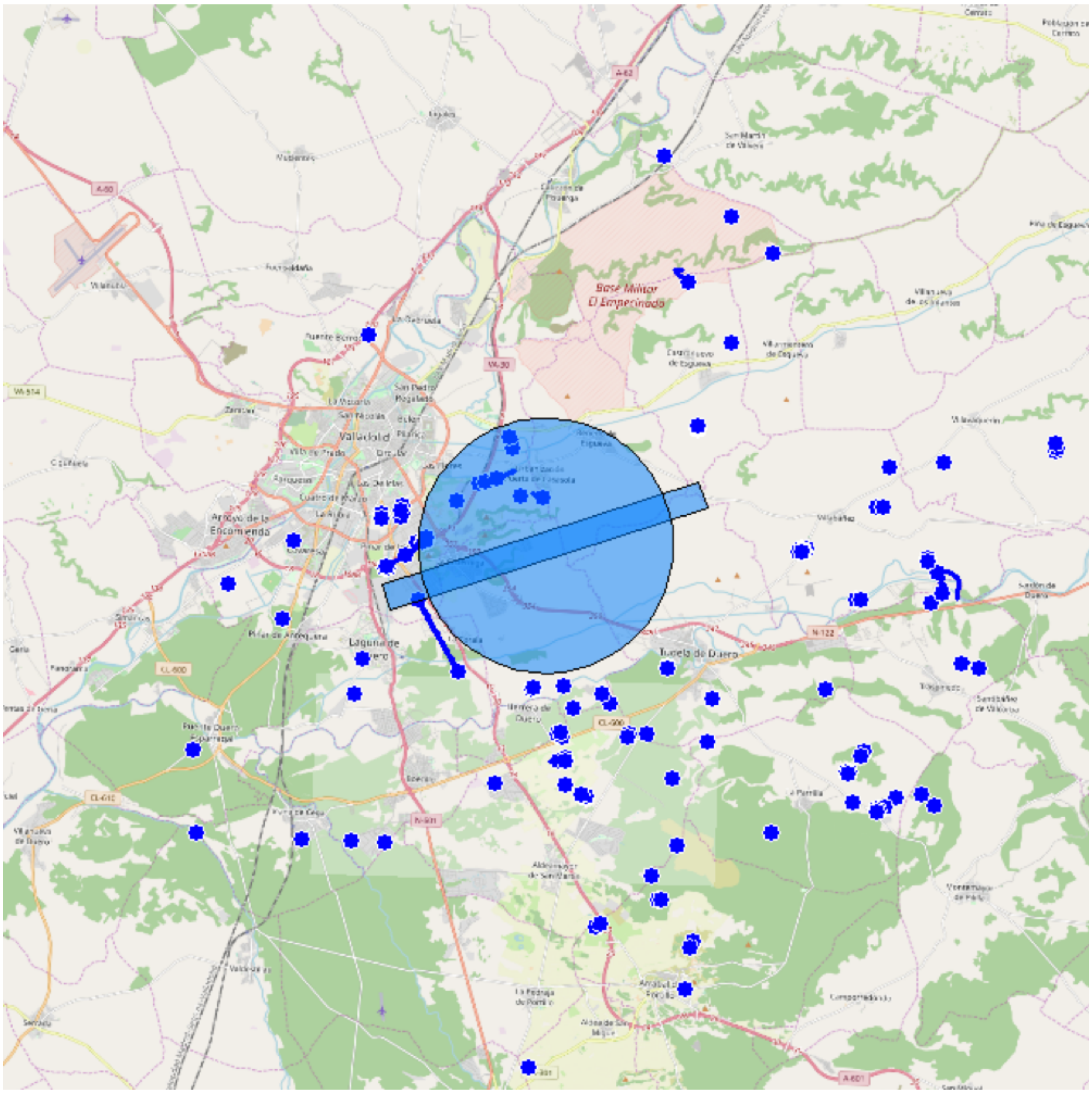

Figure 7 All detected drones in February 2020. The tracks are shown as blue lines, and the starting point of each track is marked with a blue dot.

6. DRONE BEHAVIOUR ANALYSIS

Drone behavior analysis includes information about illegal and daily drone operations, drone flight time, duration and distance, as well as zone and surface penetrations (see Figure 9).

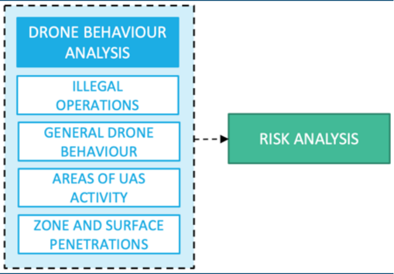

Figure 8 Drone behavior analysis data included in the risk analysis

6.1. ILLEGAL OPERATIONS

Detected drone flights with a maximum altitude above 400 ft AGL and above 500 m AGL, and flights within the FRZ are shown in Figure 10. The two maximum altitude limits are marked with different colors and the flight restriction zones are shown for the reference.

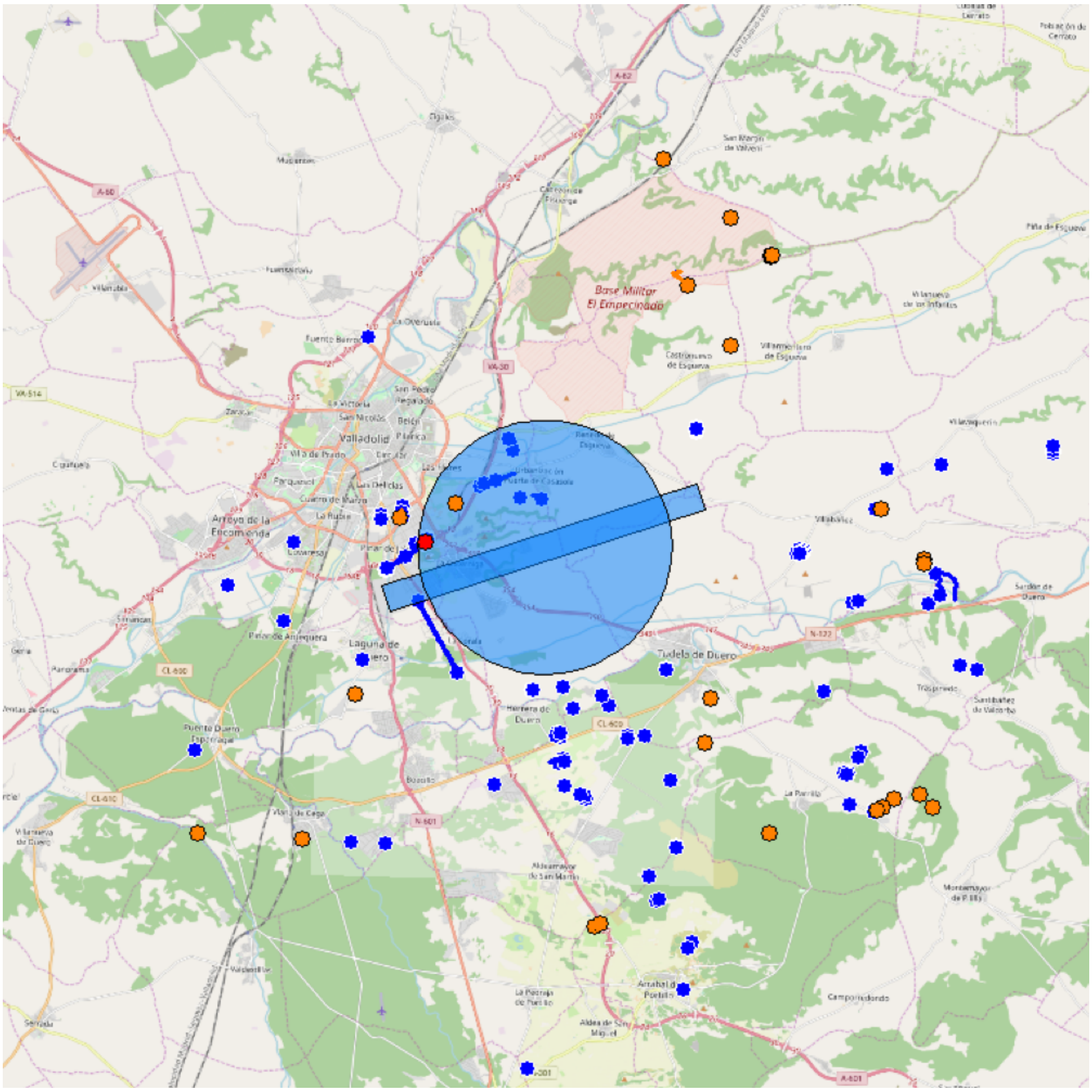

Figure 9 Drones detected with a high altitude. The detected drone flights with an altitude above 400 feet are marked with orange tracks and orange starting points. The detected drone flights with an altitude above 500 m are marked with red tracks and red starting points. The remaining detected drones are marked in blue. The flight restriction zones are shown for reference.

6.1.1. Drone flights within the FRZ

Number of detected drone flights within the FRZ:	27
Number of unique drone IDs	7

Drone flights within the FRZ are described in more detail in section 6.4.1.

6.1.2. Drone operations above 400 ft

400 ft AGL is the maximum legal flight height outside restriction areas.

Number of detected drone flights above 400ft:	27
Number of unique drone IDs	18
Total time of drone operations above 400 ft	30 min.

Unique drone IDs are listed in section 9.4.

Drones are classified by weight according to the classes defined in the EU regulations[1].The duration of the detected drone flights above 400 ft divided into drone classes:

CLASS	0	1	2	3
DURATION	5	10	15	0

6.1.3. Drone operations above 500 meters

500 meters is the maximum altitude setting on the DJI drones. If a drone user wishes to fly higher it requires to change the configuration of the software. Drone pilots operating drones above 400ft have intentionally changed the settings for maximum flight altitude of their drone. To conclude, drone flights above 500 meters are performed by drone pilots that are making an effort to reconfigure their drone to fly at high and illegal altitudes. Therefore, the risk is also higher when the drone ID's presented below are operating, since they have both the intention and ability to fly drones in altitudes where aircraft operations take place.

Number of detected drone flights above 500 m:	1
Number of unique drone IDs	1
Total time of drone operations above 500 m	0.4 min.

Unique drone IDs are listed in section 9.5.

The duration of the detected drone flights above 500 m divided into drone classes:

CLASS	0	1	2	3
DURATION (min.)	0	0	0.4	0

6.2. LEGAL DRONE FLIGHTS THAT COULD POSE A RISK TO AIRCRAFTS

6.2.1. Penetrations of ICAO annex 14 and AOC surfaces

Understanding both the position of the drone and the drone's altitude (in regard to the airport elevation as opposed to terrain elevation) at the position where the drone is operating is essential in order to asses if the drone is operating in the same airspace as the air traffic. Therefore, all data from drones that includes an AGL elevation is corrected by the terrain elevation at the drone location (see Figure 10). The Flight Restriction Zones are defined from AGL and up. However, we have chosen to include an analysis of the drones' elevation compared to both the ICAO Annex 14 surfaces and the AOC surfaces since penetration of these may also be a risk indicator. The surfaces are extending beyond the FRZ but in comparison to the FRZ they have an upward incline (except for the inner horizontal surface that is located 45 meters above airport reference point (ARP)).

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R0945 In annex part 1 to 4.

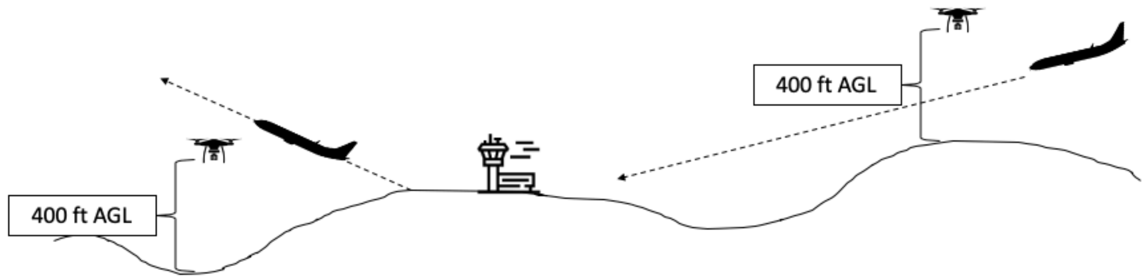

Figure 10 Terrain impact on drone operations related to aircraft operations

Below is an analysis of terrain elevation in Airport X surroundings to identify the areas where drones could be operated legally below 400 ft AGL but due to terrain elevation still could penetrate the Annex 14 and AOC surfaces.

6.2.2. ICAO annex 14 surfaces potential legal penetration areas

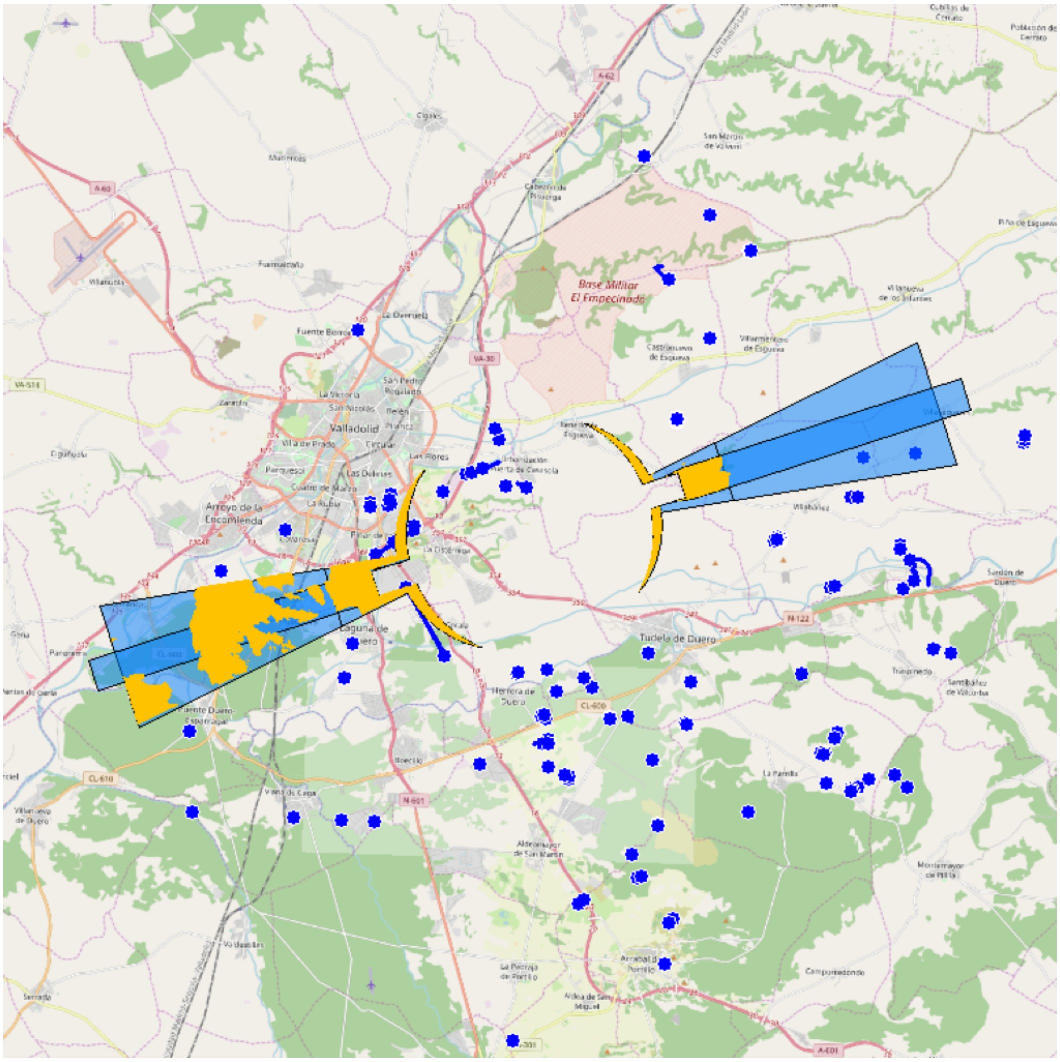

Figure 11 Legal height penetration for the Annex 14 surfaces. The Annex 14 surfaces that are outside the flight restriction zones are marked in blue. The orange areas outside the flight restriction zones mark where the distance between the terrain and the most limiting surface is less than 400 ft.

6.2.3. Legal drone flights penetrating the annex 14 surfaces

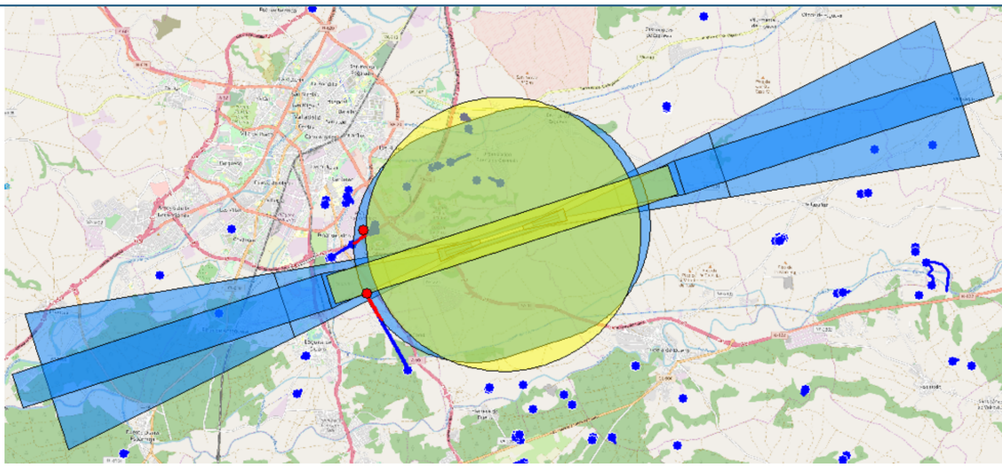

Figure 12 Drones detected above the Annex 14 surface, outside the Flight Restriction Zones and below 400 feet. The Annex 14 surfaces are marked in blue, and the Flight restriction zones are marked with yellow. The detected drones that are above the Annex 14 surfaces, outside the Flight Restriction zones, and have a maximum altitude below 400 feet are marked as red tracks and red starting points. The remaining detected drones are marked in blue.

Considering that the ILS approaches in Airport X are based on a 3-degree (5.24%) glide slope this should be investigated further. The recommendation is an analysis of potential penetrations of PANS-OPS surfaces connected to the approached at Airport X.

6.2.4. AOC surfaces potential legal penetration areas

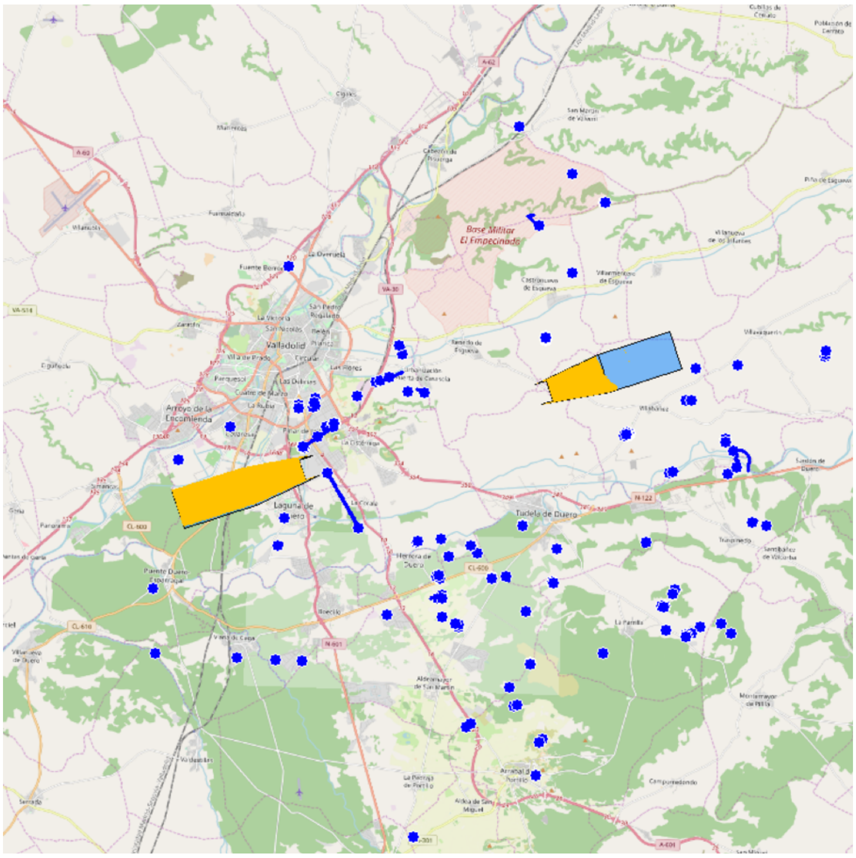

Figure 13 Legal height penetration for the AOC surfaces. The AOC surfaces that are outside the flight restriction zones are marked in blue. The orange areas outside the flight restriction zones mark where the distance between the terrain and the surface

6.3. GENERAL DRONE BEHAVIOUR

6.3.1. Daily drone operations

The drone activity distribution over the time of day is shown in Figure 14. The bar chart depicts the number of flights during each hour of the day for this month. For the purpose of the risk assessment this information is compared to the hour by hour aircraft operations (see section 4.) in order to identify peak risk periods.

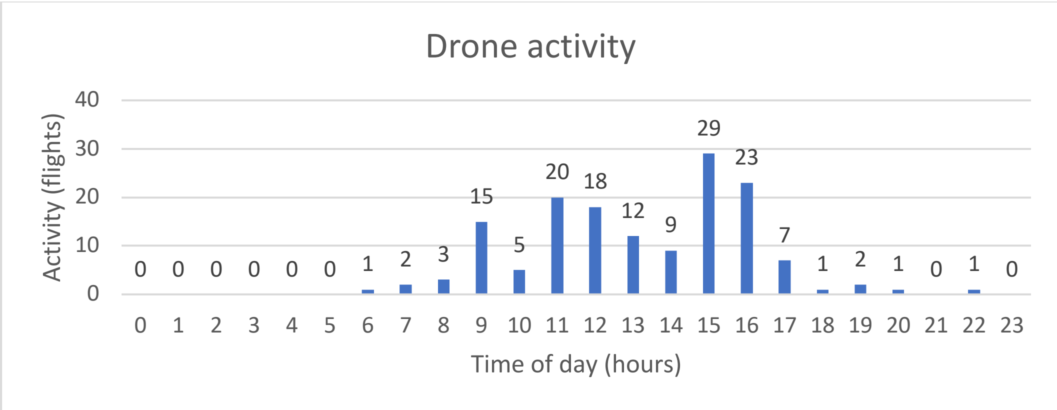

Figure 14 Detected drone activity over the time of day. Each column depicts the number of detected drone flights starting in the given hour.

6.3.2. Drone flight time compared to drone class

Total combined duration of drone operations in February	212 min.

Based on 149 drone flights in February 2020, the average flight time was 1 minute and 25 seconds. The flight duration over the time of day is shown in Figure 15.

The drone flight duration for each drone class:

CLASS	0	1	2	3
DURATION (min.)	24	44	142	1

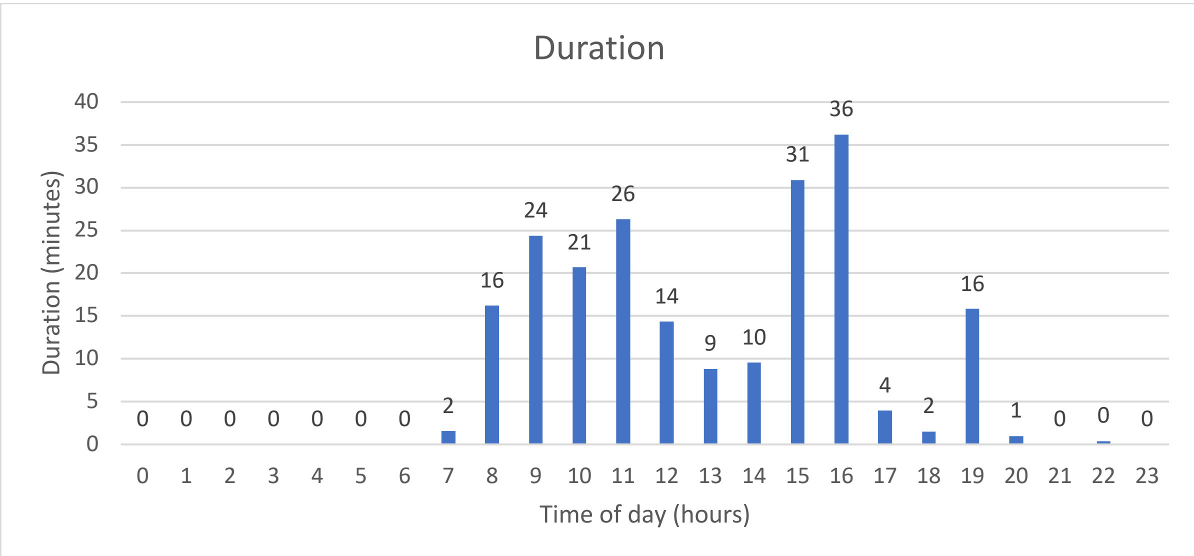

Figure 15 Duration of detected drones over the time of day. Each column illustrates the duration of the detected drone flights within the given hour. Note: The durations are added for all the individual drone flights operating during a specific hour, so the total duration in some cases can be more than 60 minutes.

6.3.3. Airport distance

In Figure 16 the detected drone data is presented based on distances to the Airport Reference Point (ARP). The bar chart represents the total drone flight duration for each distance. The distances are divided into 20 groups of 1 km each.

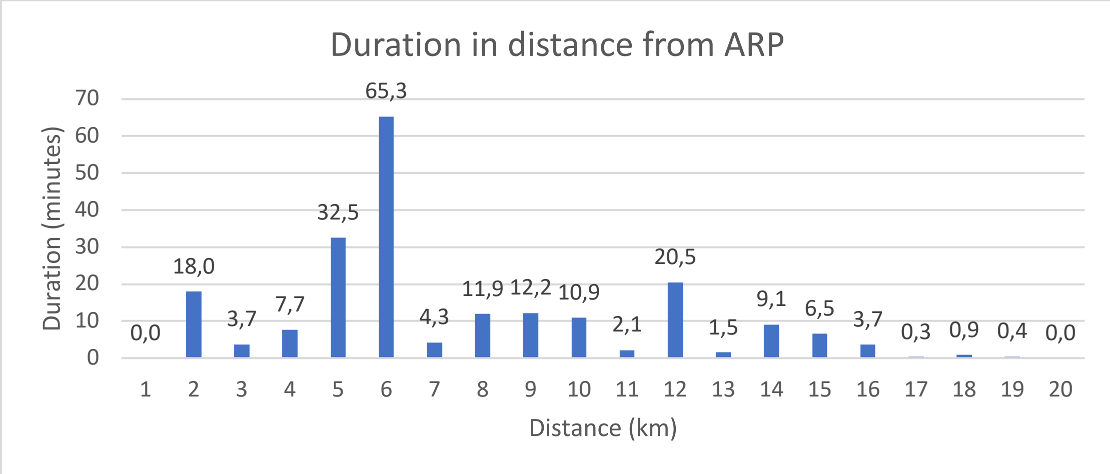

Figure 16 Duration of detected drones over distance to the Airport Reference Point (ARP). Each column shows the duration of drone flights within the given distance to the ARP, e.g. the column marked 5 contains the duration of drone flights with a distance between 4 and 5 km of the ARP.

6.3.4. Drone flight distance analysis

The drone flight distance is defined as the maximum distance between the points on the drone track and the home position of the drone. The home position is the position the drone had at takeoff, which the sensor reads from the drone's memory. The drone flight distances have been divided into intervals shown in Figure 18, and the percentage of the total number of drones is presented in Table 3. This information is applied to assess the statistical probability for a track to move into an area where a new operational category applies.

Flight distance (m)	Drone percentage
0-100	56.4%
100-200	18.8%
200-300	6.0%
300-400	4.7%
400-500	4.0%
500-600	1.3%
600-700	1.3%
700-800	2.0%
800-900	0.7%
900-1000	0.0%
1000-1100	0.0%
1100-1200	1.3%
1200-1300	1.3%
1300-1400	0.0%
1400-1500	1.3%
1500-1600	0.7%
1600-1700	0.0%
1700-1800	0.0%
1800-1900	0.0%
1900-2000	0.0%
>2000	0.0%

Table 3 The drone flight distances distributed over 100 m intervals as a percentage of the total number of drones.

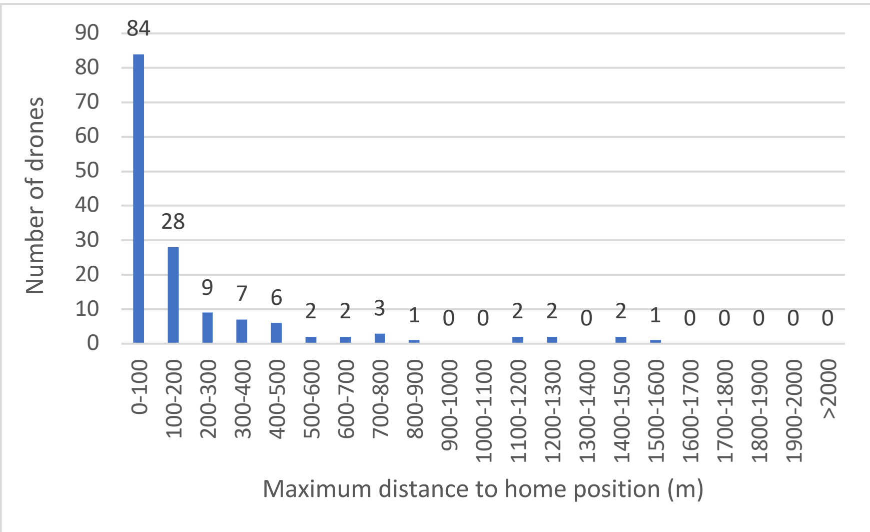

Figure 17 The drone flight distances. Each column represents the number of drones that have a drone flight distance in the given interval. The drone flight distance is defined as the maximum distance of any point on the drone track to the home position of the drone.

6.4. AREAS OF UAS ACTIVITY

6.4.1. UAS ACTIVITY in the Flight Restriction zone (FRZ)

With a reference to the CAA CAP722 regulation and the definitions of *Flight Restriction Zone* (FRZ) and *Runway Protection Zone* (RPZ), the initial collected UAS historical data is focused with these boundaries.

Based on historical data over a period of one month the UAS activity within the FRZ and RPZ was 27 flights (see Figure 18).

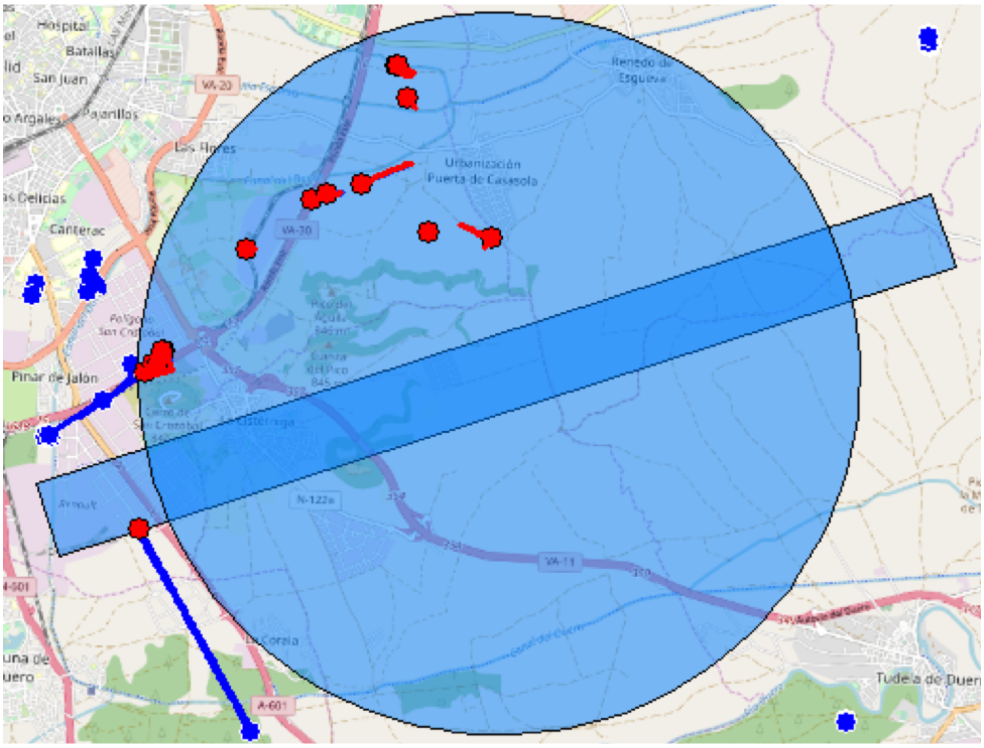

Figure 18 Drones detected in the drone flight restriction zones. The Aerodrome Traffic Zone (circle) and the Runway Protection Zone (above runway) are marked in blue. The detected drones within the zones are marked as red tracks with red starting points. The remaining detected drones are marked in blue.

UAS activity within the FRZ and RPZ based on data sources (section 9.1) the flights where registered from ground to 1650ft AGL:

Total UAS activity within the FRZ and RPZ	27 flights	7 drone IDs
Sensor	27 flights	7 drone IDs
Pilot and airport reports	0	0
Approved operations	0	0

Furthermore, historical data over a period of one month of the UAS activity outside the FRZ and RPZ but above 400 feet was 27 flights.

UAS activity outside the FRZ and RPZ above 400 feet based on data sources (sections 9.4 and 9.5) the flights where registered from ground to 1525ft AGL:

Total UAS activity outside the FRZ and RPZ	26 flights	18 IDs
Sensor	26 flights	18 IDs
Pilot and airport reports	0	0
Approved operations	0	0

6.4.2. Annex 14 limitation surfaces

The Annex 14 limitation surfaces used in this risk assessment: approach, balked landing, inner approach, inner horizontal, inner transitional, takeoff, and transitional. These surfaces are shown in Figure 19 with the detected drones above the surfaces marked in red. These surfaces have height restrictions, so the drones above the most limiting surfaces according to the Annex 14 are included. The elevation of the drones has been calculated using the SRTM GL1 global elevation dataset.

Number of detected drone flights above the Annex 14 limitation surfaces:	16
Number of unique drone IDs	6
Total time of drone operations above the Annex 14 limitation surfaces:	56 min.

Unique drone IDs are listed in section 9.2.

The duration of the detected drone flights above the Annex 14 limitation surfaces divided into drone classes:

CLASS	0	1	2	3
DURATION (min.)	1	5	50	0

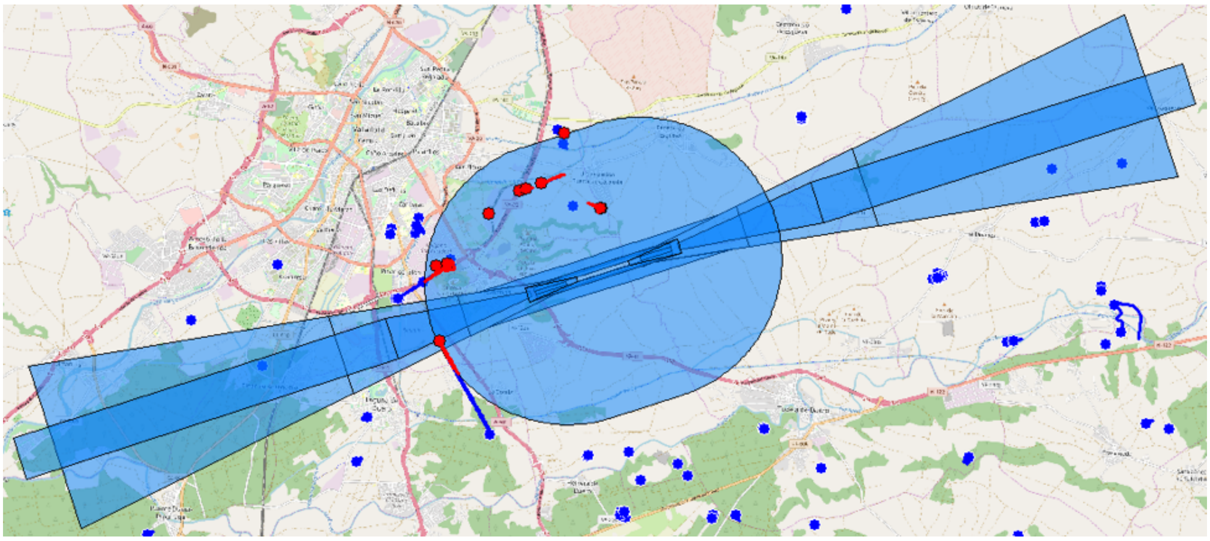

Figure 19 Drones detected above the Annex 14 limitation surfaces. The surfaces are marked in blue. The detected drones above the surfaces are marked as red tracks and red starting points. The remaining detected drones are marked in blue.

6.4.3. AOC surface

The AOC surface is shown in Figure 20 with the detected drones above the surface marked. This surface has a height restriction, so only the drones above the surface are included. The elevation of the drones has been calculated using the SRTM GL1 global elevation dataset.

Number of detected drone flights above the AOC surface:	0
Number of unique drone IDs	0
Total time of drone operations above the AOC surface:	0

Unique drone IDs are listed in section 9.3.

The duration of the detected drone flights above the AOC surface divided by drone class:

CLASS	0	1	2	3
DURATION (min.)	0	0	0	0

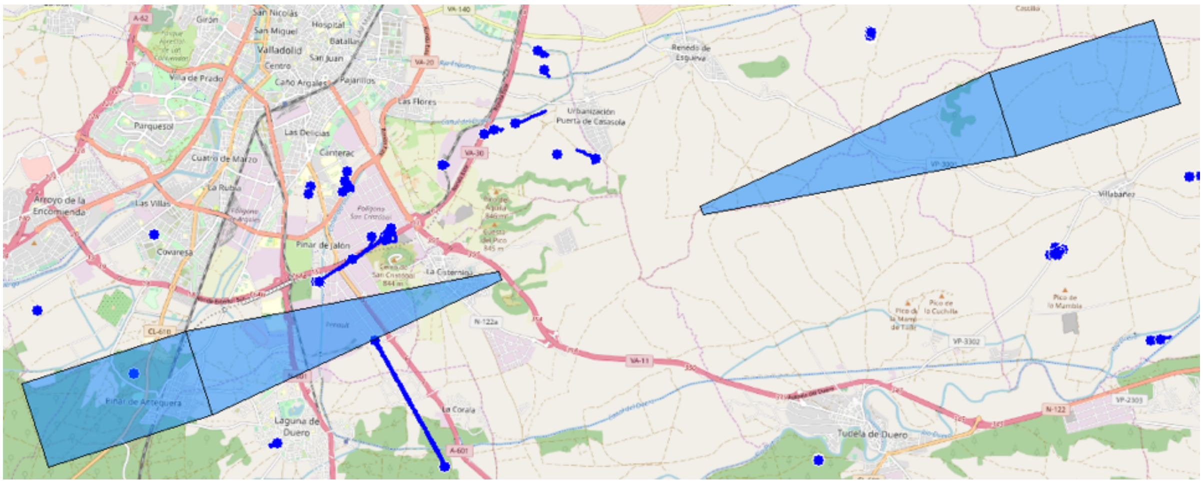

Figure 20 Drones detected above the AOC surface. The AOC surface is marked in light blue. The detected drones within the zones are marked as red tracks and red starting points. The remaining detected drones are marked in blue.

7. RISK ASSESMENT MODEL

7.1. DATA FOUNDATION

Based on the information presented above the risk assessment is performed. Data flow for this risk assessment is presented in the Figure 21.

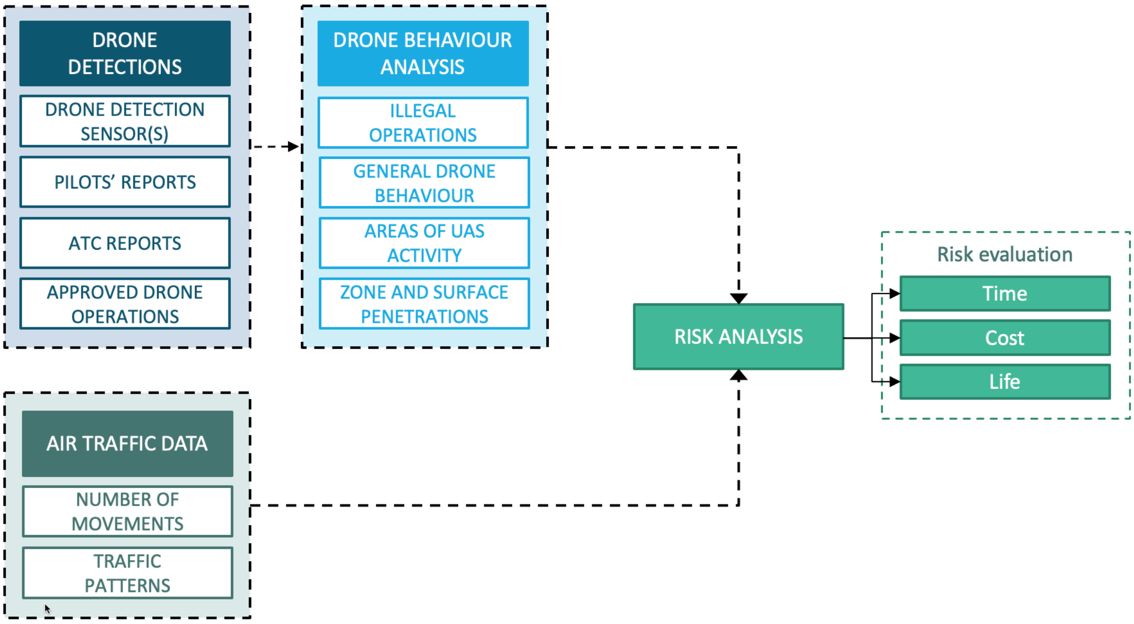

Figure 21 Data flow for the risk assessment

7.2. MODEL

Airport X evaluates and determines the risk of the UAS's on a monthly basis. The risk assessment is based on the data described above being applied in the model described below.
The risk assessment model is based on a combination of probability and severity, as presented below.

7.2.1. Probability

Probability is defined as five levels of likelihood:

LIKELIHOOD		DESCRIPTION
Relative	Numerical	
Unlikely	0,1	Highly unlikely to occur
Seldom	0,3	Will most likely not occur
Occasional	0,5	Possible to occur
Likely	0,7	Likely to occur
Frequent	0,9	Highly likely to occur

Figure 22 Likelihood evaluation

7.2.2. Severity

Severity is defined in Figure 23 depending on mentioned elements (cost, time, and life):

	SEVERITY			
ELEMENT	Negligible	Moderate	Critical	Catastrophic
Cost	Insignificant change in cost	< 20% increase	20-40% increase	>40% increase
Time	Insignificant change in cost	< 10% increase	10-20% increase	>20% increase
Life	Slight/No injury	Minor injury/no hospitalization	Major injury/ hospitalization	Fatality

Figure 23 Severity evaluation

7.2.3. RISK MATRIX

In order to identify your risk, combine severity and likelihood results for each element (presented in the risk matrix in Figure 24.

	LIKELIHOOD				
SEVERITY	Frequent	Likely	Occasional	Seldom	Unlikely
Catastrophic	Very High	Very High	High	High	Medium
Critical	Very High	High	High	Medium	Low
Moderate	High	Medium	Medium	Low	Low
Negligible	Medium	Low	Low	Low	Low

Figure 24 Risk matrix

8. SUBJECTIVE RISK ASSESSMENT

Subjective risk assessment is based on objective information presented earlier in the document in section 8.1, as well as subjective assessment of risk and probability. Assessment of the severity and probability of a drone impact to the safe continuous operations at Airport X it is done in relation to the individual elements described below in sections 8.2-8.4.
It is important to underline that day to day changes to probability may occur if:

a. Authorities increase the security level for a terrorist attack using drones.
b. Authorities or Eco-terrorists give notice about planned attempts to disrupt air traffic.

If these points apply the probability should be reassessed for each individual incident.

8.1. OBJECTIVE FACTS

a. There were 10000 Aircraft operations, that equals to 345 daily average movements in February 2020 (see section 4).
b. At peak hour 6-7 AM there were 26,0 aircraft movements, that equals to one aircraft movement every 2 minute 18 seconds.
c. There were 27 flights within the FRZ divided on 7 different drone ID's (see section 6.4.1)
d. There was one flight above 500 meters within the FRZ (see section 9.5)
e. There were two flights between 400 ft and 500 meters in the FRZ (see section 9.4)
f. There were 16 drone flights penetrating the Annex 14 surfaces (some of these are also represented as flights within the FRZ) (see section 6.4.2).
g. There were zero drones penetrating the AOC surface at Airport X (see section 6.4.3).
h. There were 149 individual drone flights (see section 5.2) totaling 212 minutes total flight time (see section 6.3.2) resulting in an average flight time of 1 minute and 25 seconds.
i. The highest probability based on the number of drones per hour vs. the number of aircraft movements per hour is 15-18 in the afternoon (see figures in sections 6.3.1, 6.3.2, and 4). In this period there is approximate 2 min between aircraft movements (based on air traffic information in section 4).
j. Within a 20 km radius of the ARP there were 26 flights between 400 ft and 500 meters (1640 ft) (see section 6.1.1)
k. 96% of all drone flights had a drone flight distance of less than 800 meters and 100% has a flight distance of less than 1600 meters. (See section 6.3.4)
l. 70% of the time RWY 26 is in use (and 30% RWY 08). The detected drones in the FRZ are mainly to the north and west. Climb gradient is higher than descent.
m. There are areas where drone operators can fly legally and still penetrate AOC and Annex 14 surfaces as described in section 6.2

8.2. TIME (DELAYS) SEVERITY AND PROBABILITY ASSESSMENT

Probability: When assessing the probability of a drone impacting the continuous operations at Airport X it is taken into account that during February 2020 there were drone flights within the FRZ, there are flights above 400 ft and up to 503 meters (1650 ft). Additionally, the average drone flight time compared to the peak movement operations justifies that there have been aircrafts operating within the FRZ at the same time as drones have been operating within the FRZ. The AOC surfaces had no detected drone penetrations. We are considering this to be relevant as the AOC surfaces also describe the minimum altitude of aircraft operations in the airport surroundings. Based on these arguments, probability is assessed to be occasional (see Table 4).

LIKELIHOOD		DESCRIPTION
Relative	Numerical	
Unlikely	0,1	Highly unlikely to occur
Seldom	0,3	Will most likely not occur
Occasional	0,5	Possible to occur
Likely	0,7	Likely to occur
Frequent	0,9	Highly likely to occur

Table 4 Time probability evaluation

Severity: In peak risk time periods, the airport is operating at close to maximum capacity. If the traffic is disturbed for 10-20 minutes the ripple effect will continue for hours. Considering an average movement rate of 30 aircraft per hour in peak activity periods it is our assessment that 50-100 movements would be affected by a 10-20 minutes traffic disruption due to drone operations.

This would lead to a low total of 7 hours and 30 minutes delays (average 15 minutes delay of 30 aircrafts) and a high total of 25 hours and zero minutes (average 15 min delay of 100 aircrafts). Additionally, this would result in subsequent delays on subsequent flights. This effect has not been quantified. As a consequence, the severity is assessed to be critical (see Table 5).

	SEVERITY			
ELEMENT	Negligible	Moderate	Critical	Catastrophic
Time	Insignificant change in cost	< 10% increase	10-20% increase	>20% increase

Table 5 Time severity evaluation

The time risk is a combination of probability (Occasional) and severity (Critical) = High Risk (see Figure 25).

	LIKELIHOOD				
SEVERITY	Frequent	Likely	Occasional	Seldom	Unlikely
Catastrophic	Very High	Very High	High	High	Medium
Critical	Very High	High	High	Medium	Low
Moderate	High	Medium	Medium	Low	Low
Negligible	Medium	Low	Low	Low	Low

Figure 25 Time risk assessment

8.3. COST SEVERITY AND PROBABILITY ASSESSMENT

Probability: The cost probability criteria is considered to be the same as in the section above (see section 8.2) probability is assessed to be occasional (see Table 6).

LIKELIHOOD		DESCRIPTION
Relative	Numerical	
Unlikely	0,1	Highly unlikely to occur
Seldom	0,3	Will most likely not occur
Occasional	0,5	Possible to occur
Likely	0,7	Likely to occur
Frequent	0,9	Highly likely to occur

Table 6 Cost probability evaluation

Severity: Direct costs arise in case of prolonged taxi time and holding. Indirect costs can include: re-routing passengers, crew and passenger accommodation, burned fuel replacement, contractual penalties, additional airport or air traffic control charges or loss of confidence and perceived damage to airline brand.[2] Even though it is hard to identify the exact monetary value of delays, the average cost of aircraft block (taxi plus airborne) for passenger airlines (USA) in 2017 was approx. €61 per minute (direct costs including labour, fuel, food, aircraft ownership, airport landing fees, insurance, utilities, interest)[3]. Last, but not least, in case of delays passengers experience inconveniences, as well as direct and indirect costs, that might not be covered by airlines (to illustrate, average value of the passenger's time is assumed to be approx. €43 per hour[3]). In case of a 10-20-minute disruption to air traffic this would lead to a low total of 7 hours and 30 minutes delays (average 15 minutes delay of 30 aircrafts) and a high total of 25 hours and zero minutes (average 15 min delay of 100 aircrafts).

The estimated cost of a 15-minute disruption to air traffic at Airport X is expected to be a total low financial impact: €116.325 and a total high financial impact of €387.750. Based on this the severity is assessed to be moderate (see Table 7).

	Low		High	
Value of passenger time*	150 × 7,5 × 43 =	€48.375	150 × 25 × 43 =	€161.250
Value of airline cost	7,5 h × €61 pr. min =	€27.45	25 h × €61 pr. min =	€91.500
Value of airport cost**	$\frac{€18}{2}$ × 30 aircraft ×150 passengers=	€40.500	$\frac{€18}{2}$ × 100 aircraft ×150 passengers=	€135.00
Total	€116.325		€387.750	

* Value of passenger time and airport cost is calculated for an aircraft with a passenger capacity of 150.
**Value per customer is calculated based on a 50% loss of the average value per customer of €18.

	SEVERITY			
ELEMENT	Negligible	Moderate	Critical	Catastrophic
Cost	Insignificant change in cost	< 20% increase	20-40% increase	>40% increase

Table 7 Cost severity evaluation

The cost risk is a combination of probability (Occasional) and severity (Moderate) = Medium risk (Figure 26).

	LIKELIHOOD				
SEVERITY	Frequent	Likely	Occasional	Seldom	Unlikely
Catastrophic	Very High	Very High	High	High	Medium
Critical	Very High	High	High	Medium	Low
Moderate	High	Medium	Medium	Low	Low
Negligible	Medium	Low	Low	Low	Low

Figure 26 Cost risk assessment

[2] http://worldbirdstrike.com/IBSC/Amsterdam/IBSC25%20WPSA8.pdf
[3] Airlines for America, *U.S. Passenger Carrier Delay Costs*, available at: http://airlines.org/dataset/per-minute-cost-of-delays-to-u-s-airlines/

8.4. LIFE SEVERITY AND PROBABILITY ASSESSMENT

Probability: In case of impact on life (injury or death) we are no longer talking about an impact on the operations but an actual collision between drone and aircraft followed by loss of control and an accident. Therefore, the preconditions for the probability are not the same as in the case of cost and time. As a consequence, the probability should be assessed separately for this item. Considering the relatively short flight distance (see section 6.3.4) of the drones, the number of operations in the FRZ as well as penetrations of the ICAO annex 14 surface and AOC surfaces in combination with the fact that 70% of approaches and departures are performed to RWY 26 (climb gradient is higher than descent it is our assessment that all aircrafts departing from RWY 26 would out climb the drones detected in February 2020. It is noted that legal flights potentially can penetrate protective surface in airport surroundings (see section 6.2) The probability is assessed to be seldom (see Table 8).

LIKELIHOOD		DESCRIPTION
Relative	Numerical	
Unlikely	0,1	Highly unlikely to occur
Seldom	0,3	Will most likely not occur
Occasional	0,5	Possible to occur
Likely	0,7	Likely to occur
Frequent	0,9	Highly likely to occur

Table 8 Life probability evaluation

Severity: According to the simulations presented in chapter 4 of technical volumes II [3] and III [4] in the UAS Airborne Collision Severity Evaluation[4], an airborne collision between a commercial transport jet and either a 1.2 kg (2.7 lb) quadcopter UAS or a 1.8 kg (4.0 lb) fixed-wing UAS at 250 knots may result in a damage severity level of medium-high (3-4) in the horizontal and vertical stabilizer, medium (2-3) in the leading edge of the wing and medium-low (2) in the windshield. Figure 27 illustrates the damage severity levels at different locations on the commercial transport jet airframe analyzed.

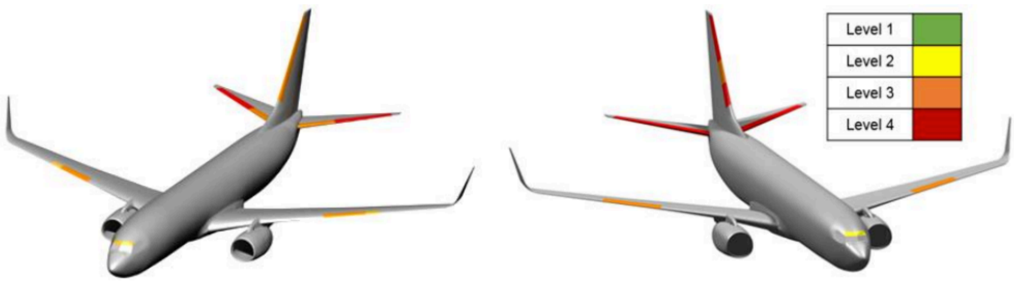

Figure 27 Damage severity levels to commercial transport jet airframe

Based on the mentioned study the severity assessment for a commercial jet depends on speed, position of impact, and battery type. For the purpose of this risk assessment the relatively low speed in connection with approach and departure is taken into account. The severity is assessed to be critical (see Table 9).

	SEVERITY			
ELEMENT	**Negligible**	**Moderate**	**Critical**	**Catastrophic**
Life	Slight/No injury	Minor injury/no hospitalization	Major injury/ hospitalization	Fatality

Table 9 Life severity evaluation

[4] https://ascendxyz.com/wp-content/uploads/2020/03/Rapport-om-Collision-Hazard-Drones-vs.-Aircraft.pdf

The cost risk is a combination of probability (Seldom) and severity (Critical) = Medium risk (see Figure 28).

Note: The study mentioned in life the severity evaluation focused on a 737 aircraft and a DJI phantom drone. 737 and 320 are the most common aircraft operated at Airport X and DJI phantom is a class 2 drone which is the most commonly detected drone in the surroundings of Airport X. Therefore, it is our conclusion that the study is relevant for risk assessment at Airport X.

	LIKELIHOOD				
SEVERITY	Frequent	Likely	Occasional	Seldom	Unlikely
Catastrophic	Very High	Very High	High	High	Medium
Critical	Very High	High	High	Medium	Low
Moderate	High	Medium	Medium	Low	Low
Negligible	Medium	Low	Low	Low	Low

Figure 28 Life risk assessment

9. DRONE DATA TABLES

The following drone data tables have four columns: drone ID (DroneId), detected drone flight starting time in local time of the airport (StartTimeLoc), detected maximum flight altitude compared to the flight starting point in meters (MaxAltitude), and flight ID (FlightId).

9.1. DRONE FLIGHT RESTRICTION ZONES

DroneId	StartTimeLoc	MaxAltitude in meters	FlightId
Intentionally left out	2020-02-01 12:09	133.8	Intentionally left out.
Intentionally left out	2020-02-24 15:51	108	Intentionally left out.
	2020-02-24 15:54	90	Intentionally left out.
	2020-02-24 15:56	99.8	Intentionally left out.
Intentionally left out	2020-02-12 15:38	143.7	Intentionally left out.
	2020-02-12 15:40	503.7	Intentionally left out.
	2020-02-12 15:47	51.6	Intentionally left out.
	2020-02-12 16:01	59.7	Intentionally left out.
Intentionally left out	2020-02-05 10:05	59.5	Intentionally left out.
	2020-02-05 11:13	100.4	Intentionally left out.
	2020-02-05 11:18	76.9	Intentionally left out.
	2020-02-05 11:30	28.6	Intentionally left out.
Intentionally left out	2020-02-12 15:20	10.4	Intentionally left out.
	2020-02-12 15:22	65.4	Intentionally left out.
	2020-02-12 16:21	105.9	Intentionally left out.
	2020-02-12 16:28	97.3	Intentionally left out.
	2020-02-12 16:34	50.4	Intentionally left out.
	2020-02-29 20:16	31.4	Intentionally left out.
Intentionally left out	2020-02-27 14:52	0	Intentionally left out.
	2020-02-27 15:02	0	Intentionally left out.
	2020-02-27 15:16	0	Intentionally left out.
	2020-02-27 15:17	0	Intentionally left out.
	2020-02-27 16:45	0	Intentionally left out.
	2020-02-27 16:46	0	Intentionally left out.
Intentionally left out	2020-02-26 17:47	27	Intentionally left out.
	2020-02-26 18:05	120.2	Intentionally left out.
	2020-02-27 16:13	56.4	Intentionally left out.

Table 10 The detected drones that entered the drone flight restriction zones.

9.2. ANNEX 14 LIMITATION SURFACES

The penetration height column indicates the difference between the maximum height of the drone flight, and the surface height in the point on the drone flight that has the lowest surface height in any of the surfaces.

DroneId	StartTimeLoc	MaxAltitude	PenetrationHeight	FlightId
Intentionally left out	2020-02-01 12:09	133.8	71.3	Intentionally left out.
Intentionally left out	2020-02-24 15:51	108	67.8	Intentionally left out.
	2020-02-24 15:54	90	49.8	Intentionally left out.

	2020-02-24 15:56	99.8	59.6	Intentionally left out.
Intentionally left out	2020-02-12 15:38	143.7	103.4	Intentionally left out.
	2020-02-12 15:40	503.7	463.4	Intentionally left out.
	2020-02-12 15:47	51.6	11.3	Intentionally left out.
	2020-02-12 16:01	59.7	19.4	Intentionally left out.
Intentionally left out	2020-02-05 10:05	100	55.6	Intentionally left out.
	2020-02-05 11:10	100.4	64.1	Intentionally left out.
	2020-02-05 11:18	76.9	40.6	Intentionally left out.
Intentionally left out	2020-02-12 15:23	65.4	17.1	Intentionally left out.
	2020-02-12 16:21	105.9	57.6	Intentionally left out.
	2020-02-12 16:28	97.3	49.0	Intentionally left out.
	2020-02-12 16:36	50.4	2.1	Intentionally left out.
Intentionally left out	2020-02-27 16:14	56	23.2	Intentionally left out.

Table 11 The detected drones that flew above the Annex 14 surfaces.

9.3. AOC SURFACE

The AOC surfaces are used described in ICAO annex 4 under item 3.8.1.

They are used to publish obstacles that could be relevant when departing the airport. We have chosen to include a drone penetration analysis of the AOC surfaces because it is an indication of risk in connection to aircraft departures (and approaches) at Airport X.

DroneId	StartTimeLoc	MaxAltitude	PenetrationHeight	FlightId

Table 12 The detected drones that flew above the AOC surface.

9.4. ALTITUDE 400 FT – 500 M

400 ft AGL is the maximum legal flight height outside restriction areas. 500 meters is the maximum altitude setting in the DJI drones. Drone pilots operating drones above 400ft has intentionally changed the settings for maximum flight altitude in their drone.

DroneId	StartTimeLoc	MaxAltitude in meters	FlightId
Intentionally left out	2020-02-01 12:09	133.8	Intentionally left out.
Intentionally left out	2020-02-26 16:09	283.7	Intentionally left out.
Intentionally left out	2020-02-05 12:34	220.6	Intentionally left out.

DroneId	StartTimeLoc	MaxAltitude in meters	FlightId
Intentionally left out	2020-02-01 12:16	130.2	Intentionally left out.
	2020-02-05 11:56	125.9	Intentionally left out.
Intentionally left out	2020-02-07 09:30	464.8	Intentionally left out.
Intentionally left out	2020-02-13 15:03	160.6	Intentionally left out.
Intentionally left out	2020-02-29 12:10	125.5	Intentionally left out.
Intentionally left out	2020-02-12 15:38	143.7	Intentionally left out.
Intentionally left out	2020-02-14 14:42	140.2	Intentionally left out.
Intentionally left out	2020-02-11 13:08	124.9	Intentionally left out.
Intentionally left out	2020-02-27 15:51	179.5	Intentionally left out.
	2020-02-27 16:27	206.1	Intentionally left out.
Intentionally left out	2020-02-06 07:34	141.4	Intentionally left out.
Intentionally left out	2020-02-07 11:35	150.1	Intentionally left out.
Intentionally left out	2020-02-06 12:43	255.7	Intentionally left out.
	2020-02-06 15:47	260.4	Intentionally left out.
	2020-02-06 15:48	252.2	Intentionally left out.
	2020-02-06 15:52	244.4	Intentionally left out.
Intentionally left out	2020-02-08 12:50	289.8	Intentionally left out.
Intentionally left out	2020-02-07 16:25	124.7	Intentionally left out.
Intentionally left out	2020-02-07 09:42	137.6	Intentionally left out.
	2020-02-07 09:43	157.4	Intentionally left out.
Intentionally left out	2020-02-17 14:35	198.7	Intentionally left out.
	2020-02-26 15:43	126.7	Intentionally left out.
	2020-02-26 15:47	126.1	Intentionally left out.

Table 13 The detected drones with a maximum altitude above 400 ft and below 500 m.

9.5. ALTITUDE ABOVE 500 M

500 meters is the maximum altitude setting in the DJI drones, if you want to fly higher you need to change the configuration of the software. In conclusion, drone flights above 500 meters are performed by drone pilots that are making an effort to reconfigure their drone to fly at high and illegal altitudes. Therefore, the risk is also higher when the below drone ID's are operating, they have both the intention and ability to fly drones in altitudes where you also have aircraft operations.

DroneId	StartTimeLoc	MaxAltitude	FlightId
Intentionally left out	2020-02-12 15:42	503.7	Intentionally left out

Table 14 The detected drones with a maximum altitude above 500 m.