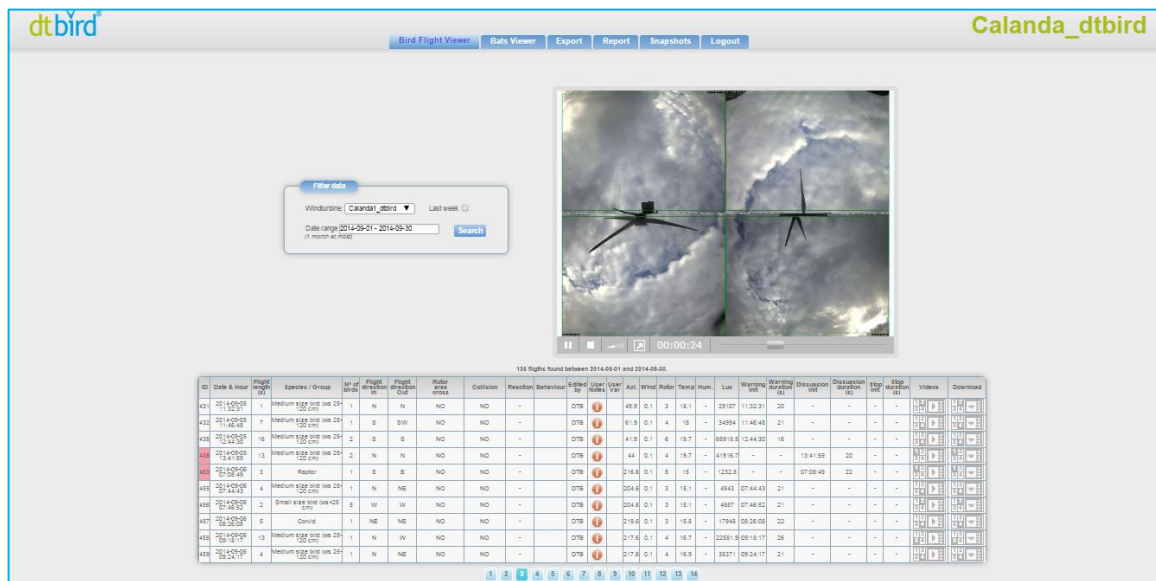




DTBird[®] SYSTEM PILOT INSTALLATION

SERVICE RESULTS OF MIGRATORY PERIOD:

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A. INTRODUCTION

DTBird[®] is a self-working system developed to reduce bird mortality in wind farms, that detects flying birds in real-time and takes automatic actions, as dissuasion of birds flying in collision risk areas or automatic Stop of a Wind Turbine Generator (WTG, hereinafter).

At the request of the company CALANDAWIND/INTERWIN, DTBird[®] System has been installed in the WTG Calandawind (Chur, Graubünden, Switzerland), with the scope to monitor bird activity around the WTG in migratory periods, and to reduce bird mortality due to collision with the WTG.

Calandawind is the highest WTG installed in Switzerland, at the time of DTBird[®] System installation, and also the highest WTG where DTBird[®] has been installed, with a tower height of 119 m, and a rotor diameter of 112 m. The Rotor Swept Area (RSA, hereinafter) extends from 63 m to 175 m above the ground level.

Calandawind is located in an industrial area, surrounded by factories, highways and power lines.

Target Species with collision risk, have not been defined in Calandawind, and will be defined along the *Study Period*; therefore, the *installation* of DTBird[®] System in Calandawind has been designed to register bird activity from the ground level to the RSA height.

Due to the height of the WTG Calandawind and the location in an industrial area, the installation of DTBird[®] System in Calandawind is considered a *Pilot installation*, which has been summarized in the document “DTBird[®] Installation Summary. Wind Farm Calanda” (confidential document).

The following components of DTBird[®] System have been installed in the WTG Calandawind:

- 1 *Analysis Unit*: to control DTBird[®] operation.
- DTBird[®] Modules:
 - *Detection Module*: to detect flying birds in real-time.
 - *Dissuasion Module*: to activate Warning and Dissuasion Signals to birds flying in collision risk areas.
 - *Stop Control Module*: to trigger automatically a Stop of a WTG when bird flights in collision route or within a high collision risk area are detected.
 - *Collision Control Module*: to record potential collisions of medium to big size birds with the WTG.

DTBird[®] Modules are interconnected between them and to DTBird[®] Analysis Unit, which is in turn connected with the WTG to interchange information. DTBird[®] Analysis Unit has Internet connection for remote control.

Every bird flight detected by DTBird[®] Detection Module triggers video and audio records, that are uploaded to DTBird[®] Data Analysis Platform (DAP, hereinafter), an online Software Platform.

DTBird[®] DAP has several access levels for the User, and allows to review video and audio records, to analyze flights, and to export and report data.

This document analyses briefly the *Service Results* of the first 2 months of Operation of the *Pilot installation* of DTBird[®] System in the WTG Calandawind, with the following *Modules* installed:

- *Detection Module.*
- *Dissuasion Module.*
- *Stop Control Module.*
- *Collision Control Module.*

Additionally, the analysis leads to the proposal of adjustments in the Pilot Installation of DTBird[®] System, and Software refinements.

B. DETECTION MODULE

B.1. Introduction

DTBird® *Detection Module* surveys the airspace around the WTG Calandawind, and detects flying birds in real-time.

The installation features of DTDBird® *Detection Module* in the WTG Calandawind have been summarized in the document “DTBird® Installation Summary. Wind Farm Calanda” (confidential document).

Briefly, the following components of DTDBird® *Detection Module* have been installed:

- 4 Detection sensor.
- 4 Fixing/elevation and ice falling protection system.
- Cables and connections.

The 4 Detection sensors have been installed outdoors, evenly located around the tower:

- 2 Detection sensors have been installed at 31 m height to the ground level, in opposite sides of the tower, covering the whole rotor swept area (360° around): 1 sensor covers the North side, and the other sensor covers the South side. These Detection Sensors are devoted to detect individual birds and flocks flying at the *RSA* height, and close to the collision risk area.
- 2 Detection sensor have been installed at 5 m height to the ground level, in opposite sides of the tower, covering the whole rotor swept area (360° around): 1 sensor covers the West side, and the other sensor covers the East side. These Detection Sensors are devoted to detect any size of birds flying below the *RSA* height, and medium/big size birds and flocks flying in collision route at the *RSA* height.

DTBird[®] *Detection Module* has been configured with the following Settings:

- Daily Service: light > 50 lux¹.
- Flight Detectability: > 80% of Target Species flights².
- FP/day < 2 FP/day
- Target Species, Maximum Detection Distance to the Detection sensor (*MDD*, hereinafter): According to the function³: $X = 1,5 * Y / 0,017$, where X is the *MDD*, and Y is the wing span of the bird. Individual birds and flocks actually located at further distances can be eventually detected. *MDD* for 3 common Species potentially present in the area: 70 m for *Falco tinnunculus*, 145 m for *Milvus milvus*, 200 m for *Aquila chrysaetos*.
- High collision risk area (*HCRA*): Area at the *RSA* height, and less than 25 m to the actual position of the blades.
- Moderate collision risk area (*MCRA*): Area at the *RSA* height, and between 100 and 25 m to the actual position of the blades.

The following records and information are automatically recorded and uploaded daily to DTBird[®] *DAP*:

- Video Record of every bird flight, with sound record embedded.
- Date and time of every bird flight.
- Flight duration.
- WTG parameters along the bird flight.
- Environmental parameters along the bird flight: T^a, wind speed, humidity and rain.

In addition, the User with Analyst access level can edit the following fields of data in DTBird[®] *DAP*:

- Species/Group.
- N° of birds.
- Flight direction in.
- Flight direction out.
- Rotor area cross: Yes, No, Not determined (ND).
- Reaction.
- Behavior.
- User notes.
- User Var.

¹ 400 lux corresponds to sunrise and sunset light on a clear day.

² According to Norwegian Institute for Nature Research (NINA), Report 910.

³ Function has been calculated with the assumptions that bird is detected in the image, with the wings completely extended (maximum wing span) and in the center of the field of view.

B.2. Analysis

The *Study Period* has been the bird migration period of autumn, from 25/08/2014 to 31/10/2014, which corresponds to the first 2 month of Operation of DTBird® System.

Along the *Study Period*, bird flights detected by DTBird® *Detection Module* have been recorded and uploaded daily to DTBird® *DAP*.

DTBird® Team has reviewed and analysed all the bird flights within the *Study Period* recorded in DTBird® *DAP*, and has filled the following fields of data:

- Species/Group: Identification performed at any of the following levels: Species, Group (raptor, corvid, etc.), Size class (small, medium, big, very big), or not identified at all.
- N° of birds.
- RSA cross: A cross of the RSA has been noted when it has been observed in the video records that a bird has crossed the area swept by the blades.

With the Report tool of the *DAP* an automatic Service Report for the *Study Period* of 25/08/2014 to 31/10/2014 has been produced.

The organization *Vogelwarte Sempach* is in charge of a detailed Analysis of DTBird® *Detection Module* Detectability, relying on a *Field Study* from *vantage points*, that is out of the scope of DTBird® Team.

Nevertheless, in order to adjust DTBird® System installation in Calandawind, to the target Species registered along the *Study Period*, and to refine the performance, DTBird® Team has analyzed the following features of DTBird® *Detection Module*:

- DTBird® *Detection Module* operation: Hardware and Software.
- FP/day.
- Flight height, with 3 categories: at RSA height, below RSA and above RSA.
- RSA height includes a buffer of 10 m below the minimum height reached by the blades (63 m), and 10 m above the maximum (175 m).
- Minimum distance to any part of the blades (m), with 5 categories: <10 m, 10-25 m, 25-50 m, 50-100 m, >100 m.

The flight height and the minimum distance to the blades have been grossly estimated using the bird size and its location in the images recorded by DTBird® *Detection Module*.

A detailed 3D projection of the flights detected by DTBird® *Detection Module* within the *Field Study Period*, including every bird position data (X,Y,Z), has been released to *Vogelwarte Sempach*.

B.3. Results

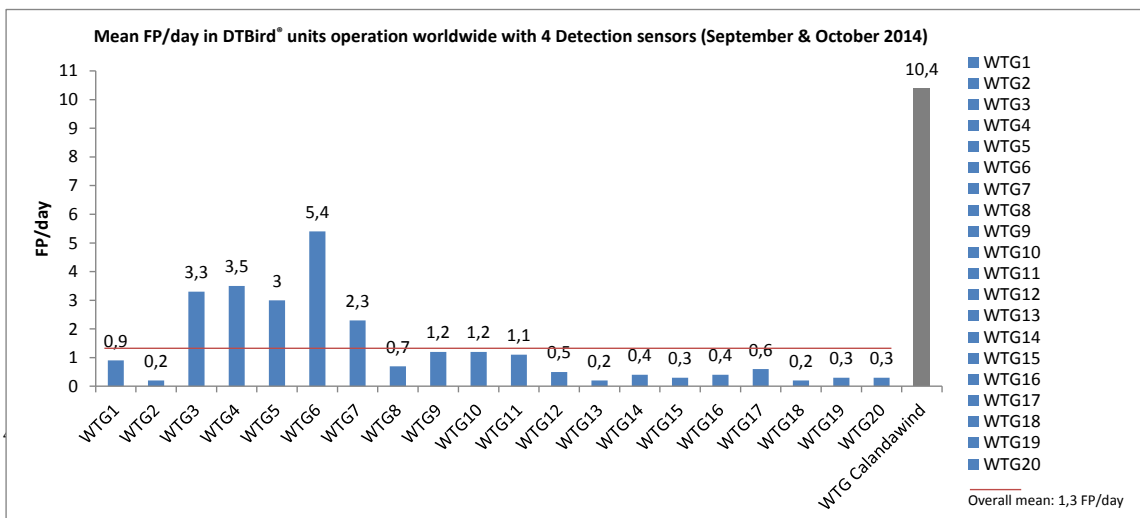
The following results of DTBird® *Detection Module* for the *Study Period* of 25/08/2014 to 31/10/2014 are highlighted:

- Operation:
 - DTBird® Detection Module in Service 100%⁴ of the days, during daylight (>50 lux), a mean of 11,7 hours/day, excluding 6 days with a repetitive failure of a third party device that communicates DTBird® System with the WTG, which has limited the days of the Study Period to include in the Analysis.
 - 1 single failure of 1 camera registered along the Study period.
- Flights detected:
 - N° flights: 4,1 bird flights/day, with video & audio records of every flight (total: 274 bird flights detected, and 423 birds in the flights). Images of some birds detected are provided in the Appendix I.
 - Flight height: 77% of the bird flights below the RSA, and 23% at the RSA height. No flight has been observed above the RSA height.
 - Birds per flight: Solitary birds in 79% of the flights (range 1-30 birds).
 - Large flocks of migratory birds: There have not been large flocks (>10 birds) of migratory birds detected at the RSA height, and there have been only 2 flights of 5 to 10 birds. Below the RSA there have been only 2 flights of more than 10 birds, which corresponded to passerines.
 - Flights Composition: Corvids 15%, Raptors 3%, Medium size birds 61%, Others 21%.
 - False Positives rate: 10 FP/day.

False Positives rate has been higher than expected (<2 FP/day), and has been produced mainly by Helicopters or Airplanes (53%), and insects (44%).

Helicopters have been detected flying within the valley that surrounds the WTG Calandawind a mean of 5 times per day, which is a unique feature of this location.

Typical FP rates of all DTBird® units in operation worldwide during the same period (25/08/2014 to 31/10/2014), with 4 detection sensors, with more than 2 months of operation, are presented below. Calandawind is an outlier, but it was within the first 2 months of operation, so FP rate was not optimized.



C. DISSUASION MODULE

C.1. Introduction

DTBird[®] *Dissuasion Module* triggers *Warning/Dissuasion Signals* to birds detected by DTBird[®] Detection Module flying in collision risk areas around the WTG Calandawind.

DTBird[®] *Dissuasion Module* emits two kinds of *Sound* signals to birds flying in collision risk areas:

- *Warning Sound.*
- *Dissuasion Sound.*

The *Warning Sound* is intended to *Warn* birds flying in moderate collision risk areas (*MCRA*, hereinafter) of the presence of a potential hazard (the WTG and/or moving blades); and the *Dissuasion Sound* is intended to *Scare* away birds flying in high collision risk areas (*HCRA*, hereinafter).

Therefore, the intended effects of DTBird[®] *Dissuasion Module* are:

- To *Warn* birds flying in *MCRA* of the presence of a hazard (the WTG and/or the blades moving).
- To *Scare* away birds flying in *HCRA*.

The installation features of DTBird[®] *Dissuasion Module* in the WTG Calandawind, have been summarized in the document “DTBird[®] Installation Summary. Wind Farm Calanda” (confidential document).

Briefly, the following components of DTBird[®] *Dissuasion Module* have been installed:

- 4 Speakers.
- 1 Amplifier.
- Cables and connections.

The 4 Speakers have been installed outdoors on the tower, distributed in 2 couples. Every couple of Speakers has been locked at 31 m to the ground level, in opposite sides of the WTG, in order to cover the whole *RSA* (360° around): 1 couple of Speakers covers the North side of the *RSA*; and the other couple covers the South side of the *RSA*.

DTBird[®] *Dissuasion Module* has the same Daily Service of DTDBird[®] *Detection Module*: light > 50 lux, and has been configured with the following Settings:

- Type of Signal:
 - Warning Sound:
 - Emitted by 4 Speakers, powered by Amplifier, with a Sensitivity per Speaker up to 117 dBA.
 - Sound trigger: Birds detected flying in Moderate Collision Risk Area (MCRA).
 - Sound duration: As long as the bird is detected flying in MCRA, plus 20 seconds.
 - Dissuasion sound:
 - Emitted by 4 Speakers, powered by Amplifier, with a Sensitivity per Speaker up to 121 dBA.
 - Sound trigger: Birds detected flying in High Collision Risk Area (HCRA), or within the spherical area potentially swept by the blades (center: nacelle; radius: 57 m).
 - Sound duration: As long as the bird is detected flying in HCRA, plus 20 seconds.

The following records and information are provided and uploaded daily to DTDBird[®] DAP, for every bird flight detected, with Warning/Dissuasion Sound trigger:

- Video Record of the bird flight associated to the Sound trigger.
- Sound Signal record, included in the Video record.
- Dissuasion/Warning Signal init time, end time, and duration (s).

C.2. Analysis

The evaluation of DTBird® *Dissuasion Module* requires to determine if it *Warns* birds flying in *MCRA* of the presence of the WTG/Moving blades, and *Scare away* birds flying in *HCRA*.

To analyse if a particular bird has been *Warned* or *Scared away* by the *Warning/Dissuasion Sounds*, requires to record the bird flight in the vicinity of the WTG, and to relate features of bird flight that represent a *Warn* or *Scare away* behavior with the emission of *Warning/Dissuasion Sounds*.

Nevertheless, changes in bird behavior and activity can be a natural response to the mere presence of the WTG, to the moving blades, or moreover, to high wind speeds, that secondarily are associated to blades movement. For example, birds that perceive the WTG or the moving blades as a potential hazard at enough distance, can naturally avoid flying close to them; or when the perception is at short distance, they can show avoidance behaviors with sudden changes in flight features.

Accordingly, in order to evaluate the *Performance* of DTBird® *Dissuasion Module*, it is necessary to distinguish the *Warning* and *Scare away* effects of DTBird® *Warning/Dissuasion Sounds*, from the mere effect of the WTG presence and the moving blades.

An *Experimental Design* to evaluate the effect of DTBird® *Warning/Dissuasion Sounds* on flight activity/features in Collision Risk Areas around the WTG Calandawind, has been defined, with 2 major factors to analyse:

- DTBird® *Warning/Dissuasion Sounds*.
- Blades Movement.

The *Experimental Design* schedules to Mute/Emit the *Warning/Dissuasion Sounds* in a weekly basis, that represent 2 possible states of DTBird® *Dissuasion Module*. The blades movement has not been experimentally manipulated, but it has been recorded along the *Study Period*, with 2 possible states:

- Blades Moving.
- Blades Stop.

Therefore, 4 experimental cases have been defined (Table 1):

- *Warning/Dissuasion Sounds* Muted & Blades Moving;
- *Warning/Dissuasion Sounds* Muted & Blades Stop;
- *Warning/Dissuasion Sounds* Emitted & Blades Moving;
- *Warning/Dissuasion Sounds* Emitted & Blades Stop.

<i>Warning/Dissuasion Sounds</i>	Blades
Muted	Moving
	Stop
Emitted	Moving
	Stop

Table 1. Experimental cases defined in the *Experimental Design*.

The bird migration period of autumn has been been defined as the *Study Period*, and along this period, bird flights have been monitored with DTBird® *Detection Module*.

DTBird® *Detection Module* detects flying birds in real-time, and potential collisions with the WTG, and DTBird® *Analysis Unit* records videos of every flight detected, with embedded audio records, that are uploaded daily to DTBird® *DAP*. In addition to the audio records, DTBird® *Analysis Unit* draws in the videos a green frame along the *Warning Sound* emission, and a yellow frame along the *Dissuasion Sound* emission. The color frames are intended to assist in the analysis of the flight features, and particularly, bird reactions to *Warning/Dissuasion Sounds*.

DTBird® *Dissuasion Module* records automatically the following parameters of every bird flight detected (in addition to the parameters recorded automatically by DTBird® *Detection Module*):

- *Warning Sound* init Time.
- *Warning Sound* duration (s).
- *Dissuasion Sound* init Time.
- *Dissuasion Sound* duration (s).

Along the weeks with *Warning/Dissuasion Sounds* Emitted, the init and end time of every *Sound* and the color frames in the videos, have been recorded in DTBird® *DAP*, and the *Sounds* can be listened in the video records. Along the week with *Warning/Dissuasion Sounds* Muted, the same parameters have been recorded; therefore, the only difference is that the *Warning/Dissuasion Sounds* have not been emitted, and only background sound can be listened in the video records.

DTBird® Team has reviewed and analyzed all the bird flights within the Study Period recorded in DTBird® *DAP*, and has taken note of the following User variables:

- Flight direction in.
- Flight direction out.
- Reaction: Yes, No, Not determined (ND). Reactions have been considered visible changes within 5 s from *Warning/Dissuasion Sound* trigger in any of the following flight features: flight direction (at least 15° turn), flight speed or pattern of wing beat.
- Lapsed Time to Reaction (s): The lapse of time between the *Warning/Signal Sound* trigger and the first reaction observed, with negative value when it occurs before the trigger, positive value if it occurs after the trigger, and lapse 0 when it occurs simultaneously.
- Collision flight: Flight in the route to cross the *RSA* at any moment along the flight recorded in the *DAP*.
- Collision Avoidance flight: Collision flight that changed to a route without cross of the *RSA* within 5 s to a *Sound Trigger* (virtual or actual), and later did not take again a route toward the *RSA*.

For the estimation of the flight direction, the 2 D track of the flight in the video records has been related with geographical azimuths using an orthonormal projection of the surveillance area of every camera, and it has been estimated the flight direction at the beginning of the flight (Flight direction in), and at the end (Flight direction out).

The *Experimental Design* and the parameters described above, have been used to analyse the effect of DTBird® *Warning/Dissuasion Sounds* on flight features around the WTG Calandawind.

The following results are expected:

- Bird activity:
 - Bird activity within Maximum Detection Distance: Independent of DTBird® Warning/Dissuasion Sounds state, and lower bird activity with moving blades.
 - N° flights and Reactions of birds flying in HCRA: Lower number of flights, higher number of reaction, and earlier reactions observed in birds flying in HCRA when DTBird® Warning/Dissuasion Sounds have been Emitted.
 - Duration of flights in collision risk areas: Shorter flights registered in collision risk areas when DTBird® Warning/Dissuasion Sounds have been Emitted.
- Collisions and RSA crosses:
 - N° Collisions and RSA crosses: Lower number of Collisions and RSA crosses registered when DTBird® Warning/Dissuasion Sounds have been Emitted.
 - Collision Avoidance flights: Higher number of Collision Avoidance flights observed when DTBird® Warning/Dissuasion Sounds have been Emitted.

C.3. Results

Study Period and hours of operation

The *Study Period* has been the bird migration period of autumn, from 25/08/2014 to 31/10/2014, which corresponds to the first 2 month of Operation of DTBird® System. Along this period there have been deviations from the scheduled *Experimental Design* of Mute/Emit the *Warning/Dissuasion Sounds* in a weekly basis, due to failures in a third party device, that eventually interrupted DTBird® System operation, and to a bug in a software plug-in to follow automatically the weekly schedule, that was solved at the beginning of the experiment.

Warning/Dissuasion Sounds have been Muted 35 days (374 hours), and Emitted 27 days (312 hours), and there have been differences in the number of hours per day that DTBird® System has been in operation (Table 2). Therefore, for comparative purposes the days of operation with *Warning/Dissuasion Sounds* Muted and Emitted have been normalized to days of 12 hours of operation.

There have been 31 normalized days of operation with *Warning/Dissuasion Sounds* Emitted, and 26 with *Sounds* Muted, that represent 55% and 45% of the whole study period, respectively.

Warning / Dissuasion Sounds	Days of operation	Hours	Days of operation (12 hours/day)	% Hours of operation
Muted	35	373:57:43	31	55%
Emitted	27	311:53:56	26	45%
Total	62	685:51:39	57	100%

Table 2. Days and hours of operation of DTBird® System with Warning/Dissuasion Sounds Emitted and Muted, along the Study Period (25/08/2014 to 31/10/2014).

The hours of normalized operation with the blades moving and the blades Stop have been similar (Table 3): 48% and 52%, respectively.

The hours of operation of DTBird® System within every one of the 4 cases studied defined in the *Experimental Design* has been quite balanced, with values close to ¼ of the total operation time per case (Table 3). Nevertheless, the *Warning/Dissuasion Sounds* have been Emitted with the Blades Moving in ca. 1/5 of the time, instead of 1/4.

Warning/Dissuasion Sounds	Blades	Hours	% Hours of operation
Muted	Moving	189	27,5%
	Stop	185	27,0%
Emitted	Moving	141	20,6%
	Stop	170	24,8%
Total		685	100%

Table 3. Days and hours of operation of DTBird® System with Warning/Dissuasion Sounds Emitted and Muted, along the Study Period (25/08/2014 to 31/10/2014).

Bird activity (flights/hour) within Maximum Detection Distance

Along the *Study Period*, mean Bird activity around the WTG Calandawind has been 0,40 flights/hour, when *Warning/Dissuasion Sounds* have been Muted, and 0,41 flights/hour when *Sounds* have been Emitted (Table 4).

Mean Bird activity has been 0,18 flights/hour when the blades have been moving, and 0,61 flights/hour when the blades have been Stop (Table 4).

		Total N° Flights	Flights/hour of operation	
Warning/Dissuasion Sounds	Blades			
Muted	Moving	35	0,19	0,40
	Stop	113	0,61	
Emitted	Moving	24	0,17	0,41
	Stop	102	0,60	
Total		274	-	

Table 4. Total N° of flights, and flights/hour of operation, with Warning/Dissuasion Sounds Emitted/Muted and with blades Moving/Stop, along the Study Period (25/08/2014 to 31/10/2014).

Along the *Study Period* there have been 274 bird flights detected by DTBird® *Detection Module* around the WTG Calandawind.

Circa $\frac{3}{4}$ of the flights (77%) have been observed below the *RSA*, and $\frac{1}{4}$ at the height of the *RSA* (23%) (Table 5).

The number of flights has decreased at shorter distances to the blades, with only 3% (9 flights) observed at <10 m to the blades. On the other hand, only 9% of the flights have been detected at >100 m to the blades.

N° Flights							
Minimum Distance to the Blades (m)							
Flight Height	<10 m	10-25 m	25-50 m	50-100 m	>100 m	Total	%
Below RSA		5	59	125	22	211	77%
At RSA	9	9	31	11	3	63	23%
Total	9	14	90	136	25	274	100%
%	3%	5%	33%	50%	9%	100%	-

Table 5. N° of flights detected with respect to the RSA height, and distance to the blades, along the Study Period (25/08/2014 to 31/10/2014).

Number of bird flights and reactions observed in HCRA

Along the *Study Period*, at the RSA height, when *Warning/Dissuasion Sounds* have been Emitted and with the blades moving, there have been 16 bird flights in 30 days of normalized operation, but no flights had reached a distance <25 m to the moving blades (Table 6). However, with the Sounds Muted there have been 18 bird flights, 8 flights had reached a distance of <25 m to the blades, and no one would had a visible reaction (ND reaction).

		N° flights (normalized to 30 days of operation) at the RSA height & blades moving						
		Distance to the blades (m)						
Warning/Dissuasion Sounds	Reaction	<10	10- 25	25- 50	50- 100	Total	% Reaction	% Reaction, at <50 m
Muted	ND	4	4	6	4	18	0%	0%
	Yes	0	0	0	0	0		
Emitted	ND	0	0	5	3	8	50%	60%
	Yes	0	0	8	0	8		
	Total	4	4	19	7	34		

Table 6. N° of flights with visible reaction, normalized to 30 days of operation, registered at the RSA height and with the blades moving, for every State of Warning/Dissuasion Sounds (Muted/Emitted), and distance to the blades, along the Study Period (25/08/2014 to 31/10/2014).

Along the *Study Period*, visible reactions have been observed in 19% (53 flight) of the 274 flights registered. With respect to the virtual or actual *Warning/Dissuasion Sounds* Trigger, 72% of the reactions have occurred after the *Sound* Trigger, and 28% before or simultaneously (Table 7). Therefore, the reaction of the bird has occurred 3 times more often after the *Sound* Trigger (virtual or actual trigger).

With the *Warning/Dissuasion Sounds* actually Emitted (not virtual), 82% of the reactions have occurred after the *Sound Trigger*, and 18% before; and with the *Sound Muted*, 47% occurred after and 53% before or simultaneously.

Therefore, with the *Sound* actually Emitted reactions have occurred nearly 4 times more often after *Sound Trigger* than before or simultaneously; but with the *Sound Muted*, a similar number of reaction occurs at any time.

% Flights (within brackets N° flights)			
Reaction with respect to Sound Trigger	Sound		
	Muted	Emitted	Total
After	47% (7)	82% (31)	72% (38)
Before	33% (5)	18% (7)	22% (12)
Simultaneous	20% (3)	0% (0)	6% (3)
Total	100% (15)	100% (38)	100% (53)

Table 7. Flights with visible reaction with respect to the Sound trigger, for every State of Warning/Dissuasion Sounds (Muted/Emitted), along the Study Period (25/08/2014 to 31/10/2014). To note that with the Sounds Muted, reactions are referred to a software trigger time marked in the video recordings and DTBird® DAP, but no Sound was actually emitted.

With *Warning/Dissuasion Sounds* Muted and with the blades moving, no reaction has been registered in birds flying at the RSA height (Table 8); however, with the *Sound* Emitted there have been a visible reaction in 60% of the flights registered at the RSA height and <50 m to the blades.

In flights registered below the RSA and <50 m to the blades, Emitted there have been 3 to 5 times more reaction observed with *Warning/Dissuasion Sounds*, than in flights registered with the *Sound* Muted.

Warning/Dissuasion Sounds	% Reaction, at <50 m to the blades (within brackets, N° flights in 30 days of operation)			
	At the RSA height		Below the RSA height	
	Blades moving	Stop	Blades moving	Stop
Muted	0% (12)	35% (33)	17% (11)	9% (62)
Emitted	60% (13)	45% (42)	50% (6)	42% (51)

Table 8. Visible Reactions at <50 m to the blades, with respect to the RSA height, for every State of Warning/Dissuasion Sounds (Muted/Emitted) and blades (Moving/Stop), along the Study Period (25/08/2014 to 31/10/2014). To note that with the Sounds Muted, reactions are referred to a software trigger time marked in the video recordings and DTBird® DAP, but no Sound was actually emitted.

Duration of bird flights in collision risk areas

The duration of the flights detected by DTBird® *Detection Module* does not show a normal distribution, because most flights have been of short length (<5 s), and there have been only some flights of long length (>30 s).

Within the bird flights that have reached the RSA height, the mean flight duration has been 5,4 s when *Warning/Dissuasion Sounds* have been Emitted and the blades have been moving (Table 9), and 43% of the flights (3/7 flights) have had a duration >5 s; however, with the *Sounds Muted* the mean duration has been 17,8 s, and the proportion of flights with a duration >5 s rise to 78% (7/9 flights).

Therefore, the shortest flights have been observed with *Warning/Dissuasion Sounds* Emitted and the blades moving.

<i>Warning/Dissuasion Sounds</i>	<i>Blades</i>	Flights that reach the RSA height Total flight duration (s)		N° Flights
		Mean value	Maximum	
Muted	Moving	17,8 s	90 s	9
	Stop	10,2 s	42 s	22
Emitted	Moving	5,4 s	17 s	7
	Stop	9,6 s	54 s	25

Table 9. Mean and Maximum Duration of flights that reach the RSA height, for every State of Warning/Dissuasion Sounds (Muted/Emitted) and blades (Moving/Stop), along the Study Period (25/08/2014 to 31/10/2014).

N° Collisions and RSA crosses

According to the review of video and audio recordings by DTBird® Team, along the *Study Period* there have not been any Collision in the 274 bird flights (423 birds) detected by DTBird® *Detection Module* (see epigraph DTBird® *Collision Control Module*).

With the *Warning/Dissuasion Sounds* Muted and the blades moving, there has been 1 flight with cross of the RSA; and there has been another flight in the same conditions and at <10 m to the blades, where it was not possible to determine accurately the actual cross of the RSA (ND cross) (Table 10).

With the *Warning/Dissuasion Sounds* Emitted and the blades moving there have not been any cross of the RSA.

		N° Flights with RSA Cross	
Warning/Dissuasion Sounds	Blades	Yes	ND
Muted	Moving	1	1
	Stop	0	1
Emitted	Moving	0	0
	Stop	1	0
Total		2	2

Table 10. N° flights with RSA cross, for every State of Warning/Dissuasion Sounds (Muted/Emitted) and blades (Moving/Stop), along the Study Period (25/08/2014 to 31/10/2014).

Collision Avoidance flights

Along the *Study Period*, there have been 19 flights (7%) observed in Collision route with the WTG, at any time along the flight, within the 274 bird flights detected by DTBird® *Detection Module*: 9 flights have been registered with *Warning/Dissuasion Sounds Muted*, and 10 flights with *Sounds Emitted* (Table 11).

With *Warning/Dissuasion Sounds Emitted* and the blades moving, there have been 100% of Collision Avoidance flights (2/2 flights), and with the blades Stop, 75% of Avoidance (6/8 flights); however, with the Sound Muted and the blades moving there have been 0% Avoidance (0/1 flights), and 25% of Avoidance with the blades Stop (2/8 flights).

		Collision Flights		
		Avoidance		
Warning/Dissuasion Sounds		NO	YES	% Avoidance Flights
Muted	Moving	1	-	0%
	Stop	6	2	25%
Emitted	Moving	-	2	100%
	Stop	2	6	75%
Total		9	10	

Table 11. Collisions flights and Avoidance behaviour for every State of Warning/Dissuasion Sounds (Muted/Emitted) and blades (Moving/Stop), along the Study Period (25/08/2014 to 31/10/2014).

C.4. Conclusions

DTBird[®] *Dissuasion Module* has been installed in the WTG Calandawind with the scope to reduce bird mortality due to collision with the WTG.

DTBird[®] *Dissuasion Module* emits *Warning/Dissuasion Sounds*: *Warning Sound* is intended to Warn birds flying in MCRA of the presence of a potential hazard (the WTG and/or moving blades); and the *Dissuasion Sound* is intended to Scare away birds flying in HCRA.

The Performance of DTBird[®] *Dissuasion Module* has been analyzed for the bird migration period of autumn of 2014, with the following conclusions:

- Bird activity within DTBird[®] *Detection Module* Surveillance area is not reduced by DTBird[®] *Dissuasion Module*: circa 0,40 bird flights/hour with Sounds Emitted and Muted. However, bird activity has been 3,4 lower when the blades of the WTG have been rotating (0,18 flights/hour), than when the blades have been Stop (0,61 flights/hour).
- DTBird[®] *Dissuasion Module* activation has reduced the number of collision risk flights: No flight at the RSA height has reached <25 m to the moving blades when *Warning/Dissuasion Sounds* have been Emitted, but when the *Sounds* have been Muted, 8 flights have reached <25m to the moving blades in 30 days of standardized operation.
- DTBird[®] *Dissuasion Module* activation has produced higher number of reactions in birds flying at the RSA height and <50 m to the moving blades: when *Warning/Dissuasion Sounds* have been Emitted, there have been visible reaction in 60% of the flights (8/13 flights), but no reaction has been observed when the *Sounds* have been Muted (0/14 flights).
- DTBird[®] *Dissuasion Module* activation has produced a high proportion of reactions associated to the Sounds emitted: when *Warning/Dissuasion Sounds* have been Emitted, there have been 38 reactions observed, and 82% have occurred after Sound trigger. However, with the *Sounds* Muted, there have been only 15 reactions observed, and only 47% occurred after Sound trigger.
- DTBird[®] *Dissuasion Module* activation has shortened the duration of the flights that reach the RSA height with the blades moving: when *Warning/Dissuasion Sounds* have been Emitted and the blades have been moving, mean flight duration has been 5,4 s, and there have been <50% of the flights with a duration >5 s (3/7 flights that reach the RSA height); however, with the *Sounds* Muted, the mean flight duration has been 17,8 s, and the proportion of flights with a duration >5 s rise to >75% (7/9 flights that reach the the RSA height).
- There have been 0 collisions with the WTG Calandawind within the 274 bird flights detected, independently of DTBird[®] *Dissuasion Module* state and the blades movement.
- DTBird[®] *Dissuasion Module* activation has lead to 0 flights with RSA cross, but with the *Sounds* Muted there have been 1flight with RSA cross.
- DTBird[®] *Dissuasion Module* activation has produced higher number of Collision Avoidance flights: with blades moving and *Warning/Dissuasion Sounds* Emitted, there have been 100% of Collision Avoidance flights (2/2 flights); but with the *Sounds* Muted, no Collision Avoidance has been observed (0/1 flights); with the blades Stop, the *Warning/Dissuasion Sounds* Emitted have produced 75% of Collision Avoidance behavior

(6/8 flights), but with the *Sounds* muted there has been only a 25% of Collision Avoidance behavior (2/8 flights).

- To avoid the emission of Sound signals for flights detected with the blades Stop or moving slowly (< 3 rpm), it is proposed to Mute Sound Emission or to emit Sounds at low volume when the blades are not moving or move slowly (< 3 rpm).

D. STOP CONTROL MODULE

D.1. Introduction

DTBird® *Stop Control Module* automatically Stop the WTG when it is detected a bird flight in collision route or within a high collision risk area.

The installation features of DTBird® *Stop Control Module* in the WTG Calandawind have been summarized in the document “DTBird® *Installation Summary. Wind Farm Calanda*” (confidential document).

DTBird® *Stop Control Module* is composed of the following *components*:

- Stop Control Software, installed in the *Analysis unit*.
- Stop Control device.
- Cables and connections.

DTBird® *Stop Control Module* has the same Daily Service of DTBird® *Detection Module*: light > 50 lux, and has been configured with the following Settings:

- Stop trigger: Flight in collision route or within a high collision risk area.
- Stop length: 90 s.

The following information is provided and uploaded daily to DTBird® *DAP*:

- Stop init Time.
- Stop duration (s).

D.2. Analysis

The *Study Period* has been the bird migration period of autumn, from 25/08/2014 to 31/10/2014, which corresponds to the first 2 month of Operation of DTBird® *System*. Along this period, only *Virtual Stops* have been triggered.

The *Virtual Stops* do not produce a real Stop of the blades, but the *Stop trigger* time and duration is equal to a real Stop, and it is marked in the video records and DTBird® *DAP*. All data of *Virtual Stops* are produced and uploaded daily to DTBird® *DAP*, and allow to analyse the potential efficiency of DTBird® *Stop Control Module*.

A detailed Analysis of DTBird® *Stop Control Module* performance is out of the scope of DTBird® Team. Nevertheless, the following features have been analyzed by DTBird® Team, in order to adjust the *Pilot installation* of DTBird® *System*, and to refine DTBird® *Stop Control* to the Target Species detected along the *Study Period*:

- DTBird® *Stop Control Module* operation: Hardware and Software.
- Stops triggered by bird flights with the blades moving.
- False Negatives, no Stop triggered and:
 - Collision.

- RSA Cross with the blades moving.
- Bird flights in Collision Route at the RSA height, that reach <50 m to the blades that do not trigger a Stop.
- False Positives (FP), Stops rate, and FP class.

D.3. Results

The following results of DTBird® *Stop Control Module* are highlighted:

- DTBird® *Stop Control Module* has been in Service 99%5 of the days, during daylight (>50 lux), a mean of 11,7 hours/day, excluding 6 days with a repetitive failure of a third party device that communicates DTBird® System with the WTG, which has limited the days of the Study Period to include in the Analysis.
- There have been cases with the blades moving slowly, at 3-4 rpm, where the rotor has been considered Stop, but there could be still a small Collision risk.
- Stops triggered by bird flights, and with the blades moving: 0 bird flights.
- False Negatives:
 - No Stop triggered and:
 - Collision: 0 flights.
 - RSA Cross with the blades moving: 0 flights.
 - Bird flights in Collision Route at the RSA height, that reach <50 m to the blades: 2 bird flights: 1 flight of a not identified bird, and 1 raptor flight; both flights with Warning/Dissuasion Sounds Muted. The Raptor flights was registered very close to highest point reached by the blades, and it was detected too late to trigger a Stop.
- FP Stops rate:
 - 0,4 Virtual Stops/day, with a mean duration of 36 s/day (27 Stops/67 days). In practice, this is 1 Stop every 2-3 days, with a duration of 90 s.
 - FP Stops have been produced mainly by Helicopters (70%) and Airplanes (26%).

D.4. Conclusions

DTBird® *Stop Control Module* has been installed in the WTG Calandawind, with the scope to Stop the WTG when a bird flight is detected in collision route or within a high collision risk area.

DTBird® *Stop Control Module* has been in Service along the *Study Period* without any repetitive failure of hardware or software component.

Along the *Study Period*, there have not been any flight with rotor swept area cross and the blades moving, nor Stops triggered by birds, but there have been 2 bird flights at the *RSA* height and in

- 5 In addition, there has been 1 single camera failure, which was out of service for 11 days, until recovery.

Collision Route at <50 m to the blades, that are considered collision risk flights: 1 flight of a not identified bird, and 1 raptor flight.

The results of the *Study Period* points out that raptors are protected Species that fly at the *RSA* height, and should be considered target Species, but no large flocks of migratory birds (>10 birds) have been detected at the *RSA* height.

The following modifications of DTBird® *System Pilot installation* and software refinements are proposed:

- Elevation of Cameras 2 and 4, from 5 m to 31 m height, with an expected reduction of bird flights detected below the *RSA* to <20%, better adjustment to the *RSA* height, and improved detectability at the highest height reached by the blades.
- Lower Filed of view of the Cameras 1 and 3, to detect target Species flights in Collision route at further distance, and to increase the time available to Stop the WTG.
- Soften the Stop criteria, to trigger Stops earlier.

The overall expected result is to trigger Stops in >75% of the target Species flights detected in Collision Route with the *RSA*, that reach <50 m to the blades.

There have been FP Stops triggered mainly by Helicopters and Airplanes. The following improvement is proposed to reduce these FP Stops:

- Software filter out of Helicopter/Airplanes

The expected result is to have < 0,2 Stops/day triggered by False Positives, with a mean duration <20 s/day.

Finally, it is proposed to reduce the Rotor Speed threshold to trigger a Stop to >3 rpm.

E. COLLISION CONTROL MODULE

E.1. Introduction

DTBird® *Collision Control Module* is a Software tool installed in the Analysis unit of DTBird® *System*, that allows to register in DTBird® *DAP* collisions of Medium to Big size birds, observed by the *Analyst* in the video and audio records of every bird flight.

In addition, it allows to request automatically an inspection *in situ* to confirm/discard collisions and to recover collided/injured birds, or to review potential collisions that have not been possible to discard with the review of video and audio records of the bird flight (No determined collision).

DTBird® *Collision Control* has the same Daily Service of DTBird® *Detection Module*: light > 50 lux.

The *Analyst* has a Collision field of data within DTBird® *DAP*, and has the following options to select for every bird flight:

- Collision: Yes, No, Not determined (ND).

When the *Analyst* register a Collision (YES) or a Not determined Collisions (ND), a data sheet is automatically produced, and the *Analyst* can store information regarding bird Species/Group, N° individuals, and particular environmental conditions. In addition, as noted above the *Analyst* can request automatically an inspection *in situ*, that is sent by email to the person in charge of these inspections.

According to DTBird® Team calculations, *Collision Detectability* in video and audio records should be >90%; therefore, It should be possible to detect Collision with the review of video and audio records, in >90% of the bird flights registered by DTBird® *System*.

E.2. Analysis

The *Study Period* has been the bird migration period of autumn, from 25/08/2014 to 31/10/2014, which corresponds to the first 2 month of Operation of DTBird® *System*.

DTBird® Team has reviewed and analysed all the bird flights within the Study period recorded in DTBird® *DAP*.

A collision has been noted when it has been observed in the video records that a bird has collided with the blades, the nacelle or the tower, and has been discarded when the bird has been observed flying away normally (not injured) from the *RSA* at the end of the video record. A Not determined collision (ND) has been noted when it has not been possible to discard the collision.

E.3. Results

According to the review of video and audio recordings by DTBird® Team, there have not been any Collision in the 274 bird flights (423 birds) detected by DTBird® *Detection Module* along the Study Period.

E.4. Conclusions

DTBird® *Collision Control Module* has been installed in the WTG Calandawind, with the scope to register collisions of Medium to Big size birds

DTBird® *Collision Control Module* has allowed to determine Collisions in 100% of the bird flight detected DTBird® *Detection Module*, quite above the expected result of >90%.

F. APPENDIX I. EXAMPLES OF BIRDS DETECTED

