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WILD LIFE FOR EVER
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The Project is co-funded by the European Regional Development Fund (ERDF) and by national funds of the countries participating in the Cooperation Programme Interreg V-A "Greece-Bulgaria 2014-2020.

Wild Life For Ever

D5.5.1. End user's requirements and definition of the flying surveillance system specifications

Project starting date: 10/11/2017	Project Duration: 50 months
Deliverable Responsible:	Aristotle University of Thessaloniki (PB5)
Work Package Leader:	Aristotle University of Thessaloniki (PB5)
Project Coordinator:	Region of Eastern Macedonia and Thrace (PB1)
Version:	1-0

Project website: http://www.wildlife4ever.eu

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1 Summary

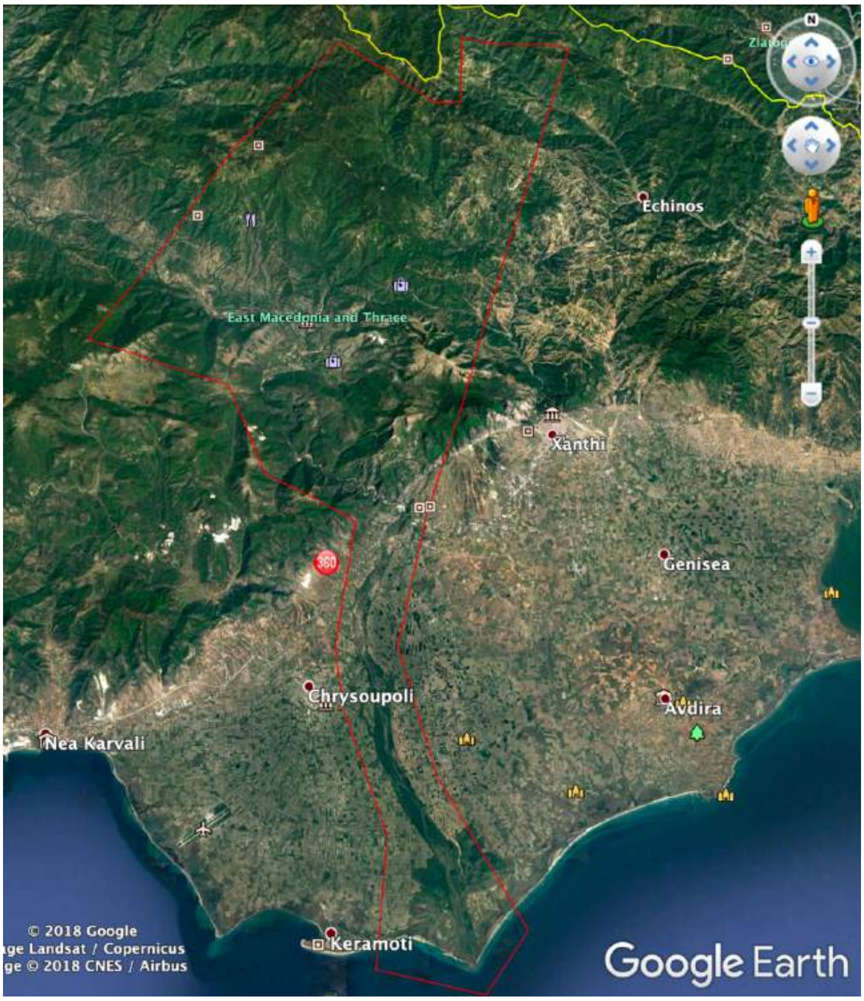
The present report was produced by the Aristotle University of Thessaloniki-AUTH (PB5 entity) and serves as the deliverable D5.5.1 – End user's requirements and definition of the flying surveillance system specifications and aims to the extraction of the technical specifications of an Unmanned Aerial System (UAS), which will be able to cover the operational requirements posited by Decentralized Administration of Macedonia & Thrace/ General Directorate of FORESTS & RURAL AFFAIRS (PB2) as the end user of the system.

More specifically, PB2, based on their requirements as the end user of the system, defined the types of missions the UAS must perform, which cater to needs for the aerial coverage of the Nestos area wildlife, live stream transmission at the visitor reception point in Stavroupoli, Xanthi, the depiction and mapping of the Nestos estuary area (Nestos Delta), as well as the surveillance of the areas of interest.

Based on the flight missions the UAS must accomplish, which were defined by PB2, as well as the occurring operational requirements, PB5, through aerodynamic analyses and using the verified tools of the aerodynamic design team of AUTH for aerodynamic analysis, design and manufacture of unmanned aerial vehicles, will determine the essential technical specifications of the UAS, based on which PB2 will purchase it.

2 UAS Operational Requirements

Based on the requirements of the Wild Life For Ever project, the UAS must operate in the Greek-Bulgarian border area and more specifically, in the Nestos and Rhodope Area. The operational area of the UAS is demarcated by the red frame in Picture 1.



Picture 1: The coverage area into which the UAS will operate

PB2 has defined the missions the UAS will perform so as to cover the needs *(and accounting for the approved budget for the purchase of the UAS*) for:

1. Monitoring the wildlife in the Rhodope and Nestos area (subregion inside the red outline in Picture 1).
2. Live stream transmission from the coverage area (subregion inside the red outline in Picture 1, determined by the UAS operator accounting for visibility and weather conditions) to the visitor reception station in Stavroupoli, Xanthi.
3. High definition photo and video recording, aiming for use in educational, scientific as well as exhibition purposes, as well as for the surveillance and protection of the areas of interest (e.g, feeders located at determined points in the forest).
4. Mapping the area adjacent to the Nestos estuary (Nestos Delta) as well as the rest of the areas of interest.

Furthermore, PB2 required that the UAS be capable of easy and quick assembly, deployment and transportation to the field, as well as the ability to be transported in a backpack, so that one and only one person can transport and deploy the UAS in the field of operation. Accounting the need for UAS deployment by one and only one person, the ability to connect the controller with an operating system is required, as well as the ability for automatic navigation in mapping missions.

Table 1: UAS operational requirements based on flight mission

#	Mission description	Mission requirements
1	Monitoring of fauna in the Rhodope and Nestos area (sub-region within the red polygon in Figure 1)	• Capability of 720p resolution of image capturing • Capability 360p / 720p video streaming (live-streaming) • At least 4km maximum range • At least 45min endurance • At least 150m maximum flight altitude • Fast and easy transportation (portability)
2	Live streaming video at Stavroupoli Xanthi guest reception (coverage area: sub-area within the red border of Figure 1)	• Capability of 720p resolution of image capturing • Capability 360p / 720p video streaming (live-streaming) • At least 4km maximum range • At least 45min endurance • At least 150m maximum flight altitude • Fast and easy transportation (portability)
3	High resolution videos and images for educational, scientific and demonstration purposes, as well as for monitoring areas of interest (e.g feeders located in specific areas in the forest)	• Capability of 1080p resolution of image capturing • Vertical takeoff and landing capability, hovering capability • Fast and easy portability • Capability of extended endurance via extra battery packs
4	Mapping of the area adjacent to the estuary of Nestos (Delta of Nestos) and other areas of interest.	• At least 59 min of endurance • At least 7.5 km range • Capability of remote control via PC or tablet with a ground station navigation system • Camera equipment for photogrammetric applications • Photogrammetric software • Fast and easy transportation (portability)

Based on the operational requirements resulting from the abovementioned flight missions, the aerodynamic design team of AUTH (PB5) will determine the technical specifications of the UAS, based on which PB2 will proceed to the purchase of the UAS.

3 UAS Technical Specifications

The technical specifications of the UAS result from aerodynamic analyses, performed by the aerodynamic design team of AUTH (PB5). The computations and aerodynamic analyses were conducted using the verified tools of the aerodynamic design team of AUTH (PB5) for aerodynamic analysis, design and manufacture of unmanned aerial vehicles.

For each type of mission prescribed by PB2 and based on the resulting operational requirements, an aerodynamic analysis and calculation of geometrical and aerodynamical features was conducted, aiming for the determination of the optimal UAS specifications, so that the UAS fulfills the operational requirements of the corresponding mission. The results of the aerodynamic analyses showed that, for optimal coverage of the entirety of the missions of Table 1, a system of three (3) UAVs is required, two (2) fixed wing UAVs and one quadcopter UAV. The results of the aerodynamic studies for each of the four missions from Table 1 are presented comprehensively below.

1st and 2nd Missions

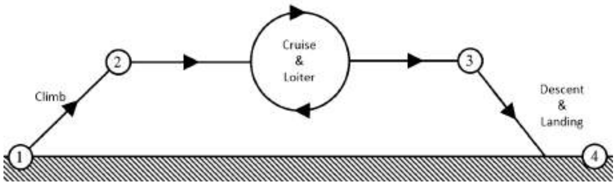
Based on the operational requirements of the 1st and 2nd missions, as defined in Table 1, a need is shown for an Unmanned Aerial Vehicle (UAV) capable of performing a flight mission with the following features:

- Capability of photo capture with a definition of at least 720p
- Capability of live stream transmission with definition 360p/720p
- Maximum range of at least 4km
- Maximum endurance of at least 45min
- Maximum flight altitude of at least 150m
- Capability of quick and easy transport

Flight profile of the 1st & 2nd missions

The profile of the mission performed by the UAV is defined for optimal performance and coverage of each mission's requirements, which in this particular case (1st mission) includes monitoring the wildlife in the area of interest, as well as (2nd mission) live streaming transmission from the point of interest to the visitor reception point in Stavroupoli, Xanthi.

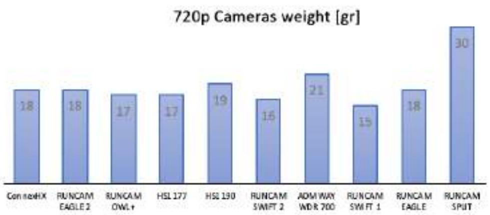
The mission profile (1st & 2nd) is qualitatively shown in Picture 2. These missions are studied together, as they have the same requirements in equipment as well as flight characteristics. The mission profile consists of the climb phase (1-2) up to the flight altitude of 150m, the monitoring phase (2-3) during which the 1st mission is performed by monitoring the area's wildlife with the camera equipment, and the landing phase (3-4).



Picture 2: Flight profile of the 1st & 2nd missions of the UAV

Payload

The camera equipment, capable of photo/video recording with a definition of at least 720p and live streaming, is defined as the payload the UAV must carry for the 1st and 2nd missions. The main feature of this type of equipment, regarding the determination of the UAV's technical specifications, is its weight. Consequently, extensive research was conducted throughout the aerodynamic study, regarding the weight of equipment fulfilling the specifications of the 1st mission, (picture recording and transmission with a 720p definition), resulting in a maximum weight of camera equipment, capable of 720p photo/video recording, of approximately 30gr, as shown in the chart in Picture 3.

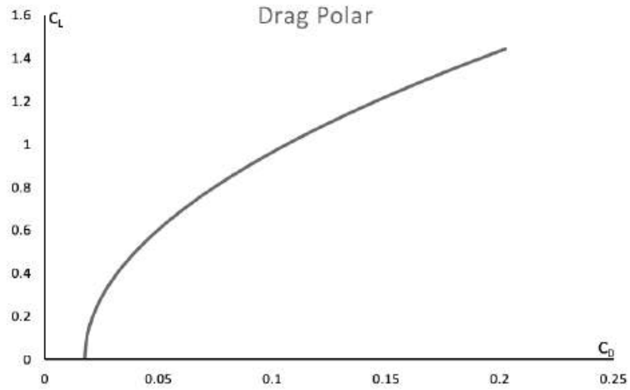


Picture 3: Weight of camera equipment with photo and video of 720p definition recording capability

Furthermore, the weight of the autopilot equipment, the live streaming transmission of photo/video and the weight of the sensors necessary for the UAV's optimal flight (velocity measurement sensor or Pitot tube) was estimated, after researching the market-available sensors, at 150 gr.

Geometrical and flight specifications of the UAV

Based on the mission-defined maximum range (at least 4km), flight endurance (at least 45min), as well as payload weight (180gr), the aerodynamic analyses conducted by AUTH (PB5) showed that, for the optimal accomplishment of the 1st and 2nd missions, a fixed wing UAV is required, with a drag polar similar to the one presented in the chart in Picture 4 and with geometrical and technical specifications similar to those presented in Table 2.



Picture 4: Drag polar of the UAV performing the 1st & 2nd missions

Table 2: *Geometrical and technical specifications the UAV must satisfy during the 1st & 2nd missions*

#	Type	Requirement
1	UAV type	Fixed wing
2	Engine-motor type/number	Electric/one(1)
3	Battery type	Li-Poly
4	Material	Expanded Polystyrene Foam (EPF)
5	Weight	< 800gr
6	Maximum endurance	45min
7	Wingspan	115cm
8	Nominal RF range	2km
9	Recording equipment	Digital camera 1080p with image stabilizer and pan & tilt ability
10	Quality of live streaming video	Video streaming 360p/720p
11	Takeoff	Hand launched
12	Landing	Automatic and manual
13	Flight control	GPS + GLONASS
14	Wind velocity sensor	Pitot tube
15	Altitude sensor	Altimeter
16	Measuring equipment that define the distance between the UAV and the ground	Ultrasonic sensor
18	Software compatibility	Android & iOS
19	Portability	Removable wings for easy transport and storage
20	Transport equipment	Compact backpack that can store all the equipment (batteries, charger, UAV and transmitter)

UAV ground control station specifications

In order for the UAV to be able of optimally executing the 1st and 2nd missions of Table 1, it must be navigated by a modern software adhering to the specifications of Table 3.

Table 3: Ground control station software specifications

#	Type	Requirement
1	operating system compatibility	Android & iOS
2	Display	telemetry and imaging data support
3	Controllability via software	Manual adjustment of cameras

3rd Mission

Based on the operational requirements of the 3rd mission, as defined in Table 1, a need is shown for an Unmanned Aerial Vehicle (UAV) capable of performing a flight mission with the following features:

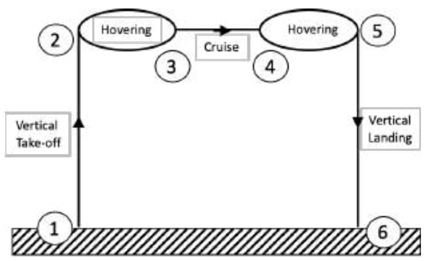
- Capability of photo capture with a definition of at least 1080p
- Capability of vertical takeoff and landing, and hovering, aiming for photo/video recording over areas with limited optical accessibility
- Capability of vertical camera transposition, aiming for photo/video recording which will follow the monitored "target"
- Capability of quick and easy transport
- Capability of endurance extension through backup batteries, aiming for coverage of mission requirements

Flight profile of the 3rd mission

The profile of the mission performed by the UAV is defined for optimal performance and coverage of requirements for vertical takeoff and landing, as well as stationary image capture at locations with limited optical accessibility. Specifically, for photo capture in areas with limited optical accessibility, the ability of hovering above the area of interest, as well as the ability of vertical takeoff/landing and automatic flight, is required.

For the optimal execution of this type of mission, the UAV selected must be a multicopter Unmanned Aerial Vehicle, which will follow a flight profile similar to the one in Picture 5.

The mission profile is qualitatively shown in Picture 5. The mission consists of the vertical takeoff phase (1-2), the hovering phase (2-3), during which the stationary picture and video recordings required by the 3rd mission can be carried out, the horizontal flight phase (3-4) up to the next hovering position (4-5), during which further photo and video recordings are conducted, and, finally, the vertical landing phase. (5-6).



Picture 5: Flight profile of the 3rd mission of the UAV

Payload

The camera equipment, capable of photo/video recording with a definition of at least 1080p, live stream transmission and vertical transposition, in order to guide photo and video recording to follow the "target", is defined as the payload the UAV must carry during the 3rd mission. The main feature of this type of equipment, regarding the determination of the UAV's technical specifications, is its weight. In this case, the weight of the camera equipment, as well as the rest of the UAV's navigational equipment, after extensive research of market-available camera/navigation systems, was estimated at 100gr.

Technical specifications of the UAV

Based on the mission-defined takeoff/landing type (vertical takeoff/landing) and flight type (hovering) of the UAV, the photo/video recording quality (at least 1080p), the vertical camera transposition capability, as well as payload weight (100gr), the aerodynamic analyses conducted by AUTH (PB5) showed that, for the optimal execution of the

3rd mission, a multicopter (and specifically quadcopter) unmanned aerial vehicle is required, with technical specifications similar to those presented in Table 4.

Table 4: Technical specifications the UAV must satisfy during the 3rd mission

#	Type	Requirement
1	UAV type	TQuadcopter
2	Engine-motor type/number	Electric/four(4)
3	Battery type	Li-Poly
4	Takeoff and landing	Vertical takeoff and landing
5	Adverse wind conditions	50 km/h
6	Weight	< 390gr
7	Maximum endurance	25min
8	Flight	Flight capability using a ground PC and radio-telemetry station
9	Nominal RF range	2km
10	Recording equipment	Gimbal with 21 mega-pixel camera (3-axis stabilizer)
11	Quality of live streaming video	Liv e streaming 4k video
12	Camera control	Ability of vertical camera control about 180^o
13	Software compatibility	Android & iOS
14	Portability	Retractable gears for easy transportation
15	Transport equipment	Compact backpack that can store all the equipment (batteries, charger, UAV and transmitter)
16	Spare flight equipment	The UAV will have 4 spare propellers, 4 spare batteries and a 16 Gb SD card

UAV ground control station specifications

In order for the UAV to be able of optimally executing the 3rd mission of Table 1, it must be navigated by a modern software adhering to the specifications of Table 5.

Table 5: Ground control station software specifications

#	Type	Requirement
1	operating system compatibility	Android & iOS
2	Display	telemetry and imaging data support
3	Controllability via software	Manual adjustment of cameras

4th Mission

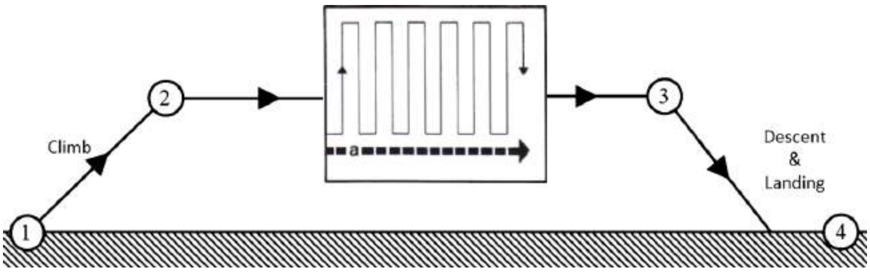
Based on the operational requirements of the 4th mission, as defined in Table 1, a need is shown for an Unmanned Aerial Vehicle (UAV) capable of performing a flight mission with the following features:

- Maximum endurance of at least 59 min
- Maximum range of at least 7.5 km
- Capability of computerized flight with a customized navigation system from a ground control station
- Appropriate camera equipment, capable of capturing photos appropriate for photogrammetry applications
- Photogrammetric picture analysis software, capable of producing orthophotomaps as well as ground modelling in lidar point cloud (LAS) format
- Capability of quick and easy transport

Flight profile of the 4th mission

The profile of the mission performed by the UAV is defined for optimal performance and coverage of the mission's requirements, which in this case includes the mapping of the region adjacent to the Nestos estuary (Nestos Delta), as well as the rest of the areas of interest, through photogrammetric techniques and analyses.

The profile of the 4th mission is qualitatively shown in Picture 6. The mission consists of the climb phase (1-2) and the phase (2-3) of capturing the necessary photos for the mapping. Phase (2-3) is the most important at mapping/photogrammetry missions, during which flight must be autonomous/automatic and be performed with specific flight patterns. Finally, the flight is completed with the landing phase (3-4).



Picture 6: *Flight profile of the 4th mission of the UAV*

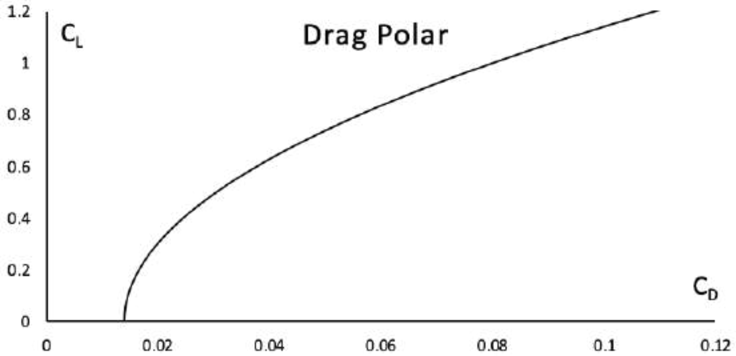
Payload

The camera equipment, capable of capturing photos appropriate for photogrammetry applications, is defined as the payload the UAV must carry during the 4th mission. The main feature of this type of equipment, regarding the determination of the UAV's technical specifications, is its weight. Consequently, extensive research was conducted throughout the aerodynamic study, regarding the weight of equipment fulfilling the specifications of the 4th mission, resulting in a maximum weight of camera equipment, capable of capturing pictures appropriate for photogrammetry applications, of 300gr.

Furthermore, the weight of the autopilot equipment, the recording and storage system, as well as the weight of the sensors necessary for the UAV's optimal flight, (velocity measurement sensor or Pitot tube) was estimated, after researching the market-available sensors, at 150 gr.

Geometrical and flight specifications of the UAV

Based on the mission-defined flight endurance (at least 59min), as well as payload weight (550gr), the aerodynamic analyses conducted by AUTH (PB5) showed that, for the optimal accomplishment of the 4th mission, a fixed wing UAV is required, with a drag polar similar to the one presented in the chart in Picture 7 and with geometrical and technical specifications similar to those presented in Table 7.



Picture 7: Drag polar of the UAV performing the 4th mission

Due to the peculiarities of the type of the 4th mission (mapping), specific attention has been paid to the technical specifications of the camera (lens, shutter speed, ISO range, lens aperture e.a.).

Table 6: Geometrical and technical specifications the UAV must satisfy during the 3rd mission

A/A	Type	Requirement
1	UAV type	Fixed wing
2	Engine-motor type/number	Electric/one(1)
3	Battery type	Li-Poly
4	Weight	< 1400gr
5	Maximum endurance	59min
6	Wingspan	From 100cm to 120 cm
7	Nominal RF range	3km
8	Maximium RF range	8km
9	Flight speed	40-110km/h
10	Adverse wind conditions	12m/s
11	Takeoff	Hand launched
12	Landing	Automatic and manual
13	Flight	Flight capability using a ground PC and radio-telemetry station
14	Automatic navigation accuracy	RTK GPS which will achieve accuracy up to 2.5cm without the use of control points
15	Wind velocity sensor	Pitot tube
16	Measuring equipment that define the distance between the UAV and the ground	Range finer
17	Recording equipment	Camera 20 mega-pixel & sensor of 1 inch category
18	Camera lens	Camera 29mm that match 35mm
19	Lens diaphragm	f2.8 - 11
20	Shutter speed	1/500s – 1/2000s
21	ISO - range	100 – 9000 (automatic white balance)
22	Camera mounting system	Gimbal system to automatically capture a vertical photo and two sidewalls at each shooting position in order have accurate 3D modeling of the physical space
23	Software compatibility	Android & iOS

UAV ground control station specifications

In order for the UAV to be able to optimally execute the 4th mission of Table 1, it must be navigated by a modern software, capable, among others, of flight planning on a map, confining the UAV's flight inside a user-defined area, reading and importing necessary files for mapping and photogrammetry applications (.kml files), as well as defining an automatic landing point different to the takeoff point.

Due to the peculiarity of the 4th mission (mapping and photogrammetry), a lot of attention is paid to the specifications of the ground control station software, so that the mission is performed optimally, safely and with minimum error possibility. Table 7 presents all the necessary specifications of the ground control station software, which must be fulfilled for the optimal execution of the 4th mission of Table 1.

Table 7: Ground control station software specifications

#	Type	Requirement
1	Operating system compatibility	Windows 7 or newer
2	Mission planning	Flight planning on a free (open source) map cartographic data services
3	Geofencing	The software allows the introduction of horizontal and vertical geofencing so that the UAV will operates within a certain region
4	Data compatibility	The software allows the import of raster map of the user as well as kml type files
5	Auto flight planning	The software must be able provide an appropriate automatic flight planning routine with parameters such as desired pixel size and photo overlay rate
6	Flight simulation	Ability to simulate the flight taking into account parameters such as wind speed and direction in order to generate statistics such as photo overlap rate, number of photos, flight duration and flight distance
7	Set landing position	Ability to set the point of landing
8	Visualization of the flight path	Ability to 3D visualize the cartographic background and flight lines

Photogrammetry software specifications

To complete the 4th mission of Table 1, after the end of the flight of the UAV, the pictures captured must be collected and imported in a suitable photogrammetry software, so that the mapping process is complete. For this reason, the UAS must contain a photogrammetry software cooperating with the UAV's photographic equipment. Table 8 presents the necessary specifications the photogrammetry software of the UAS must satisfy.

Table 8: Photogrammetry software specifications

#	Type	Requirement
1	Operating system compatibility	Windows 7 or newer
2	Compatibility with photographic equipment	Full support of the photographic equipment of the proposed UAV of the 4th mission as well as, upgrade possibility to a NIR in Multispectral and thermal camera
5	Orthophoto maps development	Ability of TIF orthophoto maps development
6	Tie points calculation	Auto calculation of 2D and 3D tie points
7	Manual waypoints	Available tools for manual waypoints
8	Image processing	Provide False color image processing routines and NDVI image generation capability
9	Drawing representation	Ability to render drawings on the cloud by calculating 3D lengths and volumes as well as the ability to store lines and polygons in 2D / 3D format and in Dxf and Shapefile format
10	Production of models from video	Ability to produce 3D models from video
11	Interaction with other software	Ability to titrate and interact with other software

4 Results & Conclusions

Based on the results of the aerodynamic analyses, aiming for the optimal performance of the entirety of the missions of Table 1, the AUTH (PB5) entity proposes the purchase of a UAS consisting of three (3) UAVs, in order to cover the operational requirements of the PB2 entity. Specifically, the purchase of two (2) fixed wing UAVs and one (1) quadcopter UAV is proposed. The required technical and geometric specifications, as well as the required specifications of the ground control station and photogrammetry software, are described in Tables 2 to 8 of Chapter 3.

A UAS adhering to the abovementioned technical specifications can optimally perform all the missions of table 1 (also accounting for the approved available budget), posited by the Decentralized Administration of Macedonia & Thrace/ General Directorate of FORESTS & RURAL AFFAIRS entity (PB2) as the end user of the system.

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Wild Life For Ever

D5.5.2. Selection, purchase and modifications/adaptations of the flying surveillance system

Project starting date: 10/11/2017 Project Duration: 50 months

Deliverable Responsible:	Aristotle University of Thessaloniki (PB5)
Work Package Leader:	Aristotle University of Thessaloniki (PB5)
Project Coordinator:	Region of Eastern Macedonia and Thrace (PB1)

Version: 1-0

Project website: http://www.wildlife4ever.eu

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1 Summary

The present report, that serves as the deliverable D5.5.2 - Selection and modifications / adaptations of the purchased by PB2 flying surveillance system, was produced by the Aristotle University of Thessaloniki-AUTH (PB5 entity). Its aim is to present, the methods regarding the selection the Unmanned Aerial Systems (UASs) that will perform missions defined by the Decentralized Administration of Macedonia & Thrace/ General Directorate of FORESTS & RURAL AFFAIRS (PB2 entity), provide a range of possible platforms capable of achieving the aforementioned missions and describe any necessary modifications.

More specifically, PB5 selected three different UAS that can be used for the missions defined by PB2, based on the requirements presented in D5.5.1. The selection was based on the desired flight characteristics, software compatibility, as well as portability, and the UAS selected are capable of performing the required missions in the best possible manner, after the necessary modifications.

2 Selection and modification of the UAS

Based on the mission profiles defined by the Decentralized Administration of Macedonia and Thrace (PB2), the necessary mission requirements of the UAS have been defined in D5.5.1 – End user's requirements and definition of the flying surveillance system specifications, by the AUTH team. These mission requirements serve as guidelines for the identification of suitable UAS, their selection based on the possible modifications that can be performed, and finally for their purchase proposal by PB2. The mission requirements of missions 1 and 2 (Monitoring of fauna in the Rhodope and Nestos area & Live streaming video at Stavroupoli Xanthi guest reception) are identical, and thus a single UAS can perform both missions. For that reason, only three different UAS are selected.

1st & 2nd Mission

Missions 1 and 2 among others require adequate live video streaming (with resolutions higher than 360p), good image capturing capability, a weight of less than 800gr and typical range and endurance. Based on these requirements the battery powered, fixed-wing Parrot Disco Unmanned Aerial Vehicle (UAV) is identified and selected. In Figure 1 the UAV is shown fully assembled, as well as packed in it's dedicated backpack case for fast and easy transportation.

Figure 1: The Parrot Disco UAS that is selected for the 1st & 2nd mission

In Table 1 the mission requirements of the first and second missions that are fullfiled by the Parrot Disco are presented. Though the UAS fullfills all the necessary mission requirements as defined in D5.5.1, it is deemed necessary to perform specific modifications, to ensure that the live video streaming capability of the UAV will not be compromissed when operating at its maximum range (as in the case of mission 1, when the Nestos area is covered). In order to achieve that, a 4G video transmitter was properly installed, thus eliminating any video streaming related contrains. In Figure 2 a photo taken during the modifications by the AUTh team is presented.

Table 1: Mission requirements and Parrot Disco capabilities

1st & 2nd Mission Requirements	Parrot Disco
Capability of 720p resolution of image capturing	✓
Capability 360p / 720p video streaming (live-streaming)	✓
At least 4km maximum range	✓
At least 45min endurance	✓
At least 150m maximum flight altitude	✓
Fast and easy transportation (portability)	✓
Live streaming at the UAVs maximum range	✓

Figure 2: Members of the AUTH team while performing the modifications to the Parrot Disco UAS

3rd Mission

Regarding mission 3, the most important requirement is that of the Vertical Take Off and Landing (VTOL), as well as hovering capability by the UAV, to provide stationary image capture at locations with limited optical accessibility. The VTOL related requirements combined with the relatively small endurance, dictate that the suitable UAV must be a multirotor configuration rather than a fixed-wing, so that the overall weight is kept as low as possible and thus increasing the UAS's portability. The Anafi work UAS (Figure 3) is identified and selected as the most suitable for this specific mission profile, due to its excellent flight and handling qualities, video capturing capability and ease of operation and transportation. In Table 2 the mission requirements of the third mission that are fullfiled by the Anafi Work are presented. The Anafi Work has an adequate control software, compatible with both Android & iOS, supports telemetry and data imaging, and allows manual adjustment of its camera.

Figure 3: The Anafi Work UAS that is selected for the 3rd mission

Table 2: Mission requirements and Anafi work capabilities

3rd Mission Requirements	Anafi work
Capability of 1080p resolution of image capturing	✓
Vertical Take Off and Landing capability, hovering capability	✓
Fast and easy transportation (portability)	✓
Capability of extended endurance via extra battery packs	✓

4th Mission

The requirements of the 4th mission are greater than the previous three and thus a more advance UAS is required. Specifically, during its mission the UAS will perform mapping of the region adjacent to the Nestos estuary (Nestos Delta) through photogrammetric techniques, and thus must have the capability to be remote controlled via PC or tablet with a ground station navigation system. Due to the greater endurance and maximum range that is required for this mission, as well as the heavier and more sophisticated camera payload and autopilot system, the UAV must have a fixed-wing configuration. The most suitable candidate is the eBee X UAS, presented in Figure 4. In Table 3 the mission requirements of the fourth mission that are fullfiled by the eBee X are presented. The eBee X is navigated by a moden software that allows map flight planning and fully autonomous operation.

Figure 3: The eBee X UAS that is selected for the 4th mission

Table 3: Mission requirements and eBee X capabilities

4th Mission Requirements	eBee X
At least 59 min of endurance	✓
At least 7.5 km range	✓
Capability of remote control via PC or tablet with a ground station navigation system	✓
Camera equipment for photogrammetric applications	✓
Photogrammetric software	✓
Fast and easy transportation (portability)	✓

3 Conclusions

Based on the mission requirements and technical specifications identified by AUTh (PB5) in deliverable D5.5.1 – End user's requirements and definition of the flying surveillance system specifications, three UAS are selected, and suggested for purchase by the Decentralized Administration of Macedonia & Thrace/ General Directorate of FORESTS & RURAL AFFAIRS (PB2). These UAS, after the necessary modification required for the successful completion of mission 1, are capable of optimally performing all the mission profiles defined by the end user (PB2). Specifically, missions 1 and 2 can be performed by the Parrot Disco (fixed-wing), mission 3 by the Anafi Work (quadcopter) and mission 4 by the eBee X (fixed-wing).

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WILD LIFE FOR EVER
European Regional Development Fund

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Wild Life For Ever

D5.5.2. [Additional Activities] – Studies of modifications on the flying surveillance system to minimize any negative impact on fauna of Nestos and Ardas region.

Project starting date: 10/11/2017	Project Duration: 50 months
Deliverable Responsible:	Aristotle University of Thessaloniki (PB5)
Work Package Leader:	Aristotle University of Thessaloniki (PB5)
Project Coordinator:	Region of Eastern Macedonia and Thrace (PB1)
Version:	1-0

Project website: *http://www.wildlife4ever.eu*

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1 Summary

The present report, that serves as the deliverable D5.5.2-additional actions, was produced by the Aristotle University of Thessaloniki-AUTH (PB5). Its aim is to present, the methods and adaptations regarding the optical and acoustic camouflage of the selected Unmanned Aerial System (UASs) that will perform missions defined by the Decentralized Administration of Macedonia & Thrace/ General Directorate of FORESTS & RURAL AFFAIRS (PB2 entity). More specifically, PB5 assessed the weather and terrain conditions of Nestos and Ardas area. More specifically, PB5 took into consideration the cloud coverage, the rain forecast, the terrain patterns and the local flora. Additionally, PB5, conducted computational fluid dynamics (CFD) analyses regarding the flow-field around the selected UAS in order to recognize and assess the noise production sources and noise propagation in the flow field.

2 Optical Camouflage of the UAS

During the analyses, a new painting scheme selection process was followed. First of all, the terrain as well as the weather conditions of Nestos area were examined thoroughly (Figure 1).

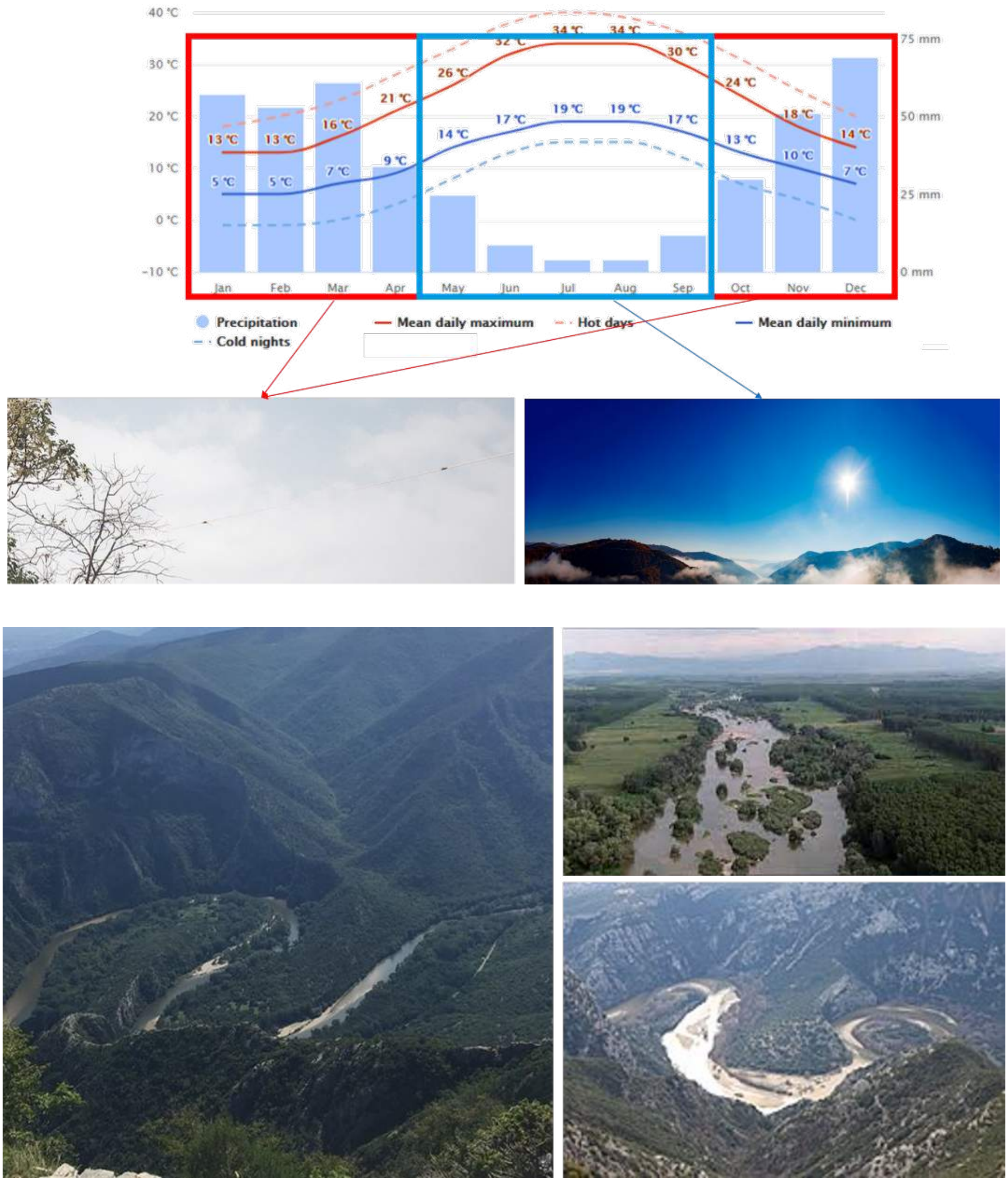

Figure 1: Nestos weather conditions (top) Nestos terrain (bottom).

It is clear from Figure 1, that the Nestos area is mostly covered by clouds (high cloud coverage from January to April and October to December) with low temperatures. Additionally, the terrain is mostly cover with dark-green flora and rocks, thus leading to darker colour schemes.

The impact of the terrain as well as the weather conditions on the optical camouflage painting scheme of the UAS can be seen at Figure 2.

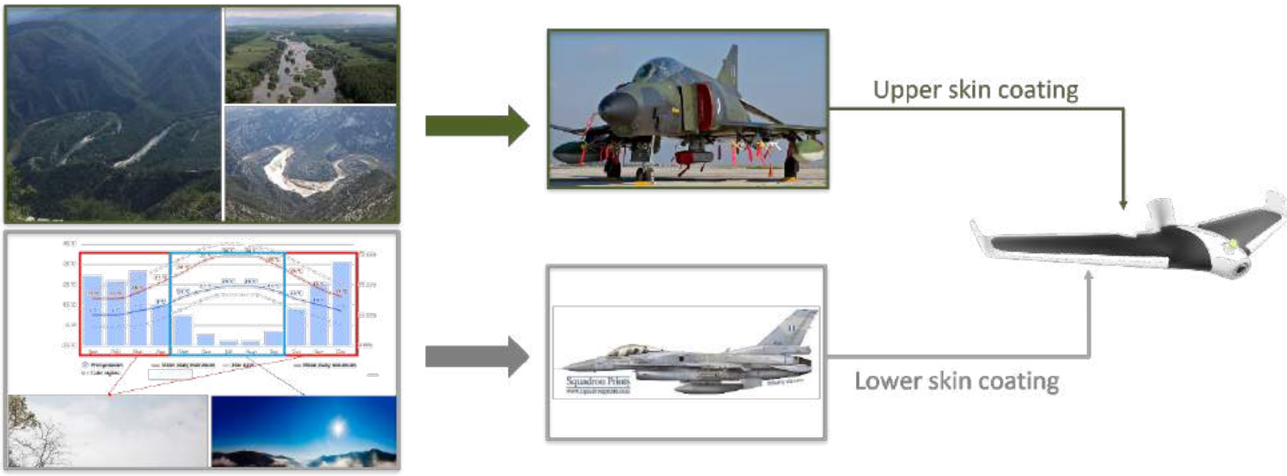

Figure 2: Nestos terrain and Nestos weather conditions and their respective impact on the UAS camouflage.

It is really important to mention here that, the selected painting schemes, have already been used successfully at the Hellenic Air Force (HAF) manned aircrafts.

3 CFD computations

In an attempt to simulate the aerodynamic phenomena and the noise emitted for the selected UAS, a number of computational fluid dynamics (CFD) simulations should be carried out. Three different angles of attacks (AoA) were studied (0o, 2o and 4o). These angles were selected as typical values encountered during the cruise flight phase. The selected Unmanned Aerial System (UAS) was the Parrot Disco FPV.

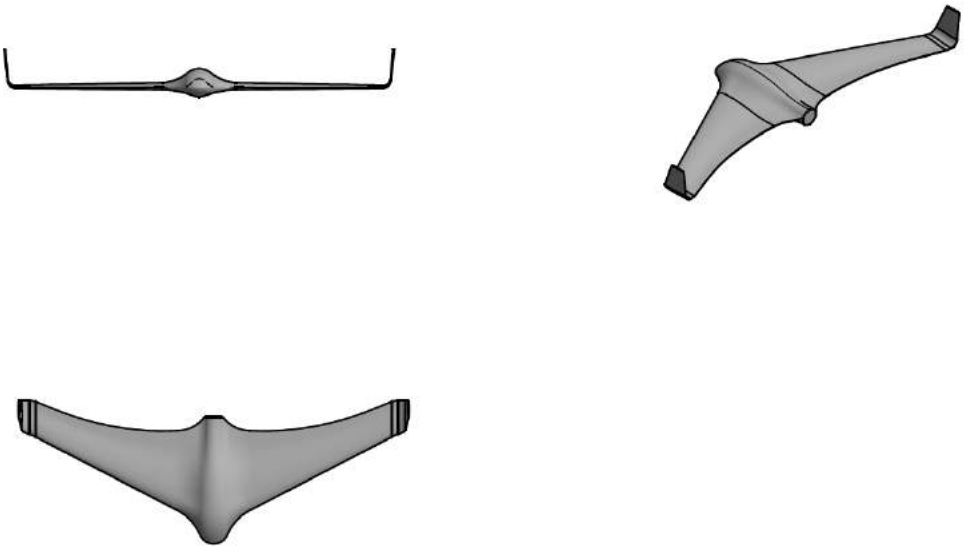

Figure 3: Parrot Disco FPV UAs.

3.1 Computational mesh

To conduct the CFD computations, the appropriate computational mesh was constructed. The examined CAD file was inserted to the BETA CAE Systems ANSA mesh generator, and around the UAS model, a computational domain was made. The control volume dimensions were 3500 mm in front of, above and below the UAS, 7000 mm behind and 5600 mm in the spanwise direction (Figure 4).

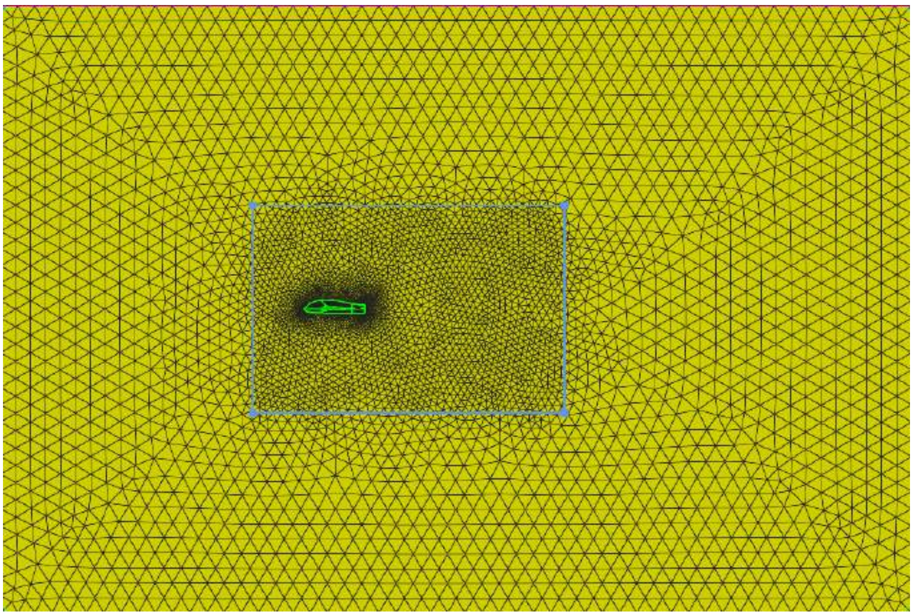

Figure 4: Computational domain at symmetry plane.

The constructed mesh was a combination of structured and unstructured grid. The unstructured grid (triangular elements) was used at the UAS's and the control volume's surfaces. The grid was finer at the areas of interest, such as the leading edge, the trailing edge and the winglet region (Figures 5 and 6), in an attempt to improve the accuracy of the computations. These regions experience phenomena like flow separation, intense velocity and pressure gradients and the wingtip vortex.

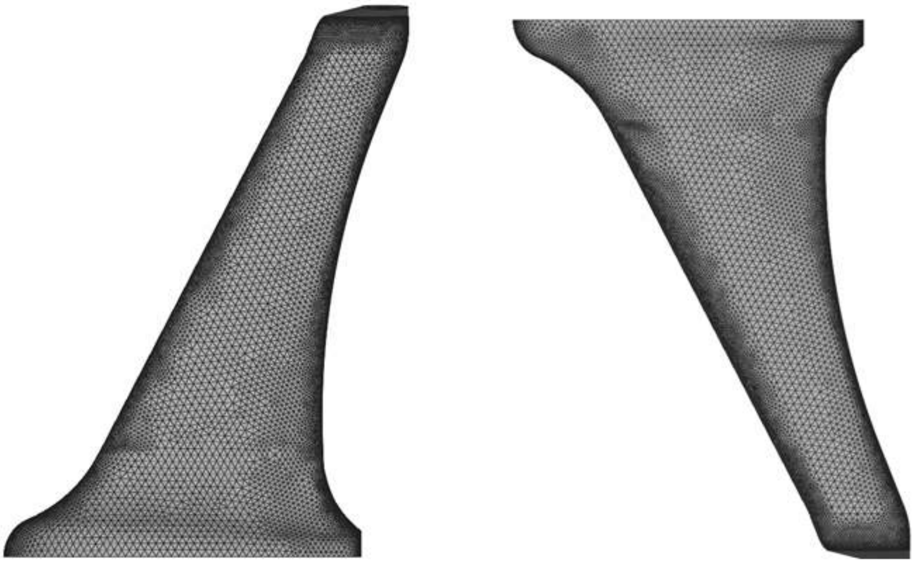

Figure 5: Surface mesh at the top and bottom UAS' surfaces.

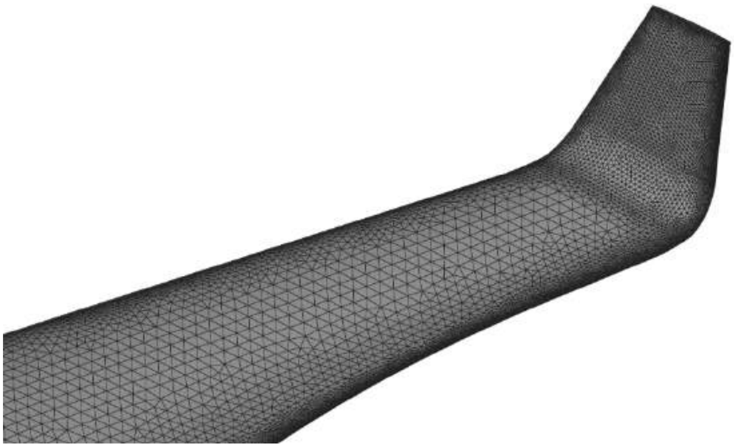

Figure 6: Surface mesh at the wingtip region.

The structured grid (quad elements) was used at the regions close to the UAS' surfaces to encapsulate accurately the boundary layer phenomena (Figure 7). To achieve this, the first layer height was set to 0.017 mm and the calculated y+ value was below five (the maximum value was located close to the leading edge) for the examined cases (Figure 8). The aforementioned choices ensure the accuracy of the boundary layer related calculations.

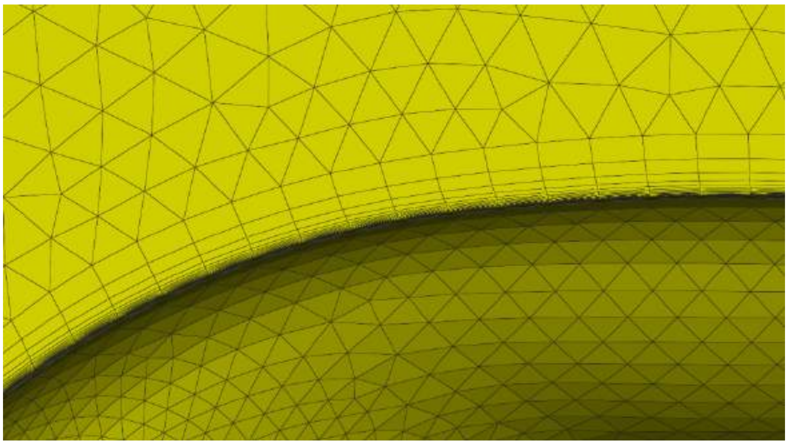

Figure 7: Structured grid (inflation layers).

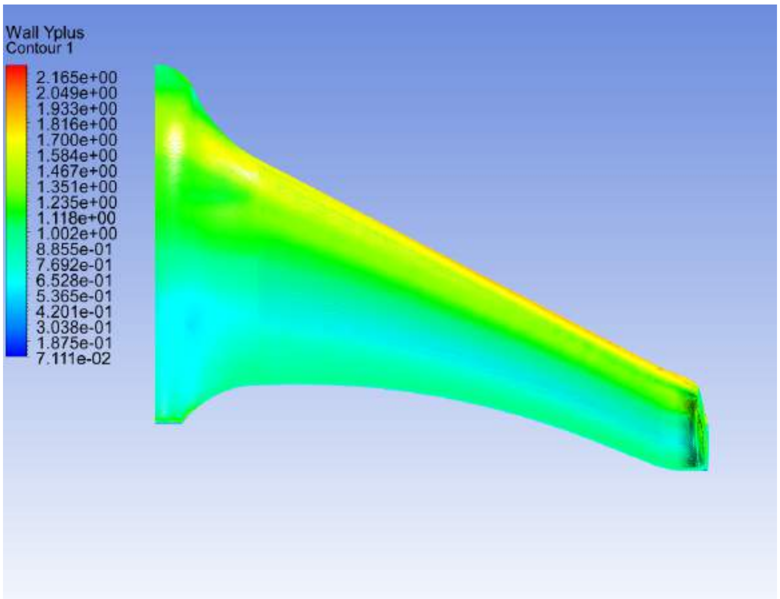

Figure 8: Y+ contour at angle of attack (AoA) 2° (suction side).

In addition, a size box, in which the mesh was denser, was constructed to better capture the wake, the wingtip vortex and the fluidic phenomena close to the UAS (Figure 9).

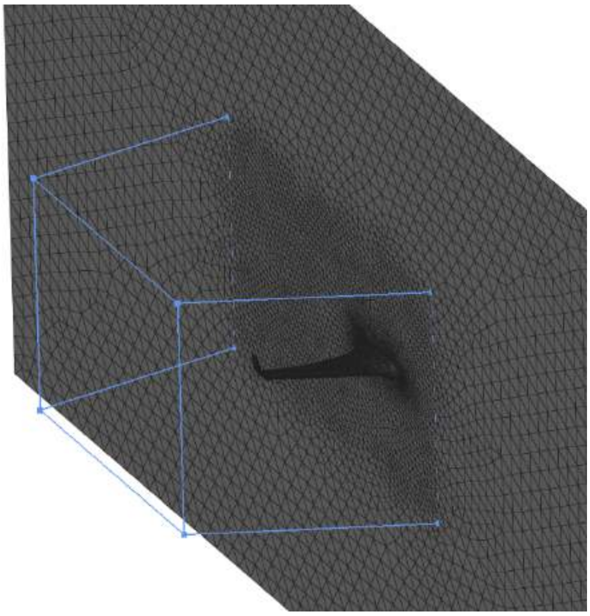

Figure 9: Size box around the UAS model.

The resulted mesh consisted of 6,199,737 cells or 2,072,554 nodes.

3.2 CFD setup

The computational analyses were conducted in the ANSYS Fluent. The flow was assumed to be incompressible (constant density throughout the flow field), due to the very low Mach number. Also, the steady state (time independent) Reynolds Averaged Navier Stokes (RANS) equations were solved. The RANS equations were closed with the two- equation k-w SST turbulence model for the turbulence modeling. The accuracy of the aforementioned turbulence model is proven in the aerospace industry by the literature. The simulated fluid was air, the operational conditions correspond to sea level conditions and the free stream velocity was 19 m/s. The reference length was the mean aerodynamic chord length of the wing, which was equal to 0.369 m. For the turbulence model, the turbulent kinetic energy and the specific dissipation rate were chosen as the boundary conditions. The calculated values for the turbulence model were calculated using the appropriate equations from "***Effective Inflow Conditions for Turbulence Models in Aerodynamic Calculations***" by P.R.Spallart and C.L.Rum-sey. A complete value catalog is given in Table 1.

Table 1: Boundary and operational conditions.

Quantity	Value
Free stream velocity [m/s]	19
Density [kg/m3]	1.225
Pressure [Pa]	101,325
Temperature [K]	288.16
Dynamic viscosity [kg/m*s]	0.000017894
Mean aerodynamic chord length [m]	0.369
Turbulent kinetic energy [m2/s2]	0.000361
Specific dissipation rate [1/s]	135

For the computational domain, its inlet boundaries were simulated by inserting the velocity components and the turbulent boundary conditions, while its outlet boundaries by inserting the gauge pressure (it was assumed as 0 Pa), and again, the same turbulent boundary conditions. The rest of the domain's boundaries were simulated as symmetry boundaries.

The model's equations were discretized using second order discretization schemes for improved accuracy. The pressure and the velocity were coupled with the SIMPLE scheme. The number of iterations was set to 1,500.

The acoustic analyses were conducted by choosing the 'Broadband noise source models' option in ANSYS Fluent. The reference acoustic power was set to 10-12 W/m3 and the far field speed of sound to 340 m/s, as typical values. However, it should be stated that these models calculate only the noise terms related to turbulence. Also, the models do not show how the noise propagates into the field. To analyze the noise propagation and the other aerodynamic noise sources, one can resort to different approaches, like the Fowcs-Williams-Hawkings formulation. These approaches require greatly fine computational meshes and unsteady (time dependent) computations like the URANS equations or the Large Eddy simulation model. Thus, the requirements in time and computational resources increase dramatically.

3.3 CFD results

3.3.1 Flow field

In this subsection, the results of the simulations are presented at selected planes of interest (Figure 10). The planes of interest include the symmetry plane of the computational domain, the suction (upper) surface and the pressure (lower) surface of the UAS and two YZ planes that are at the x=0.8m and x=1m locations, respectively.

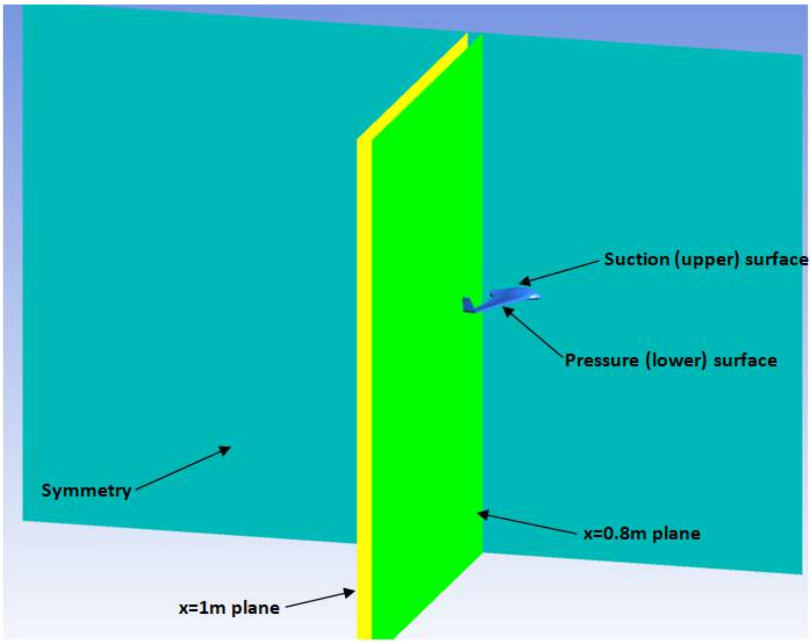

Figure 10: Planes of interest.

The two YZ planes are used to depict the wake region close to the UAS. Figure 11 presents the pressure and velocity contours at the symmetry plane at an angle of attack equal to four degrees. Also, Figure 12 depicts the surface pressure distribution on the UAS' surfaces at the same angle of attack. The observed flow field is the same for the other examined angles of attack.

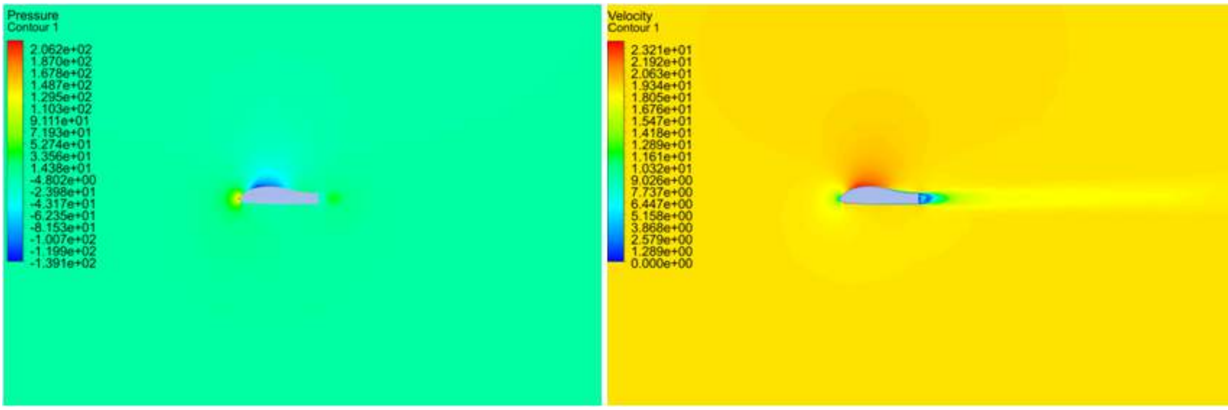

Figure 11: Pressure (left) and velocity (right) contours at the symmetry plane (AoA=4o).

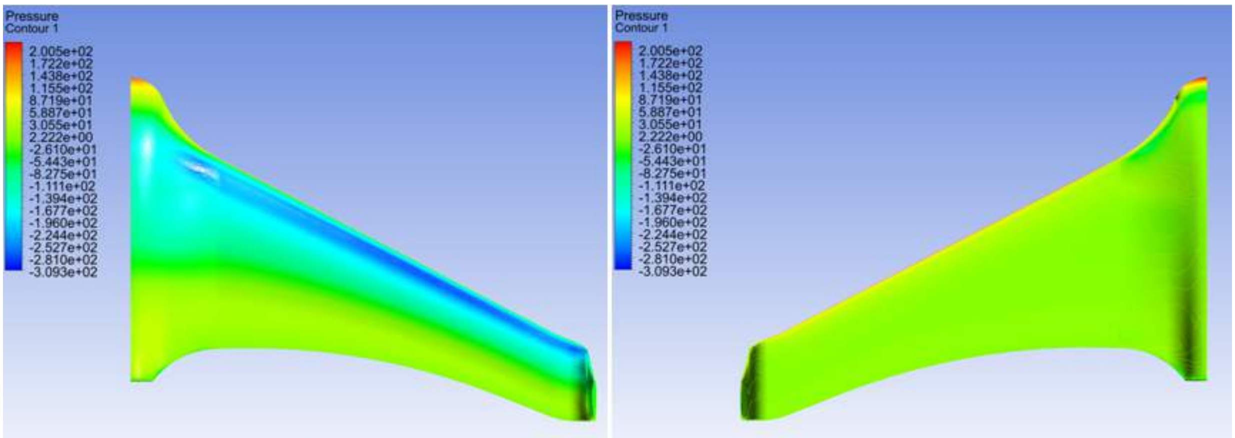

Figure 12: Pressure contours at suction (left) and pressure (right) surfaces (AoA=4o).

As seen in the above figures, the flow is accelerated above the upper surface of the UAS with an associated decrease in pressure. The difference in the exerted forces between the upper and the lower surface of the UAS results in the lift and the drag forces. In Figure 9, the wake region behind the UAS is characterized by the lower velocity relative to the surrounding regions. In front of the UAS, there is a region of high pressure and decreased velocity. This region includes the stagnation point, where the velocity is zero. In Figure 12, the pressure is high at the leading edge. This high-pressure region forms a line across the UAS' leading edge and consists of all the stagnation points. At the suction surface, the pressure rapidly decreases (the region of the maximum thickness of the UAS) and then increases along the chordwise direction. At the pressure side, the pressure no major pressure fluctuations are depicted.

The pressure contours of the wake for the three different examined angles of attack are presented in Figures 13 (YZ plane located at x=0.8m) and 14 (YZ plane located at x=1m). At Figure 13, the pressure distribution behind the UAS is higher. The higher-pressure values are located behind the winglet and the main body areas. Also, a decreased pressure area is located close to the wingtip region. In Figure 14, the higher-pressure region behind the wingtip becomes less evident. However, the higher-pressure region behind the main body area increases in size. In addition, the wingtip vortex region (red circle in Figure 15) becomes more discernible. A final observation base on the contours is the fact that the increase in angle of attack results in higher values of pressure behind the main body and in the winglet region (in absolute terms). The rise in wingtip vortex strength is the result of the increased lift force produced by the wing in higher angles of attack. However, the presence of the winglet as a flow control device decreases the size and the strength of the wingtip vortex as confirmed by the available literature.

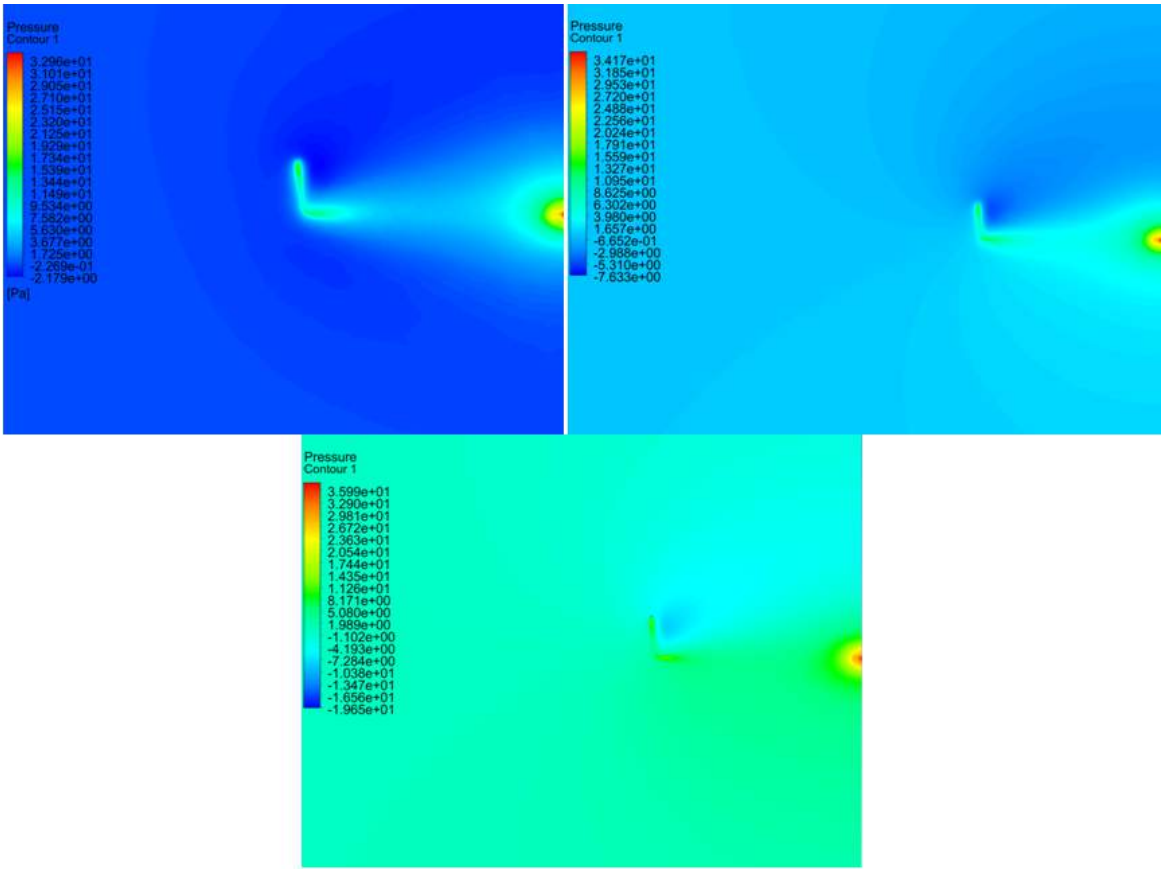

Figure 13: Pressure contours at the YZ plane located at x=0.8m (Left: AoA=0º, Right: AoA=2º, Bellow: AoA=4º).

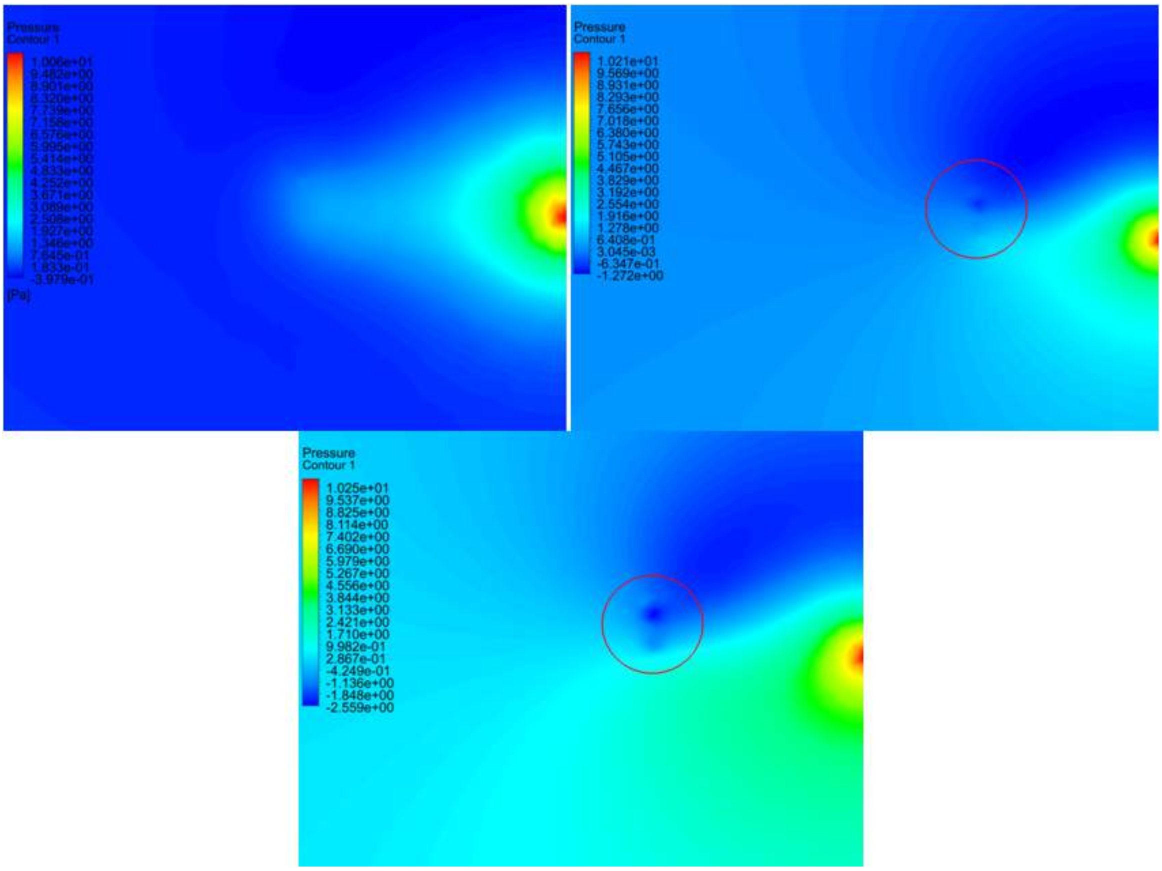

Figure 14: Pressure contours at the YZ plane located at x=1m (Left: AoA=0º, Right: AoA=2º, Bellow: AoA=4º).

3.3.2 Acoustics field

The acoustic field at AoA=4° is depicted at the Figures 15 and 16. The same results are observed at the other examined angles of attack, so for brevity reasons, they are excluded from the present deliverable. The acoustic power level (in decibels, dBs) represents the acoustic power generated by isotropic turbulence. It can be observed that the main wake regions where the acoustic power is generated are the region behind the main body and the winglet region, with the former being larger in size than the latter. At the YZ plane located at x=1m, the generated acoustic power comes from the area behind the main body.

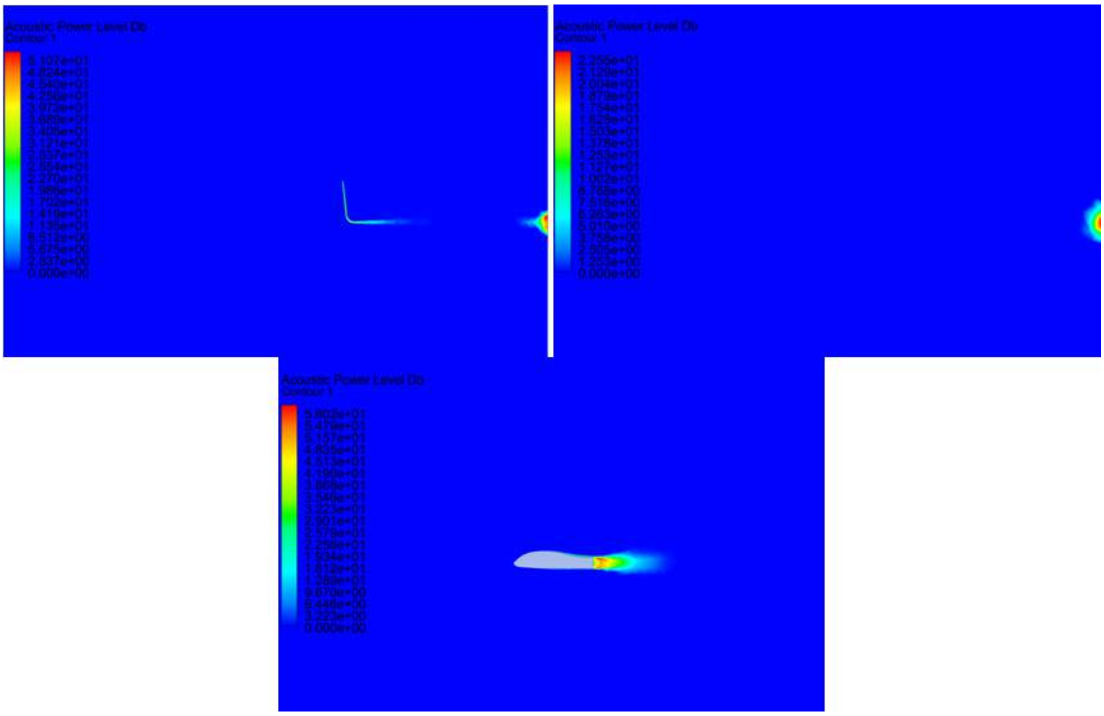

Figure 15: Acoustic power level at AoA=4° (Left: YZ plane located at x=0.8m, Right: YZ plane located at x=1m, Bellow: Symmetry plane).

At Figure 16 is presented the surface acoustic power level (in dBs) due to the boundary layer flow over the UAS surfaces. It can be noticed that the maximum generated acoustic power level is located at the leading edge. This region, as previously explained, is characterized by intense pressure and velocity gradients. The acoustic power level at the suction surface decreases in strength along the chordwise direction, and close to the trailing edge, presents slightly higher values. At the pressure surface, where milder pressure and velocity gradients exist, the generated acoustic power is relatively constant.

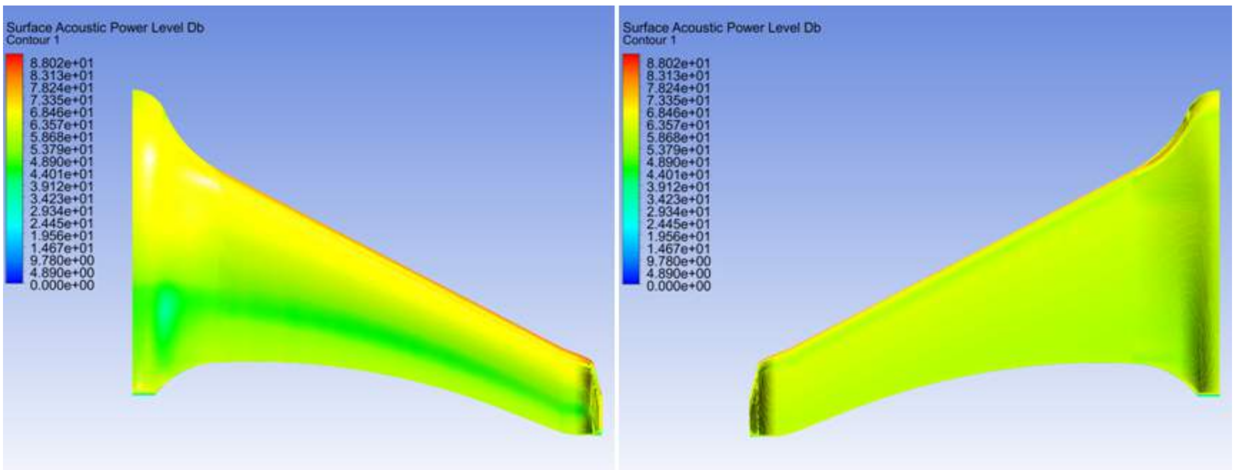

Figure 16: Surface acoustic power level at AoA=4° (Left: Suction side, Right: Pressure side).

As previously stated, the adopted acoustic models do not show how the generated sound waves propagate into the fluid medium or the noise intensity at selected receivers located at far field regions. To achieve this, different formulations and finer meshes are required. However, these lower fidelity models are effective in identifying components or surface regions that generate the most of the noise.

4 Conclusions

Based on the mission requirements, as well as the low optical and acoustic signature requirements of the UAS, AUTh (PB5) identified the noise propagation sources, the weather and terrain characteristics of Nestos area. AUTh (PB5), made all the necessary analyses regarding the flow-field around the UAS, identified the major noise production sources and analyzed the noise propagation mechanism. Moreover, AUTh (PB5) proposed the necessary adaptations on the UAS regarding the optical camouflage of the platform (new paint scheme), in order to augment the UAS' environmental blending capabilities.

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D5.5.3 Performance assessment of the flying surveillance system in real operating environment

Project starting date: 10/11/2017	Project Duration: 50 months
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1 Summary

The present report, that serves as the deliverable D5.5.3 – was produced by the Aristotle University of Thessaloniki-AUTH (PB5 entity). Its aim is to present, the flight-testing campaign that was carried out for the Unmanned Aerial Systems (UASs) selected in D5.5.2, as well as their performance assessment in real operating conditions. More specifically, PB5 organized and completed a flight-testing campaign, where the three different UAS, were tested. The UAS's flight performance was in accordance with their specifications, and following the necessary modifications described in D5.5.2, were capable of conducting the missions defined by the Decentralized Administration of Macedonia & Thrace/ General Directorate of FORESTS & RURAL AFFAIRS (PB2 entity).

2 Flight testing and UAS performance assessment

Based on the experience of PB5 in flight tests, a dedicated flight-testing campaign was organized, where all necessary performance characteristics were examined. The flight tests were performed in conditions (altitude, wind conditions etc.) that simulate the mission profiles for which the UASs were initially selected (Monitoring the wildlife in the Rhodope and Nestos area, Live streaming video at Stavroupoli Xanthi guest reception, High-definition photo and video recording aiming for use in educational, scientific as well as exhibition purposes, Mapping the area adjacent to the Nestos estuary). The results of the flight tests for each UAS are presented below.

2.1 Parrot Disco UAS

The Parrot Disco UAS has been selected for Missions 1 and 2, where adequate live video streaming and typical range and endurance are required. The Parrot Disco is hand lauched and operated via an included remote controler. The operator can use either a mobile phone/tablet setup on the remote controler, or a virtual reality headset that is also included with the UAS.

In Figure 1, photos from the launch, flight and landing of the Parrot Disco are presented. The UAS can operate for more than 45 minutes under typical flight conditions. Due to limitations in the maximum allowed operating altitude in which UASs can operate, the specific maximum flight altitude value of the UAS was not defined in the flight tests, but it was proven to be at least 150m.

Figure 1: Test flight of the Parrot Disco UAS

Additionally, the live video streaming capability of the UAS was examined during flight testing and in the unmodified version of the UAS it was limited to about 1 km. Following the modifications descreibed in D5.5.2 (4G compatibility) the live video streaming is extended to the maximum range of the UAS. The installed 4G module on the Parrot Disco UAS is presented in Figure 2. Additionally, in Figures 3 and 4 an onboard photo from the UAS and the flight path of a UAS mission are presented, respectively.

Figure 2: 4G module installed on the Parrot Disco UAS

Figure 3: On board view from a test flight of the Parrot Disco UAS

Figure 4: Flight path of a test flight of the Parrot Disco UAS

2.2 Anafi Work UAS

The Anafi Work UAS has been selected for Mission 3, where the Vertical Take Off and Landing (VTOL) and hovering capability requirements dictated the selection of a multicopter UAS. The Anafi Work is small quadcopter UAS , with excellent video and image capturing specifications. The UAS comes with a total of four battery packs, which can be simultaniously charged and extend its flight time to over one hour.

The flight test campaign for the Anafi Work, included mostly tasks related to its handling and video capturing capabilities, while the overall endurance was also tested while recording Full HD (1080p) video. In Figure 5, some images from the flight testing campaign are presented.

Figure 5: Flight test of the Anafi Work UAS

Figure 6: On board view from a test flight of the Anafi Work UAS

2.3 eBee X UAS

The eBee X UAS has been selected for Mission 4, where photogrammetric capabilites and typical range and endurance are required. The eBee X UAS is hand lauched and operates completely autonomously. The design of the mission profile, as well as information regarding the take off and landing designated areas is performed through the eMotion software and is uploaded on the UAS prior to each launch. During flight the operator can monitor the flight, is alerted for any disturbances or malfuntions and can modfy the mision parameters, through the eMotion software. The eMotion software can be installed on either a PC or tablet with Window OS that will serve as the Ground Control Station (GCS).

The flight test campaign for the eBee X UAS, included tasks related to its flight characteristics, handling and photogrammetric capabilities, while the overall endurance was also tested. During testing, different landing type options (Linear and Steep) where tested, as well as the UAS's capabilities to operate in adverse flight conditions. The UAS performed excellent and the expected warnings were sent to the GCS, when the landing strip was positioned at a not ideal direction. The operator was able to successfully modify the landing strip while the UAS was operating and upload the updated flight mission data.

In Figures 7 and 8, some images from the flight testing campaign and a demo flight path in the eMotion software are presented.

Figure7: Demo flight path for the eBee X UAS in the eMotion software

Figure 8: Demo flight path for the eBee X UAS in the eMotion software

3 Conclusions

Based on the flight-testing campaign for all the UASs, all the systems, managed to adequately cover all the End user's requirements. The UASs showed exceptional flight characteristics, video recording and photogrammetry capabilities with far from typical endurance times.