CHAMELEON

A Holistic Approach to Sustainable, Digital EU Agriculture, Forestry, Livestock and Rural Development based on Reconfigurable Aerial Enablers and Edge Artificial Intelligence-on-Demand Systems

CHAMELEON D.4.2 CHAMELEON on-boarding v1

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
UAV	Unmanned Aerial Vehicle
GSD	Ground Sampling Distance
RGB	Red, green and blue
LiDAR	Light detection and ranging
DIP	Drone Innovation Platform
AI	Artificial Intelligence
NIR	Near-Infrared
DTM	Digital Terrain Model
ALS	Aerial laser scanning
CMOS	Complementary Metal Oxide Semiconductor
TIFF	Tag Image File Format
RYB	Colour model of Red Yellow and Blue
IMU	Inertial Measurement Unit

1. EXECUTIVE SUMMARY

This document presents the first version of the CHAMELEON on-boarding solutions for agriculture and rural areas, livestock monitoring and forestry. Initially, Deliverable 4.2 provides the probability of positively identifying potential problems, including agriculture, livestock or forest, across heterogeneous sources and networks, thus supporting in-time decisions. It also provides the required minimal and optimal parameters to ensure the data quality and the most suitable equipment for bundle services. This Deliverable 4.2 illustrates the minimal and optimal technical requirements of each sensor quality and requirements for UAV’s flight, which are used in this project. On-boarding system works as a quality “inspector” for data used to fulfil bundles. Secondly, on-boarding maximizes the effectiveness of monitoring and management, as well as interoperability with legacy and future agriculture monitoring systems and networks, by utilizing modular plug-and-play bundles. Finally, on boarding will be utilizing the on-boarding tool and will be able to run in parallel achieving tailored per case environments.

2. INTRODUCTION

2.1 BACKGROUND

In many areas, drone use has become an essential part of large-scale precision farming and forestry operations already. The data collected from drones recording forests, fields and animal herds help users (foresters and farmers) plan their planting and treatments to achieve the best possible yields, understand the health status and management needs of forest and agriculture ecosystems. Drone field monitoring is also being used to monitor the health of soil and field conditions. Drones in forestry will be able to quickly and efficiently perform detection and inspection tasks, reduce costs, and improve deficiencies in forestry management. Another drone technology in development also involves machine learning. Improving Artificial Intelligence (AI) in drones is important to be able to make them more useful to smaller farmers and foresters in developing nations. Therefore, the objective of the CHAMELEON projects is to provide a suite of novel UAV - enabled AI applications and tools for sustainable agriculture, forestry, livestock ecosystems and rural area services. Taking in consideration that usually, the drone operators have enough knowledge about drone and sensor requirements, which are used for data collection, therefore Deliverable 4.2 provides the flight and data quality requirements for a specific Pilot use case and bundle. Before integrating collected data to drone innovation platform (DIP) in order to get required results about specific area, the drone operator or platform user should ensure the data quality and check if they comply with the requirements. The on-boarding requirements will be integrated into DIP in order to ensure for drone operators and CHAMELEON platform users to select sensors with optimal quality to fulfil the flight and data type requirements, which will provide high quality and accurate results.

This document outlines the main requirements for different sensors of CHAMELEON operating culture through identifying and analysing Pilot use cases and main challenges to be overcome in aerial platform development.

2.2. PURPOSE AND SCOPE

The scope of this Deliverable 4.2 is to define the minimal and optimal data and sensor requirements for agriculture-rural areas, livestock, and forestry bundles on-boarding processes. To solve problems related to these sectors by using UAV and AI technologies markets suggest different type of drone with different type of sensors. These several types of sensors are used for different purposes. RGB and Multispectral sensors mainly are used for detecting plant and soil changes, while thermal sensors are used for animal detection. Sensors used for data collection with low or not enough quality, could led to an inaccurate or in the worst-case nonsense results. In order to process and to get results from developed bundles requires time and computing power. However, collected low quality data will not ensure the high-quality results for drone operators and platform users. To protect users from programmatic misunderstandings we suggest ensuring their data quality by providing the minimal and optimal requirements in this Deliverable 4.2. Enough quality data and suggested data types will provide accurate results for the CHAMELEON platforms users and ensures the minimal errors and time delays in procedures.

The Deliverable 4.2 consists of the description and suggested optimal and minimal requirement for data collected with each sensor used in the CHAMELEON project. This document also describes the type of data needed for DIP in order to avoid miscommunication and errors in the program.

2.3. APPROACH

In this document detailed approach is provided to describe the most important on-boarding components and requirements for fluent executing of the bundles. The list of Chameleon bundles (Table 2.1) was agreed upon WP2. The on-boarding components and requirements for each bundle was set by the bundle developers and are described in the following chapters. These requirements are necessary for replicable results and high accuracy of the bundle. The main on-boarding components are considered as UAVS and sensors that are mounted in the CHAMELEON UAVS, while the on-boarding requirements, critical for bundles executing, are as follows: minimal ground resolution requirements GSD (cm/px), minimal images overlap requirements (%), camera orientation requirements, minimal/optimal flight altitude, and data format.

Table 2.1: The bundles developed by CHAMELEON for agriculture, livestock, and forestry monitoring purpose and their spectral bands.

<table>
<tr><th>Country</th><th>Use case</th><th>Partner</th><th>Bundle</th><th>Spectral bands requirements</th></tr>
<tr><td rowspan="4">AUSTRIA</td><td>AGRICULTURE</td><td>UCLM</td><td>VINEYARD WATER STRESS DUE TO DROUGHT</td><td>Multispectral/thermal</td></tr>
<tr><td rowspan="3">FOREST</td><td>USAL</td><td>VEGETATION MONITORING AND CENSUS</td><td>Drone: (RGB + NIR); Satellite: (RGB + NIR)</td></tr>
<tr><td>USAL</td><td>LARGE WOODY DEBRIS ON RIVERS</td><td>Drone: (RGB)</td></tr>
<tr><td>LAMMC</td><td>HEALTH STATUS OF VEGETATION (MAINLY BARK BEETLE), GAME BROWISING, GROUND COVER, AND FUNGAL GROWTH</td><td>RGB+NIR</td></tr>
<tr><td rowspan="3">GREECE</td><td>AGRICULTURE</td><td>UCLM</td><td>MONITORING FLORA AT HIGH-ALTITUDE GRAZING AREAS FOR SEASONAL ANIMAL FEEDING</td><td>RGB/Multispectral</td></tr>
<tr><td rowspan="2">LIVESTOCK</td><td>AIDEAS</td><td>LIVESTOCK MANAGEMENT (HERD) AND MONITORING (INVIDUAL ANIMAL)</td><td>RGB/Thermal</td></tr>
<tr><td>AIDEAS</td><td>ANIMALS’ HEALTH</td><td>RGB/Thermal</td></tr>
<tr><td rowspan="8">SPAIN</td><td rowspan="3">AGRICULTURE</td><td>UCLM</td><td>CROP GROWTH AND DEVELOPMENT MONITORING</td><td>RGB/Multispectral</td></tr>
<tr><td>UCLM</td><td>VINEYARD EATER STRESS DUE TO DROUGHT</td><td>Multispectral/thermal</td></tr>
<tr><td>UCLM</td><td>SOIL ZONIFICATION</td><td>RGB</td></tr>
<tr><td rowspan="2">LIVESTOCK</td><td>USAL</td><td>COLLECTING PARAMETERS RELATED TO THE HEALTH AND STRESS OF LIVESTOCK (IOT PROTOTYPE)</td><td>RGB</td></tr>
<tr><td>AIDEAS</td><td>LAMENESS DETECTION IN COWS</td><td>RGB</td></tr>
<tr><td rowspan="3">FOREST</td><td>USAL</td><td>CONTINUITY OF VEGETATION</td><td>Drone: (LiDAR); Satellite: (RGB + NIR)</td></tr>
<tr><td>USAL</td><td>CHARACTERIZATION OF WILDLAND-URBAN INTERFACE.</td><td>Drone: (RGB + NIR); Satellite: (RGB + NIR)</td></tr>
<tr><td>USAL</td><td>HOT SPOT IDENTIFICATION AT THE BEGINNING OF WILDFIRE</td><td>Drone: (Thermal); Satellite: (Thermal)</td></tr>
</table>

The main components:

- *Unmanned aerial vehicle (UAV).* Under CHAMELEON project it will be utilized a three-layered approach for agriculture, livestock, and forestry monitoring by exploiting two types of unmanned aerial vehicles, and satellite served content:
- Low altitude drones (ACCELIGENCE): Used for small area with RGB imaging, and LiDAR scanning.
- Medium -high altitude, fixed wing UAVS (DELAIR): Used for large area image spectrometry, large area surveillance and detection.
- Very High altitude, Satellite imaging, helping in the spectrometry and achieving cross correlation with the High Altitude UAVS achieving greater view of the areas.
- *Sensors.* The CHAMELEON project operates with this type of sensors: RGB, multispectral, thermal and LiDAR. All sensors are adapted to CHAMELEON UAVS. In this document the detailed information regarding the sensor nature, capabilities, and customization for different services are described.

The main on-boarding requirements:

- *Minimal ground resolution requirements*. The indicator selected – Ground Sampling Distance (GSD, cm/px). GSD is a metric useful for photogrammetry and measurements in drone mapping and surveying projects. GSD is defined as the distance between two adjacent pixel centers measured on the ground. This metric is related to the focal length of the camera, the resolution of the camera sensor, and the distance of the camera from the subject. It is usually expressed in centimeters per pixel (cm/px). The actual GSD requirements for each bundle will be provided in the following chapters.
- *Minimal images overlap requirements (%)*. The overlapping degree of UAV aerial imagery is an important parameter to ensure the quality of aerial photography. In general, 60% f*orward* and 50% side overlap for agriculture fields and 85% forward and side overlap for forests and dense vegetation is needed. The actual overlap requirements for each bundle will be provided in the following chapters. Flight plans can be flown automatically with the flight planning apps. One of the apps is Pix4Dcapture available on Android and iOS. For projects with multiple flights there should be overlap between the different flights and the conditions (sun direction, weather conditions, no new buildings, etc.) should be similar. The theoretical view of flight route planning and images overlap requirements are provided in Figure 2.1

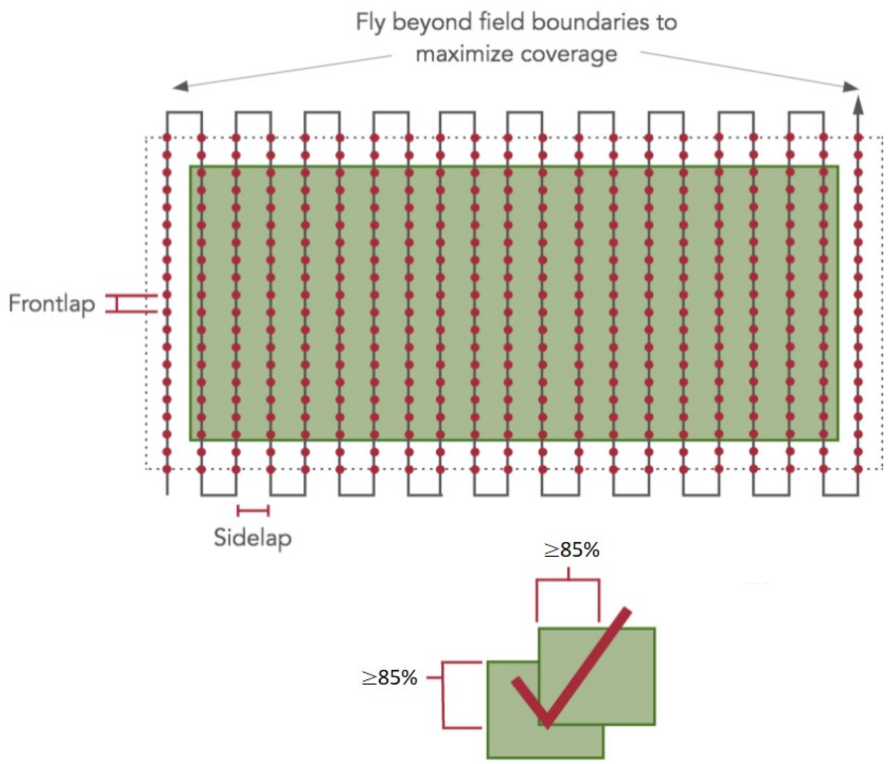

Figure 2.1: The theoretical view of flight route planning and images overlap requirements.

- *Camera orientation requirements*. There are few types of camera orientation, which depends on the type of the bundle selected – Nadir, oblique (Figure 2.2). The nadir is the direction pointing directly below a particular location; that is, it is one of two vertical directions at a specified location, orthogonal to a horizontal flat surface. While a vertical angle can help to show the location of features such as buildings, streets or open spaces, oblique aerial photos are better at giving a perspective of the appearance of features rising from the ground such as buildings, topography, foliage, etc. in relation to the ground and horizon.

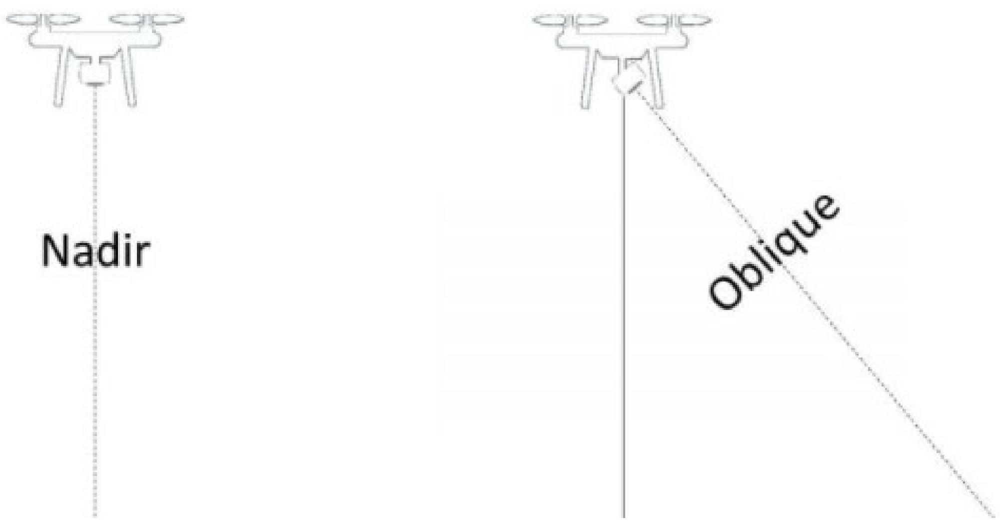

Figure 2.2: The theoretical view of images capture orientation[1]

- *Minimal/optimal flight altitude*. Flight planning – the area to be captured should be larger than the actual field of interest so that there is sufficient data all the way to the edges of the field. Flight altitude above the object should be from 20 m for drones and from 50 m for fixed wings. The flights should be performed by the expert and follow all the rules and requirements in different locations.
- *Data quality requirements*. Data quality check should be completed manually by the person which operate the bundle performance. The main data quality requirements are following the flight route and images capture points to ensure the overlap requirements, image resolution, and data format.

[1.] Nadir. Retrieved in November 2023 from https://en.wikipedia.org/wiki/Nadir

3. ON-BOARDING FOR RGB SENSORS

The ON-BOARDING FOR RGB SENSORS in the CHAMELEON drone innovation platform is providing requirements that need to be followed using RGB sensors to solve specific problems in agriculture, livestock, forestry, and rural areas. These requirements ensure enough quality data for bundles to provide an accurate result for a specific bundle. In the case of bundles that require photogrammetry processes, RGB contributes to accurate geometric characterization of the vegetation. Also, for object recognition with AI algorithms, RGB sensors are the most suitable options due to their high spatial resolution and texture quality. The RGB sensors are the most common sensors for drones in the market. Most of the solutions prepared in the DIP of CHAMELEON project are related to RGB sensors.

3.1. DESCRIPTION OF SENSOR

RGB camera is a camera with a standard CMOS sensor that captures color images of various objects. Still, photography is usually expressed in megapixels ((eg 12MP, 16MP) which define the number of pixels (ie length x height) that make up a photo.

In CHAMELEON, the selected RGB sensor is SONY A6100 camera. The Sony Alpha a6100 is a mirrorless camera featuring an APS-C sensor, a crucial component for capturing high-quality images and videos. This sensor boasts an impressive 24.2-megapixel resolution, providing ample detail and clarity in the captured visuals. Notably, the a6100's APS-C sensor is significantly larger than those typically found in compact digital cameras, enhancing its low-light performance and depth of field control capabilities. Beyond traditional photography and videography, the a6100 is well-suited for photogrammetry—a technique used to create 3D models and maps from a series of 2D images. With its high-resolution 24.2-megapixel APS-C sensor, the a6100 ensures that resulting 3D models are both detailed and accurate.

The RGB colour model is a structured system used in digital devices and light-based media to create a gamut of colours from a small set of primary colours, red, green, and blue (the name of the colour model comes from the first letter of each primary colour name). The RGB colour model is considered an additive system because it combines the wavelengths of the primary colours red, green, and blue together to create a wide spectrum of colours. If red and green colours overlapping to create yellow. Decreasing the intensity of green or increasing the saturation of red would increase the resulting mixed colour to orange. All these three colours produce white (Figure 3.1). This additive process is different from the subtractive process, one of which is the RYB colour model in which combining all the primary colours would theoretically create black. This is because paint pigments selectively absorb and reflect light to create colour. For example, yellow pigment absorbs blue and violet wavelengths and reflects yellow, green and red wavelengths. If yellow and blue pigments are mixed, green is produced because it is the only wavelength that neither pigment strongly absorbs[2].

[2.] RGB Colour model. Retrieved in November 2023 from https://www.britannica.com/science/RGB-colour-model

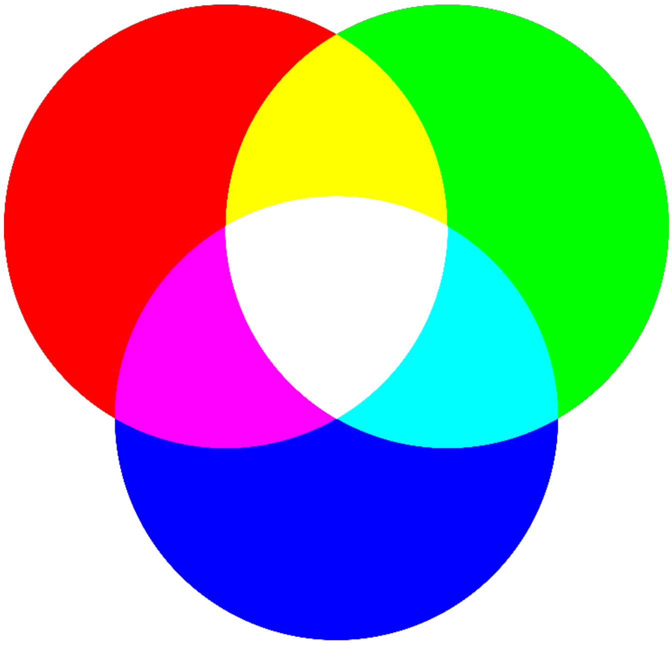

Figure 3.1: The RGB colour model

3.2. MINIMAL AND OPTIMAL REQUIREMENTS FOR RGB SENSOR QUALITY

The minimal requirements for RGB sensor should be around 3-4 cm/px, and the optimal requirement for the sensor is 1.5 cm/px. However, the minimal and optimal requirements for on-boarding procedures depend on the specific bundle. Needed requirements for the specific bundles in CHAMELEON project in which RGB sensors will be used are provided in Table 3.1. The sensor size in these types of cameras provides a centimetric resolution at low flight height. Most of them can reach a GSD lower than 2 cm for 120 m flight height.

In case AI in near-real time is aimed, the frame rate and image resolution are key factors for the overall accuracy of the solution.

Table 3.1: The minimal and optimal requirements for RGB sensor quality on the specific selected bundles for agriculture, livestock, and forestry monitoring.

Country	Use case	Partner	Bundle	Minimal ground resolution requirements GSD, cm/px
AUSTRIA	FOREST	USAL	VEGETATION MONITORING AND CENSUS	Drone: (minimal: 2 cm; optimal: 1 cm); Satellite: 10 m (Sentinel 2)
		USAL	LARGE WOODY DEBRIS ON RIVERS	Real time: minimal: 20 cm; Postprocessing: (minimal 2 cm; optimal: 1 cm)
		LAMMC	HEALTH STATUS OF VEGETATION (MAINLY BARK BEETLE), GAME BROWISING, GROUND COVER, AND FUNGAL GROWTH	from 3 cm/px

GREECE	AGRICULTURE	UCLM	MONITORING FLORA AT HIGH-ALTITUDE GRAZING AREAS FOR SEASONAL ANIMAL FEEDING	1.5 cm/px
	LIVESTOCK	AIDEAS	LIVESTOCK MANAGEMENT (HERD) AND MONITORING (INVIDUAL ANIMAL)	Centimetric
		AIDEAS	ANIMALS' HEALTH	Centimetric
SPAIN	AGRICULTURE	UCLM	CROP GROWTH AND DEVELOPMENT MONITORING	1.5-2 cm/px
		UCLM	SOIL ZONIFICATION	1.5-2 cm/px
	LIVESTOCK	USAL	COLLECTING PARAMETERS RELATED TO THE HEALTH AND STRESS OF LIVESTOCK (IOT PROTOTYPE)	Centimetric
		AIDEAS	LAMENESS DETECTION IN COWS	Centimetric
	FOREST	USAL	CONTINUITY OF VEGETATION	Drone: (minimal: 2 cm; optimal: 1 cm); Satellite: 10 m (Sentinel 2)
		USAL	CHARACTERIZATION OF WILDLAND-URBAN INTERFACE.	Drone: (minimal: 2 cm; optimal: 1 cm); Satellite: Several meters

3.3. FLIGHT REQUIREMENTS

The optimal flight altitude should be from 20 to 80 meters above the object with minimal image overlap requirements 85% and the side lapping requirements should be from 20 to 40 %. The type of orientation depends on the type of the selected bundle, it could be Nadir or oblique. The minimal and optimal flight requirements for each specific bundle provided in the Table 3.2.

Table 3.2: The minimal and optimal flight requirements for RGB sensor on the specific selected bundles for agriculture, livestock, and forestry monitoring.

Country	Use case	Partner	Bundle	Minimal image overlap requirements, %	Camera orientation requirements	Minimal/optimal Flight altitude requirements
AUSTRIA	FOREST	USAL	VEGETATION MONITORING AND CENSUS	80-85% forward overlap, 40-60% side overlap	Vertical or oblique flights	Minimal: 100 m; optimal: 50 m
		USAL	LARGE WOODY DEBRIS ON RIVERS	No requirements	Real time: Vertical flights; Postprocessing: Vertical of oblique flights	16mm: 41m, 20mm: 50m
		LAMMC	HEALTH STATUS OF VEGETATION (MAINLY BARK BEETLE), GAME BROWISING, GROUND COVER, AND FUNGAL GROWTH	85% forward overlap, 85% side overlap	Nadir	40-50m
GREECE	AGRICULTURE	UCLM	MONITORING FLORA AT HIGH-ALTITUDE GRAZING AREAS FOR SEASONAL ANIMAL FEEDING	60% overlapping, 40% sidelapping	Nadir	N/A

	LIVESTOCK	AIDEAS	LIVESTOCK MANAGEMENT (HERD) AND MONITORING (INVIDUAL ANIMAL)	No requirements	Vertical or oblique flights	30m
		AIDEAS	ANIMALS' HEALTH	No requirements	Vertical or oblique flights	30m
SPAIN	AGRICULTURE	UCLM	CROP GROWTH AND DEVELOPMENT MONITORING	60% overlapping, 40% sidelapping	Nadir	N/A
		UCLM	SOIL ZONIFICATION	60% overlapping, 40% sidelapping	Nadir	N/A
	LIVESTOCK	USAL	COLLECTING PARAMETERS RELATED TO THE HEALTH AND STRESS OF LIVESTOCK (IOT PROTOTYPE)	No requirements	No requirements	16mm: 41m, 20mm: 50m
		AIDEAS	LAMENESS DETECTION IN COWS	No requirements	Oblique flights	2-4m
	FOREST	USAL	CONTINUITY OF VEGETATION	80-85% forward overlap	Vertical or oblique flights	Minimal: 100 m; optimal: 50 m
		USAL	CHARACTERIZATION OF WILDLAND-URBAN INTERFACE.	80-85% forward overlap, 40-60% side overlap	Vertical or oblique flights	Minimal: 100 m; optimal: 50 m

3.4. DATA QUALITY REQUIREMENTS

Data quality check should be completed manually by the person which operate the bundle performance. The main data quality requirements are following the flight route and images capture points to ensure the overlap requirements, image resolution, and data format, which presented in the Table 3.3. Additionally, photo quality must be verified by zooming in to check for clarity (no blurriness), appropriate ISO (no digital noise), adequate shutter speed (no pixel blur), and importantly, verifying the number of photos taken against the plan.

Table 3.3: The minimal and optimal data quality requirements for RGB sensor on the specific bundles for agriculture, livestock, and forestry monitoring.

Country	Use case	Partner	Bundle	Data format
AUSTRIA	FOREST	USAL	VEGETATION MONITORING AND CENSUS	JPG, RAW
		USAL	LARGE WOODY DEBRIS ON RIVERS	JPG, RAW
		LAMMC	HEALTH STATUS OF VEGETATION (MAINLY BARK BEETLE), GAME BROWISING, GROUND COVER, AND FUNGAL GROWTH	Standard jpg
GREECE	AGRICULTURE	UCLM	MONITORING FLORA AT HIGH-ALTITUDE GRAZING AREAS FOR SEASONAL ANIMAL FEEDING	Standard jpg

	LIVESTOCK	AIDEAS	LIVESTOCK MANAGEMENT (HERD) AND MONITORING (INVIDUAL ANIMAL)	Standard jpg or video files
		AIDEAS	ANIMALS' HEALTH	Standard jpg or video files
SPAIN	AGRICULTURE	UCLM	CROP GROWTH AND DEVELOPMENT MONITORING	Standard jpg
		UCLM	SOIL ZONIFICATION	Standard jpg
	LIVESTOCK	USAL	COLLECTING PARAMETERS RELATED TO THE HEALTH AND STRESS OF LIVESTOCK (IOT PROTOTYPE)	JPG, RAW
		AIDEAS	LAMENESS DETECTION IN COWS	Standard jpg or video files
	FOREST	USAL	CONTINUITY OF VEGETATION	JPG, RAW
		USAL	CHARACTERIZATION OF WILDLAND-URBAN INTERFACE	JPG, RAW

4. ON-BOARDING FOR MULTISPECTRAL SENSORS

ON-BOARDING FOR MULTISPECTRAL SENSORS, on the CHAMELEON drone innovation platform, presents the requirements for multispectral cameras addressing specific challenges in agriculture, livestock, forestry, and rural areas. These requirements ensure the collection of accurate and high-quality data to obtain a specific bundle solution.

4.1. DESCRIPTION OF SENSOR

Multispectral imaging captures images in specific wavelength ranges of the electromagnetic spectrum. Wavelengths can be separated with the help of filters or detected using specially adapted devices that are sensitive to the wavelengths of the electromagnetic spectrum (infrared and ultraviolet)[3]. This can allow the extraction of additional information that the human eye is unable to capture. Multispectral imaging measures light in a small number (typically 3 to 15) of spectral bands[4]. Different combinations of spectral bands can be used to achieve different objectives[5,6,7]. They are usually represented by red, green, and blue channels, the assignment of wavebands to colors depends on the purpose of the image and analytical preferences.

For the CHAMELEON project the RedEdge-MX multispectral sensor has been chosen. The RedEdge-MX, developed by MicaSense, is a robust, professional multispectral sensor designed for advanced aerial mapping applications, particularly in agriculture, forestry, and environmental research. This high-performance tool captures all the essential spectral bands required for crop health indices, including green, red, red edge, and near-infrared. Additionally, it provides a blue band for deeper insights into specific issues and composite RGB imagery. This capability allows agricultural professionals to obtain accurate and repeatable measurements, collecting the necessary data during each flight to generate anything from basic plant health indices to advanced analytics.

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[3] Schowengerdt, R.A. Remote Sensing, Models, and Methods for Image Processing, 3rd ed.; Academic Press: Burlington, MA, USA, 2007; ISBN 978-0-12-369407-2

[4] Nicolis, O., & Gonzalez, C. (2021). Wavelet-based fractal and multifractal analysis for detecting mineral deposits using multispectral images taken by drones. In Methods and Applications in Petroleum and Mineral Exploration and Engineering Geology (pp. 295-307). Elsevier.

[5] Namin, S. T., & Petersson, L. (2012, October). Classification of materials in natural scenes using multi-spectral images. In *2012 IEEE/RSJ International Conference on Intelligent Robots and Systems* (pp. 1393-1398). IEEE. doi: https://doi.org/10.1109/IROS.2012.6386074

[6] Makki, I., Younes, R., Francis, C., Bianchi, T., & Zucchetti, M. (2017). A survey of landmine detection using hyperspectral imaging. *ISPRS Journal of Photogrammetry and Remote Sensing*, *124*, 40-53. https://doi.org/10.1016/j.isprsjprs.2016.12.009

[7] ElMasry, G., Mandour, N., Al-Rejaie, S., Belin, E., & Rousseau, D. (2019). Recent applications of multispectral imaging in seed phenotyping and quality monitoring—An overview. *Sensors*, *19*(5), 1090. https://doi.org/10.3390/s19051090

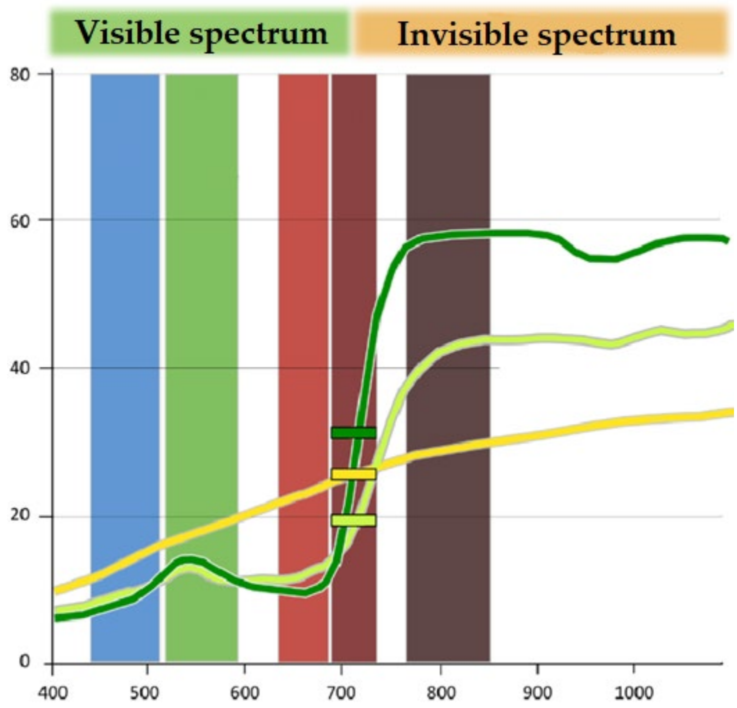

Figure 4.1: Visible and invisible spectrum diagram. Dark green - healthy vegetation, light green - damaged vegetation, yellow - areas without vegetation.

The most used spectral bands are:

True-color uses only the red, green, and blue channels mapped to their respective colors. As simple color photographs, it is suitable for the analysis of man-made objects and is easy to understand[8].

Green-Red-Infrared, where the blue channel is replaced by near-infrared, is used for vegetation that is highly reflective of the near-IR; then it is displayed as blue. This combination is often used to detect vegetation and its changes. The red-corner spectrum lies between the red and NIR bands, with no overlap. For a typical spectral reflectance of green vegetation (green line in Figure 4.1), the red corner band covers the part of the spectrum where the reflectance increases drastically from the red towards the NIR regions. The importance of the red-angle spectral region for vegetation characterization is widely recognized. Several studies have shown that the transition between this spectrum and the near-infrared (NIR) reflectance of plants can provide valuable additional information about vegetation and its characteristics. The part of the red-corner electromagnetic spectrum is one of the areas where light is strongly absorbed, while the NIR is the spectrum where the leaf cell structure strongly reflects it depending on the quality or vitality level of the plant vegetation. along with the other two bands. The different reflectance values show how the "Red Edge" band provides additional information in characterizing the spectra of plants at different levels of vitality. The sensitivity of the red-edge band to differences in leaf structure

[8] Chen, L., Wang, Y., Wang, H., & Yang, X. (2013, October). Research on multispectral true color image creation. In *Proceedings of 2013 3rd International Conference on Computer Science and Network Technology* (pp. 1107-1110). IEEE. https://doi.org/10.1109/ICCSNT.2013.6967296

and chlorophyll content may be useful for precision agriculture and resource monitoring and management[9,10].

Blue-NIR-MIR, where the blue channel uses the visible blue, the green uses the NIR (so the vegetation remains green), and the MIR is displayed as red. Such images allow water depth, vegetation cover, soil moisture content and the presence of fires to be seen in a single image. There are more other combinations used in multispectral, but they are more adapted to perform specific tasks.

Typical wavelength distribution:

Blue, 450-515/520 nm is used for atmospheric and deep-water imaging and can reach depths of up to 150 feet (50 m) in clear water.

Green, 515/520–590/600 nm, is used for imaging vegetation and deep-sea structures in clear water down to 30 m. Red, 600/630-680/690 nm, is used to image man-made objects up to 30 feet (9 m) deep, in soil and vegetation.

Near-infrared (NIR), 750-900 nm, is mainly used for vegetation imaging.

Mid-infrared (MIR), 1550-1750 nm, is used to image vegetation, soil moisture, and some wildfires.

Far infrared (FIR), 2080-2350 nm, is used to image soils, moisture, geological features, silicates, clays, and fires.

Thermal infrared, 7,000-14,000 nm, uses emitted rather than reflected radiation for imaging geological structures, thermal differences in water currents, fires, and nighttime exploration.

4.2. MINIMAL AND OPTIMAL REQUIREMENTS FOR MULTISPECTRAL SENSOR QUALITY

Minimum spectral bands requirements: NIR. (In addition, there may be red-edge and others, but near-infrared are the main ones).

Minimum ground resolution requirements GSD: 5-10 cm/px. (The word “ground” here because the actual resolution of the image data on the ground is specified by the GSD ground sample distance parameter cm/px, which depends both on the size of the sensor matrix (resolution, e.g. 6000x4000) and on the optics and flight altitude. The minimal and optimal resolution requirements in each specific bundle in CHAMELEON project using multispectral sensors are provided in Table 4.1.

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Table 4.1: The minimal and optimal requirements for multispectral sensor quality on the specific bundles for agriculture, livestock, and forestry monitoring.

Country	Use case	Partner	Bundle	Minimum ground resolution requirements GSD, cm/px
AUSTRIA	FOREST	USAL	VEGETATION MONITORING AND CENSUS	Drone: Centimetric; Satellite: Several meters
		LAMMC	HEALTH STATUS OF VEGETATION (MAINLY BARK BEETLE), GAME BROWISING, GROUND COVER, AND FUNGAL GROWTH	up to10 cm/px
GREECE	AGRICULTURE	UCLM	MONITORING FLORA AT HIGH-ALTITUDE GRAZING AREAS FOR SEASONAL ANIMAL FEEDING	5 cm/px
SPAIN	AGRICULTURE	UCLM	CROP GROWTH AND DEVELOPMENT MONITORING	5 cm/px
		UCLM	VINEYARD WATER STRESS DUE TO DROUGHT	5 cm/px
	FOREST	USAL	CONTINUITY OF VEGETATION	Drone: Centimetric; Satellite: Several meters
		USAL	CHARACTERIZATION OF WILDLAND-URBAN INTERFACE	Drone: Centimetric; Satellite: Several meters

4.3. FLIGHT REQUIREMENTS

Camera orientation requirements: nadir (Nadir means vertically down, in different angular coordinate reference systems it is 0° or 90°). Flight altitude should be > 40 meters above the object. The flights should be performed by the expert and follow all the rules and requirements in different locations.

Minimal image overlap requirements, %: up to 85 (this refers to the overlap of photos in both vertical and horizontal direction, i.e., transverse, and longitudinal image overlap). The minimum overlap depends on the bundle being executed, but if it is less than recommended, it will be difficult to generate orthophoto maps, if it is more, the final solution is also bad, because the "rays" of the same point in each image will be almost parallel. Minimum image overlap requirements are required for data collection by any type of drones or fixed wings.

The flight requirements for each specific bundle of agriculture and rural areas, livestock and forestry using multispectral sensors are provided in Table 4.2.

Table 4.2: The minimal and optimal flight requirements for multispectral sensor on the specific selected bundles for agriculture, livestock, and forestry monitoring.

Country	Use case	Partner	Bundle	Minimal image overlap requirements, %	Camera orientation requirement	Minimal/optional flight altitude requirements
AUSTRIA	FOREST	USAL	VEGETATION MONITORING AND CENSUS	60-70% forward overlap, 20-40% side overlap	Vertical or oblique flights	Minimal: 50 m; optimal: 15 m
		LAMMC	HEALTH STATUS OF VEGETATION (MAINLY BARK BEETLE), GAME BROWISING, GROUND COVER, AND FUNGAL GROWTH	85% forward overlap, 85% side overlap	Nadir	40-50m
GREECE	AGRICULTURE	UCLM	MONITORING FLORA AT HIGH-ALTITUDE GRAZING AREAS FOR SEASONAL ANIMAL FEEDING	60% overlapping, 40% sidelapping	Nadir	N/A
SPAIN	AGRICULTURE	UCLM	CROP GROWTH AND DEVELOPMENT MONITORING	60% overlapping, 40% sidelapping	Nadir	N/A
		UCLM	VINEYARD WATER STRESS DUE TO DROUGHT	60% overlapping, 40% sidelapping	Nadir	N/A
	FOREST	USAL	CONTINUITY OF VEGETATION	No requirements	Vertical or oblique flights	100m (20m/s), 80m(25m/s), 60m(30m/s)
		USAL	CHARACTERIZATION OF WILDLAND-URBAN INTERFACE	60-70% forward overlap, 20-40% side overlap	Vertical or oblique flights	Minimal: 50 m; optimal: 15 m

4.4. DATA QUALITY REQUIREMENTS

Data quality check should be completed manually by the person which operate the bundle performance. The main data quality requirements are following the flight route and images capture points to ensure the overlap requirements, image resolution, and data format, which are provided in Table 4.3. Moreover, it is necessary to assess photo quality by zooming in to ensure focus (absence of blur), verify that calibration photos for the sensor are taken at the start and end of the flight, and confirm that the number of photos aligns with the planned quantity.

Table 4.3: The minimal and optimal data quality requirements for multispectral sensor on the specific bundles for agriculture, livestock, and forestry monitoring.

Country	Use case	Partner	Bundle	Data format
AUSTRIA	FOREST	USAL	VEGETATION MONITORING AND CENSUS	TIFF (One file per band)
		LAMMC	HEALTH STATUS OF VEGETATION (MAINLY BARK BEETLE), GAME BROWISING, GROUND COVER, AND FUNGAL GROWTH	TIFF (One file per band)
GREECE	AGRICULTURE	UCLM	MONITORING FLORA AT HIGH-ALTITUDE GRAZING AREAS FOR SEASONAL ANIMAL FEEDING	16 bits Calibrated with reflectance panel
SPAIN	AGRICULTURE	UCLM	CROP GROWTH AND DEVELOPMENT MONITORING	16 bits Calibrated with reflectance panel
		UCLM	VINEYARD WATER STRESS DUE TO DROUGHT	16 bits Calibrated with reflectance panel
	FOREST	USAL	CONTINUITY OF VEGETATION	TIFF (One file per band)
		USAL	CHARACTERIZATION OF WILDLAND-URBAN INTERFACE	TIFF (One file per band)

5. ON-BOARDING FOR THERMAL AND LIDAR SENSORS

ON-BOARDING FOR THERMAL and LiDAR SENSORS, on the CHAMELEON drone innovation platform, presents the requirements for cameras addressing specific challenges in agriculture, livestock, forestry, and rural areas. These requirements ensure the collection of accurate and high-quality data to run a specific bundle solution.

5.1. DESCRIPTION OF SENSOR

5.1.1. THERMOGRAPHIC

A thermographic camera captures and creates an image of an object using thermal infrared radiation emitted by the object in a process called thermal imaging. Both visible light and infrared radiation belong to the electromagnetic spectrum, but unlike visible light, thermal infrared radiation cannot be perceived by the human eye and corresponds to the radiation emitted by the body due to its thermal state, and not to reflections of radiation. This ensures that thermal cameras are not affected by light and can clearly detect an object even in a dark environment, provided that the object is over 0K.

Thermographic cameras usually detect radiation in the long-infrared range of the electromagnetic spectrum (7,000–14,000 nm) and produce images (thermograms) of that radiation[11]. The amount of radiation emitted by an object increases with temperature, therefore, thermography allows one to see variations in temperature. When viewed through a thermal imaging camera, warm objects stand out well against cooler backgrounds; humans and other warm-blooded animals become easily visible against the environment, day, or night.

Thermographic cameras have wide applications in agriculture[12], livestock[13], and forestry[14,15] monitoring:

- *Wildfires monitoring*. The application of infrared thermal imaging cameras in forestry cover - penetrating smoke on-site rescue, directing firefighting on the hot spots, and identifying fire spread directions. When a fire occurs in the forest, the smoke produced by the flames is very large, which often covers the real ignition point and the spread of the fire. The

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infrared thermal imaging camera has a strong ability to penetrate smoke, which can effectively find the real fire point.

- *Livestock monitoring*. Thermal imaging cameras can be used in the diagnosis of several economically significant diseases of livestock, e.g., sources of lameness, bluetongue virus and bumblefoot. Early disease detection is critical to prevent and monitor diseases in the livestock sector. Thermal imaging cameras also can serve valuable information about the herds location and lost animals, especially in remote areas.

In CHAMELEON, the selected thermal sensor is the FLIR Duo Pro R, equipped with a radiometrically calibrated thermographic camera (performs the computation of temperature from thermal infrared radiation allowing the measurement of real temperatures of the objects in the image) that offers a resolution of 640x480. With a total weight of 375 g in flight, this sensor combines lightweight design with advanced imaging capabilities. It has an RGB sensor for have a picture to compare with.

Mounted on drones, thermographic sensors like the FLIR Duo Pro R provide detailed, high-resolution images and can be directed to specific locations quickly, making them ideal for immediate analysis of wildfire and wildlife tracking. Their limitations include shorter operational ranges and flight times, as well as potential susceptibility to inclement weather. In contrast, satellite thermal imaging extends these capabilities with its wide-reaching and consistent surveillance, beneficial for mid-term and long-term studies. Together, these methods form an integrated approach, enhancing the overall scope and accuracy of rural monitoring.

5.1.2. LIDAR

LiDAR sensor. Lidar is a method for determining ranges by targeting an object or a surface with a laser and measuring the time for the reflected light to return to the receiver. Aerial laser scanning (ALS) is particularly suitable for agriculture[16] forestry applications[17] for surveying sites covered by woodland, shrubs, and plants, especially when you need to penetrate through the vegetation to achieve a Digital Terrain Model (DTM); or to overcome difficult terrain or hazardous locations such as mountainous areas.

High-density ALS (10 pulses/m^2 and more) provides sufficient detail to detect individual trees, basic forest parameters such as tree diameters, height, volume, biomass, leaf area index, gap

16. Rivera, G., Porras, R., Florencia, R., Solís, J.P.S. (2023). LiDAR applications in precision agriculture for cultivating crops: A review of recent advances. *Computers and Electronics in Agriculture*, 207, 107737. https://doi.org/10.1016/j.compag.2023.107737.

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fraction or defoliation[18]. For the region scale, ALS can serve necessary information on continuity of the vegetation, and changes on it[19].

For the CHAMELEON project, the RECON-XT LiDAR from Phoenix Systems is deployed. This sensor captures data at a rate of 640K points per second with a precision of 2-5 cm at 80 m above ground level, while maintaining a maximum operational altitude of 80 m. The total weight of the sensor is 1.8 Kg. The IMU associated with the RECON-XT offers a position accuracy of 0.5 cm and an attitude accuracy below 0.01º in Pitch & Roll and 0.05º in Heading, enhancing the fidelity of data collection.

Integrating LiDAR systems like the RECON-XT onto UAVs leverages the agility and precision of drone flight to reach specific or otherwise inaccessible areas rapidly. However, the inherent weight and size of LiDAR usually presents a challenge for UAV operations. These factors can impose restrictions on flight duration and range, requiring a careful balance between sensor capability and the UAV's load capacity.

5.2. MINIMAL AND OPTIMAL REQUIREMENTS FOR THERMAL AND LIDAR SENSOR QUALITY

The minimal requirements for Thermal and LiDAR sensors for specific bundle execution provided at Table 5.1. For most of the bundles the optimal ground resolution should be 8 px/cm for the Thermal camera. For the LiDAR sensor, 80 points/m^2 should be set.

Table 5.1: The minimal and optimal requirements for thermal and LiDAR sensor quality on the specific bundles for agriculture, livestock, and forestry monitoring.

Country	Use case	Partner	Bundle	Minimal spectral bands requirements	Minimal ground resolution requirements GSD, cm/px
AUSTRIA	AGRICULTURE	UCLM	VINEYARD WATER STRESS DUE TO DROUGHT	Thermal	8 cm/px (thermal)
GREECE	LIVESTOCK	AIDEAS	LIVESTOCK MANAGEMENT (HERD) AND MONITORING (INVIDUAL ANIMAL)	Thermal	Centimetric
		AIDEAS	ANIMALS' HEALTH	Thermal	Centimetric
SPAIN	AGRICULTURE	UCLM	VINEYARD EATER STRESS DUE TO DROUGHT	Thermal	8 cm/px (thermal)

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	FOREST	USAL	CONTINUITY OF VEGETATION	Drone: (LiDAR)	LiDAR: (minimal: 80 points/m²; optimal: 100 points/m²)
		USAL	HOT SPOT IDENTIFICATION AT THE BEGINNING OF WILDFIRE	Drone: (Thermal); Satellite: (Thermal)	Drone: Decimetric; Satellite: Several meters

5.3. FLIGHT REQUIREMENTS

The minimal and optimal flight requirements for each specific bundle are provided in Table 5.2. For the livestock bundles the image overlapping is not necessary, because the videos will be captured. For the rest of the bundles, 60% front and 40% side overlapping are required. The camera orientation requirements (Nadir or oblique) for the specific bundle are given in Table 5.2. The 30 m flights are recommended for livestock bundles, while higher altitude flights for the rest of the bundles.

Table 5.2: The minimal and optimal flight requirements for thermal and LiDAR sensor on the specific bundles for agriculture, livestock, and forestry monitoring.

Country	Use case	Partner	Bundle	Minimal image overlap requirements, %	Camera orientation requirements	Minimal/optimal Flight altitude requirements
AUSTRIA	AGRICULTURE	UCLM	VINEYARD WATER STRESS DUE TO DROUGHT	60% overlapping, 40% sidelapping	Nadir	N/A
GREECE	LIVESTOCK	AIDEAS	LIVESTOCK MANAGEMENT (HERD) AND MONITORING (INVIDUAL ANIMAL)	No requirements	Vertical or oblique flights	30m
		AIDEAS	ANIMALS' HEALTH	No requirements	Vertical or oblique flights	30m
SPAIN	AGRICULTURE	UCLM	VYNEYARD EATER STRESS DUE TO DROUGHT	60% overlapping, 40% sidelapping	Nadir	N/A
	FOREST	USAL	CONTINUITY OF VEGETATION	No requirements	Vertical or oblique flights	100m (20m/s), 80m(25m/s), 60m(30m/s)
		USAL	HOT SPOT IDENTIFICATION AT THE BEGINNING OF WILDFIRE	Overlap is less critical although a minimum would be required	Vertical flights	80m

5.4. DATA QUALITY REQUIREMENTS

Data quality check should be completed manually by the person who operates the bundle performance. The main data quality requirements are following the flight route and image capture points to ensure the overlap requirements, image resolution, and data format, which are provided in Table 5.3.

Table 5.3: The minimal and optimal data quality requirements for thermal and LiDAR sensor on the specific selected bundles for agriculture, livestock, and forestry monitoring.

Country	Use case	Partner	Bundle	Data format
AUSTRIA	AGRICULTURE	UCLM	VINEYARD WATER STRESS DUE TO DROUGHT	Int 16 Temperature. It can be transformed to int16 by multiplying the temperature value by 100. For example, 25.56ºC==>2556
GREECE	LIVESTOCK	AIDEAS	LIVESTOCK MANAGEMENT (HERD) AND MONITORING (INVIDUAL ANIMAL)	JPEG/PNG and SEQ/RAW
		AIDEAS	ANIMALS' HEALTH	JPEG/PNG and SEQ/RAW
SPAIN	AGRICULTURE	UCLM	VINEYARD EATER STRESS DUE TO DROUGHT	Int 16 Temperature. It can be transformed to int16 by multiplying the temperature value by 100. For example, 25.56ºC==>2556
	FOREST	USAL	CONTINUITY OF VEGETATION	LAS
		USAL	HOT SPOT IDENTIFICATION AT THE BEGINNING OF WILDFIRE	TIFF

6. ON-BOARDING FOR SATELLITE

Satellite imagery, which includes RGB, multispectral, and thermal sensors, provides essential data that complements drone-captured images in monitoring rural, agricultural, and forestry areas. Satellites offer broad coverage and regular collection intervals, presenting a comprehensive view of large expanses that enhances the detailed, targeted observations from drones. Multispectral imagery from satellites is key for assessing plant health and soil characteristics over large areas[20]. Thermographic sensors not only identify temperature variations that pinpoint water stress or irrigation demands but are also crucial for early fire detection. By integrating these satellite and drone technologies, we can achieve a more thorough understanding of vast environmental landscapes with detailed local specificity.

To efficiently manage the vast geospatial information gathered from both satellite and drone technologies, the CHAMELEON project employs the capabilities of Google Earth Engine. This platform excels in processing large datasets, allowing the analysis and interpretation of the collected imagery with speed and accuracy. It provides a powerful suite of computational tools that enable us to harness the full potential of our Earth observation data.

In CHAMELEON, we utilize a constellation of Earth observation satellites, including Sentinel-2, Landsat 8 & 9, Terra & Aqua, the NOAA's Joint Polar Satellite System (JPSS), and the Planet satellites, to derive a variety of indices that are essential for monitoring vegetation and terrestrial surfaces. This wealth of information supports the extraction of key vegetation indices such as the Normalized Difference Vegetation Index (NDVI) and the Moisture Stress Index (MSI), which are critical for assessing plant health and water content in the landscape. A detailed classification of the specific roles and contributions of these satellites to the CHAMELEON project is presented in Table 6.1.

Table 6.1: Satellite missions, corresponding constellations and primary imaging instruments, observation capabilities and their application in CHAMELEON.

Pilot Use Case	Bundle / Function	Instruments	Spectral bands	Spatial resolution	Revisit time	Mission	Constellation
AUSTRIA	FOREST – Vegetation monitoring and census	MultiSpectral Instrument (MSI)	RGB, NIR, SWIR	10-20 m	5 days	Sentinel-2	Sentinel-2A & 2B
SPAIN	FOREST – Continuity of vegetation						
	FOREST – Characterization of WUI						
	FOREST – Hotspot identification						
AUSTRIA	FOREST – Vegetation monitoring and census		RGB, NIR, SWIR	30 m	8 days	Landsat 8 & 9	Landsat 8 & 9

[20] Dalponte, M., Marzini, S., Solano-Correa, Y.T., Tonon, G., Vescovo, L., Gianelle, D. (2020). Mapping forest windthrows using high spatial resolution multispectral satellite images, *International Journal of Applied Earth Observation and Geoinformation*. 93, 102206. https://doi.org/10.1016/j.jag.2020.102206.

SPAIN	FOREST – Continuity of vegetation	Operational Land Imager (OLI) & OLI-2					
	FOREST – Characterization of WUI						
	FOREST – Hotspot identification						
SPAIN	FOREST – Hotspot identification	Thermal Infrared Sensor (TIRS) & TIRS-2	TIR	30-100 m	8 days		
SPAIN	FOREST – Hotspot identification	Moderate Resolution Imaging Spectroradiometer (MODIS)	TIR	500-1000 m	0.25 days	Terra & Aqua	Terra & Aqua
SPAIN	FOREST – Hotspot identification	Visible Infrared Imaging Radiometer Suite (VIIRS)	TIR	750 m	0.5 days	NOAA Joint Polar Satellite System (JPSS)	JPSS
N/A	WebGIS basemap	Dove	RGB	3-5 m	1 day	Planet	PlanetScope

Technical requirements are fundamental in ensuring that satellite data adheres to the quality standards of the CHAMELEON project. Spectral bands must be carefully selected to correspond with specific observational needs, like those necessary for computing NDVI for plant health assessments. The spatial resolution should be high enough to discern individual landscape features, supporting precise cross-referencing with drone data. The revisit time is also critical, as frequent observations are needed to track swift changes in environmental conditions. Cloud cover can significantly hinder the quality of satellite imagery by obscuring the Earth's surface. To address this, modern satellites are equipped with advanced sensors that can detect clouds with remarkable precision. These sensors can often determine the presence of clouds for individual pixels in an image. For example, the Sentinel-2 satellite includes a feature that estimates the probability of clouds at the pixel level, which helps in distinguishing clear from cloudy areas. This capability is crucial for cloud masking, the process of removing the portions of the image that are covered by clouds, which in turn increases the proportion of usable data obtained during each satellite pass. These technical specifications are essential, as they guarantee the satellite data's precision, timeliness, and relevance for the CHAMELEON project, making it a reliable source for environmental analysis and decision-making.

7. CONCLUSIONS AND IMPLICATIONS

This public document is the first version (v1) of the Deliverable D4.2 CHAMELEON, On-Boarding, and stands as one of the outcomes of WP4 implementation. The type of deliverable – document, report. The information from this document will be implemented into the Drone innovation platform. The detailed requirements for each bundle will appear in the drone innovation platform before uploading collected data into the Drone Innovation Platform. This Deliverable 4.2 illustrates the minimal and optimal requirements for different sensors used in CHAMELEON ecosystem and Business use cases (bundles). This document does not contain the demonstration, pilot, or prototype attitude – this will be provided in the second version (v2) of the Deliverable 4.2 9].

This document describes the RGB, Multispectral, Thermal and LiDAR cameras and their parameters, data quality requirements, data format and etc. Deliverable also contains satellites requirements used in CAMELEON ecosystem.

The requirements are divided by different sensors together with specific Business use cases (bundles) developed in CHAMELEON project tasks 4.3, 4.4, 4.5. The information from this deliverable will help Drone innovation platform (DIP) users to get accurate results to the specific problems suggested by different CHAMELEON project bundles service. The future updates for On-boarding will be the implementation and structurization of the requirements in the Drone Innovation platform.

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A Holistic Approach to Sustainable, Digital EU Agriculture, Forestry, Livestock and Rural Development based on Reconfigurable Aerial Enablers and Edge Artificial Intelligence-on-Demand Systems

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