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Hyperspectral sensors integration in a RPAS investigation aerial platform

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ABSTRACT

Remote sensing is the science and art of obtaining information about an object, area or phenomenon starting from the data obtained through a device or instrument without any physical contact with it. These sensors capture electromagnetic energy that comes to them from the reflection or emission of the objects on the Earth's surface, and convert it into an electronic signal that once conditioned, is recorded in some kind of support for further processing and analysis.

On the other hand, the field of remotely piloted Aircraft systems, also called drones, has undergone tremendous growth in recent years. There is a possibility to integrate these remote sensing cameras on-board of them. The result is a remote sensing system applicable in the atmospheric, terrestrial and marine environment allowing a systematic analysis of many geophysical parameters of high interest to researchers, businesses, Government and the public community.

The present document explains the integration process of remote hyperspectral sensors on-board of an unmanned aircraft system as an investigation aerial platform.

Once sensor is fully integrated in the Aircraft, next step is the qualification of the system, military or civilian. The integration ends obtaining the airworthiness certificate.

Lastly, to conclude, future lines of research are exposed.

1. Introduction

Remote sensing is defined, for our purposes, as the measurement of object properties on the Earth's surface using data acquired from Aircrafts [2]. It is therefore an attempt to measure something at a distance, rather than in situ. The major optical spectral regions used for Earth remote sensing are shown in Table 1. It's important to note that the boundaries of some atmospheric windows are not distinct and one will find small variations in these values in different references.

These particular spectral regions are of interest because they contain relatively transparent atmospheric 'windows', in which (barring clouds in the non-microwave regions) the ground can be seen from above, and because there are effective radiation detectors in these regions. Between these windows, various constituents in the atmosphere absorb radiation, e.g. water vapor and carbon dioxide absorb from 2.5–3 μm and 5–8 μm.

At the frequencies of high atmospheric transmittance, microwave and radar sensors are noted for their ability to penetrate clouds, fog, and rain, as well as an ability to provide night-time reflected imaging by virtue of their own active illumination.

Remote sensing may be split into active when a signal is first emitted from Aircrafts, and passive when information is merely recorded. Active remote sensing techniques employ an artificial source of radiation as a probe. The resulting signal that scatters back to the sensor characterizes either the atmosphere or the Earth.

In Fig. 1 radiation is emitted in a beam (labeled 1) from a moving sensor on-board of the RPA (Remotely Piloted Aircraft), and the backscattered component returned from objects on the ground (labeled 2) to the sensor is measured. The motion of the sensor platform creates an effectively larger antenna, thereby increasing the spatial resolution.

Data of the backscatter spatial distribution can be stored or sent to the GCS (Ground Control Station) (labeled 3) to be reconstructed the image by computer processing of the amplitude and phase of the returned signal.

On the other hand, passive remote sensing in all of these regions employs sensors that measure radiation naturally reflected

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Table 1
Primary spectral regions used in Earth remote sensing.

Name	Wavelength range	Radiation source	Surface property of interest
Visible (V)	0.4–0.7 μm	Solar	Reflectance
Near Infrared (NIR)	0.7–1.1 μm	Solar	Reflectance
Short Wave Infrared (SWIR)	1.1–1.35 μm 1.4–1.8 μm 2–2.5 μm	Solar	Reflectance
Mid Wave Infrared (MWIR)	3–4 μm 4.5–5 μm	Solar, thermal	Reflectance and temperature
Thermal or long wave	8–9.5 μm	Thermal	Temperature

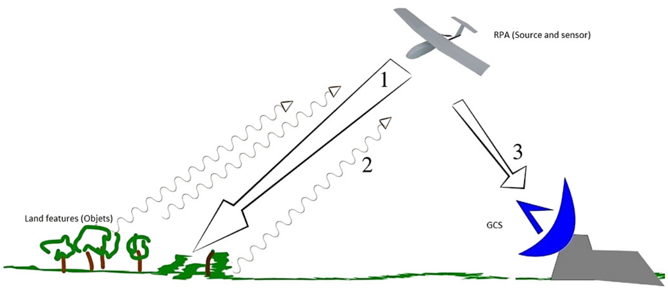

Fig. 1. Remote sensing using passive sensor system.

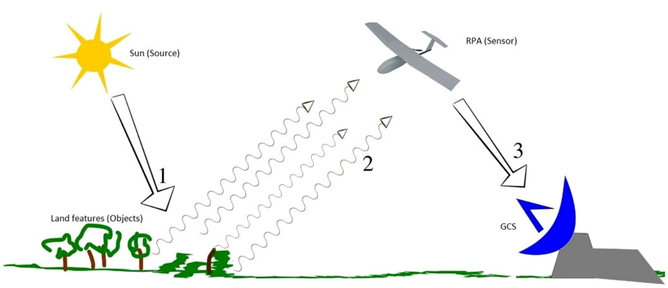

Fig. 2. Remote sensing using active sensor system.

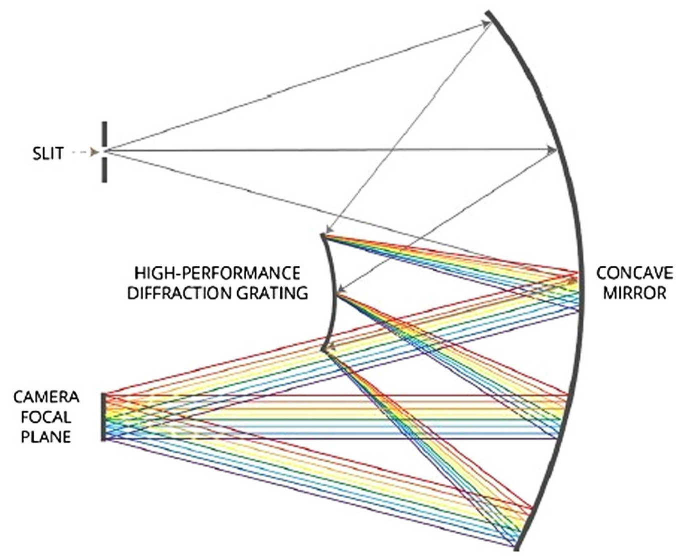

Fig. 3. Hyperspectral operating principle.

or emitted from the ground, atmosphere, and clouds. The visible, NIR, and SWIR regions (from 0.4 μm to about 3 μm) are the solar reflection spectral range because the energy supplied by the sun at the Earth's surface exceeds that emitted by the earth itself. The MWIR region is a transition zone from solar reflection to thermal radiation. Above 5 μm, self-emitted thermal radiation from the earth generally dominates. Since this phenomenon does not depend directly on the sun as a source, TIR images can be acquired at night, as well as in the daytime.

In the following Fig. 2, radiation is emitted by the sun (labeled 1). It is reflected by the objects on the ground and the sensor on-board of the RPA measures this backscattered components returned from objects on the ground (labeled 2). In the same way as before, images can be stored or can be sent to the GCS (labeled 3) to be reconstructed the image by computer processing of the amplitude and phase of the returned signal.

1.1. Operating principle

The fore camera optic shows the scene onto a slit, which only passes light from a narrow line in the scene. After collimation in the concave mirror, a high-performance dispersive element separates the different wavelengths and the light is focused through the same concave mirror onto the camera focal plane. A scheme of the operating principle is shown in Fig. 3.

The net effect of the optics is for each pixel interval along the line defined by the slit, a corresponding spectrum is projected on a column of detectors on the array. The data read out from the array thus contains a slice of a hyperspectral image, with spectral information in one direction and spatial information to the other. By scanning over the scene, the camera collects slices from adjacent lines, forming a hyperspectral image or cube, with two spatial dimensions and one spectral dimension [9].

1.2. Hyperspectral imaging

Hyperspectral imaging, or imaging spectroscopy, combines the power of digital imaging and spectroscopy [3]. For each pixel in an image, a hyperspectral camera acquires the light intensity (radiance) for a large number (typically a few tens to several hundred) of contiguous spectral bands. Every pixel in the image thus contains a continuous spectrum (in radiance or reflectance) and can be used to characterize objects in the scene with great precision and detail.

Hyperspectral images obviously provide much more detailed information about the scene than a normal color camera, which only acquires three different spectral channels corresponding to the visual primary colors red, green and blue. Hence, hyperspectral imaging leads to a vastly improved ability to classify the objects in the scene based on their spectral properties. Differences between both kinds of images are shown in Fig. 4.

1.3. Objective

The main objective of the present paper is summarize the results obtained during the research for the integration of a hyperspectral sensors on a Spanish RPAS (Remotely Piloted Aircraft System), covering all the process from the preliminary studies until the certification of the IAP (Investigation Aerial Platform).

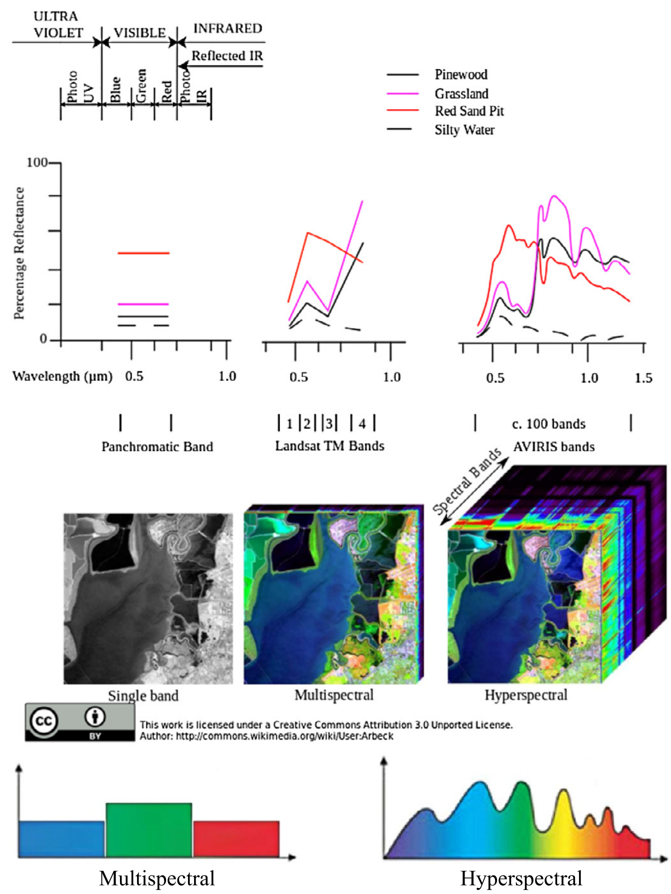

Fig. 4. Differences between multispectral and hyperspectral images. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

The idea to choice a hyperspectral system instead a multispectral system is because the first one works with much more wave lengths than the second one and as a consequence of that we will obtain better results in terms of resolution of the different images that we will obtain during the mission of our system [1]. A representation of the differences between the three possibilities when you are talking about spectral images can be seen in Fig. 4 where is clear that the hyperspectral solution is better than the others because it uses more wave length to create the image giving more resolution and better response to the different applications where we are interested to work.

1.4. *Justification*

The use of RPAS as IAP has multiple advantages, as the long range, the reduced operation costs, or the ability to operate in especially adverse environment (i.e. high ash concentrations, temperature or radioactivity) without endangering the crew as happens in manned IAP.

Therefore justifications to perform the present research are:

- Providing a RPAS as IAP capable to perform remote sensing missions, in all weather conditions for a wide diversity of scientific and industrial operators, and aeronautics industries.
- Providing a RPAS capable of serving as a tool for the development of another projects (scientific equipment, sensors, etc.) accomplished by the institute in the remote sensing field.
- Offering to the European scientific community a RPAS capable to perform remote sensing missions in extreme environments, as polar regions or desert environment.

2. State of the art

An IAP is an aerial platform modified structurally to install scientific instrumentation or test equipment to perform experiments, tests and/or research activities. These aerial platforms are complemented by another on ground facilities, such as hangars, calibration and characterization of on-board equipment laboratories, auxiliary laboratories for testing of on-board instrumentation, reception, processing, archiving and distribution of data and imagery systems, etc.

Nowadays, Spain possesses two C-212-200 Aircraft instrumented [16] for atmospheric measurements and to perform remote sensing flight campaigns. It has also recently acquired a motor glide STEMME S15, which will be fully operational soon. Such platforms are recognized as an STCI (Singular Scientific and Technological Infrastructures) and constitute unique and versatile infrastructure to undertake atmospheric and Earth's surface research projects.

3. Mission description: requirements and constraints

The RPAS will accomplish missions that have been previously planned and validated using a flight planning tool, in the INTA case we are owners of our flight planning mission tool and also we have our own flight control system designed, developed and manufactured by ourselves. Once planned, the mission should be validated automatically attending at least to the following five criteria:

- Terrain orography
- Aerial platform performances
- Fuel available
- Do not over y forbidden zones
- Radio-electric coverage

At any time, mission may be modified by the different control modes available in the GCS. These commands must be executed in real time and will be subjected to internal validation within the GCS.

Of course during the flight the Flight Control System (FCS) will take into account the variation of the CG due fuel consumption and will maintain the right values in the flight parameters that can affect de operation of the payload.

The main application of this IAP will be the acquisition of aerial remote sensing imagery of the Earth's surface, through the design, planning and performance of flight campaigns with airborne sensors, covering almost all the hyperspectral range, from UV to LWIR.

In this way, scientific community can obtain enough information to perform studies about precision agriculture, Earth mapping, terrestrial phenomenon, weather forecasting, and so on.

Particularly Spain is very interested to have small and cheap systems that can allow to accomplish missions obtaining information in real time and post fly about observation of the eath from the air as we will explain later on in this article. There are many privates companies interested in this kind of solution that cannot spend money in the investigation phase (this is one of the purpose that INTA has in Spain, to spend money in different investigation projects and offer the final solution to the industrial community for exploitation). Also and not let important is the Government interest to have the kind of solution described in this article to fix the earth observation in Spain.

Fig. 5. ATLANTE.

Table 2
ATLANTE main specifications.

MTOW	520 kg
Payload	100 kg
Range	250/600 km
TASmax	55 m/s
TAScruise	37.5 m/s
EASstall	N/A
Ceiling	20000 ft
Endurance	10 h
TO/LA	N/A
Crosswind	10 m/s

4. Reference spanish rpas overview

4.1. ATLANTE

ATLANTE (in Spanish: Avión Táctico de Largo Alcance No Tripulado Español) [15] is a system designed by EADS CASA (and manufactured by Airbus Defense and Space) to meet the requirements of the Spanish Army, to acquire the RPAS with ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance). Fig. 5 shows the ATLANTE RPAS in flight.

The system is composed by the Aircraft, the GCS, transporting, launching and collecting unit, remote video terminal and a maintenance team. ATLANTE specs are shown in Table 2.

4.2. Milano

Milano is a strategic monitoring and observation system composed of all-weather RPA linked via satellite with the GCS) [19]. Fig. 6 shows the Milano RPAS and the Milano specs are shown in Table 3.

4.3. ALO

The ALO (in Spanish: Avión Ligero de Observación) [18] is a lightweight RPAS that provides real-time reconnaissance, surveillance and target acquisition. The ALO is equipped with visible or infrared sensors, a mobile GCS, and a launch system (without landing gear). Fig. 7 shows the ALO RPAS in flight and ALO specs are shown in Table 4.

4.4. SIVA

SIVA (in Spanish: Sistema Integrado de Vigilancia Aérea) is a tactical surveillance system [20].

Its main mission is to use as a vehicle for real-time surveillance. It has several electro-optical sensors, both visible (CCD camera) and infrared (FLIR). Fig. 8 shows the SIVA RPAS in flight and SIVA specs are shown in Table 5.

Fig. 6. Milano.

Table 3
Milano main specifications.

MTOW	1050 kg
Payload	150 kg
Range	2000 km
TASmax	64 m/s
TAScruise	45 m/s
EASstall	29 m/s
Ceiling	26000 ft
Endurance	21 h
TO/LA	650 m
Crosswind	7.5 m/s

Fig. 7. ALO.

Table 4
ALO main specifications.

MTOW	55 kg
Payload	20 kg
Range	50/100 km
TASmax	50 m/s
TAScruise	32 m/s
EASstall	14 m/s
Ceiling	14000 ft
Endurance	4 h
TO/LA	160 m
Crosswind	N/A

4.5. Resume

Showing the features of the RPAS above described, the following Table 6 has been performed.

5. Reference aerial platform selection: rational and results

The main objective of integrating hyperspectral sensors onboard of the RPAS is to satisfy the demand of hyperspectral data.

Fig. 8. SIVA.

Table 5
SIVA main specifications.

MTOW	300 kg
Payload	35 kg
Range	150 km
TASmax	53 m/s
TAScruise	N/A
EASstall	26.5 m/s
Ceiling	13000 ft
Endurance	7 h
TO/LA	650 m
Crosswind	N/A

Table 6
RPAs comparison.

	ATLANTE	Milano	ALO	SIVA
MTOW	520 kg	1050 kg	55 kg	300 kg
Payload	100 kg	150 kg	20 kg	35 kg
Range	250/600 km	2000 km	50/100 km	150 km
TASmax	55 m/s	64 m/s	50 m/s	53 m/s
TAScruise	37.5 m/s	45 m/s	32 m/s	N/A
EASstall	N/A	29 m/s	14 m/s	26.5 m/s
Ceiling	20000 ft	26000 ft	14000 ft	13000 ft
Endurance	10 h	21 h	4 h	7 h
TO/LA	N/A	650 m	160 m	650 m
Crosswind	10 m/s	7.5 m/s	N/A	N/A

That is why the chosen sensor must be able to be employed in the largest possible number of applications [4,6–8,10–13].

Such applications include:

- Marine applications: sea surface winds, temperature and height; salinity, ocean currents and color, water quality, bathymetry (erosion, sedimentation, etc.), coastal management, etc.
- Atmospheric applications: weather forecast, study of atmospheric gases, prevention of disasters (storms, winds, etc.), renewable energy (wind, solar), air quality (pollution, aerosols, calimas, etc.), greenhouse gasses, climate change, etc.
- Terrestrial applications:
  - Vegetation and forests: vegetation index, forest cover and density (crown closure), inventory of forest species, biomass estimation, deforestation, protection forests, monitoring and evaluation res, etc.
  - Agriculture: crop forecast, extension and inventory; agricultural production, selection and monitoring agricultural areas, evaluation of drought or flood damage, pest control and crop diseases; detection of metabolic stress (water or nutritional), precision agriculture, etc.

Table 7
Hypersec E-Serie and μCASI 1920 comparison.

Sensor	Hyperspec E-Series	μCASI 1920
Type	Pushbroom	Pushbroom
Spectral range (nm)	250–12000	400–1000
Bands	923	288
FOV (°)	19.5	36.6
IFOV (mrad)	0.21	0.36
Image size (pixels)	1600 × 1	1920 × 1
Dynamic range (bits)	16	12
Aperture	f/2.0	f/2.0
Frame rate (fps)	100	280
Pixel size (microns)	6.5 × 6.5	5.86 × 5.86
Spectral resolution (nm)	2.5–4	<5
Size (mm)	177 × 129 × 74	190 × 102 × 198
Weight (kg)	3.5	1.5
Power (Watt)	13.2	45

Urban monitoring: urban mapping, understanding urbanization process, prevent environmental degradation and pollution, estimate population, planning (ports, airports, roads, etc.), detecting illegal buildings, analyze vulnerabilities and risks, monitor disasters, cartography of urban green areas, etc.

  - Natural disasters (fire, flood, earthquake, volcanic eruptions, etc.): disaster prevention (life, property and natural resources), real-time tracking of disaster, analysis of the effects after natural disasters, monitoring recovery activities, etc. [11].
  - Defense: security and intelligence, high-resolution mapping, verification of international treaties, border control, emergency management, etc.
  - Other applications: geology (mining, sedimentation, erosion), ground humidity, topography, DTED, archeology, geodesy, etc.

The result is a remote sensing system [5] applicable in the marine environment, terrestrial and atmospheric, allowing a systematic analysis of many geophysical parameters of high interest to researchers, businesses, government and the general public.

5.1. Remote sensing sensor

Searching for remote sensing sensor, we found that is possible to find in the market manufacturer that give us the sensor solution, as an example Headwall and iTres [22–25] have system that can cover our requirements, which are shown in Table 7.

5.2. Sensor and RPAS selection and justification

The Headwall sensor is better than iTres in terms of spectral range, bands number, FOV, IFOV, dynamic range and power.

The possibility of covering a spectral range from 250 to 12000 nm is to let the user to use it for a wide number of applications, so this is a significant characteristic that must be considered.

Another important feature is the number of bands. The possibility of record up to 923 bands is to let the user to obtain much more information of the terrain that using only 288 bands.

The dynamic range is also better in this sensor. It means that the images created will be represented more accurately, obtaining a wide range of intensity levels found in the region of interest and obtaining a better contrast between dark and clear zones.

However, the FOV, IFOV and the image size is worse in the case of the Headwall sensor than in the iTres. That means that the RPA should do more runs to cover the ROI (Region Of Interest), that is, the track will be longer.

The frame rate is higher in the case of the μCASI 1920 sensor. Nevertheless this factor depends on the ROI and the binning options selected so this characteristic won't be considered because it is not very reliable.

Table 8
RPAs comparison.

		Atlante	Milano	ALO	SIVA
MTOW	>400 kg	520 kg	1050 kg	**55 kg**	**300 kg**
Payload	>100 kg	*100 kg*	150 kg	**20 kg**	**35** kg
Range	>150 km	250/600 km	2000 km	**50/100 km**	*150 km*
TASmax	>55 m/s	*55 m/s*	64 m/s	**50 m/s**	**53 m/s**
TAScruise	40–50 m/s	**37.5 m/s**	45 m/s	**32 m/s**	N/A
EASstall	<30 m/s	N/A	29 m/s	**14 m/s**	26.5 m/s
Ceiling	>22 000 ft	**20000 ft**	26 000 ft	**14000 ft**	**13000 ft**
Endurance	>7 h	10 h	21 h	**4 h**	*7 h*
TO/LA	<700 m	N/A	650 m	160 m	650 m
Crosswind	>7 m/s	10 m/s	7.5 m/s	N/A	N/A

Regarding the size, weight and power, all the available platforms can support these parameters, so these characteristics neither will be taken into account. All other features are the same in both sensors or they are not relevant for the election.

Once all the features have been studied conscientiously, the sensor chosen is the Headwall Hyperspec E-Series.

Based on requirements described and the RPAS comparison table performed, Table 8 has been performed to show which RPAS meets these requirements.

Values in grey colour meet the specified requirements; values in italic meet them, but just in the upper or lower limit; and finally values in boldface do not meet them.

Given the requirements and characteristics of each Aircraft, one can conclude that Milano platform is the most suitable to be used.

6. The integration process

The complete system must have the following mandatory components if we needs to obtain a georeferenced and ortho-rectified hypercube: the hyperspectral camera, an IMU (Inertial Measurement Unit) [21] and a GPS. In addition we need a way to control the payload and to handle the data obtained from it. It is very important once we have selected the components to integrate and the RPAS to carry the payload to study the position of the different equipment in order to guarantee that the centre of gravity of the RPAS is in the right position.

6.1. Storage and data transfer

In order to calculate the amount of data that we need to handle the data transfer rate of the sensor will be calculated. So taking into account that the sensor frame rate is 100 fps, that it has 1600 spatial bands and 923 spectral bands, and that the resolution of each pixel is 16 bits, then:

$$100\text{ fps} \times 1600\text{ spat} \times 923\text{ spec} \times 16\text{ bits}$$
$$= 2{,}362{,}880{,}000\text{ bps} = 281.68\text{ MBps}$$

So theoretically the data transfer of each sensor is 281.68 MBps. This data transfer is obtained through the sensor data sheet. However, the manufacturer does not ensure that data transfer will be stable, recommending to choose a configuration that does not exceed between 70–80% of it, that is, in the worst case, a data transfer of 225.34 MBps.

Now, is each mission can take up to 4 h, the storage needed will be calculated as follows:

$$225.34\text{ MBps} \times 4\text{ h} \times 3600\,\frac{\text{s}}{\text{h}} = 3{,}244{,}921.86\text{ MB} = 3.09\text{ TB}$$

So the storage device needed to perform a 4 h mission is 3.09 TB.

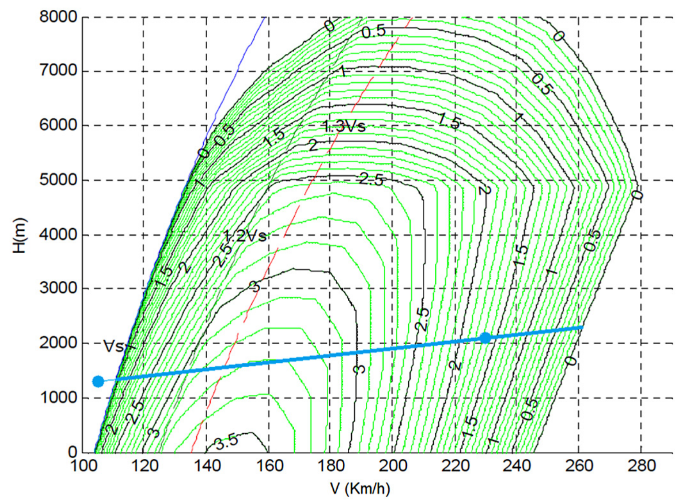

Fig. 9. Milano flight envelope.

6.2. Pixel size

One of the determining factors of carrying out a mission is the pixel size. One must take into account that, for optimum results, the pixel must be square, taking into account that using the pixel square the definition will be better because the system doesn't add any kind of deformation when we obtain the final image. Considering Milano stall speed 29 m/s (104.4 km/h), the maximum speed 64 m/s (230.4 km/h), and the maximum frame rate of the camera 100 fps, then the pixel size along track can be calculated as follows:

$$X_{\text{stall}} = \frac{V_{\text{stall}}}{\text{fps}} = \frac{29}{100} = 0.29\text{ m}$$

$$X_{\max} = \frac{V_{\max}}{\text{fps}} = \frac{45}{100} = 0.45\text{ m}$$

As the objective is that the pixel must be square, the size of the pixel along track and the size of the pixel across track must be the same. Knowing that the number of spatial bands is 1600 and that the FOV is 19.5°, the height at which the RPA must fly to make the pixel square is:

$$H_{\text{stall}} = \frac{X_{\text{stall}}}{2 \times \tan(\frac{\frac{\pi}{180} \times \frac{\text{FOV}}{\text{SB}}}{2})} = \frac{0.29}{2 \times \tan(\frac{\frac{\pi}{180} \times \frac{19.5}{1600}}{2})} = 1363.3\text{ m}$$

$$H_{\max} = \frac{X_{\max}}{2 \times \tan(\frac{\frac{\pi}{180} \times \frac{\text{FOV}}{\text{SB}}}{2})} = \frac{0.45}{2 \times \tan(\frac{\frac{\pi}{180} \times \frac{19.5}{1600}}{2})} = 2115.5\text{ m}$$

So when the Aircraft flies at 104.4 km/h, the square pixel is achieved at 1363.3 m, and when it flies at 230.4 km/h, it is achieved at 2115.5 m. Finally, if both values are transferred to Milano flight envelope, and considering that, these values are linear, the flight line in which all the pixels are square corresponds to the picture from Fig. 9.

The solution that we propose allow to obtain resolutions ranging from 2.4 to 13.7 m in typical flying height flights. This result is enough to cover most of the application that we are interested to do and mentioned in the first part of the article.

6.3. Sensor control and monitoring

In RPAS case, the payload controller is situated on ground, so the sensors must be controlled and monitored in real time from the payload position.

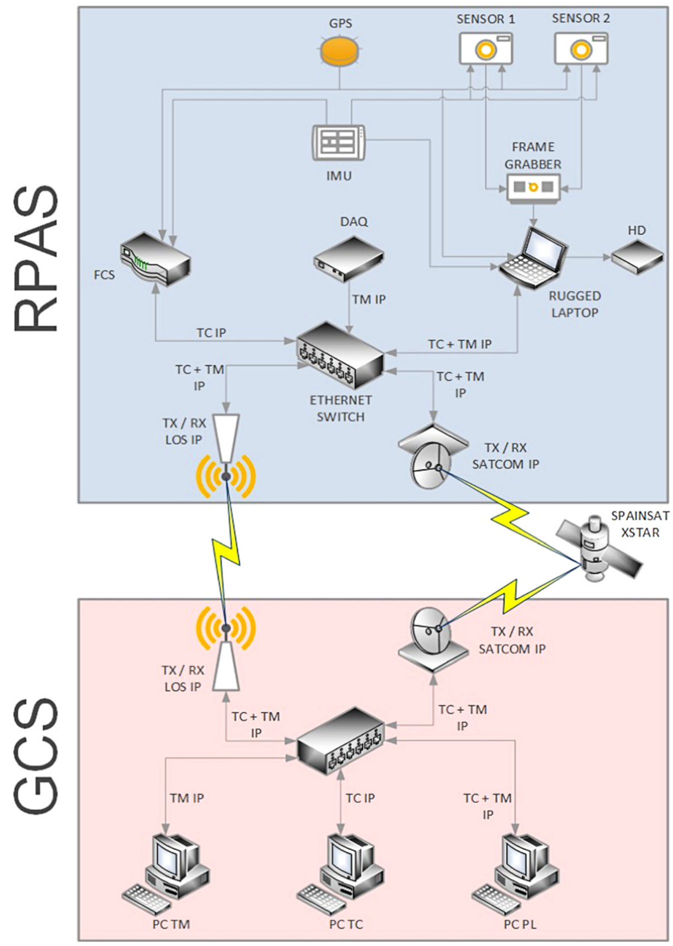

Fig. 10. Integration scheme.

Although the system can work autonomously, activating or deactivating the recording when the RPAS reaches a predetermined waypoint, there are multiple reasons for the sensors be also controlled from the GCS. The main reason is that the operator can check if the sensor is working correctly.

However, data will not be sent. The reason is because the transfer rate is too high and it cannot be sent to the GCS. So it will be stored on-board, but we will send enough information in real time that will allow the operator to decide if the "run" (time of the flight that our payload is recording data) have been good enough for the mission purposes.

Having identified all the elements that allow the integration of both sensors and the rugged laptop, Fig. 10 shows one of the different options of the final solution.

6.4. Structural integration

Once we have decided the different components of hour payload and the RPAS where we want to integrate it, it is very important to study the impact of the integration in the center of gravity (CG) of the RPAS. According with the specification of the Milano RPAS the system has a place designed to locate the different payloads but considering the position of the wing it is necessary to install the components and once we have finished the integration to calculate the amount of load that we need to guarantee that the CG is in the right position and the main characteristics of the RPAS are the same that without payload. The RPAS is designed to carry out up to 200 Kg of payload but including the weight that we will need to balance the Airframe in order to have a good position of the CG.

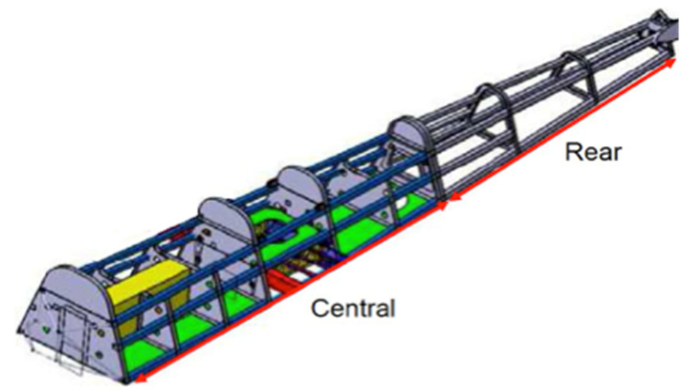

Fig. 11. Milano airframe.

Milano airframe is divided into two independent modules, central and rear, with a semi-monocoque structure, capable to hold up to 150 kg of payload. Fig. 11 shows the central fuselage (without side panels for easy viewing), and the rear fuselage (without the upper and lower skins).

In the central part of the central fuselage and the top of the rear of the fuselage two separate fuel tanks 50 liters are integrated. Avionics systems fill the rest of the central fuselage. On the other hand, the wings consist of three main elements: central, exterior right and left outside. The outer wing elements have aps and ailerons, and in the first compartment of each wing an 80 liters fuel tank is integrated. Given these premises, the only place available for boarding the sensors and is the bottom of the rear fuselage. Once we have install the sensors we will have to put some load at the front part of the fuselage to maintain the position of the CG of the RPAS.

7. The certification process

Once we have defined the system we need to certify it either using military or civilian rules depending of the way that we decide to use our system.

In Spain as in the rest of the world Airworthiness Regulations of Defense defines and regulates the various certificates to ensure the safety flight of military RPAS, and establishes procedures for the issue, the requirements that applicants must meet to obtain the certificates and the regulation to be followed by their holders and custodians to keep it operational. This regulation applies to military RPAS used by the Army, Institutes, organizations or dependent or linked to the Ministry of Defense or the Civil Guard services, or that may be of interest to them or to the Spanish defense industry. In Spain INTA is the organization in charge to give the different kinds of certifications following the STANAG procedures, in the RPAS case NATO STANAG 4671, 4702, 4703 and 4746 [14,26–30].

When we are talking about civilian certification, we have to follow the Airworthiness Regulations for civilian applications. Currently EASA is working in a European Regulation that have to be ready very soon to regulate the civilian RPAS market but in the meantime national regulation have to be applied, in Spain AESA is the organization in charge to give the certificate of each system according with the Spanish Law [15,30].

8. Future research lines

LiDAR (Light Detection And Ranging) [16,17] is a system that allows to obtain a cloud of points on the ground took them by airborne laser scanner. To perform this scan two movements are combined. One longitudinal given by the path of the airplane and other cross using a mobile mirror that deflects the laser beam emitted from the scanner.

To know the coordinates of the point cloud, the sensor position and the angle of the mirror at all times are needed. Therefore the LiDAR technology is assisted by the GPS technology and the IMU to collect altitude data. Known these data and sensor-field distance obtained with the EDM (Electronic Distance Meter) one can obtain the required coordinates. The result is tens of thousands of points per second. These data are used to de ne the ground surface and generate digital elevation models.

The use of this technology has advantages over the capture with conventional methods: requires minimum geodesic ground control and data have a higher density and higher precision.

A future research line could be the integration of a LiDAR system in Milano PAI platform. The result of this instruments fusion will be a unique system that permits simultaneous measurements of vegetation structure, foliar spectra and surface temperatures.

Nowadays multiple LiDAR options can be found in the market. A proposed option is the RIEGL VQ-580 system. It is a very compact and lightweight scanner, mountable in any orientation and even under limited space conditions as on-board RPAS. The instrument only needs one power supply and provides line scan data via the integrated LAN-TCP/IP interface.

With a very low consumption, only 65 W, with dimensions of $36 \times 21 \times 22$ cm (length $\times$ width $\times$ height) and a weight of 13 kg, this product joint to the hyperspectral sensor will produce a compact and lightweight system that can be used to support a huge number of Earth Science research projects.

Conflict of interest statement

None declared.

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