Water-tightness Airborne Detection Implementation

D.3.2 – Onboard manned aircraft (integrated) sensors system

Authors:

NTGS: Jiménez D

ONERA: Frédéric Y-M, Chatelard C, Barillot P, Krapez J.-C, Louvet Y, Hélias F, Ph. Déliot

AM: Olichon V., Mazel C.

29 March 2019

Technical references

Project Acronym	WADI
Project Title	Water-tightness Airborne Detection Implementation
Project Coordinator	Elena Gaboardi, youris.com (YOURIS) elena.gaboardi@youris.com
Project Duration	October 2016 – March 2020 (42 months)
Deliverable No.	D.3.2
Dissemination level*	PU
Work Package	WP 3 - Demonstration of Airborne Innovative Techniques
Task	T3.2 - Onboard manned aircraft sensors system.
Lead beneficiary	7 (NTGS)
Contributing beneficiary/ies	2 (ONERA), 3 (AM)
Due date of deliverable	31 March 2018
Actual submission date	29 March 2019

PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

V	Date	Beneficiary	Author
1.0	22/07/2018	NTGS	David Jiménez (NTGS)
1.1	05/03/2018	ONERA	Frédéric Y-M, Chatelard C, Barillot P, Krapez J.-C, Louvet Y, Hélias F, Ph. Déliot
1.2	05/03/2018	AM	Olichon V., Mazel C.
1.3	25/07/2018	YOU	Meneghello, V.
1.4	29/03/2019	GG	Barba Polo, J.
1.5	29/03/2019	YOU	De Ferrari A., Gaboardi E.

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689239.

The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Union. The European Commission is not responsible for any use that may be made of the information contained therein.

Executive Summary

This document, describes the design of a geo-stabilized platform that will allow the use of the selected sensor system from the document (D.3.1), for it use on the manned airplane from Air Marine. The document aims to be simple and direct in a way that can be used directly by the engineers in charge of the manned plane in the hangar.

The objective of this deliverable is to inform of the design of a gimbal platform and the different components and its integration in the WADI manned airplane that after being tested is to be applied in operational environment demonstrations over the two pilot sites (WP5 and WP6).

Table of Content

Acronyms List

D.n	Deliverable n
GNSS	Global Navigation Satellite System
IMU	Inertial Measurement Unit
MC	Multispectral Camera
TC	Thermal Camera
WP.n	Work Package n
SDK	Software Development Kit
RAIM	Receiver Autonomous Integrity Monitoring
MEMS	Microelectromechanical Systems
SSD	Solid-state drive
LWIR	Long Wave InfraRed
MWIR	Medium Wave InfraRed
CCD	Charge-Coupled Device
GPIO	General Purpose Input/Output
FET	Field-Effect Transistor
OEM	Original Equipment Manufacturer
FPA	Focal Plane Array

1 Introduction

This document details both the components integrated into the Tecnam P2006T aircraft console, and the design of the geo-stabilized platform that allows the control and movement of the sensors (cameras, IMU) to capture data (images) and other associated information (position and orientation).

The design of the platform has as main drawbacks the limited space in the aircraft and the limitations of weight and accessibility. Other integration problems are related with the use of different nature and not updated Software Development Kit (SDK) in the cameras, IMU and components.

The selected cameras have to be mounted according to the requirements and recommendations of the project and since there are not commercial solutions for integrating these state of the art remote sensing cameras we had to proceed for designing of a new geo-stabilized platform. The new platform in spite of the limited space to hold the cameras need to give also a good access to the different elements.

The adaptation and integration of the airborne sensors system was done in two iterations, during the first iteration the general design was correct but a secondary factor like the mismatch of the windows size because of the presence of cable groups not taken into account during the design phase, or the low performance of the first selection of servo-motors obliged to perform a second iteration to fix these problems.

The new parts like the trapeze, suspension link, yaw chassis, pitch chassis, roll chassis and a sensor column are all made in aluminium that has very known advantages for the aeronautic sector but is quite difficult to work since very specialised machinery are needed like laser cutters and bend machines. The platform design after the second iteration is quite satisfying, and the assemblage and disassemblage of the sensors could be done without great efforts even with the small remaining space.

2 Components to be integrated

The system is composed of the following components:

- Multispectral Camera (MC) Pixelteq SPectroCam VIS.
- Thermal Camera (TC) Noxant Noxcam
- Computer NUVO 5006 E/P.
- IMU. Spatial Dual Advanced Navigation
- BaseCam BGC Pro
- Gimbal Motor GBM 110-150T.

All of them, except the computer, are integrated into the platform and are described one by one in the following document points. The integration process has been quite easy from the hardware point of view because of the facilities given by the selected onboard computer and the different cameras and components, however for the operational integration is quite difficult because of the immaturity of the Software Development Kit (SDK) of the cameras that implies to test different compatible programming environments and even the selection of the operative system for the computer.

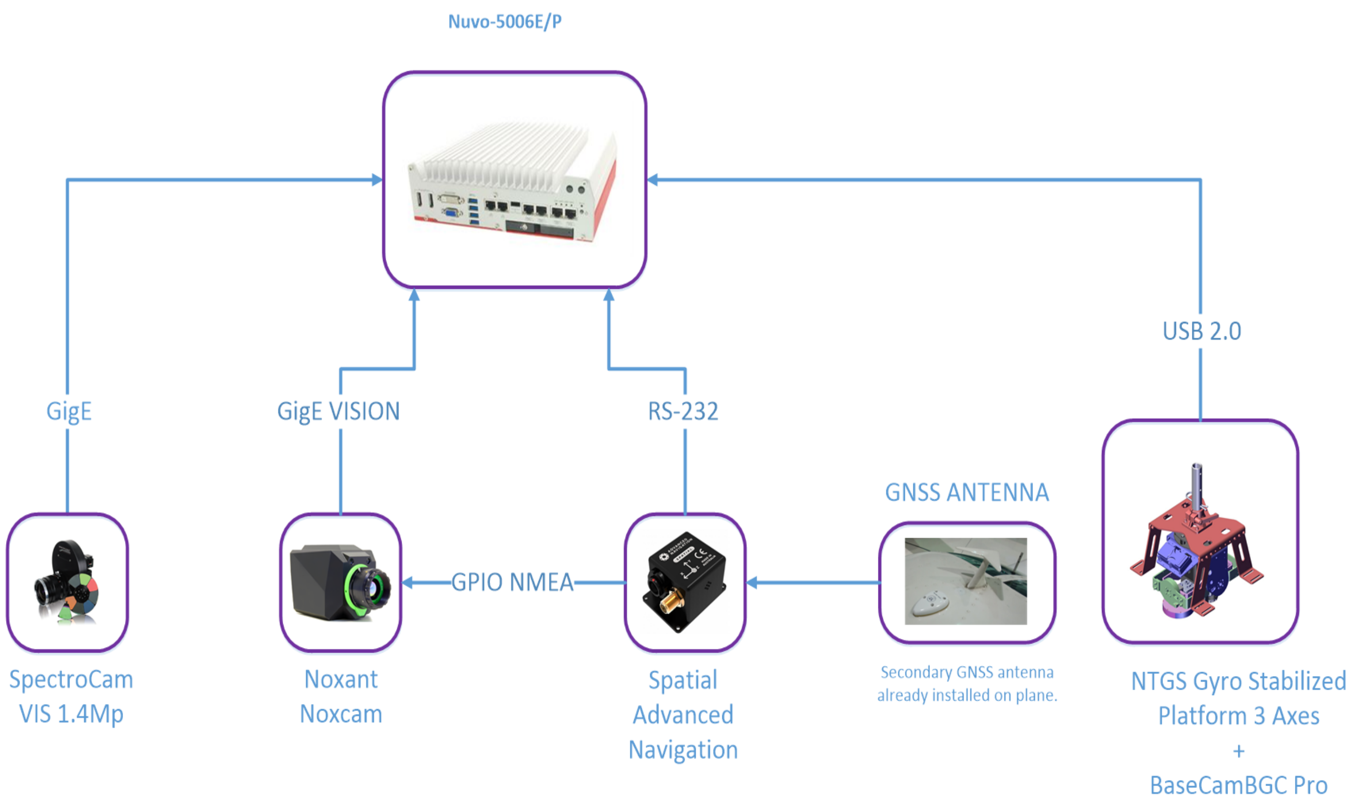

Figure 2-1 Components to be integrated

2.1 Multispectral Camera (MC) Pixelteq SPectroCam VIS

SpectroCam is the multispectral camera selected by the consortium after the analysis carried out in document D.3.1

Figure 2-2 Pixelteq SpectroCam Vis

The SpectroCam multispectral wheel cameras offer a sophisticated, flexible platform for development and deployment of various imaging applications, is designed to reduce development times and simplify the design cycle, SpectroCam features a high speed, continuously rotating filter wheel containing 6-8 interchangeable optical filters.

Combined with the scientific grade CCD array, this filter design creates a fully portable and configurable, high speed multispectral imaging system. It has minimal pixel shift and high frame rates, and utilizes a wideband CCD capable of UV-enhanced measurements.

The system can also be customized for integration into specific OEM products. The platform is readily modified to meet mechanical and environmental needs like is our case in the WADI project. The camera utilizes a wideband CCD capable of UV-enhanced measurements.

The main benefits of using this camera are:

- Sequential 6-8 band multispectral imaging
- Full frame resolution at up to 25 frames/second
- Interchangeable standard & custom spectral filters
- Intuitive acquisition software
- High speed digital video output

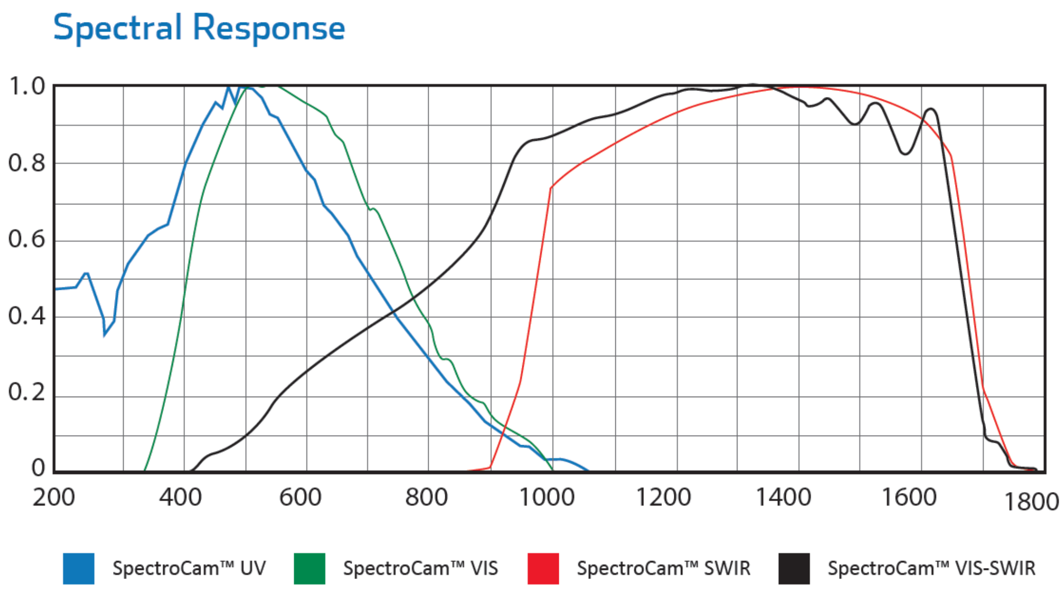

Figure 2-3 Pixelteq SpectroCam spectral response

The camera main features are shown in the following table:

	Main features
Power	• 12 Vdc (pluggable connector)
Dimensions	• 124 x 136 mm
Weight	• 680 g
Others	• 6-8 spectral bands at full-frame resolution (up to 20 frames per second) • Interchangeable spectral filters • C++SDK • Proprietary protocol over Gig-E 12 bit • External triggering and GPIO • No input GNSS/IMU data

Table 2-1 SpectroCam VIS Features

2.2 Thermal Camera (TC) Noxant Noxcam

Noxant Noxcam is the thermal chamber selected after the analysis carried out in D.3.1. This is a high performance radiometric cameras based on the NoxEngine technology, that include all the features required for Industrial and measurement applications (Non-destructive testing, Advanced Thermography, Research, etc.) and of course the required for the WADI project. Radiometricaly calibrated, NoxCam provides measurement data of very high accuracy.

It is equipped with the latest generation of thermal detector, cooled by stirling engine, offering an unmatched performance and flexibility in a reduced footprint, together with ease of use provided by on-board raw calibrated data recording, embedded control software and compatibility with industry standard analysis software such as Matlab or ImageJ. It has a quite stiff and robust housing for harsh environments and is indicated for applications requiring speed imaging and interfaces while maintaining the camera ease of use.

Figure 2-4 Noxcam 640L

Its measurement range goes from typical 5°C to 300°C but the radiometric measurement ranges are optimized to fit any application requirements and can be set between sub-zero to up to 3000°C. A Radiometric measurement evaluation is performed for each case.

Noxant's Radiometric Measurements are compensated against temperature deviation. Ultra low jitter input signal allows to synchronize the photon collection time with an external event, such as rotation coder or a photoelectric cell.

Another interesting point is the software compatibility, the camera is compatible with all major operating systems such as Windows, Mac OS X or Linux. File format, radiometric calibration data and procedures could also be provided on demand.

The main benefits of using this camera are:

- Accurate Radiometric Measurement. Thanks to the Noxant's radiometric processing.
- Sensor Synchronization Input. Photon collection timing is accurately controlled.
- Compatible with standard Industry and research software.
- Spectral Filter Selector. For application dedicated spectral filtering.
- On-board image recording. No Computer configuration issues. NoxCam provides cutting edge recording performances whatever the computer operating system is.
- SSD HardDrive Port. Recorded sequences are easily available.

The camera main features are shown in the following table:

	Main features
Dimensions	• 191 x 131 x 141 mm
Weight	• 2250 g
Others	• Snapshot Infrared FPA • Band 3 - 7.7µm to 9.3 µm , LWIR • Cooled by Stirling engine for unmatched sensitivity • Integrated optical filter selector • 640x512 pixels f/2 to f/5.5 • NoxEngine embedded • Automatic Dynamic Image Improvement • (Flat field / Dark field / Automatic Defective Pixel Detection) • GigEVision / Genicam • Onboard Radiometric RAW or h.264 recording on 2.5'' SSD Drive • Digital Streaming thru HDMI with advanced colour overlay • Low jitter Sync Input • Fixed focal length (25 mm) or zoom, motorized focus • Small footprint (186L x 126l x 136h) (mm w/o optics)

Table 2-2 Noxcam 640L Features

2.3 Computer NUVO 5006 E/P.

The processing unit is a computer NUVO 5006 E/P, that is a next-generation rugged fanless embedded controller with performance and versatility. It supports socket-type 6th-Gen Core™ processors and has an efficient fanless heat-dissipating design offers true -25°C to 70°C wide-temperature operation and very useful port connections like Gigabit Ethernet, USB3.0/ USB2.0, COM ports, VGA/DVI/DP triple display outputs. We have used and optimized the most of the computer capabilities with good test results.

The main benefits of using this computer are:

- It covers the needs of real-time processing. Intel 6th-Gen Core
- Space limitations
- Rugged, -25°C to 70°C fanless operation
- Up to 32 GB, DDR4-2133 SODIMM
- Up to 6x GigE ports, supporting 9.5 KB jumbo frame
- Accommodates two 2.5" SATA HDD/SSD with RAID 0/1 support
- VGA/ DVI/ DP triple independent display, supporting 4K2K resolution
- Interface for easy function expansion
- PCI/PCIe add-on card accommodation

Figure 2-5 NUVO 5006 E/P. Front view.

Figure 2-6 NUVO 5006 E/P. Back view.

Specifications

System Core	
Processor	Intel® Core™ i7-6700 (8M Cache,3.4/4.0 GHz, 65W TDP)* Intel® Core™ i5-6500 (6M Cache, 3.2/3.6 GHz, 65W TDP)* Intel® Core™ i3-6100 (3M Cache, 3.7 GHz, 51W TDP)* Intel® Pentium® G4400 (3M Cache, 3.3 GHz, 54W TDP)* Intel® Celeron® G3900 (2M Cache, 2.8 GHz, 51W TDP)* Intel® Core™ i7-6700TE (8M Cache, 2.4/3.4 GHz, 35W TDP) Intel® Core™ i5-6500TE (6M Cache, 2.3/3.3 GHz, 35W TDP) Intel® Core™ i3-6100TE (4M Cache, 2.7 GHz, 35W TDP) Intel® Pentium® G4400TE (3M Cache, 2.4 GHz, 35W TDP) Intel® Celeron® G3900TE (2M Cache, 2.3 GHz, 35W TDP)
Chipset	Intel® Q170 Platform Controller Hub
Graphics	Integrated Intel® HD Graphics 530/510
Memory	Up to 32 GB DDR4-2133 SDRAM by two SODIMM sockets
AMT	Supports AMT 11.0
TPM	Supports TPM 2.0
I/O Interface	
Ethernet	2x Gigabit Ethernet ports by Intel® 1x I219 and I210 (Nuvo-5002E/P) 6x Gigabit Ethernet ports by Intel® 1xI219 and 5x I210 (Nuvo-5006E/P)
PoE+	Optional IEEE 802.3at PoE+ PSE for GbE Port 3 ~ Port 6, 80 W total power budget
USB	4x USB 3.0 ports via native XHCI controller 4x USB 2.0 ports
Video Port	1x stacked VGA + DVI-D connector 2x DisplayPort connectors, supporting 4K2K resolution
Serial Port	2x software-programmable RS-232/422/485 port (COM1 & COM2) 1x RS-232 port (COM3)
Audio	1x Mic-in and 1x Speaker-out
Storage Interface	
SATA HDD	2x Internal SATA port for 2.5" HDD/SSD installation, supporting RAID 0/1
mSATA	1x full-size mSATA port (mux with mini-PCIe)

Expansion Bus	
PCI/PCI Express	1x PCI slot in Cassette (Nuvo-5002P/5006P) 1x PCIe x16 slot @ Gen3, 8-lanes PCIE signals in Cassette (Nuvo-5002E/5006E)
Mini PCI-E	1x internal mini PCI Express socket with front-accessible SIM socket 1x internal mini PCI Express socket with internal SIM socket (mux with mSATA)
Expandable I/O	1x MezIO™ expansion port for Neousys' MezIO™ modules
Power Supply	
DC Input	1x 3-pin pluggable terminal block for 8~35VDC DC input
Remote Ctrl. & Status Output	1x 10-pin (2x5) wafer connector for remote on/off control and status LED output
Mechanical	
Dimension	240 mm (W) x 225 mm (D) x 90 mm (H)
Weight	4.4 kg (incl. CPU, memory and HDD)
Mounting	Wall-mounting (standard) or DIN-Rail mounting (optional)
Environmental	
Operating Temperature	with i7-6700TE, i5-6500TE, i3-6100TE, Pentium G4400TE (35W TDP) -25°C ~ 70°C ** with i7-6700, i5-6500, i3-6100 (65W/51W TDP) -25°C ~ 70°C */** (configured as 35W CPU mode) -25°C ~ 50°C */** (configured as 65W/51W CPU mode)
Storage Temperature	-40°C ~ 85°C
Humidity	10%~90% , non-condensing
Vibration	Operating, 5 Grms, 5-500 Hz, 3 Axes (w/ SSD, according to IEC60068-2-64)
Shock	Operating, 50 Grms, Half-sine 11 ms Duration (w/ SSD, according to IEC60068-2-27)
EMC	CE/FCC Class A, according to EN 55022 & EN 55024

Figure 2-7 NUVO 5006 E/P. Specifications

We have summed up the main features of the installed model in the following table:

	Main features
Dimensions	• 240 x 225 x 90 mm
Weight	• 4400 g
Others	• 32 Gb DDR4-2133 Mhz SDRAM (2xSODIMM) • 2 x port GigE ethenet • 2 X 2.5" SATA HDD/SDD in RAID 0/1 • 4 x USB3, 2 x USB2 • Rugged embedded -25°C to 70°C fanless operation • Power supply 8-35 Vdc (1x3-pin pluggable terminal block)

Table 2-3 NUVO 5006 E/P Features

2.4 IMU. Spatial Dual Advanced Navigation

The selected Inertial Measurement Unit (IMU) follows the requirements and recommendations of D.3.1. This IMU, Spatial Dual from Advanced Navigation is a ruggedized miniature GNSS aided inertial navigation system and AHRS that provides accurate position, velocity, acceleration and orientation under the most demanding conditions. It combines temperature calibrated accelerometers, gyroscopes, magnetometers and a pressure sensor with a dual antenna RTK GNSS receiver. These are coupled in a sophisticated fusion algorithm to deliver accurate and reliable navigation and orientation under the most demanding conditions.

Figure 2-8 Spatial Dual

It features dual antenna moving baseline RTK. This allows it to provide highly accurate heading while both stationary and moving. It is an excellent choice for applications where magnetic heading is not usable due to interference or where additional accuracy is required. It contains very high performance MEMs inertial sensors. These are put through Advanced Navigation's intensive calibration process to increase their performance further still and provide consistently accurate data over an extended temperature range of -40°C to 85°C. Advanced Navigation's custom calibration process is the only full sensor calibration that can provide dynamic ranging, allowing to select a sensor range for high accuracy or high accelerations on the fly.

It contains a triple frequency Trimble RTK GNSS receiver that provides up to 8mm accuracy positioning and supports all of the current and future satellite navigation systems, including GPS, GLONASS, GALILEO and BeiDou. It also supports the Omnistar service for hassle free high accuracy positioning. It also contains a sensor fusion filter. The filter is more intelligent than the typical extended Kalman filter and is able to extract significantly more information from the data by making use of human inspired artificial intelligence. It was designed for control applications and has a high level of health monitoring and instability prevention to ensure stable and reliable data.

It has a rugged aluminium enclosure that is waterproof and dirt-proof to the IP67 standard and shockproof to 2000g, allowing it to be used in the most extreme conditions. A sophisticated venting system allows the unit to measure air pressure whilst keeping water out. Its minimal size, weight and power requirements allow for easy integration into almost any system. It contains a next generation battery backup system that allows it to hot start inertial navigation from its last position in 500 milliseconds and obtain a GNSS fix in approximately 3 seconds. The battery backup system lasts for the lifetime of the product and will provide backup for 48 hours without power. Advanced Navigation's Spatial series are the only GNSS/INS in the world to provide hot start inertial navigation.

It is built on top of a safety oriented real time operating system and all software is designed and tested to safety standards with fault tolerance in mind. The hardware is protected from reverse polarity, overvoltage, surges, static and short circuits on all external interfaces. The GNSS contains RAIM, which excludes both malfunctioning, and tampered satellite signals. It features four general purpose input output pins that support an extensive number of peripherals. Including odometer and wheel encoder inputs for ground vehicles, external RTK GNSS systems, NMEA input/output, event triggers and more. For an integration fee, custom peripheral devices can be added.

NAVIGATION	
Horizontal Position Accuracy	1.2 m
Vertical Position Accuracy	2.0 m
Horizontal Position Accuracy (with SBAS)	0.5 m
Vertical Position Accuracy (with SBAS)	0.8 m
Horizontal Position Accuracy (with RTK or Kinematica PPK)	0.008 m
Vertical Position Accuracy (with RTK or Kinematica PPK)	0.015 m
Velocity Accuracy	0.007 m/s
Roll & Pitch Accuracy	0.1 °
Heading Accuracy (1m Antenna Separation)	0.1 °
Roll & Pitch Accuracy (Kinematica Post Processing)	0.03 °
Heading Accuracy (Kinematica Post Processing)	0.06 °
Slip Accuracy	0.1 °
Heave Accuracy	5 % or 0.05 m (whichever is greater)
Range	Unlimited
Hot Start Time	500 ms
Internal Filter Rate	1000 Hz
Output Data Rate	Up to 1000 Hz

GNSS	
Model	Trimble BD982
Supported Navigation Systems	GPS L1, L2, L5 GLONASS L1, L2 GALILEO E1, E5 BeiDou B1, B2
Supported SBAS Systems	WAAS EGNOS MSAS GAGAN QZSS Omnistar HP/XP/G2 Trimble RTX
Update Rate	20 Hz
Hot Start First Fix	3 s
Cold Start First Fix	30 s
Horizontal Position Accuracy	1.2 m
Horizontal Position Accuracy (with SBAS)	0.5 m
Horizontal Position Accuracy (with RTK)	0.008 m
Velocity Accuracy	0.007 m/s
Timing Accuracy	20 ns
Acceleration Limit	11 g

COMMUNICATION	
Interface	RS232 (RS422 optional)
Speed	4800 to 2M baud
Protocol	AN Packet Protocol or NMEA
Peripheral Interface	2x GPIO and 1x Auxiliary RS232
GPIO Level	5 V or RS232
GPIO Functions	1PPS Odometer Stationary Pitot Tube NMEA input/output Novatel GNSS input Trimble GNSS input AN Packet Protocol input/output Packet Trigger Input Event Input

HARDWARE	
Operating Voltage	9 to 36 V
Input Protection	-40 to 100 V
Power Consumption (Typical)	2.64 W
Hot Start Battery Capacity	> 48 hrs
Hot Start Battery Charge Time	30 mins
Hot Start Battery Endurance	> 10 years
Operating Temperature	-40 °C to 85 °C
Environmental Protection	IP67 MIL-STD-810G
MTBF	> 50,000 hrs
Shock Limit	75 g
Dimensions	90x127x31 mm
Weight	285 grams

SENSORS

SENSOR	ACCELEROMETERS	GYROSCOPES	MAGNETOMETERS	PRESSURE
Range (Dynamic)	2 g 4 g 16 g	250 °/s 500 °/s 2000 °/s	2 G 4 G 8 G	10 to 120 KPa
Bias Instability	20 ug	3 °/hr	-	10 Pa
Initial Bias	< 5 mg	< 0.2 °/s	-	< 100 Pa
Initial Scaling Error	< 0.06 %	< 0.04 %	< 0.07 %	-
Scale Factor Stability	< 0.06 %	< 0.05 %	< 0.09 %	-
Non-linearity	< 0.05 %	< 0.05 %	< 0.08 %	-
Cross-axis Alignment Error	< 0.05 °	< 0.05 °	< 0.05 °	-
Noise Density	100 ug/√Hz	0.004 °/s/√Hz	210 uG/√Hz	0.56 Pa/√Hz
Bandwidth	400 Hz	400 Hz	110 Hz	50 Hz

Figure 2-9 Spatial Dual. Specifications

We have summed up the main features of the installed model in the following table:

	Main features
Dimensions	• 90 x 127 x 31 mm
Weight	• 285 g
Others	• GNSS: u-Blox M8P (GPS L1, Glonass L1, Galileo E1 & Beidu L1) • IMU: Output data rate: up to 1000Hz. Latency 0,4ms • Satellite Based Augmentation System (WAAS,EGNOS,MSAS, GAGAN & QZSS) • Dual antenna. • Rugged: -40°C -85°C • Power supply: 9-36V.

Table 2-4 Spatial Dual Features

2.5 BaseCam BGC Pro.

The BaseCam is the controller selected in the project that allows to manage the three motors to allow controlling the sensor column position. With its 32-bit ARM processor the board possesses enough power for any practical level of complexity for algorithms, and together with premium MEMS gyros it uses high-efficiency FETS which gives it enough power to drive most professional equipment when properly configured, it is small enough to fit into just about many applications.

It has high-power motor drivers with current capabilities up to 13A per motor, that provides a capability to build a gimbal for virtually any camera systems presented in the market (5…50 kg weight) and is delivered with a full set of protections: overcurrent, short-circuit, over-temperature, under-voltage protection in DC converters and motor drivers

It has a battery voltage sensor, a Current sensor for precise power consumption monitoring and battery lifetime estimating and a voltage drop compensation

The communication options are also relevant, with a built-in Bluetooth (BLE) module compatible with latest iOS and Android devices, 3 dedicated ports to connect absolute rotary position sensors (encoders) by SPI, PWM or I2C protocol and 2 CAN ports for future support of high-quality gyro sensors and extension boards.

The modular design has 3 modules: power board, logic board and interface board. It gives more freedom in customization to better fit into your product. The LC-filters on motor outputs to suppress high-frequency PWM harmonics.

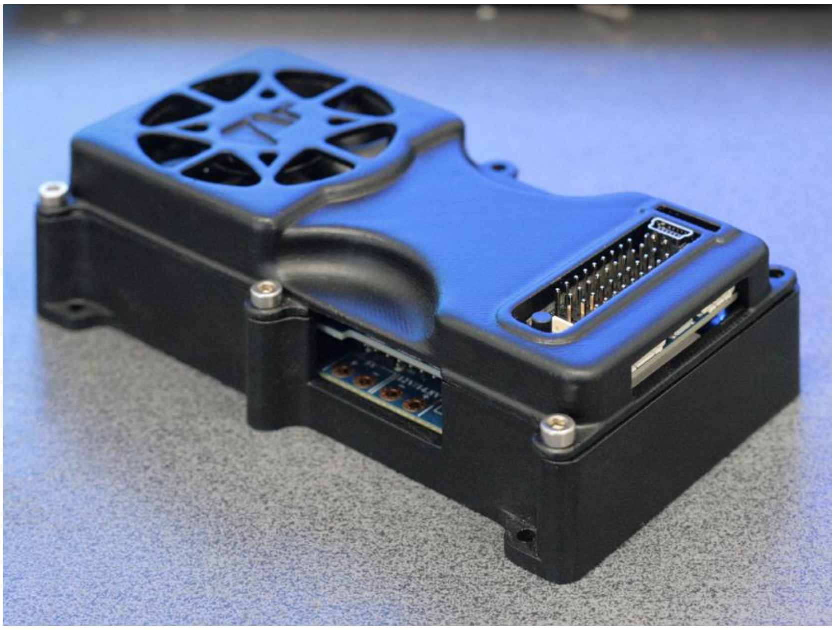

Figure 2-10 BaseCam BGC Pro

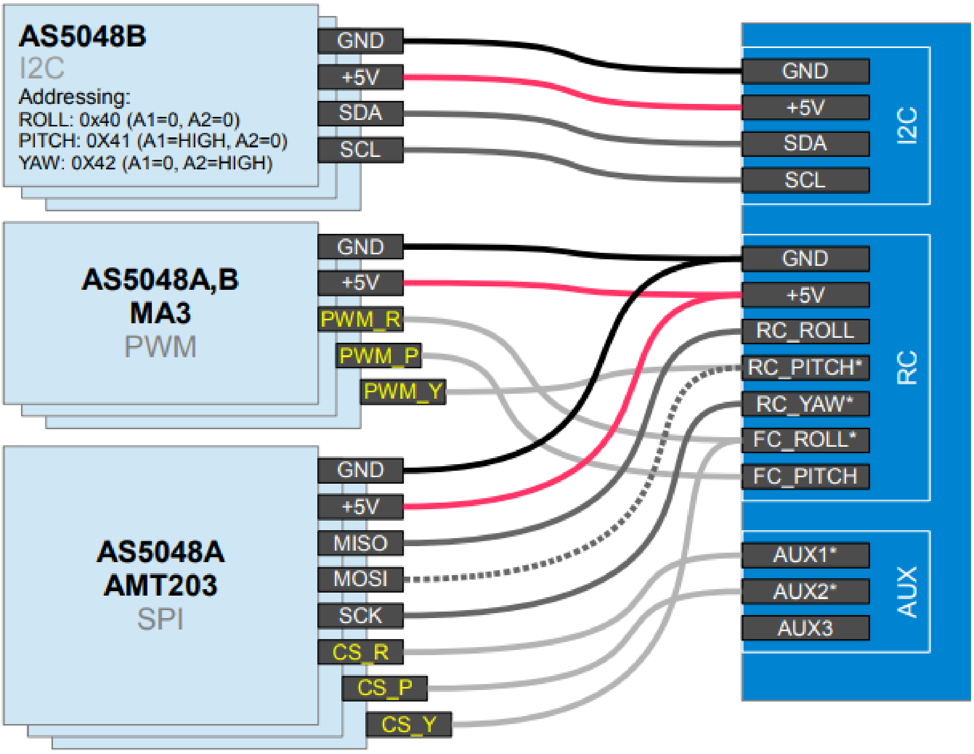

Figure 2-11 BaseCam BGC Pro. Board encoders connection.

We have summed up the main features of the installed model in the following table:

	Main features

Dimensions	• 115 x 50 x 20 mm
Weight	• 292 g
Others	• USB port for PC connection • UART port to connect serial modem, Bluetooth module or any other device that implements Serial API protocol • 4 analog inputs for analog joystick or potentiometers connection with flexible function mapping • 5 PWM inputs/outputs with 5V supply for hobby RC or servo connection • Spectum/s-bus signal input • 4 AUX inputs/outputs for various functions • Menu button • Status LEDs • Analog joystick port • CAN port • I2C port • Logic board connectors • 3x Encoder ports • 3x PWM servo outputs • CAN port • 2x I2C ports • 3x temperature sensor ports

Table 2-5 BaseCam BGC Pro Features

2.6 Gimbal Motor GBM110-150T.

After the first iteration of the gimbal platform we realize that the first selected motors (Motor GB85-1) worked well with standard conditions but they had a poor performance after they were exposed to the airplane accelerations, therefore for the second iteration of the gimbal platform it was decided to replace the motors for more powerful ones able to work under accelerations of at least 2.5 g (gravitational force).

The selected model was the motor GBM110-150T, with this model we can guarantee a good performance under the airplane acceleration conditions and control each of the three axes (roll, pitch and yaw) fulfilling the power needs so that they maintain the preferred position of the camera, being controlled through the BaseCam BGC Pro. It's a high quality brushless gimbal motor it features sealed bearing and housings to help prevent dust and sand from entering. High-end bearings used from the MT series of motors.

The selected gimbal is one of the most powerful gimbal motors available with over 12 Kgs / cm of torque, that's the double that was support with the first iteration. This is an ideal motor for stabilizing the heaviest of cameras, and also ideal for pan control on mid to large gimbals, where high torque is necessary to prevent weather cocking.

It also features a hollow central bearing designed to take slip rings, which allow signals to be passed through the motor, yet give continuous uninterrupted rotation without tangling of wires.

Figure 2-12 Motor GBM110-150T

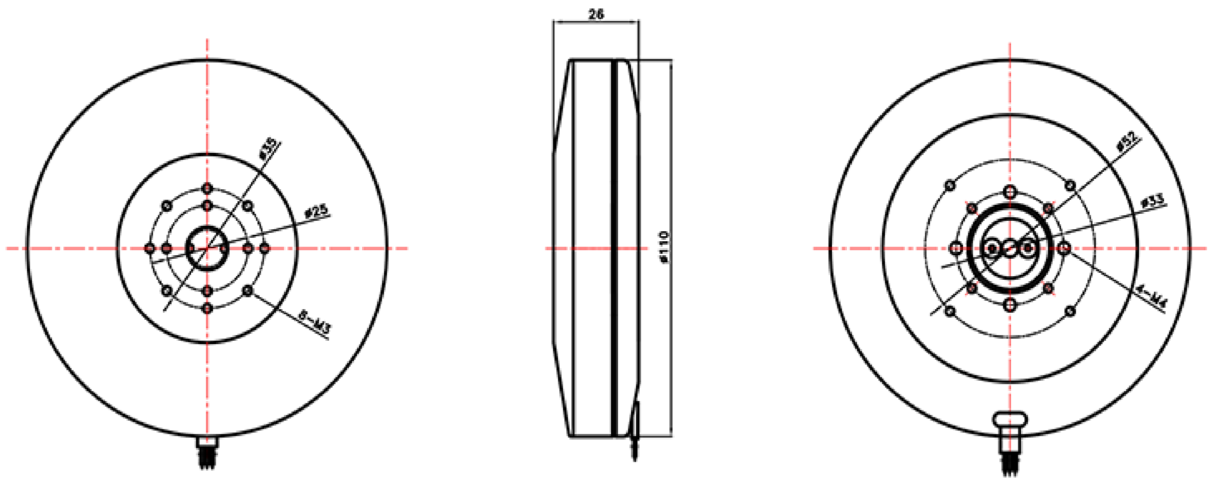

Figure 2-13 Motor GB85-. Dimensions

Some features are shown in the following table:

	Main features
Dimensions	• 110 diameter x 26 mm
Weight	• 554 g
Others	• Copper wire(OD):0.32mm • Configuration:24N28P, provide more torque • Resistance:17.8 ohms • Base center pitch：25mm 35mm • Pre-wound: with 150 turns, Hollow shaft for slip-ring • Hollow Shaft Diameter:12.6mm • Voltage:20A • Current:0.066A • Max Current:13A • Rotational Speed:137rpm

Table 2-6 Motor GBM110-150T Features

3 Geo-stabilized Platform

Taking into account the previous description of cameras and equipment we have proceed to integrate the cameras in the manned aircraft. However, for mounting the new cameras and according to the requirements and recommendations of the project we had to proceeded to design a new geo-stabilized platform. Because of the size and dimensions of the payload a bigger size and grip adaptations were needed to hold the cameras with safety allowing also a good access to the different elements. Some of the new designed components are a trapeze, suspension link, yaw chassis, pitch chassis, roll chassis and a sensor column.

As we can see in the following pictures, we had a very restrictive room for embedment of the inertial/georeferenced platform, the system must fit inside the AIRMON mounting frame (mandatory) through below fuselage hatchway and with capacity for auxiliary power supply and onboard computer in existing console.

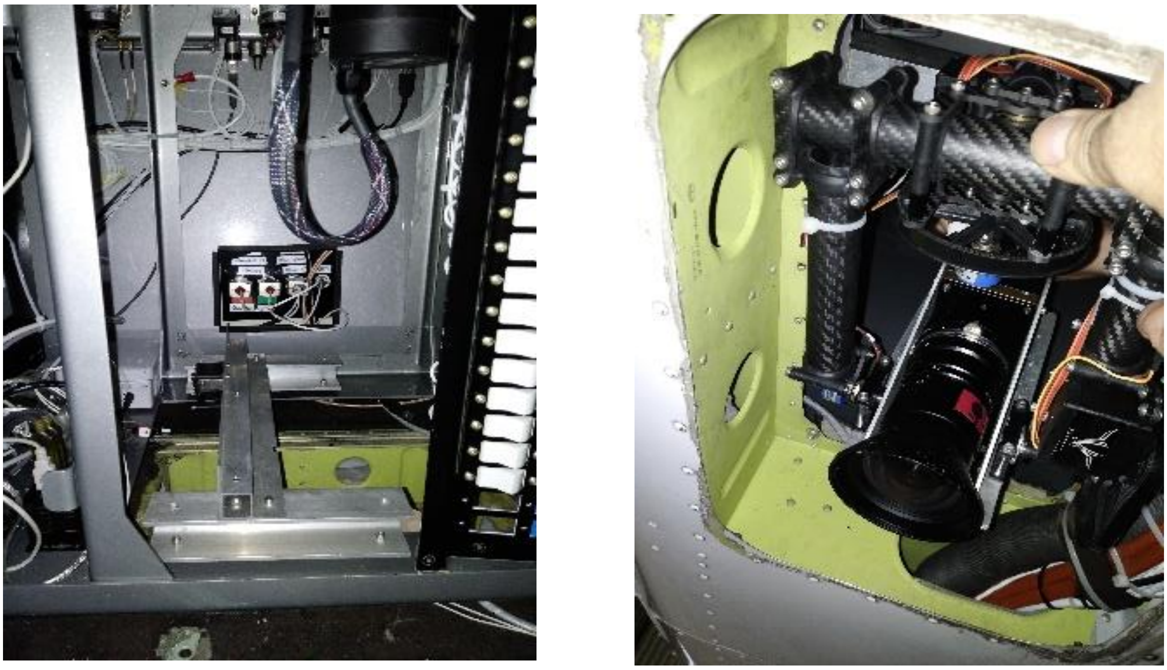

Figure 3-1 Upper access to fuselage hatchway and bottom view gyro-mount embedment.

These new designed parts were manufactured in aluminium for its unique properties like lightness that makes it ideally suited for frames and components and has an easy integration of inserts, links and functionality, resulting in high-speed, precise assembly. However, due to the unexpected presence of a cable group of the airplane and a window size mismatch, the gimbal platform had to suffer a second iteration for dealing with this problem. This section shows in the following points the geo-stabilized platform designed in a first iteration by NTGS to be integrated into the aircraft including the previously defined sensors and elements, the dimensions are correct but there were not taken into account the position of important cables groups of the airplane that couldn't be moved for not interfering in the gimbal installation. This problem motivated definitively a second iteration.

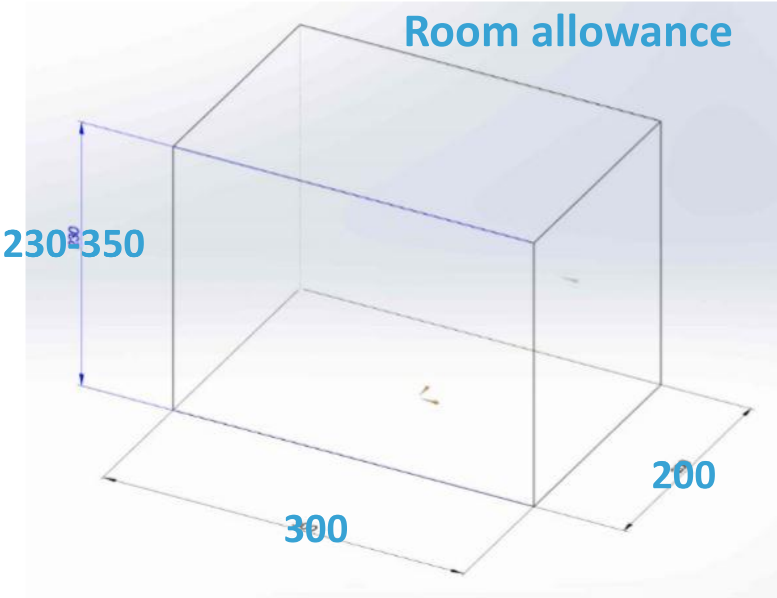

Figure 3-2 Window dimensions for installing the gimbal.

3.1 First iteration

3.1.1 Geo-stabilized Platform

This is the complete structure designed by NTGS. Has been used aluminium of 5 mm thickness, which allows to obtain sufficient robustness to support the necessary weight, but is quite difficult to work since very specialised machinery are needed like laser cutters and bend machines.

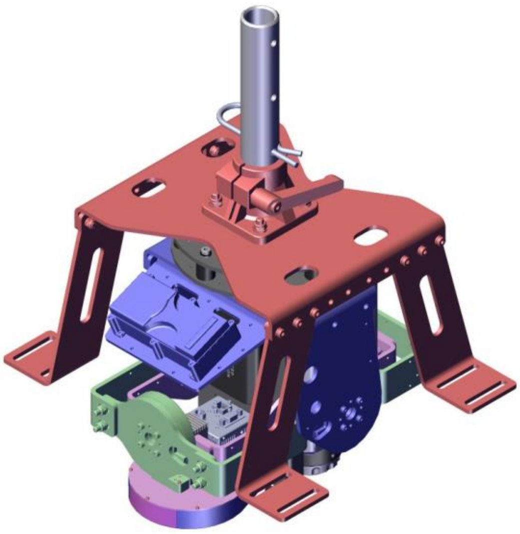

Figure 3-3 New designed geo-stabilized platform

3.1.2 Components.

The structure and components design was done using the software SolidWorks.

- **Trapeze.**

The trapeze is the support of the entire structure. It is designed to adapt to the dimensions of the console and allow movement in all three axes. In addition, it holds everything to the plane's console.

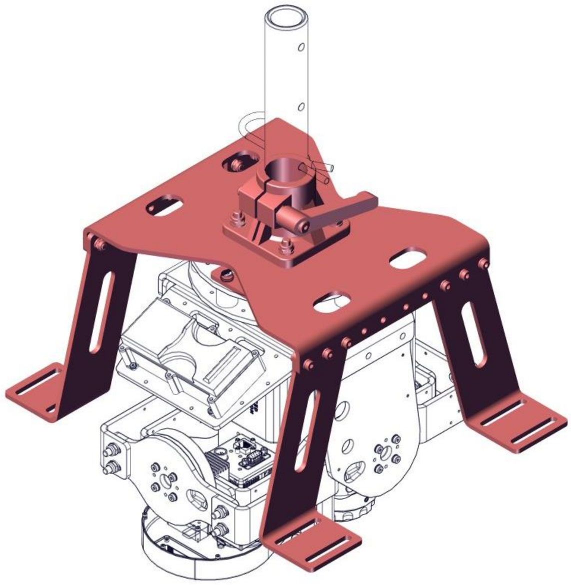

Figure 3-4 Trapeze

- **Suspension Link.**

This is the cushioned support, where the turning motor (yaw) is integrated. It is the piece joins with the chassis and is the one that joins all the supports with the trapeze.

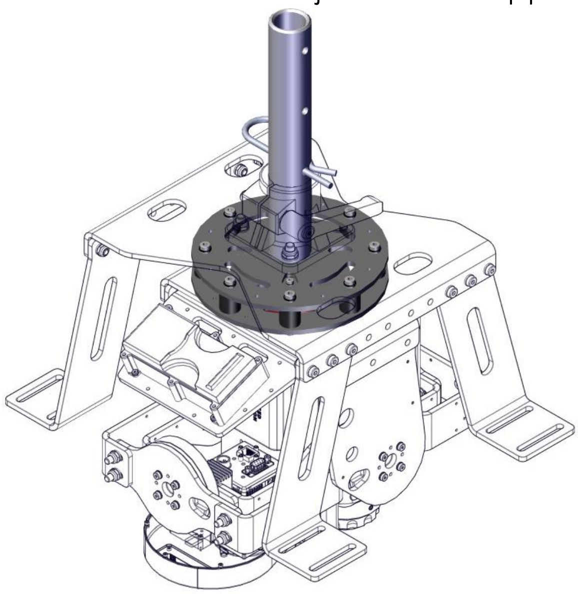

Figure 3-5 Suspension Lin

- **Yaw Chassis.**

This is the chassis that supports yaw rotation, coupled with yaw motor. On this support is integrated the pitch turning motor, which is also connected to the pitch chassis.

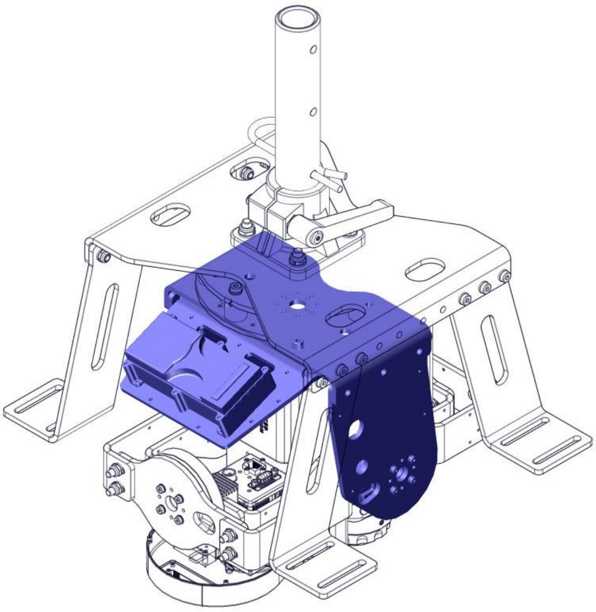

Figure 3-6 Yaw Chassis

- **Pitch Chassis.**

This is the chassis that supports the pitch rotation and is connected to the pitch rotation motor. On this support, the roll turning motor is integrated, which also joins it with the roll chassis.

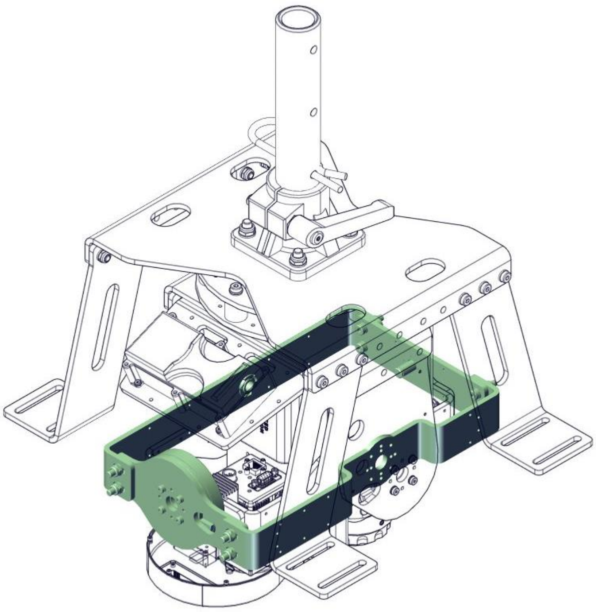

Figure 3-7 Pitch Chassis

- **Roll Chassis.**

This is the chassis that supports roll spin, and is attached to the roll spin motor. On this chassis finally joins the column of sensors that will assume the turns in the 3 directions, limited to + - 15º in each of the axes.

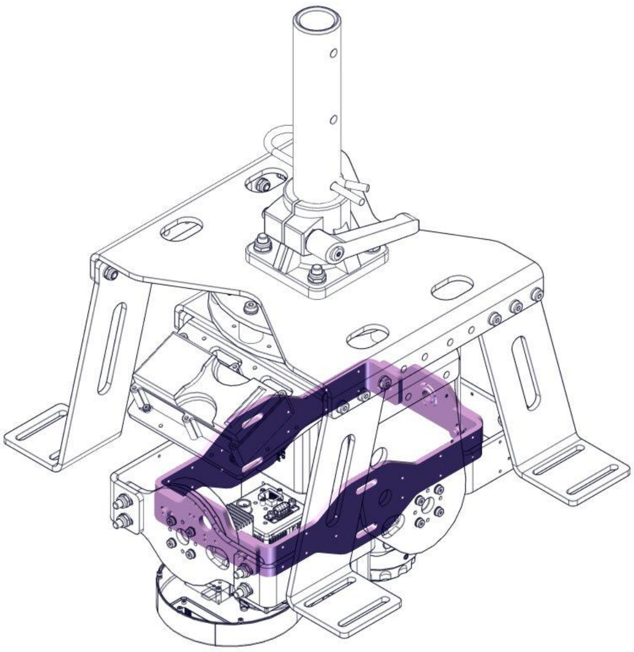

Figure 3-8 Roll Chassis

- **Sensor Column.**

This is the structure that supports all the sensors, that is, the two cameras and the IMU. And therefore the one that moves from the rest of the chassis.

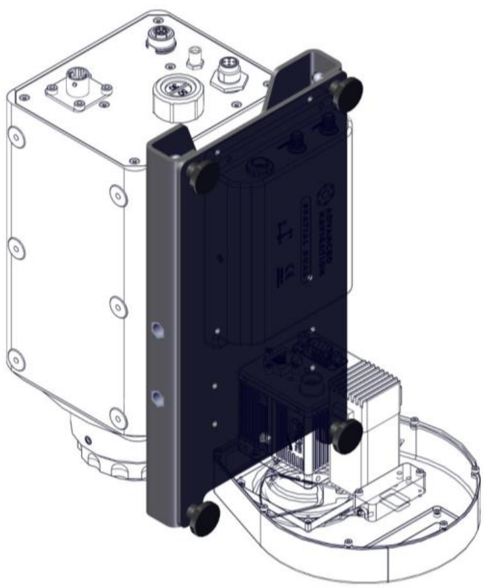

Figure 3-9 Sensor Column

3.1.3 Assembly

For the assembly of the structure, first the engines are placed on each of the chassis. Then chassis are joined through the axles. Once the chassis is attached, the link suspension is attached to the chassis and the axles are left and the link suspension is added to the yaw chassis. The link suspension is integrated on the trapezoid that supports the entire structure on the aircraft console. Finally, on the structure once completed you can assemble and disassemble the sensors on your column as shown in the integration section.

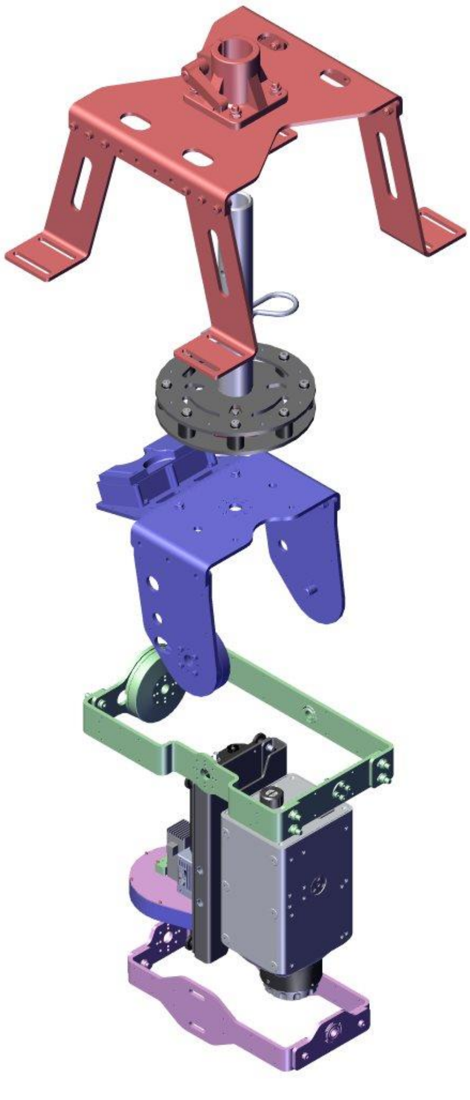

Figure 3-10 Exploded view of the structure

3.1.4 Integration of components

This section shows the integration of the sensors inside the platform after the first iteration, and the assembly of the platform on the aircraft console We can see that the assembly and disassembly of the sensors inside the platform is quite difficult because of the space limitations.

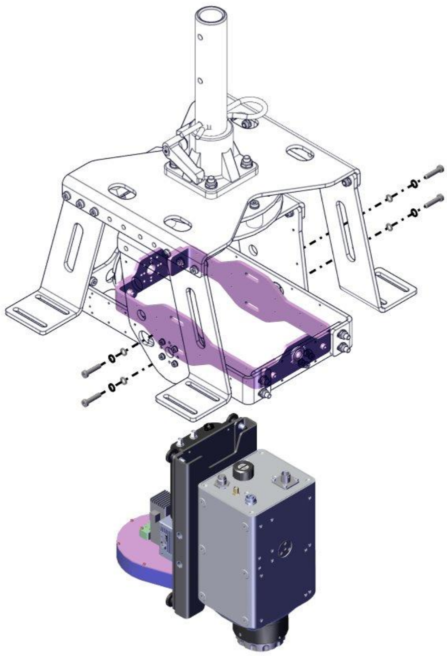

Figure 3-11 Disassembly of sensor column

We can see below how are mounted both cameras multispectral and thermal integrated the sensor column:

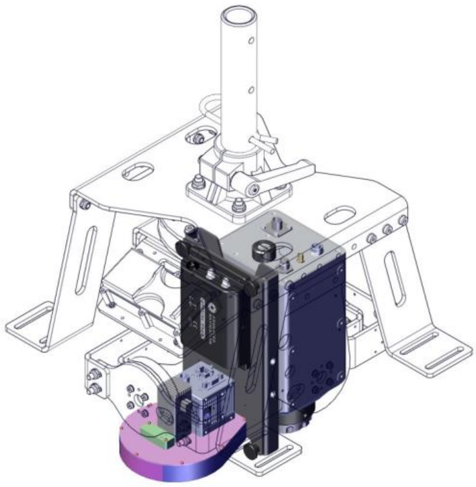

Figure 3-12 Sensor Column with cams and IMU

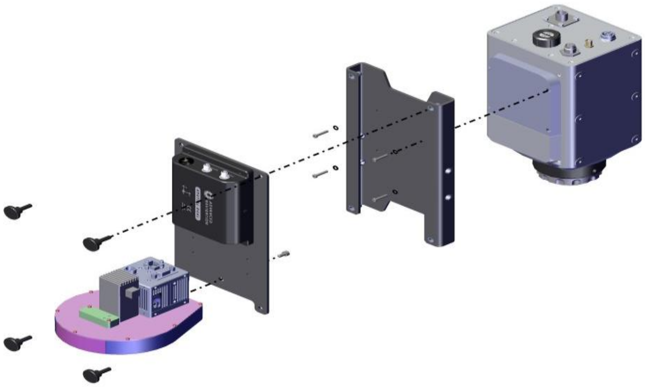

Figure 3-13 Disassembly cams and IMU

3.2 Detected problems

After the first iteration we detected some unexpected errors like the window size mismatch because of the presence of group of airplane cables or the low performance of the gimbal motors. Below we can see the mismatch problem detected with the window size and the presence of a group of cables.

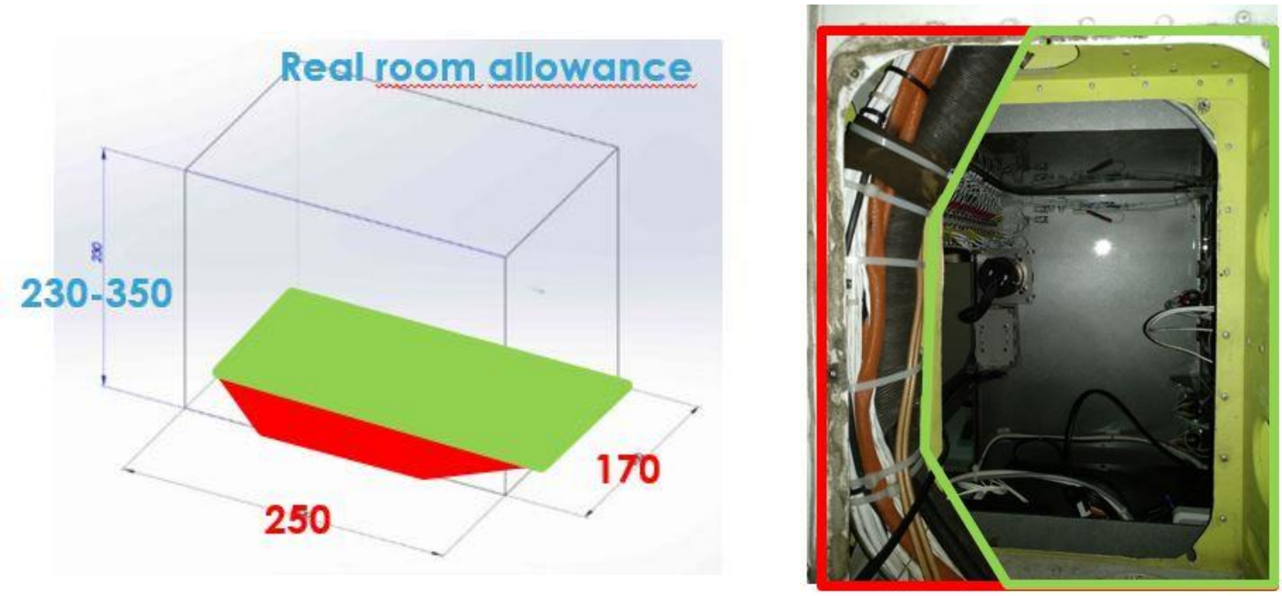

Figure 3-14 Window dimensions after taking into account the cables problem. It's rather a trapezoid.

In the following images we can see the final result of the first iteration and the airplane group of the airplane cables that covered part of the windows and that could not be moved

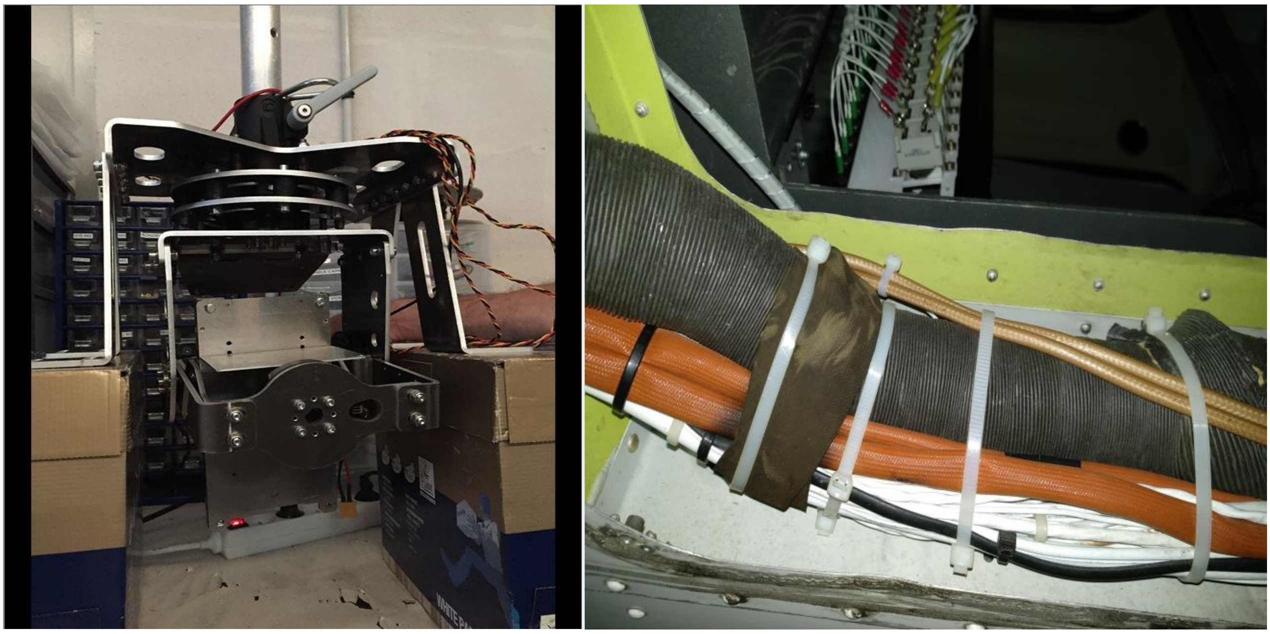

Figure 3-15 First gimbal platform version. Group of problematic airplane cables.

3.3 Second iteration

In the second iteration the detected problems were solved and we also lightened the gimbal platform. Below we can see the technical specifications for mounting the different servos:

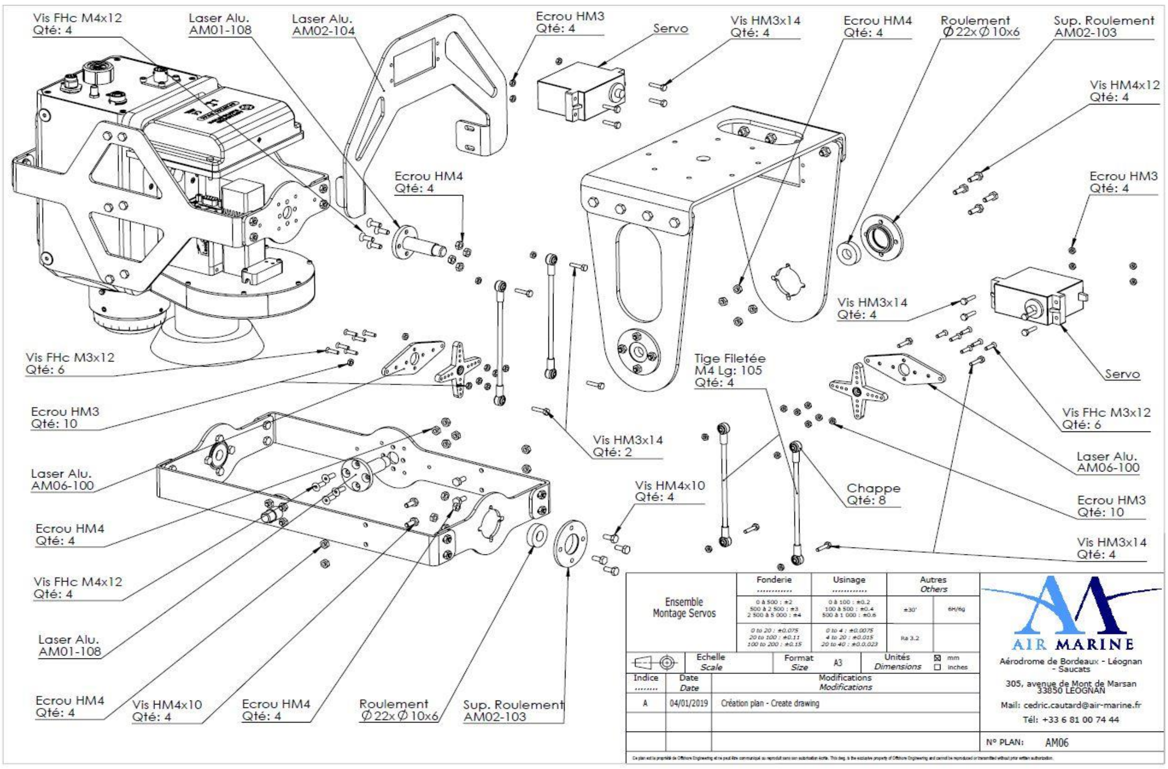

Figure 3-16 Servos mounting

And also for mounting the cameras and the IMU:

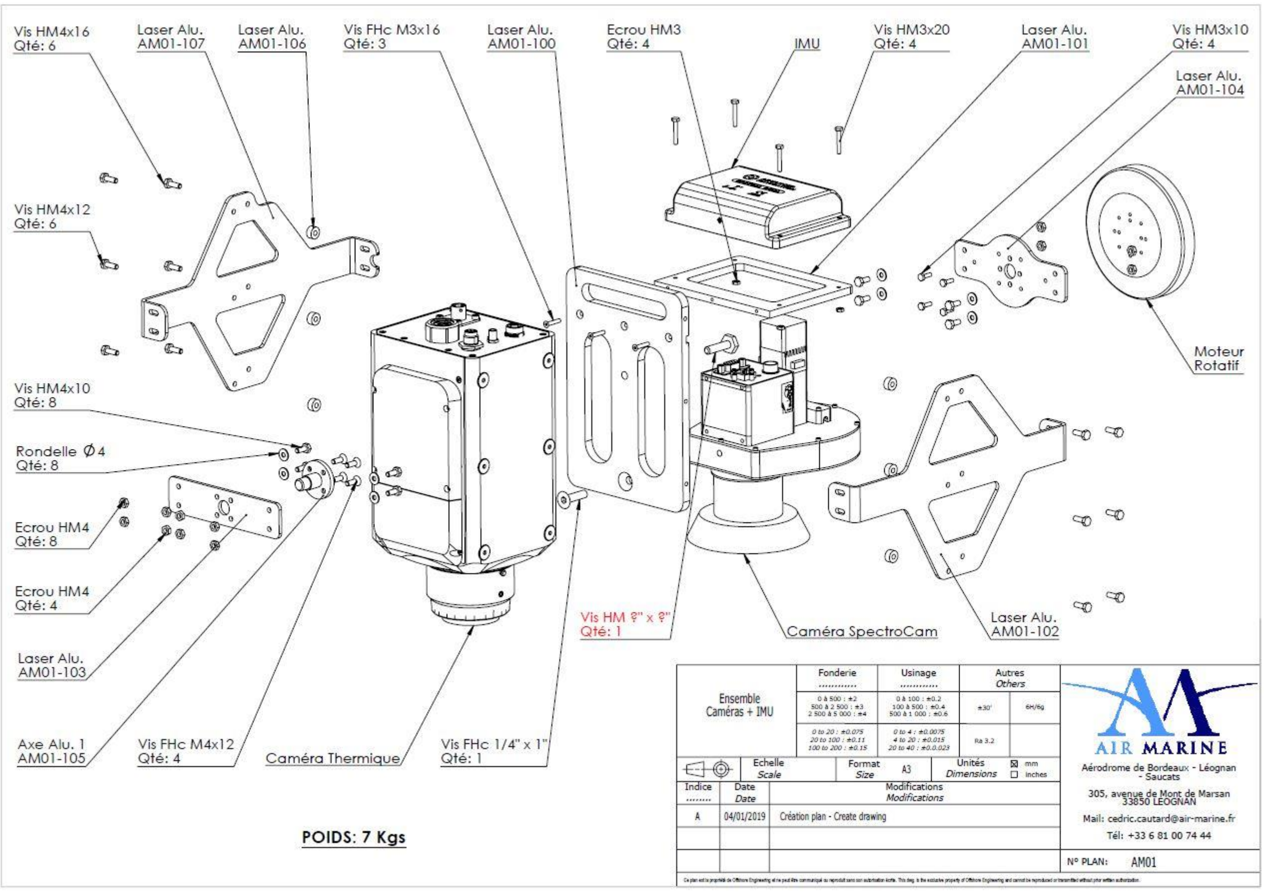

Figure 3-17 Camera and IMU mounting

With this second iteration we can mount without problems the gimbal platform in the airplane and has a more simplified design, less weight and a better performance in the servos motors.

Figure 3-18 Integration process

In the following images we can see the mounted gimbal on-board the airplane

Figure 3-19 Final configuration and installation in the airplane

4 Conclusions

The objective of this deliverable is to inform of the design of a gimbal platform and the different components and its integration in the WADI manned airplane that after tested is to be immediately applied in operational environment demonstrations over the two pilot sites (WP5 and WP6). The most significant findings can be outlined as follow:

- Airborne sensors (TC and MC) selection accomplishes with the stated requirements and recommendation of D.3.1.
- The selected sensors are not designed specifically for being easily integrated in professional payload plane models and then its integration it's quite difficult.
- The cameras have been integrated after a process of design of a sensor column.
- Both cameras are configured with an onboard computer.
- The integrated system is ready for its development and tests.
- The proposed integration accomplishes with the WADI's innovative concept of integrating existing airborne oriented and affordable sensors in the market.