

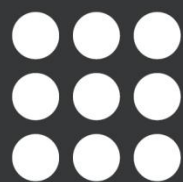


MAIA

The multispectral camera

User Guide

Rev.2.03 - 05/2019



MAIA

the multispectral camera

Disclaimer

The information in this document is provided solely in connection with the product and a reasonable effort has been made to have it accurate and reliable, however, we do not assume any liability whatsoever for the accuracy and completeness of the above information. The manufacturer reserves the right to make changes, corrections, modifications or improvements to this document, and to the products and services described herein, at any time and without notice. No representations or warranties, either express or implied, of merchantability, fitness for a particular purpose or of any other nature are made hereunder with respect to information/specification or the products to which information refers and no guarantee with respect to compliance to the intended use is given. In particular, this also applies to the stated possible applications or areas of applications of the product.

The customers are responsible for the appropriate, safe and legal use, processing and handling of our products.

Manufacturer

This product is manufactured in Italy by Eoptis Srl.

Life-support policy

The product is not designed for use in life-support appliances, devices or systems where malfunction of these products can reasonably be expected to result in personal injury. Customers using or selling these products for use in such applications do so at their own risk, and agree to fully indemnify the manufacturer for any damages resulting from such improper use or sale.

Copyright, Trademarks and IP

All of the materials in this document are protected by copyright and other laws of intellectual property. They are not allowed to be copied, reproduced or modified for any use without the written permission of Eoptis.

Eoptis and the Eoptis logo are trademarks of Eoptis Srl.

SAL Engineering and the SAL Engineering logo are trademarks of SAL Engineering Srl.

MAIA and the MAIA logo are trademarks of Eoptis Srl and SAL Engineering Srl.

Eoptis and SAL Engineering convey no patent, copyright, or other trade mark right to this product and do not assume any liability for any patent and/or other trademark rights of a third party resulting from any use of the product.

The company names and other product names in this document might be the trademarks and trade names of their respective owner(s), and are hereby acknowledged.

WorldView-2 is a commercial Earth observation satellite owned by DigitalGlobe. Sentinel-2 are a fleet of two identical satellites developed by the European Space Agency (ESA) to perform terrestrial observations. The Sentinel-2 and WorldView-2 are trademarks of their respective owners. Neither DigitalGlobe nor the ESA are endorsing the MAIA camera.

WEEE

This product should not be treated as household waste. Please ensure that this product is correctly disposed of, as inappropriate waste handling can cause potential hazards to the environment and human health.

MAIA is a product of



SAL Engineering Srl

Via Godo Vecchia 23/a - 48026 Russi (RA) - Italy
Tel: +39 328 760 9924



Eoptis Srl

Via Alto Adige, 152 - 38121 Trento (TN) - Italy
Tel: +39 0461 260552
Email: info@eoptis.com

Contents

1	Introduction	5
1.1	Applications.....	6
1.2	Contents of the package	6
2	System overview	7
2.1	Connectors and interfaces	8
2.1.1	Electrical specifications	11
2.2	Optical characteristics	12
2.3	Mechanical design.....	14
2.4	Power dissipation	15
3	Interfacing the camera.....	16
3.1	Quick access via keyboard.....	16
3.2	Video control menu.....	16
3.3	Web interface.....	17
3.3.1	Cable connection	17
3.3.2	Wifi connection	17
3.3.3	Recommended connection modes.....	18
3.4	Remote control from a radio controller	19
3.4.1	CH1 Radio channel.....	19
3.4.2	CH2 Radio channel.....	19
3.5	LEDs.....	20
3.5.1	Acquisition LED	20
3.5.2	WiFi LED.....	20
3.5.3	Power LED.....	20
3.5.4	Memory LED	21
3.6	Power-up and Power-down Sequence.....	21
3.6.1	Power-up	21
3.6.2	Power-down	21
4	Parameters settings	22
4.1	Parameters settings from the Web interface.....	22
4.1.1	Home	22
4.1.2	Acquisition	23
4.1.3	Exposure	25
4.1.4	Interfaces.....	27
4.1.5	Network.....	27
4.1.1	Information (Info).....	27
4.2	Parameter settings from the keyboard/Overlay menu	28
4.3	Parameters settings from a radio controller	30
5	Incident light sensor.....	31
5.1	Overview	31
5.2	Connections and mountings.....	31
5.3	Data acquisition.....	32
5.4	Operations of the embedded GNSS receiver	33
5.4.1	Standard-precision GNSS.....	33
5.4.2	High-precision GNSS with RTK correction	33
5.5	LED status.....	35
5.6	Mechanical design.....	36
6	Acquisition procedures	37
6.1	Pre-flight operations	37
6.2	Flight operations	37
6.3	Post-flight operations.....	37
6.4	New acquisition.....	37
7	Download of the images	38

7.1	Download data from a Linux platform	38
7.2	Download data from a Windows platform	38
7.3	Notes	38
8	Image-processing software	39
8.1	Starting panel	39
8.2	Create M-layer TIFF Menu.....	39
8.2.1	Radiometric correction through reflectance target	42
8.2.2	Radiometric correction through reflectance target when not correctly framed	43
8.2.3	Relative automatic radiometric correction	44
8.2.4	radiometric correction using ILS – Irradiance Light Sensor	47
8.2.5	Example of creation of multi-layer TIFF.....	48
8.2.6	Tips for correct data processing	48
8.3	Create View menu	50
8.4	Create Index Image menu	51
8.5	Menu preview	52
8.6	Menu crop	53
8.7	Menu EXPORT	54
9	Technical specifications	55
9.1	Specifications of the MAIA camera	55
9.2	Specifications of the MAIA ILS sensor	57
10	Terms of licence	58
10.1	Credits	58
11	Revision history	59

1 INTRODUCTION

MAIA is a multispectral camera that provides simultaneous acquisition of high-resolution images at different wavelengths in the visual (VIS) and near infrared (NIR) regions. It is designed to be used on-board remotely piloted aircraft systems and on-board aircraft, as well as having several terrestrial uses.

The MAIA multispectral camera is based on an array of nine sensors, each with its relevant band-pass filter that precisely defines the radiation range to be detected. The sensitivity interval is from 390 nm to 950 nm, which allows the camera to be used for several applications in agricultural, industrial and environmental monitoring. Two filter sets are offered by default, matching the bands of the WorldView-2™ or Sentinel-2™ satellites. Other filters within the sensitivity interval can be supplied on request, depending on the customer's needs.

The sensors have 1.2 Mpixel resolution, which generates a total resolution of 10.8 Mpixel per shot, separated into the various bands. The sensors provide excellent performance in terms of their sensitivity, and they operate in global shutter mode. Thus, all of the sensors are exposed simultaneously, with the images acquired without the spatial distortions that are typically related to rolling shutter sensors, even at high flight speeds. The sensors are thus ideal for all applications where high quality and radiometric precision are needed.

The MAIA multispectral camera provides fine regulation of all parameters related to the acquisition of the images, from the exposure time of each sensor, to their exposure frequency. The automatic configurations supplied are suitable for standard use.

The images are stored to an internal solid disk (SSD) that has no moving mechanical parts and that promises long-term durability. The capacity is designed to save 10,000+ images. It is possible to save RAW image files of up to 12 bit, which provides for the saving of excellent levels of information, even for the most advanced procedures.

The User can have access to the camera to configure the parameters, to visualise the images in real-time during the acquisition, and to download just the saved images to the internal storage. For these purposes, various interfaces are available: the control keyboard, NTSC/PAL video output, a web panel, and two inputs for remote controllers. Internet access is available through either a high-speed GigaEthernet connection or Wifi connection to a PC, tablet or smartphone, to provide efficient use in the field.

The MAIA multispectral camera can interact with other devices to embed the information acquired with the images:

- an external GNSS receiver to geo-reference the images;
- a radio transmitter to send images to the User for real-time evaluation;
- a link to a remote controller to set some of the functions during a flight;
- a gimbal that can read the inertial sensor inside the camera to maintain constant orientation during a flight;
- other devices that can provide or need a synchronisation signal at the precise moment of the image exposure.

The MAIA multispectral camera is supplied with the dedicated Incident Light Sensor (ILS), specifically designed to seamlessly operate with the camera. The ILS measures the down-welling radiation at the same wavelengths measured by the camera and provides the information to compensate for light changes and calculate the true reflectance ratios for the correct index calculations. The ILS features a GNSS receiver, a 6-axis IMU and Pressure, Temperature, Humidity sensors.

The optical systems for each multispectral camera are individually calibrated geometrically. Using the professional MAIA software for the elaboration of the images, they can be corrected geometrically to produce undistorted images and to correlate the images from the wavelength bands of each exposure into a single multi-layer TIFF file with pixel-by-pixel correspondence, for coregistration of images. Furthermore, the software provides different modes of radiometric correction, and can accurately calculate, for example, different vegetational indices, such as the NDVI, GNDVI and SAVI, and others that can be defined by the User. It is also possible to generate false-colour images and multichannel images, and to export these in formats that are accepted by standard remote sensing imaging and photogrammetric processing software. In this way, for example, it is possible to obtain a multilayer (or multichannel) georeferenced orthophoto of an entire study area through the processing of the individual exposures by the software.

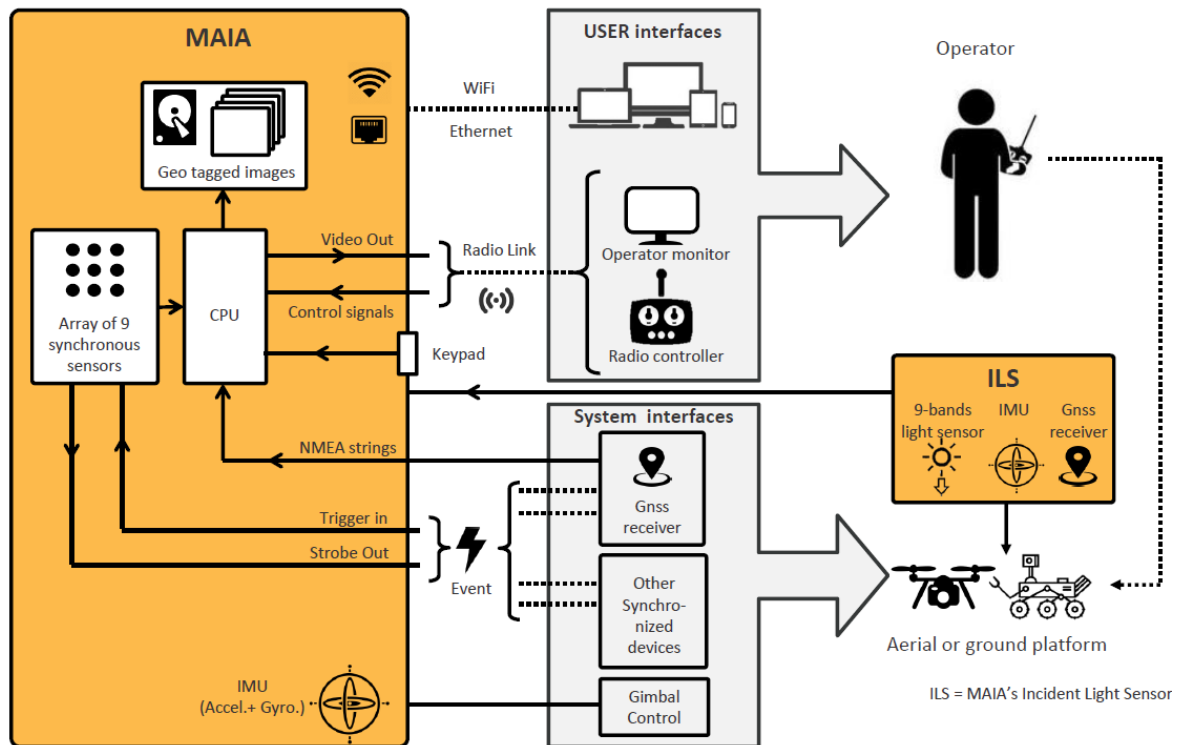


Figure 1. Architecture of the MAIA multispectral camera system with the Incident Light Sensor (ILS) and its interfaces.

1.1 APPLICATIONS

Precision farming

- Vegetative index mapping
- Water supply planning
- Optimization of pesticide use
- Fertilization tuning
- Yield estimation
- Health condition monitoring
- Early detection of diseases

Industry

- Remote chemical imaging
- Industrial plant inspection
- Material sorting

Environmental monitoring

- Spill of pollutant or hazardous substances in water and soil
- Classification of hazardous waste
- Landfill monitoring
- Detection of unauthorized landfills

Geology and survey

- Classification of soil
- Chemical characterization of soil
- Detection of paleochannels
- Specie classification
- Biomass mapping

1.2 CONTENTS OF THE PACKAGE

The product package includes:

- | | |
|---|---|
| 1 | MAIA multispectral camera; |
| 1 | ILS Incident light sensor (if ordered); |
| 1 | Cable kit; |
| 1 | Mains adapter; |
| 1 | User guide; |
| 1 | Rigid transport case. |

2 SYSTEM OVERVIEW



Figure 2. Back (left) and front (right) views of the MAIA multispectral camera with the controls, number of sensors, and recommended flight heading (see Table 1).

Number	Description
1	Control keyboard
2	Rapid access buttons; on/off, acquisition, WiFi hotspot
3	Menu control buttons
4	LED status indicators
5	Cover of the interface connectors
6	Acquisition LED

Table 1. List of the components indicated for MAIA multispectral camera shown in Figure 2.

2.1 CONNECTORS AND INTERFACES



This section has been changed since User Guide Rev.2.0 and DOES NOT APPLY to cameras with serial number 16xxxxxxx: permanent damages to these cameras might occur if the following instructions are used. The User owning cameras with serial number 16xxxxxx is asked to refer to User Guide Rev.1.04 for the latest valid document section related to Hardware interfaces.

The MAIA multispectral camera includes the following connectors to interface with other devices.

Code (see Fig. 3)	Connettor	Function
J1	Gigabit Ethernet	This is a service interface that should not be active during flight operations. It provides access by a broadband connection to the data stored in the internal memory.
J2	Power	This is the power connector of the camera. It is recommended to verify the correct polarity applied to the cables and to check that the power input is within the indicated limits, to avoid the potential of permanent damage to the camera or the system.
J3	IMU/GYRO	An IMU/GYRO (accelerometer/gyroscope; Invensense MPU6000) is installed on-board the camera for active stabilisation of the gimbal. The sensor is fixed to and powered by the camera, and its I2C channel inputs are directly accessible from the exterior.
J4	Synchronism In/Out	This includes the trigger input and strobe output signals to synchronise the image exposure start between the camera and external devices.
J5	Radio PWM Input	This includes the two inputs through which an external radio receiver forwards the received PWM signals. Events are generated that depend on the duration of the signals, which allows the operator to control some of the functions during a flight.
	Composite video output	This is a composite video output port that is useful to externally monitor the images acquired by the sensor of choice. Images to be saved to memory are forwarded to this output. Therefore, the frame rate is matched to the active acquisition mode and the relative configuration. Port can be configured for the PAL or NTSC standards. The menu is superimposed on the screen images, and is accessible using the keyboard, to also provide some other useful information.
J6	GNSS Serial Input	This is the serial port RX input, to which a GNSS receiver TX output can be connected for image geotagging. The configuration of the baud rate is automatic. When the ILS is connected to J6, this port receives the signals from the GNSS embedded into the ILS. The simultaneous connection of the ILS and a third-party GNSS is not possible.
	ILS interface	These pins are reserved for the ILS interface and power supply. Absolutely no other devices can be connected, in order to avoid permanent damages to the camera.

Table 2. Summary of the connectors and their functions.

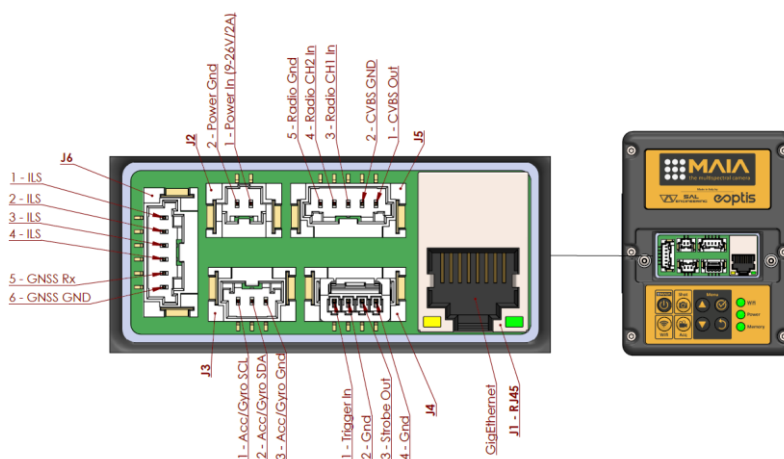


Figure 3. Position of the connectors and their relative access pins.

Name	Pin	Signal	Colour	Direction	Logic level	Function
J1	-	GigEthernet	-	-	-	-
J2	1	Power IN	Red	Pwr	9-26 V	Power supply
	2	Power GND	Black	Gnd	-	
J3	1	MPU_SCL	Yellow	In	5V	IMU/GYRO
	2	MPU_SDA	White	In	5V	
	3	MPU_GND	Black	Gnd	-	
J4	1	Trigger	White	In	5V CMOS	SYNC I/Os
	2	GND	Black	Gnd	-	
	3	Strobe	Green	Out	5V CMOS	
	4	GND	Black	Gnd	-	
J5	1	CVBS Signal	Yellow	Out	CVBS standard	Composite Video
	2	CVBS Gnd	Black	Gnd	-	
	3	Radio CH1	Blue	In	5V CMOS	RADIO
	4	Radio CH2	Green	In	5V CMOS	
	5	Radio GND	Black	Gnd	-	
J6	1	ILS	Red	-	-	ILS
	2	ILS	Black	-	-	
	3	ILS	Yellow	-	-	
	4	ILS	Green	-	-	
	5	GNSS Serial Rx	Blue	In	3.3V LVTTTL	GNSS
	6	GND	Black	Gnd	-	

Table 3. Detailed summary of the connector pins and their functions. 3.3V input pin marked with (*) is 5V tolerant.

When the camera is not powered, no voltage has to be applied on any of its input pins. Never leave external devices connected and powered if the camera is off. Permanent damage to the camera might happen.

A complete cable kit is supplied with the MAIA multispectral camera. Should there be the need for further connections, contact your vendor. Molex DuraClik™ connectors have to be used, according to the part numbers given in **Table 4**. This connector family requires the Molex 638190500 hand crimp tool and the 502128000 contacts, for AWG24 wires.

Connector	Part number
J2	Molex 5023510200
J3	Molex 5023510300
J4	Molex 5023510400
J5	Molex 5023510500
J6	Molex 5023510600

Table 4. Connector housing part numbers.

2.1.1 ELECTRICAL SPECIFICATIONS

The electrical specifications for the input and output interfaces of the MAIA camera are listed in

Signal Param.	5V CMOS IN <i>Trigger</i> <i>Radio CH1</i> <i>Radio CH2</i>	5V CMOS OUT <i>Strobe</i>	3.3V LVTTTL IN <i>GNSS Rx</i>	5V I2C <i>MPU SCL</i> <i>MPU SDA</i>	Notes
V _{IH}	3.5V	-	2V	-	High level input threshold
V _{IL}	1.5V	-	0.8V	0.5V	Low level input threshold
V _{IMAX}	0V / 5V	-	0V / 5V	0V / 5V	Max input voltage range
V _O	-	0V / 5V		0V / 5V	Typical output voltage range
V _{OH}	-	3.8V		-	High level output threshold
V _{OL}	-	0.55V		0.9V	Low level output threshold
I _{OUT}	-	+/-20mA		-	Max output current

Table 5.

Signal Param.	5V CMOS IN <i>Trigger</i> <i>Radio CH1</i> <i>Radio CH2</i>	5V CMOS OUT <i>Strobe</i>	3.3V LVTTTL IN <i>GNSS Rx</i>	5V I2C <i>MPU SCL</i> <i>MPU SDA</i>	Notes
V _{IH}	3.5V	-	2V	-	High level input threshold
V _{IL}	1.5V	-	0.8V	0.5V	Low level input threshold
V _{IMAX}	0V / 5V	-	0V / 5V	0V / 5V	Max input voltage range
V _O	-	0V / 5V		0V / 5V	Typical output voltage range
V _{OH}	-	3.8V		-	High level output threshold
V _{OL}	-	0.55V		0.9V	Low level output threshold
I _{OUT}	-	+/-20mA		-	Max output current

Table 5. Electrical specifications for the MAIA camera I/Os.

Input voltage that exceeds the maximum range can cause permanent damages to the camera.

The SDA and SCL pins of the Invensense MPU6000 inertial unit are connected to the MPU_SCL and MPU_SDA pins of connector J3 through an isolator stage. MPU_SCL and MPU_SDA pins of J3 are pulled-up by means of 2.2kΩ resistors to a 5V power supply. This power supply is:

- generated internally by the camera;
- isolated from other power supply nodes of the camera;
- referred to MPU_GND, that is electrically isolated from GND.

2.2 OPTICAL CHARACTERISTICS

The MAIA multispectral camera is based on an array of nine sensors with a resolution of 1208 x 960 pixel. The pixel size is 3.75 μm x 3.75 μm , resulting in an active area of 4.8mm x 3.6mm.

Each sensor is linked to a band-pass filter that precisely defines the detected wavelength range (band). Filters are high-quality ultra-hard coated, with long life and stable performance over temperature and moisture within the specified range for the camera. The filters are not designed to be changed by the User, although on request it is possible to configure the MAIA multispectral camera with an array of custom-defined filters. The camera is factory equipped with two filter sets, that the user can specify at the time of order. The two filter sets WV-2 and SN-2 match the bands of the WorldView-2™ or Sentinel-2™ satellite in the VIS-NIR range, from 390 nm to 950 nm.

For the WV-2 filter set, the camera features:

- 1 colour sensor (RBG, Bayer pattern)
- 8 mono-chromatic sensors.

For the SN-2 filter set, the camera features

- 9 mono-chromatic sensors.

The bands detected are listed in Table 6 and Table 7 and depicted in Figure 4 and Figure 5.

Sensor	Start WL (nm)	Stop WL (nm)	CWL (nm)	FWHM (nm)	Colour
S1	395	450	422.5	55	Violet
S2	455	520	487.5	65	Blue
S3	525	575	550	50	Green
S4	580	625	602.5	45	Orange
S5	630	690	660	60	Red
S6	705	745	725	40	Red Edge
S7	750	820	785	70	NIR 1
S8	825	950	887.5	125	NIR 2
S9	-	-	-	-	RGB

Table 6. Summary of optical bands detected by the MAIA multispectral camera sensors with WV-2 filter set.

Sensor	Start WL (nm)	Stop WL (nm)	CWL (nm)	FWHM (nm)	Colour
S1	433	453	443	20	Violet
S2	457.5	522.5	490	65	Blue
S3	542.5	577.5	560	35	Green
S4	650	680	665	30	Red
S5	697.5	712.5	705	15	Red Edge 1
S6	732.5	747.5	740	15	Red Edge 2
S7	773	793	783	20	NIR 1
S8	784.5	899.5	842	115	NIR 2
S9	855	875	865	20	NIR 3

Table 7. Summary of optical bands detected by the MAIA multispectral camera sensors with SN-2 filter set.

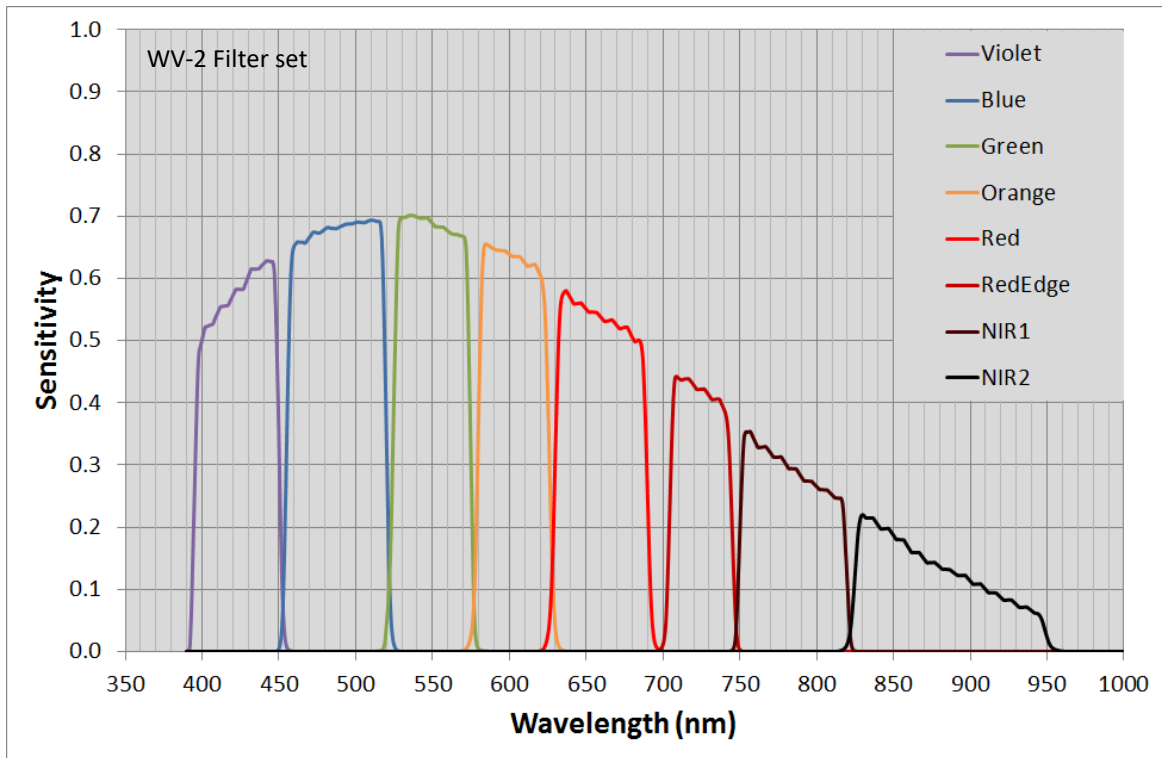


Figure 4. Sensitivity of the MAIA multispectral camera optical bands with WV-2 filter set. The sensitivities shown are the products of the quantum efficiency of the sensors and the transmittance of the filters.

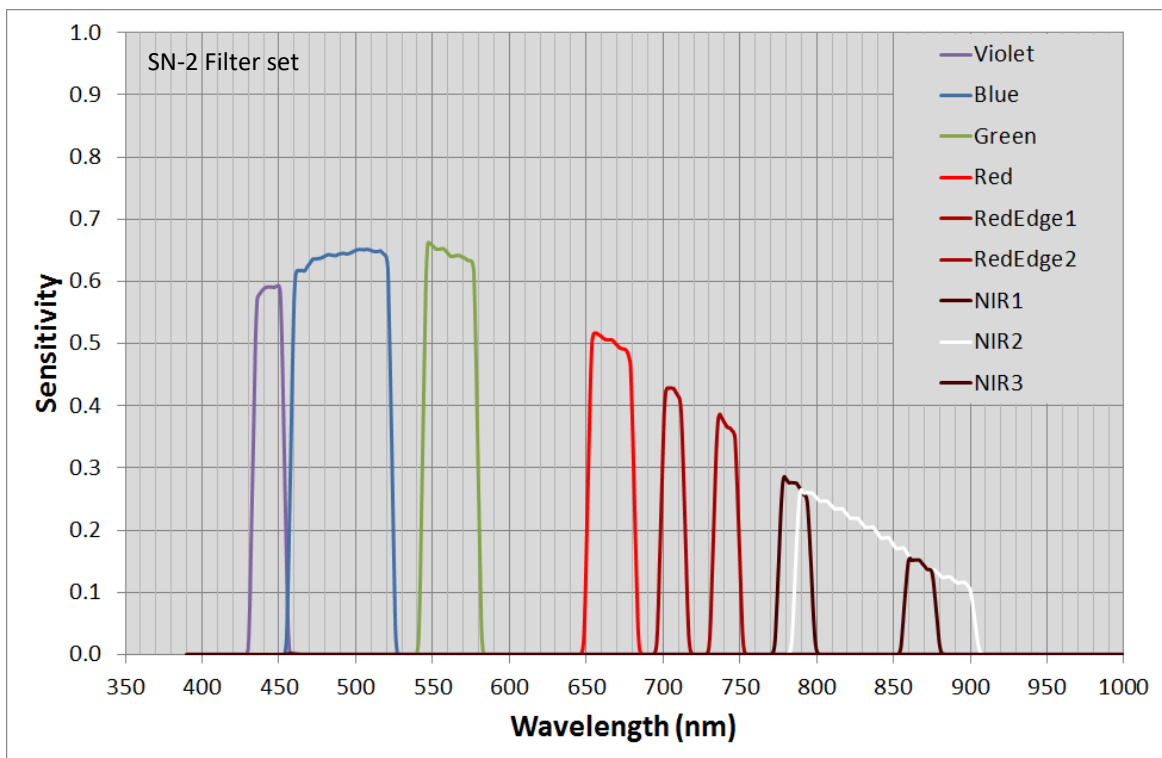


Figure 5. Sensitivity of the MAIA multispectral camera optical bands with SN-2 filter set. The sensitivities shown are the products of the quantum efficiency of the sensors and the transmittance of the filters.

Each sensor has a fixed-focus lens with:

Nominal focal length	7.5 mm
Aperture	f/#2.8
Field of view	about 35° HFOV; 26° VFOV; 43° DFOV

The lens focus is factory adjusted and is not configurable by the User.

The focal length of the lens and the sensor characteristics determine the field of view of the apparent size of the object in the image. In particular, the ground sample resolution (ground sampling distance; GSD) and the field of view (FOV) that can be obtained depending on the flight altitude (altitude above ground level; AGL) are shown in Table 6. Table 6 also gives the resulting maximum speed of the rover or aircraft so as to avoid the generation of images with motion blur, while considering a ‘drag’ effect of 0.5 pixels as acceptable. This information is supplied for use by the operator and does not constitute a technical feature of the product. The required maximum speed of the aircraft has to be determined according to the overlap needed between the images and the frame rate in use. A reasonable safety margin is recommended in order to tolerate for rapid pitching and rolling of the aircraft, also in case the camera is mounted on a stabilized gimbal.

AGL (m)	GSD (mm/pixel)	FOV (m ²)	Maximum UAV speed for 10 ms exposure (m/s) – (km/h)	Maximum UAV speed for 1 ms exposure (m/s) – (km/h)
50	23	30 × 23	2.3 – 8.4	23 – 84
75	35	45 × 34	3.5 – 12.7	35 – 127
100	47	60 × 45	4.7 – 16.9	47 – 169
150	70	90 × 68	7.0 – 25.3	70 – 253
200	94	120 × 90	9.4 – 33.8	94 – 338
300	141	180 × 135	14.1 – 50.6	141 – 506
400	188	240 × 180	18.8 – 67.5	188 – 675

Table 8. Field of view, ground resolution and flight speed for the MAIA multispectral camera at various altitudes above ground level.

2.3 MECHANICAL DESIGN

The size of the camera is 99mm x 129mm x 45mm. The camera can be fixed on a gimbal or other holders by means of four holes with M3x0.5 thread.

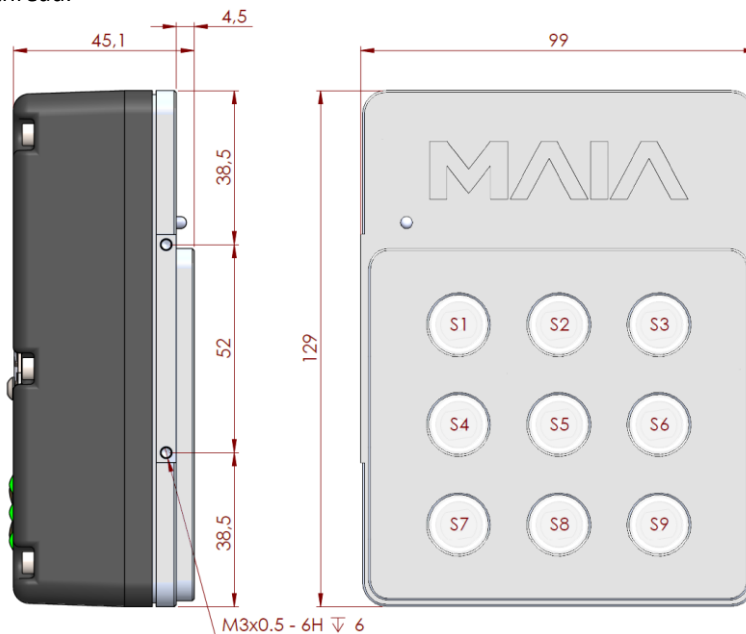


Figure 6. Mechanical design of the camera. Dimensions are in mm. Third angle projection.

2.4 POWER DISSIPATION

The front aluminium plate acts also as power dissipator and becomes hot during operations. In order to keep the temperature of the internal components within the operating limits and not to incur into automatic performance cut-off, it is very important to ensure proper ventilation of the camera. In particular, the front plate has not to be covered by any means and some clearance between the sides of the camera and the holder has to be left. Usually, with these precautions, the ventilation by the air flow caused by the drone during flight is enough to ensure proper operations. However, in specific cases, it might be necessary to actively cool the camera by supplying additional air flow.

3 INTERFACING THE CAMERA

The camera has several User interfaces for configuration of the operating parameters:

- rapid access buttons;
- control buttons for the menu video;
- web interface;
- control through the remote controller.

The operations of the MAIA multispectral camera can be monitored through the status LEDs on the on-board keyboard and through the menu superimposed on the video output.

3.1 QUICK ACCESS VIA KEYBOARD

The control keyboard allows for the turning on and off of the Wifi channel, the general system, and the image acquisition.

Button	Function
	<p>POWER On/off button for the system. When the system is turned off, press to turn it on. When the system is turned on, press for 2 seconds to turn it off. See §3.6 for information about the power-up and power-down phase.</p>
	<p>WiFi hotspot switch Pressing the button activates and disactivates the Wifi channel of the camera. This control might be limited according to events happening on the radio channels (see §3.4). See the LED status section (§3.5.2) for informations about the Wifi status LED.</p>
	<p>Shot (exposure) Pressing the button activates a single camera exposure. The single image is saved to the internal memory of the camera, as taken with the defined acquisition parameters.</p>
	<p>Acquisition Pressing the button starts/stops the acquisition, in terms of the saving to the internal memory of the camera of the images taken by the sensors with the defined acquisition parameters. While acquisition is in progress, some parameters are no longer changeable by the User. This control might be limited according to events happening on the radio channels (see §3.4).</p>

Table 9. Functions of the quick access buttons.

3.2 VIDEO CONTROL MENU

The camera control keyboard allows navigation through the video menu, and for some of the parameters to be set. This menu is visible overlaid on the images in the Composite Video output.

Button	Function
	<p>OK Confirm button. This shows the main menu and submenus, and confirms the selection of the submenus.</p>

	<p>ESC This returns to the main view, without confirming any selection of the submenus.</p>
	<p>UP/DOWN Buttons to navigate through the menu and submenus.</p>

Table 10. Funcions of the buttons for the video menu.

3.3 WEB INTERFACE

The web interface allows the control of all of the acquisition parameters of the camera, and it is the preferred control interface for the selection of the acquisition parameters. The camera needs to be connected via a cable connection or via Wifi and to have access through a web browser¹, indicating as necessary the IP address of the camera. The following details are needed for access:

Username: *operator*

Password: *operatorpsw*

3.3.1 CABLE CONNECTION

The camera can be connected through an Ethernet cable to a LAN (through a web switch) or can be connected directly in the Ethernet input of a computer. The default IP address of the camera is 192.168.11.151, which needs to be inserted into the address window of the browser to have access to the web interface. To have access to the camera, it is therefore necessary to set the LAN through which it is to be connected. If it is connected directly to a computer, for example, it is necessary to modify the network settings using these parameters:

- IP address: 192.168.11.xxx
- Gateway: 192.168.11.1
- Netmask: 255.255.255.0

From the Network tab of web interface (see section 4.1.5) it is possible to modify the network parameters of the camera. It is important to know that 192.168.11.1 is also the default gateway address of the camera itself. In case the user needs to change this setting either on the camera or on the PC, the same address has to be used both on the camera and on the PC.

3.3.2 WIFI CONNECTION

The camera works as a Wifi hotspot to which the system used (e.g., PC, smartphone, tablet) can be connect. Always check that the Wifi channel of the camera is on (see sections on 'Quick access buttons' and 'Status LEDs'). Furthermore, it should be verified that the network SSID *Maia_xxxxxx* (where xxxxxx is a unique 6-digits hex number for each camera) is visible to the device on the list of the available networks, to which it should be connected (network password: *password*). Once the Wifi hotspot is switched on, the network may take a while to be listed in the available connections. Refresh the list and wait until the PC/tablet/smartphone has detected it.

Once the camera is connected, the device receives the address 192.168.111.xxx, as assigned to the camera. The IP address of the camera is 192.168.111.1, which needs to be inserted in the address window of the browser.

¹ It is possible to use any updated and recent browser to configure the camera. It is recommended to use Mozilla Firefox in Linux/Android, or Bowser in iOS.

When a PC with Windows OS is connecting to the WiFi hotspot of the camera, the PC needs to identify the network and the user is prompted to assign it to the home, business or public domain. This operation requires some time to be completed and the web interface is not accessible in the meanwhile. The recommended setting is Home.

3.3.3 RECOMMENDED CONNECTION MODES

The wired and wireless interfaces can be used to set up several connection modes between the MAIA camera and a tablet, smartphone or computer. Depending on the use case and the operation scenario, some modes are better suited than others. The following table summarizes the most common ones, highlighting pros and cons of each.

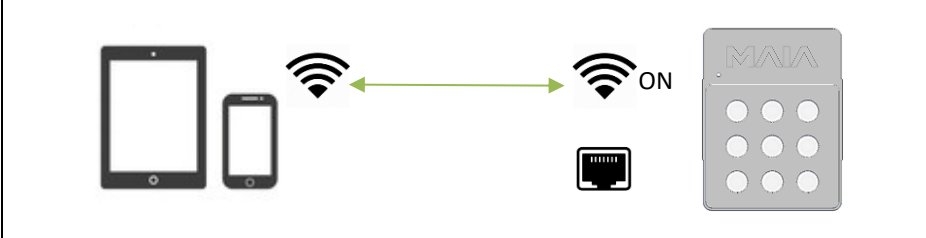
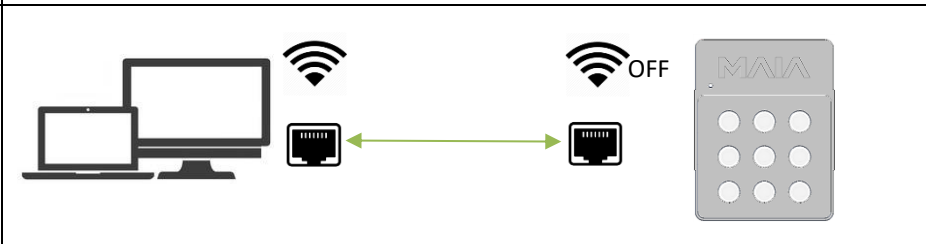
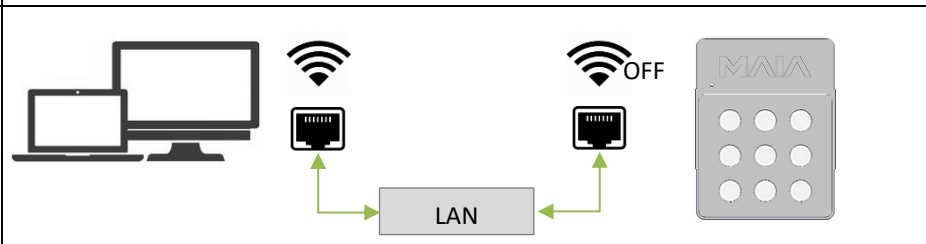
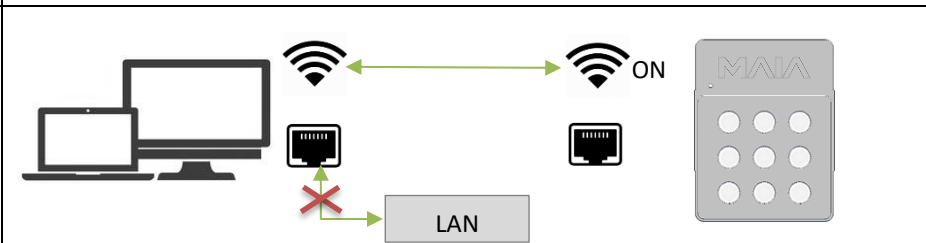
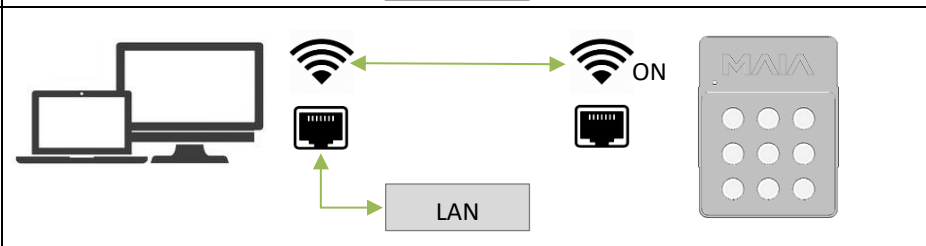
<p>Mode 1</p>	<p>Easy on-field access to configure MAIA and see live images</p> <ul style="list-style-type: none"> ☺ Live image streaming ☺ Configuration ☹ Image download 	
<p>Mode 2</p>	<p>In-lab access to download the images at high speed</p> <ul style="list-style-type: none"> ☺ Live image streaming ☺ Configuration ☺ Image download 	
<p>Mode 3</p>	<p>In-lab access to download the images at high speed</p> <ul style="list-style-type: none"> ☺ Live image streaming ☺ Configuration ☺ Image download 	
<p>Mode 4</p>	<p>In-lab access to configure MAIA and see live images</p> <ul style="list-style-type: none"> ☺ Live image streaming ☺ Configuration ☹ Image download 	
<p>Mode 5</p>	<p>Not recommended</p> <ul style="list-style-type: none"> ☹ Live image streaming ☹ Configuration ☹ Image download 	

Table 11. Most recommended modes to set up a connection to the MAIA camera.

3.4 REMOTE CONTROL FROM A RADIO CONTROLLER

Connection to the camera of a receiver for a radio controller makes it possible to set the functions through the remote radio controller. This function is useful to control some of the settings, even during flight operations. The radio commands have priority over the commands that come from other interfaces, and they block the settings until the radio controller is deactivated, according the mode of operations described in §3.4.1 and §3.4.2.

The radio signal of the radio controller is a radio frequency burst with TTL3.3V levels, a period between 33 ms and 14 ms (30-70 Hz base frequency) and a duration of the high phase between 1 ms and 2 ms. To be recognized as valid, the radio frequency burst must last at least 500 ms. The kind of command received depends on the duration of the pulse captured in each channel, according the details given in Table 9.

Event	Minimum duration of pulse (ms)	Maximum duration of pulse (ms)
A	1.00	1.20
B	1.25	1.45
C	1.50	1.70
D	1.75	1.95

Table 12. Radio pulse durations and related events.

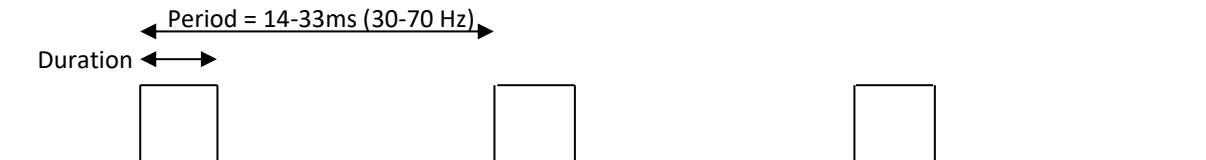


Figure 7. Temporal diagram of the radio frequency burst.

3.4.1 CH1 RADIO CHANNEL

The events captured on the CH1 channel activate/deactivate the acquisition by the camera. In 'Continuous acquisition' mode, the interval of acquisition is also set; in 'External trigger' mode, only activation/deactivation of the acquisition is available. The interval of acquisition can be chosen among the three available intervals previously set in the Web interface. The activation/deactivation of acquisition via the radio controller overrides the possibility to modify this control from other interfaces, until the radio channel is released.

Event	Camera setting
Any -> no event	This releases the lock on the control for the other interfaces. The status of acquisition does not change.
No event	No changes for the status.
A	This deactivates the acquisition.
B	This activates the acquisition with the 'Shot interval' 0
C	This activates the acquisition with the 'Shot interval' 1
D	This activates the acquisition with the 'Shot interval' 2

Table 13. Actions related to the events captured on the CH1 channel.

3.4.2 CH2 RADIO CHANNEL

The events captured on the CH2 channel activate/deactivate the Wifi channel of the camera, and allows the selection of the sensor on the video (Web interface and/or video channel to the operator). The activation/deactivation of the Wifi channel via the radio controller overrides the possibility to modify this control from other interfaces, until the radio channel is released.

Event	Camera setting
Any -> no event	This releases the lock on the Wifi control for the other interfaces. The status of the Wifi channel does not change.
No event	No changes for the status
A	This deactivates the Wifi channel
B	This deactivates the Wifi channel
C	This activates the Wifi channel
B->A->B	This increases the index of the sensor visualised by one ; once the number of sensors of the camera is reached, the index starts again from the first.

Table 14. Actions related to the events captured on the CH2 channel.

3.5 LEDs

Several LEDs on the camera provides the User with immediate visual feedback about the system status. Three are located on the keyboard and one on the front panel (see **Figure 2**).

3.5.1 ACQUISITION LED

The Acquisition LED gives information about the status of the Wifi channel of the camera

Camera status	LED status
Camera OFF	OFF
System power-up or power-down in progress	Orange
Image acquisition is in progress, the LED blinks exactly when the image is being acquired	Flashing red

Table 15. Description of the status of the Acquisition LED.

3.5.2 WIFI LED

The Wifi LED gives information about the status of the Wifi channel of the camera.

Camera status	LED status
Camera OFF	OFF
System power-up or power-down in progress	Flashing green
Deactivated Wifi channel via Web interface/ Quick access buttons	OFF
Deactivated (and blocked) Wifi channel via radio controller	Red ON
Activated Wifi channel via Web interface/ Quick access buttons	Flashing green
Activated (and blocked) Wifi channel via radio controller	Flashing red

Table 16. Description of the status of the Wifi LED.

3.5.3 POWER LED

The power LED gives information about the general status of the camera, and about the activation/ deactivation of the image acquisition.

Camera status	LED status
Camera OFF	OFF
System power-up or power-down in progress	Flashing green
System ready, deactivated acquisition via Web interface/ Quick access buttons	Green ON
Deactivated (and blocked) acquisition via radio controller	Red ON
Activated acquisition via Web interface/ Quick access buttons	Flashing green
Activated acquisition via radio controller	Flashing red
Single shot	Red pulse

Table 17. Description of the status of the power LED.

3.5.4 MEMORY LED

The memory LED gives information about the status of the internal memory of the camera.

Camera status	LED status
Camera OFF	OFF
System power-up or power-down in progress	Flashing green
Available memory over the threshold defined by the User	Green ON
Reached memory threshold defined by the User; memory exhausted	Flashing Red
Exhausted memory; data can no longer be acquired	Red ON

Table 18. Description of the status of the memory LED.

3.6 POWER-UP AND POWER-DOWN SEQUENCE

The power-up and power-down phase is initiated by pressing the Power button on the camera's keyboard.

3.6.1 POWER-UP

- 1) Make sure that the power supply cable is connected to a suitable source, which voltage is within the accepted range (9 to 26V) and capable of delivering enough current (at least 2A) . Then, connect the power cable to J2 connector (see §2.1);
- 2) Press the Power button (see §3.1);
- 3) The acquisition LED becomes orange and after some seconds it is turned. In the meanwhile the three LEDs on the keyboard show some initial glitches with random blinks and few seconds of steady green state. Afterwards they start blinking with "heartbeat" pulses. The boot phase lasts about 20-25s and, once completed, the heartbeat pulse stops. This indicates that the boot has completed and since then the LEDs on the Keyboard behave according to their relative function, as described in §3.5.

3.6.2 POWER-DOWN

- 1) Make sure the acquisition is not in progress and press the Power button (see §3.1) for 2s;
- 2) The keyboard LEDs start the "heartbeat" pulses and the acquisition LED is turned on orange. The power-down phase lasts about 20-25s and the keyboard LEDs stop blinking before it has completed.
- 3) When the power-down has completed, the Acquisition LED is turned off. From this moment, it is possible to safely remove the power supply cable from the camera.

Important warning:

When the camera is not powered, no voltage has to be applied on any of its input pins. As a general rule, this is ensured if no external devices are connected and powered when the camera is off. Permanent damage to the camera might happen otherwise.

4 PARAMETERS SETTINGS

The acquisition parameters of the MAIA multispectral camera can be set to operate on three User interfaces:

- Web interface;
- Menu/control keyboard;
- Radio controller.

The main parameters that can be set are:

- acquisition mode (external on trigger, continuous);
- exposure mode (automatic, manual);
- trigger (leading and trailing edges);
- strobe (activation, minimal duration);
- exposure interval for use with continuous acquisition (three interchangeable levels);
- exposure parameters (target value, exposure time of the sensors, maximum exposure time);
- file format (RAW12, RAW10, RAW8);
- sensor to forward to the video output;
- activation/ deactivation of the video output;
- threshold for the warning about the available space in the internal memory;
- network settings (IP address).

The Web interface provides the more complete control, and in this section, the parameters and functions will be described in detail. In the sections concerning the keyboard and the radio controller, only their particular functionalities will be explained, leaving the User to read the Web section for the common parts.

4.1 PARAMETERS SETTINGS FROM THE WEB INTERFACE

The Web interface is accessible through a browser, as described in the 'Web interface' section 3.3, and this is the preferred channel to manage the operative parameters, as it provides access to all of the camera settings. Access to the interface requires the following details:

Username: *operator*

Password: *operatorpsw*

The Web interface is divided over several pages, each of which considers the individual parameters of the camera.

4.1.1 HOME

This is the main page of the interface. This allows basic functions or settings to be set, such as the acquisition start/stop and the sensor visualised. Furthermore, there is a counter of the saved images during the current acquisition (or for the last conducted) and the residual memory.

It is possible to adjust the exposure parameters (exposure time or exposure target) of the selected sensor. There is a window where it is possible to see the image as live streaming, if the "Live view" control is activated. This feature requires the H.264 decoding support by the browser.

If the acquisition is started while live streaming is active, the streaming is stopped and its switch button is set to OFF and inhibited. Once the acquisition has ended, it is necessary to refresh the Home page in the browser before clicking on the switch to turn on the streaming.

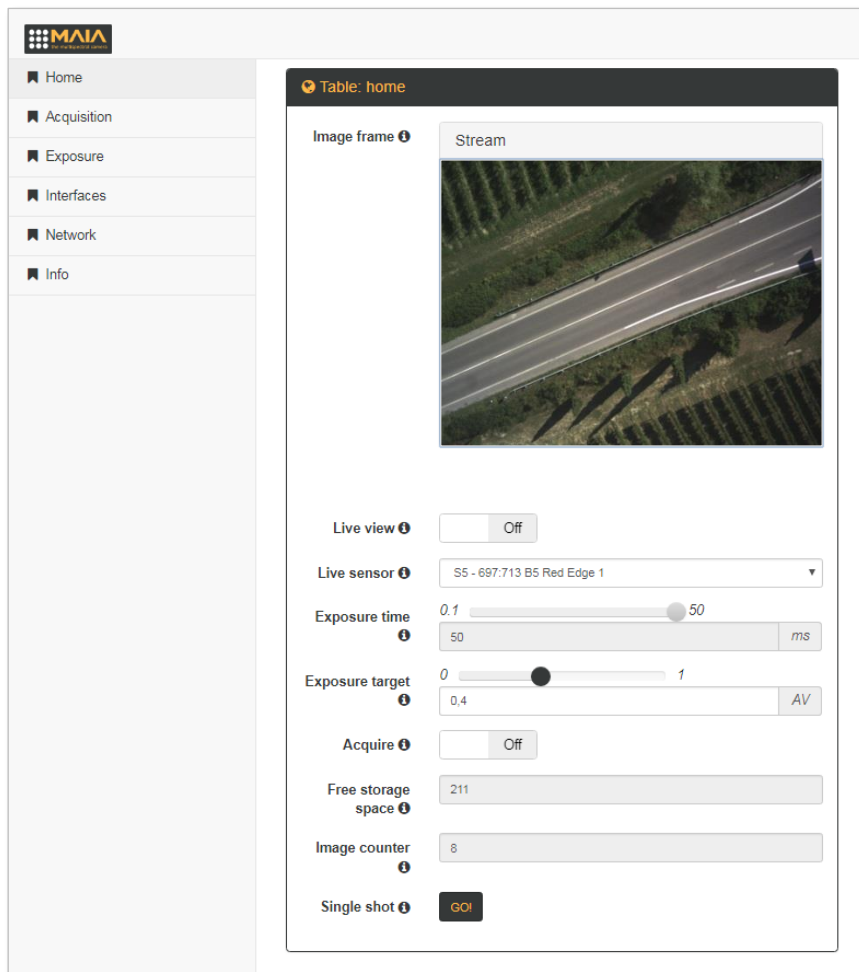


Figure 8. Screenview example from the Web interface – Home page.

4.1.2 ACQUISITION

This page contains the controls for the acquisition procedures. It is possible to set the trigger mode (continuous acquisition and related period, or external trigger), the parameters of the strobe signal, and the threshold for memory occupation that is indicated by the memory LED. Furthermore, it is possible to select the file format in which to save images (RAW8, RAW10, RAW12).

The acquisition of the images is configurable according to two modes:

- *External trigger*: The camera acquires an image in correspondence with the leading or trailing edge (one is chosen) of the trigger signal. An eventual trigger signal that is received before the camera has finished saving the previous image will be ignored. The frequency of the trigger edges cannot exceed the limits of the frame rate in continuous mode.
- *Continuous*: The camera acquires images continuously, with a frame rate defined by the user. It is possible to set three predefined frame rates and to change from one to another while the image acquisition is in progress, also by means of the radio controller (see §3.4.1).

The start of the image acquisition is always linked to an event generated by the User, independent of the defined mode and also if the trigger signal is always present on the related connector pin. The acquisition stops when the memory is full or when the User stops it.

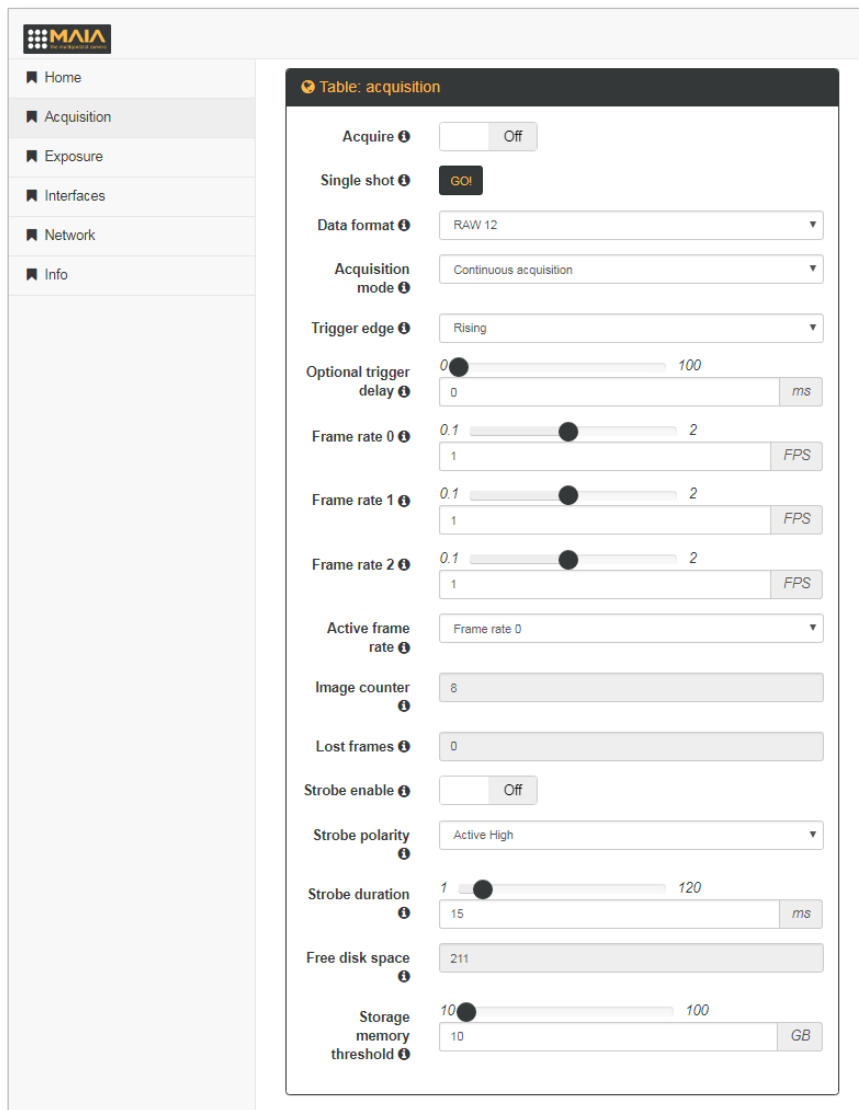


Figure 9. Screenview example from the Web interface – Acquisition page.

The events that start/stop the image acquisition are:

- Pressing the Acq (acquisition) button on the keyboard;
- Sending the proper signal on CH1 of the radio controller (see §3.4.1);
- Using the acquire button on the Web interface.

In addition to the external trigger or continuous modes, it is possible to acquire a single exposure also by pressing the 'Shot' button on the keyboard.

The camera can also generate a synchronisation signal directly towards to external if the 'Strobe' output is activated in the Web interface. In this case, at the beginning of the acquisition of each image, the camera sets the 'Strobe' connector pin to the high level (or low, depending on User choice), for a duration that can be set by the User.

The supported file formats are:

- RAW10 and RAW 12, which correspond to 10 bit and 12 bit per pixel as non-compressed RAW files;
- RAW8, which corresponds to 8 bit per pixel as non-compressed RAW files.

All of the formats are lossless, and the images of the RGB sensor (if present) are always saved in the 16 bit per pixel format with de-bayer 5-6-5. The choice of one format over another is left to the User, who can balance the

considerations for the need for more detailed information (i.e., RAW12 format) or to use less of the internal memory space (i.e., RAW8).

The names of the image files are generated automatically, and these depend on an the absolute progressive number in the series and the date and time of the acquisition, according to the following code:

yyyymmddhhmssfff_xx-pppp.raw

where:

- 'yyyymmdd' gives the date as year/month/day;
- 'hhmssfff' gives the time as hour/minute/second/millisecond, in UTC time;
- 'xx' is the progressive serial number of the acquisition, reset at 00 each time the camera is switched on;
- 'pppp' is the progressive serial number of the image.

ATTENTION: The seconds of the exposures refer to UTC time, as well as the name and the time of saving the file. UTC time is different from the local time depending on the time zone and on the legal time period.

For every acquisition of an image, information that useful for the following processing is saved, as:

1. Exposure time for each sensor;
2. Timestamp of the system at the moment of the exposure;
3. Last GNSS data (i.e., time, position, speed, fix status) available at the moment of the exposure.

These data are saved within each image as embedded data, and then coded by the processing software (see below). The data related to the timestamp and the GNSS are also saved as a text log file (if save is activate in the '*Interfaces*' panel), to interpolate the GPS positions on the basis of the timestamp, and then to define the exact exposure position.

The positioning that are data saved for each exposure are the last valid data received BEFORE the start of the exposure. Interpolation is possible because the timestamp of the exposure is obtained from a clock synchronised to within a few milliseconds of the UTC given supplied by the GNSS. The availability of the GNSS data assumes that a suitable global positioning sensor is connected to the dedicated port of the camera.

4.1.3 EXPOSURE

This panel allows the exposure parameters of each sensor to be checked. The expected exposure modes are:

- *Manual*, where it is possible to set the exposure time of every single sensor to 0.1 ms to 50 ms.
- *Automatic*, where it is possible to set the exposure target for each sensor and an automatic algorithm will set the necessary exposure time to obtain this, where possible. The exposure target is estimated as the average value of the digital number (DN) for the entire frame. Automatic exposure needs a certain number of frames for the convergence, which might not be possible for some light conditions.
For improved control in '*Automatic*' mode, it is possible to select the maximum exposure time that can be applied to each sensor.

Independent of the choosen modality, all of the sensors start their exposure in the same moment, and they stop according to the exposure time applied to each sensor.

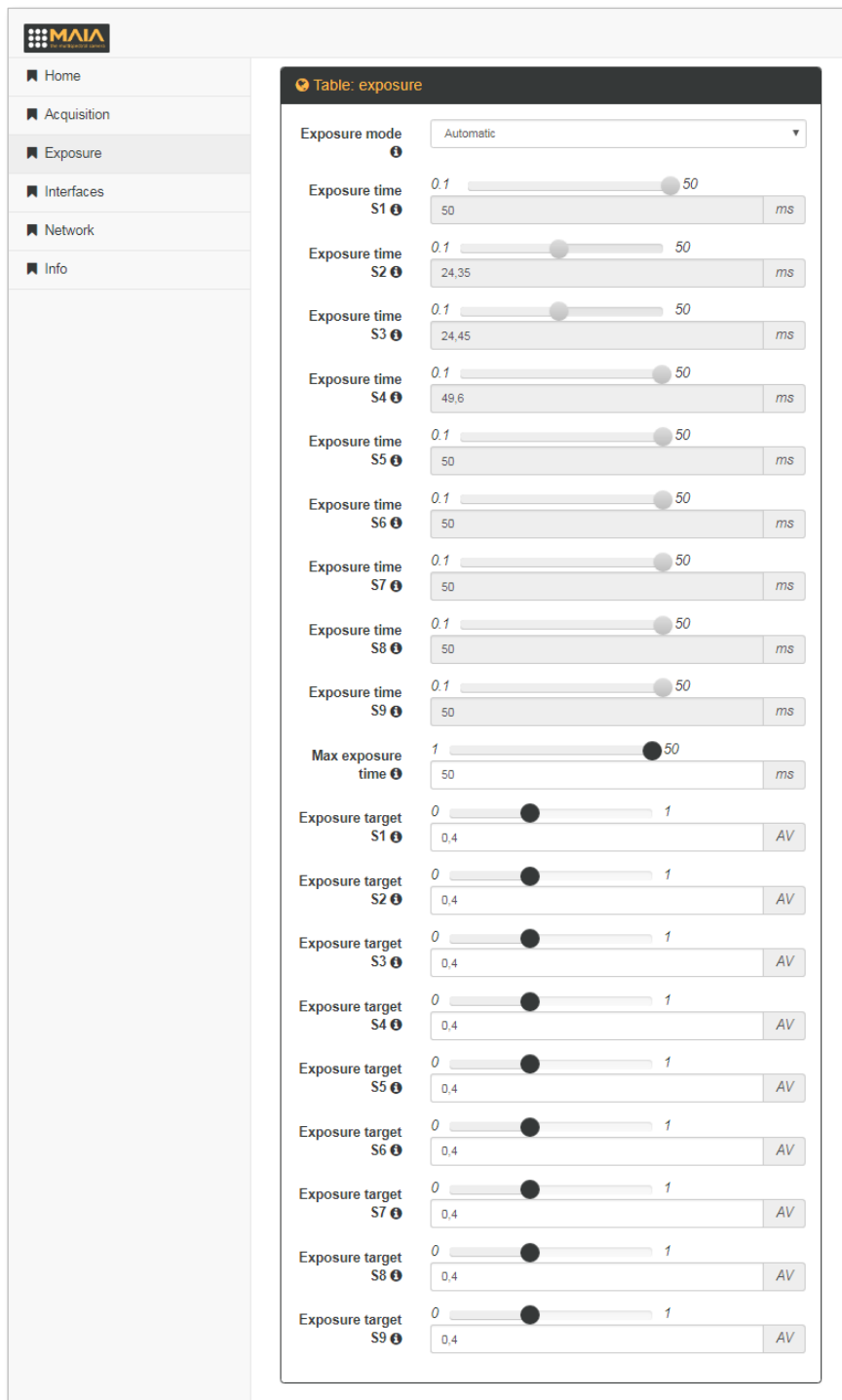


Table: exposure

Parameter	Range	Current Value	Unit
Exposure mode	Automatic	Automatic	-
Exposure time S1	0.1 - 50	50	ms
Exposure time S2	0.1 - 50	24,35	ms
Exposure time S3	0.1 - 50	24,45	ms
Exposure time S4	0.1 - 50	49,6	ms
Exposure time S5	0.1 - 50	50	ms
Exposure time S6	0.1 - 50	50	ms
Exposure time S7	0.1 - 50	50	ms
Exposure time S8	0.1 - 50	50	ms
Exposure time S9	0.1 - 50	50	ms
Max exposure time	1 - 50	50	ms
Exposure target S1	0 - 1	0,4	AV
Exposure target S2	0 - 1	0,4	AV
Exposure target S3	0 - 1	0,4	AV
Exposure target S4	0 - 1	0,4	AV
Exposure target S5	0 - 1	0,4	AV
Exposure target S6	0 - 1	0,4	AV
Exposure target S7	0 - 1	0,4	AV
Exposure target S8	0 - 1	0,4	AV
Exposure target S9	0 - 1	0,4	AV

Figure 10. Screenview example from the Web interface – Exposure page.

4.1.4 INTERFACES

The Web page allows the interfaces of the camera to be checked.

- **GPS:** activation/deactivation of the saving of the GPS log. Feedback is provided according to the status of the fix.
- **VIDEO:** activation/deactivation of the streaming on the Composite video output port, choice of standard (NTSC or PAL) and the sensor visualised.
- **RADIO:** activation/deactivation of the radio channel event detection, and feedback on the last received command.

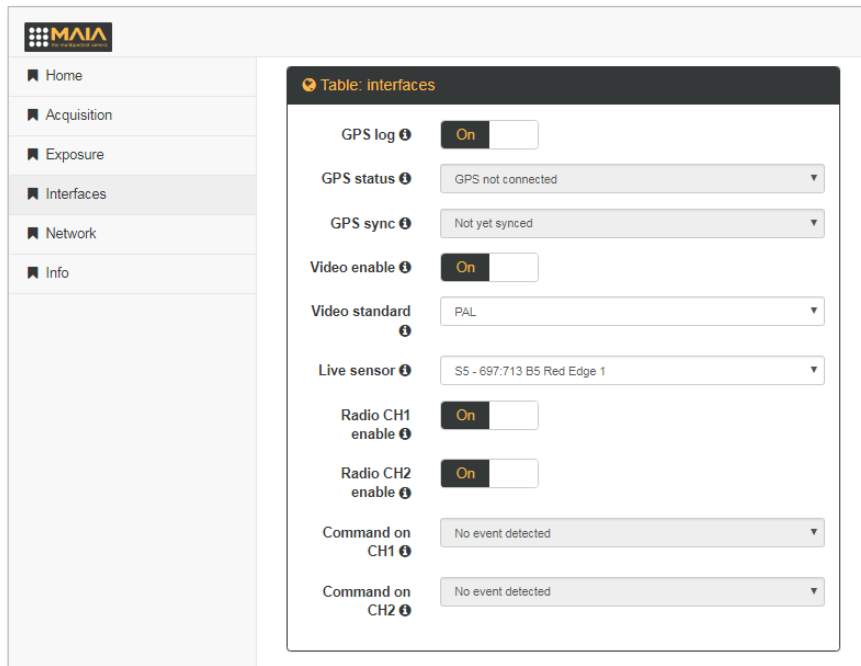


Figure 11. Screenshot example from the Web interface – Interfaces page.

4.1.5 NETWORK

This provides for the setting of the network parameters of the camera.

- **WiFi:** activation/deactivation of the Wifi channel, and setting of the network password.
- **GigE:** activation/deactivation of the DHCP modality, or manual setting of static settings.

The activation/deactivation of the Wifi channel is immediate upon activating the control switch. The other settings must be confirmed by pressing the *GO!* button.

4.1.1 INFORMATION (INFO)

This page summarises some off the information about the system: UTC date/time of the system, serial number, available internal memory.

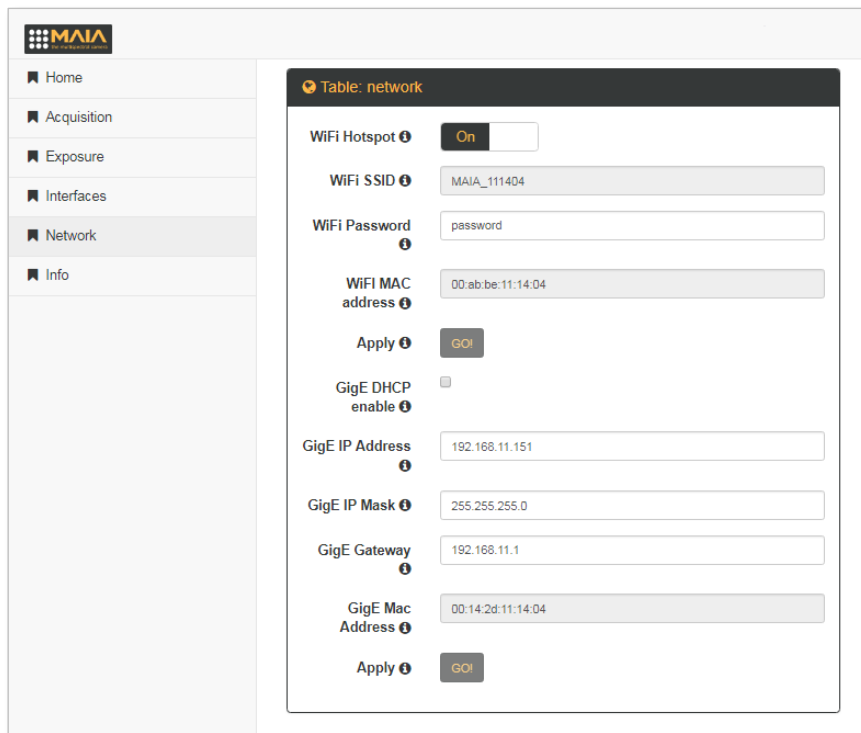


Figure 12. Screenview example from the Web interface – Network page.

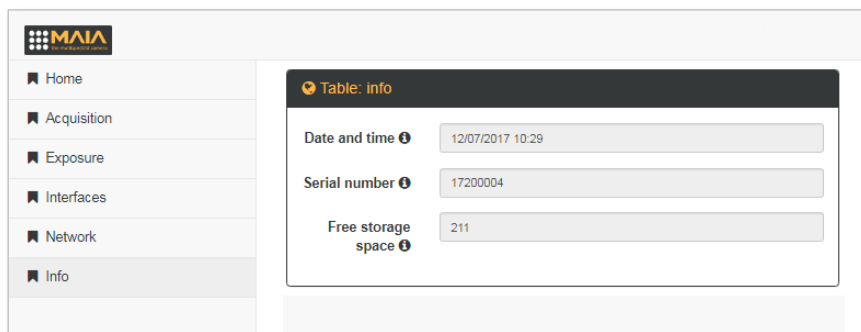


Figure 13. Screenview example from the Web interface – Info page.

4.2 PARAMETER SETTINGS FROM THE KEYBOARD/OVERLAY MENU

The control keyboard allows the setting of some of the acquisition parameters without the need for access to the Web interface. The Quick access buttons can be used to check on the status of the acquisition and the activation of the Wifi channel (see §3.1 for details). The menu control buttons are used to check the video menu, which is visible on a screen connected to the Video output port, and eventually on a screen in the field using a radio link for video transmission.

On the menu, it is possible to see the main camera parameters, as updated in real time:

- Index of input sensor (S1 to S9);
- Status of acquisition (activated/deactivated);
- Selected exposure interval (if continuous acquisition) or 'trig' note (if external trigger acquisition);
- File format (RAW12/10/8);
- Free storage memory (in GB);
- Wifi status (on/off);
- Radio channels status;

4.3 PARAMETERS SETTINGS FROM A RADIO CONTROLLER

During the flight, it is possible to set some of the parameters using a radio controller. See the 'Remote control from a radio controller' (§3.4) section, where there is a description of setting parameters and the radio events that allow those settings.

5 INCIDENT LIGHT SENSOR

5.1 OVERVIEW

The MAIA Incident Light Sensor (ILS) measures the level of the ambient light for each band of the camera. It allows the correction for downwelling light changes during the flight, such as those caused by clouds covering, and calculate the true reflectance ratios for the correct index calculations. Furthermore, the ILS features a 6-axis inertial unit for motion processing, an environmental sensor for pressure, temperature and humidity measurement and a GNSS receiver with an embedded antenna that provides timestamp and position information for accurate geotagging of each image acquired by the MAIA camera. The ILS connects directly to the MAIA camera and is powered and controlled by it, without any specific action required by the user for its operation, once properly mounted on the UAV. All parameters measured by the ILS are automatically stored into the log files of the image acquisition and are available by the MAIA processing software.

Key features

- Irradiance levels of light measured with bands matched with the camera;
- GNSS receiver with on-board antenna, supporting the use of an external active or passive antenna;
- 6-axis IMU and pressure, temperature, humidity sensors;
- Seamless connection to the MAIA camera;
 - data of each measured parameter are included in the camera log file;
 - single-cable connection to MAIA for power supply and control;
- 1s measurement rate of all parameters, synchronized with the image acquisition;
- micro SD card for additional log files storage (8GB bundled);
- USB2.0 interface to access the SD from host computer without removing the SD.



Figure 16. The MAIA Incident Light Sensor

5.2 CONNECTIONS AND MOUNTINGS

The features of the ILS sensor are depicted in Figure 17. The ILS should be mounted on top of the UAV, in a place where no other objects can cause shadows or obstructions. A clear view of a full hemisphere of the sky is very important for the correct measurement of the down-welling radiation and for the optimal performance of the GNSS module.

The ILS should be mounted such that the forward flight direction is aligned as depicted in Figure 18 and the top surface, where the light input port is located, is parallel to the horizon. With this set-up, the pitch and roll angles are approximately zero when the UAV is hovering in no-wind conditions.

Use the four screw mounts (M3x0.5) to secure the ILS to the top of the aircraft.

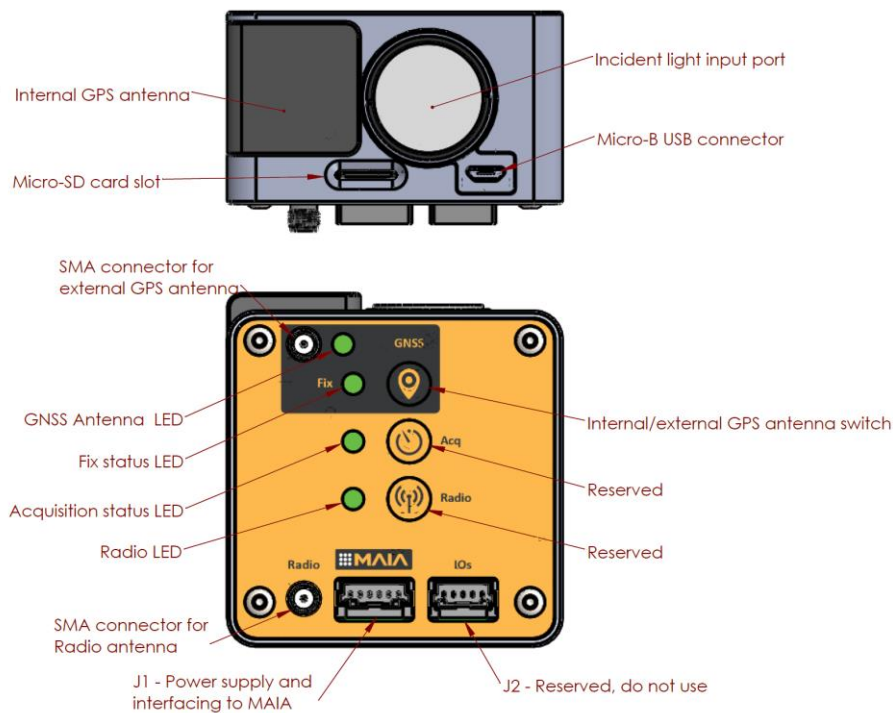


Figure 17. Features of the MAIA Incident Light Sensor.

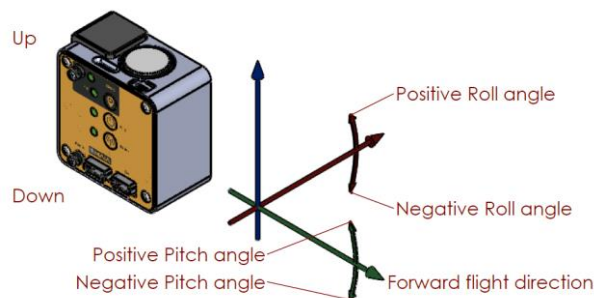


Figure 18. Mounting orientation and pitch and roll angles sign convention.

The ILS has to be connected to the MAIA camera using the 6-wire cable supplied. This cable carries power, ground and a serial communication signals MAIA and the ILS and has to be mated with the J1 connector on the ILS and J6 connector on MAIA. The J2 connector on the ILS is reserved for future use.

When the ILS is connected to the MAIA camera and the camera is powered on by pressing the power button, also the ILS is powered. The power-up phase lasts few seconds and when the ILS is ready the *Acquisition status* LED is ON red.

5.3 DATA ACQUISITION

When the image acquisition on the MAIA camera is started, the ILS automatically starts to acquire the data from its sensors (GNSS, accelerometer, gyroscope, temperature, pressure, humidity) and to send the values to the MAIA camera. These data are stored in the image log files on the MAIA camera and thus made automatically available to the MAIA image processing software. When the acquisition is running, the *Acquisition status* LED is green blinking.

It is not possible to start the image acquisition on MAIA by acting on the button labelled with *Acq* on the ILS. This button is not active and reserved for future use.

To properly operate, the ILS needs a microSD card formatted with the FAT32 file system, and a size of 4, 8 or 16GB. The ILS saves the data collected by all the onboard sensors also on a log file on the microSD card. Since the data are also sent to the MAIA camera and saved in the image log files as well, the user is not requested to access the micro SD card to gather them.

5.4 OPERATIONS OF THE EMBEDDED GNSS RECEIVER

The ILS features a GNSS receiver, which provides the geo-tagging information to the images saved by the MAIA camera. The simultaneous connection of the ILS and a third-party GNSS is not possible. The GNSS of the ILS can operate with the internal antenna or with an external antenna, connected to the SMA port. Both active and passive antennas are supported. The selection of the antenna to be used is possible by means of the *GNSS antenna* switch (see Figure 17) on the ILS front panel, operating when the ILS is powered on. The *GNSS antenna* led, located next to the SMA connector, highlights which of the antenna is currently active: OFF in case of the internal antenna, green ON in case of the external one. The internal antenna is always active by default after power-on, regardless of the selection at the time of shutdown. This ensures that the GNSS unit is always ready to receive a valid signal after power-up, speeding up the time to fix.

All the positioning information are forwarded to the MAIA camera, which logs them and shows the fix status on the web interface and by means of the LEDs on the keyboard. When the fix status changes, the transition needs some time to propagate from the ILS to the camera and to be displayed on the keyboard LEDs and the web interface. In this case, a temporary misalignment between the indicators might therefore occur.

The ILS unit can be ordered with a standard-precision GNSS receiver or with a high-precision receiver featuring RTK correction. The operation differs, as described in the following sections.

5.4.1 STANDARD-PRECISION GNSS

The standard-precision GNSS receiver is easy to operate and the sole requirement is a clear and unobstructed view of the sky by the antenna. It is therefore recommended to mount the ILS on top of the UAV, as requested for the proper operations of the light sensor.

It might take from 30 seconds to some minutes for the GNSS receiver to initially reach the fix status under good satellite coverage. The "Fix status" Led highlights the level achieved: OFF when no fix is possible, Red in case of 2D Fix and Orange in case of 3D Fix.

5.4.2 HIGH-PRECISION GNSS WITH RTK CORRECTION

The ILS with high-precision GNSS receiver features the RTK correction to achieve centimetric positioning accuracy. The RTK-grade ILS work in pairs: one Rover unit, mounted on the UAV or the land vehicle and one Base unit at ground. Both units feature a concurrent GNSS receiver that can receive and track GPS and GLONASS constellations and both will be used in the RTK solution. The base station uses its measurements from the available satellites to broadcast its position and satellite observation data to the rover over a UHF long range radio link (LoRa).

The Base station and the Rover unit have to be configured by writing the proper parameters in the *config.ini* file that must be present in the root directory of the SD card.

The Base Station must be configured with a fixed position or have completed a survey-in operation before it can output the RTCM reference station position message. The Base Station can be set to operate in a fixed position mode or to self survey-in its position, depending on the user's knowledge of the Base Station's antenna reference position.

When the base station coordinates are fixed and known with accuracy, they can be input in the *config.ini* file in the "Position section".

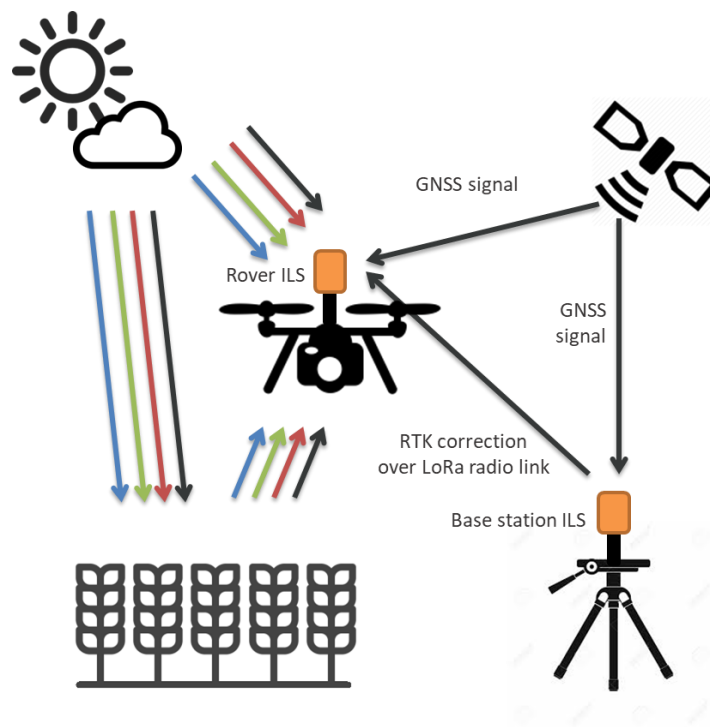


Figure 19. RTK operations

If the coordinates of the Base Station antenna are not known to sufficient accuracy, the Base Station can be configured to self survey its location. When working in Survey-in Mode the Base Station will determine its own position by building a weighted mean of all valid 3D position solutions. Two fields in the config.ini file can be set in the “Survey section” for this purpose:

- The “Mean duration” field , defines a minimum amount of observation time regardless of the actual number of valid fixes that were used for position calculation. Reasonable values range from one day for applications that require high absolute accuracy, to a few minutes for applications that only require high relative accuracy.
- The “Accuracy” field forces the calculated Base station position to be of at least the given 3D position accuracy. This 3D position accuracy is derived estimate from the survey algorithm. The actual absolute surveyed in accuracy will be no better than approximately 1m.

In case the unit is configured as Rover, the “Position section” and “Survey section” fields are ignored. In its default state, the Rover will automatically apply the RTCM corrections it receives. When the navigation solution has converged sufficiently it will enter RTK float mode and assuming circumstances allow for it, eventually reach RTK fixed mode. The Rover requires a minimum of five ambiguities to attempt fixing. RTK fixed status can be reached when either of the following requirements is fulfilled: 1) six satellites from a single constellation are available, or 2) eight satellites from two different constellations are available.

The RTK feature is fully working when using the internal antenna of the ILS, both on Rover and Base. In case higher performance is needed, an external antenna can be connected to the dedicated port on the ILS. Please specify this request at the time of order or contact the technical support to purchase the supported antennas. The internal antenna is always active by default after power-up and the external antenna has to be manually enabled by pressing the interna/external antenna switch.

The UHF radio link is a long-range low-power transmission operating in the 433MHz or 868MHz frequency bands. The band has to be specified at the time of order, depending on the country where the unit is to be sold. Despite of the very

low output power of +10dBm, the high sensitivity of the receiver and the spread spectrum communication, high interference immunity and extended range are achieved.

The transmission can be configured by selecting the desired communication channel among the 8 available in the “CH” field of the *config.ini* file. It is usually not necessary to change the default setting but in case other devices communicating in the same frequency region are present near the Base. The Channel of Base and Rover must match, in order to establish the communication link. It is also possible to adjust the output power for transmission by tuning the “PWR” field in the 1-15 range (lowest to highest power). In order to exploit the maximum range, it is recommended to leave this parameter set at 15.

The efficiency of the radio link strongly depends on the features of the antennas used both on the rover and on the base and on a clear line of sight between the twos. A Rover to Base distance of some km can be usually achieved and distances of up to 15km have been successfully tested in favourable scenarios.

The ILS that acts as Base station can be powered by a LiPo 2S battery or by a 5V_{DC}/1A power supply.

5.5 LED STATUS

Several LEDs on the ILS provides the user with immediate visual feedback about the system status. The meaning of the LEDs is as shown in the next tables.

GNSS Antenna	LED status
Camera OFF	OFF
System power-up in progress	OFF
Internal antenna active	OFF
External antenna active	Green ON

Table 19. Description of the status of the GNSS Antena LED.

Fix status for the standard-precision GNSS version	LED status
Camera OFF	OFF
System power-up in progress	OFF
No fix found	OFF
2D Fix	Red ON
3D Fix	Orange ON
Fix status for the RTK GNSS version, Base unit	LED status
Camera OFF	OFF
System power-up in progress	OFF
No fix found	OFF
In <i>Survey-In</i> mode: when survey-in is in progress The blink frequency increases following the improvement in the position accuracy	Orange blinking
In <i>Survey-In</i> mode: when Survey-In is completed	Green ON
In <i>Position</i> mode: 3D Fix reached	Green ON
Fix status for the RTK GNSS version, Rover unit	LED status
Camera OFF	OFF
System power-up in progress	OFF
No fix found	OFF
2D Fix	Red ON
3D Fix	Orange ON
RTK Float The blink frequency increases following the improvement in the position accuracy and three thresholds: 500mm, 250mm 50mm	Green blinking
RTK Fixed	Green ON

Table 20. Description of the status of the Fix status LED.

Acquisition status	LED status
Camera OFF	OFF
System power-up in progress	OFF
System up and ready to acquire	Red ON
Acquisition in progress	Green blinking

Table 21. Description of the status of the Acquisition status LED, valid for all GNSS versions.

Radio status for the RTK GNSS version, Base unit	LED status
Camera OFF	OFF
System power-up in progress	OFF
No radio transmission	OFF
RTCM strings Radio transmission active	Red blinking
Radio status for the RTK GNSS version, Rover unit	LED status
Camera OFF	OFF
System power-up in progress	OFF
No radio reception	OFF
RTCM strings reception	Green blinking

Table 22 Description of the status of the Radio Led. This Led is not used in the Standard-precision GNSS units.

5.6 MECHANICAL DESIGN

The size of the ILS sensor is 70mm x 70mm x 40mm, excluding connectors. The ILS sensor can be fixed on a gimbal or other holders by means of four holes with M3x0.5 thread.

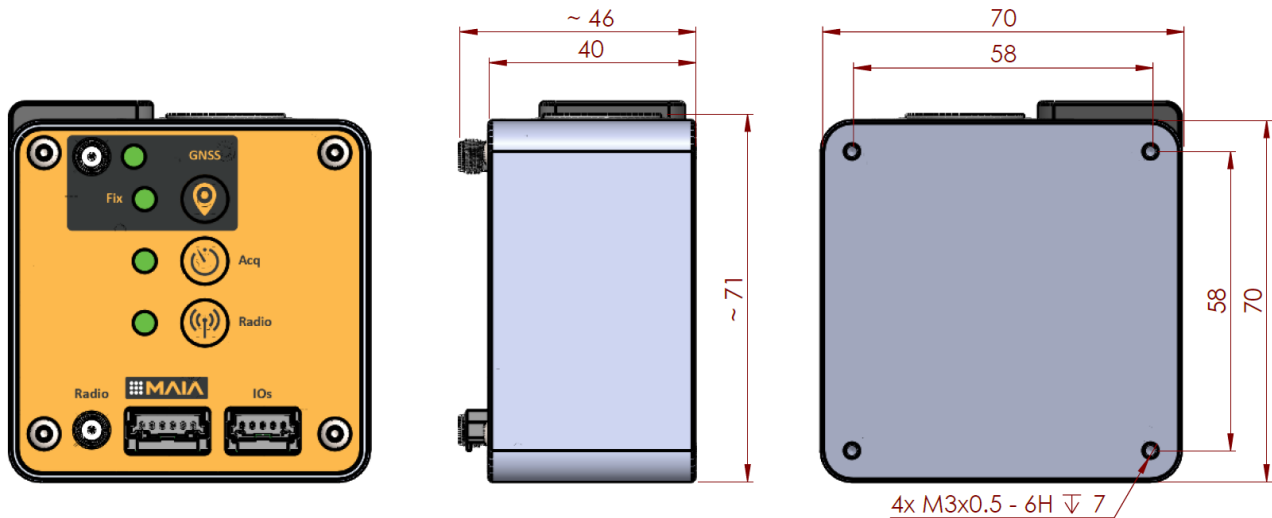


Figure 20. Mechanical design of the ILS sensor. Dimensions are in mm. Third angle projection.

6 ACQUISITION PROCEDURES

This section describes a typical acquisition procedure, from the camera settings to the data download.

6.1 PRE-FLIGHT OPERATIONS

1. Position the MAIA multispectral camera on the gimbal of the aircraft, keeping the optics pointing towards the ground. The preferential orientation of the camera is illustrated in Figure 2.
2. Connect the power cable of the camera and the other connectors, such as the GPS, the trigger, and the radio controller decoder.
3. Turn on the MAIA multispectral camera by pressing the power button. Wait while the LEDs flash for 15 seconds to 20 seconds. The camera is ready when the power LED is on and not flashing.
4. Access the MAIA multispectral camera through Wifi (make sure the Wifi channel is activated) or LAN for the control of the exposure parameters, the available memory, and the correct operation of the GPS, if it is connected.
5. Visualise the status of the main parameters and the live images of one sensor at a time, on a screen connected to the Video output port.
6. If necessary, clear out the memory of the camera.
7. Disconnect from the MAIA multispectral camera and switch off the Wifi channel (if enabled).
8. Press the acquisition button, and the MAIA multispectral camera will start to the exposures and save the images to the internal memory.
9. Carry out the required flight.

6.2 FLIGHT OPERATIONS

1. During the flight, the MAIA multispectral camera acquires images until the memory is full, or until it is explicitly commanded to stop the acquisition via the radio controller.
2. Use the radio controller to change some of the functions of the MAIA multispectral camera during the flight (see §3.4 'Remote control from a radio controller').

6.3 POST-FLIGHT OPERATIONS

1. Stop the acquisition by pressing the Acq button;
2. Check the data of the acquired images via LAN or Wifi (the channel has to be re-activated);
3. Download the acquired data and clear the memory, in case the available space is not enough to carry out further acquisitions. It is recommended to transfer the data to a PC after each acquisition flight. It is suggested to use the Ethernet port to download the data.

6.4 NEW ACQUISITION

For a further acquisition flight, follow the instruction from the section above of 'Pre-flight operations':

- from point 6, if it is not necessary to change the parameters of the MAIA multispectral camera;
- from point 4, it is necessary to change the parameters of the MAIA multispectral camera.

7 DOWNLOAD OF THE IMAGES

The images are saved to the internal memory of the camera, which has a capacity of 210GB (net usable space). Each image is 22MB as RAW12 or RAW10 files, and 12MB as RAW8 files. For every cycle of acquisition, and if the setting is activated, a GPS log is embedded in the image file, which contains the GPS informations for each of the images acquired. The activation of this setting has to be through the Web interface. (*Interfaces -> GPS log*).

After a connection with the camera has been set up (see §3.3.1, 3.3.2, 3.3.3), the MAIA multispectral camera is managed as a network HD, and so it is accessible through the IP address of the camera. It is advisable to download the data using a cable connection, which is faster compared to the WiFi connection.

7.1 DOWNLOAD DATA FROM A LINUX PLATFORM

From the file manager, go to the address `smb://192.168.11.151` and insert the access details for the Web interface (*operator; operatorpsw*). Once access is established, it is possible to manage the files as if they were on an external HD.

7.2 DOWNLOAD DATA FROM A WINDOWS PLATFORM

From the file manager, go to the address `\\192.168.11.151` and insert the access details of the camera for the Web interface (*operator; operatorpsw*). Once access is established, it is possible to manage the files as if they were on an external HD.

7.3 NOTES

In the procedures described, the LAN default address of the camera is used. Consequently, this should be modified if some changes to the settings have been introduced or if the camera is operated via Wifi (address 192.168.111.1).

From the file manager, it is possible to delete data that is saved to the camera. ATTENTION: This operation is not reversible! It is suggested memory is cleaned before a new cycle of acquisition, to avoid reaching the memory capacity during a flight.

8 IMAGE-PROCESSING SOFTWARE

This section describes the use of the image-processing software supplied with the MAIA multispectral camera. It is professional software for geometric correction, and coregistration and radiometric correction of the multispectral images in the RAW format obtained by the MAIA multispectral camera, with a tool for the creation of indices (e.g., NDVI) and the generation of false-colour images. The software automatically recognizes if images are from MAIA WV-2 or MAIA SN-2 sensor and, automatically, adopts the correct parameters for the different filters

Windows users: you must have installed the 64-bit version (8.1+) of the JVM, downloadable from the Sun website (<http://www.oracle.com/technetwork/java/javase/downloads/jre8-downloads-2133155.html>)
- the software can be run from: MAIA.bat (only old version)

LINUX users: is necessary to doing some preparations:

- the hugin-tools package must be installed on your system (sudo apt install hugin-tools)
- is always required 64-bit JVM (1.8+) for Linux, always be downloaded from the Sun website
- the software can be run from: MAIA.sh or from command line with: `java -Xmx4G -jar <file-name.jar >`

8.1 STARTING PANEL

After the launch of the software, and once the accompanying activation code has been inserted (only for the first access), the screenview of the starting panel will appear (Fig. 10) with the buttons that provide access to four main functions:

- Create M-Layer TIFF: To correct and coregister the RAW images and to create the exportable dataset of multi-TIFF images (see section 7.2);
- Create View: To create false-colour images from the multi-TIFF (see section 7.3);
- Create Index Image: To create index images from the multi-TIFF image (see section 7.4);
- Preview: to visualise the channels of multi-TIFF as a preview (see section 7.5).

IMPORTANT: Each time you enter a numeric parameter manually, you must confirm with the ENTER key



Figure 21. Starting panel of the image processing software.

8.2 CREATE M-LAYER TIFF MENU

By clicking on 'Create M-Layer TIFF', it is possible to access the menu captured in Figure 11, where the use of correction processes selectable by the User makes it possible to create exportable datasets of multi-TIFF images.

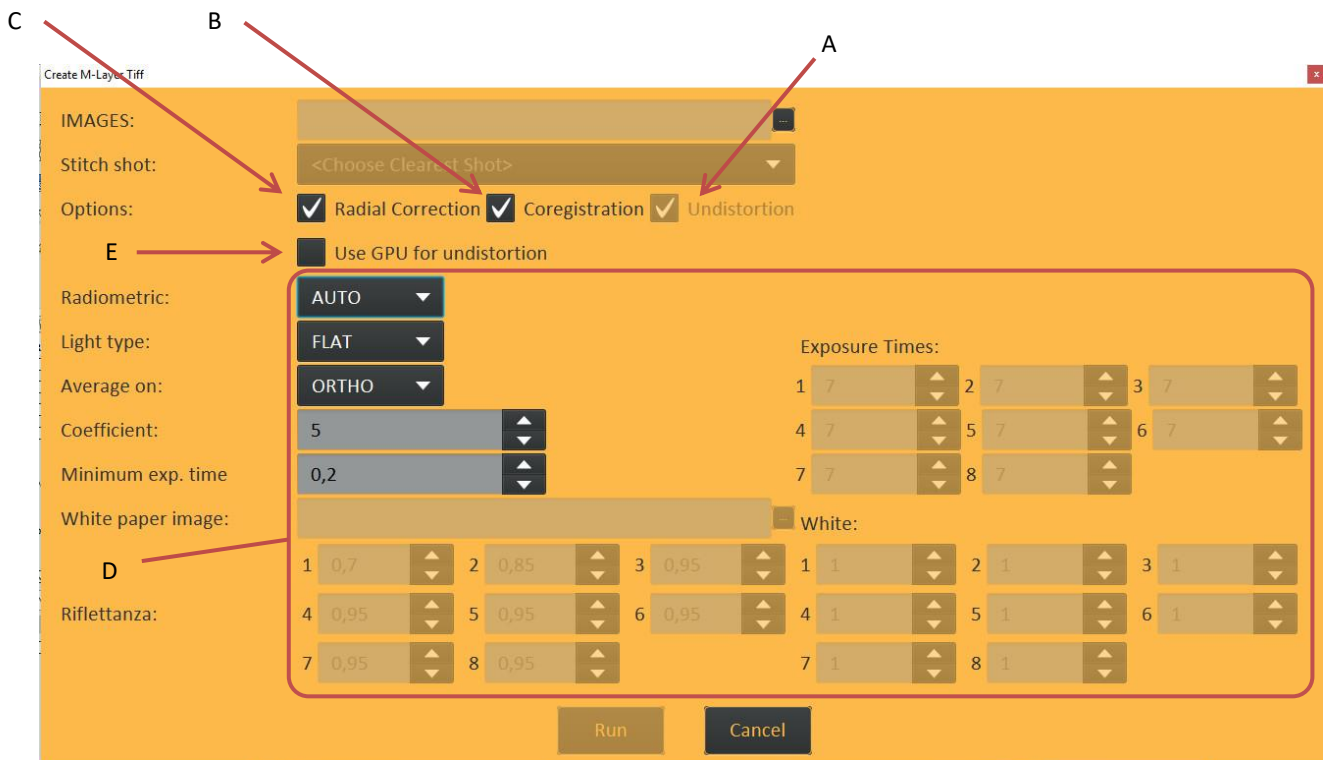


Figure 22. The 'Create M-Layer TIFF' menu.

The correction processes are:

- A. Geometric correction and generation of 'undistorted' images through the calibration parameters that are included with each sensor (enabled as a tick; otherwise disabled).
- B. Coregistration (or *Stitching*) based on a reference image for image stitching of each band, with pixel-by-pixel convergence (enabled as a tick; otherwise disabled).
- C. Radial radiometric correction: This is active as a tick, and it corrects the border effects of the image (usually darker pixels) that can arise due to lens curvature.
- D. Radiometric correction: This is based on the following selectable options in the field 'Radiometric':
 1. WHITE Based on the reference white (or any colour) target, where it is possible to have the values of the specific reflectance for each band;
 2. MANUAL Based on the reference white (or any colour) target where it is possible to have the values of the specific reflectance for each band, when this was not correctly framed in the centre of the reference image;
 3. SENSOR Based on the incident light sensor (when present);
 4. AUTO The relative automatic procedure.
 5. NONE No radiometric correction will be conducted.

The radiometric correction options are described in detail in the following sections. With the tick on Radiometric correction, only the GPU will be used to compute the geometric correction and for the generation of 'undistorted' images.

The MAIA multispectral camera was designed to give to the User the freedom to select every possible combination of correction procedure (see **Table 23**), even if not all of the combinations generate significant data. For example, creating indices from just one radiometric correction without any geometric correction or any coregistration with pixel-by-pixel convergence will produce false data.

Option	Undistorted (Geometric correction)	Coregistration (Stitching pixel-by-pixel)	Radiometric correction	Radial radiometric correction	Generated folder name	Reference image folder	Indices validity	Utility'
1	✗ NO	✗ NO	✗ NO	✗ NO	--	✗ NO	✗ NO	Extraction of raw multi-layer images from RAW images
2	✓ YES	✗ NO	✗ NO	✓ YES	GEOM+RADIAL	✗ NO	✗ NO	Photogrammetric processing for single bands with undistorted images, and possibility to apply customised models of radiometric correction
3	✓ YES	✓ YES	✗ NO	✓ YES	GEOM+STITCH+RADIAL	✓ YES	✗ NO	Radiometric correction with other software and photogrammetric processing with coregistered and undistorted multi-layer images
4	✗ NO	✗ NO	✓ YES	✓ YES	RADIO+RADIAL	✗ NO	✗ NO	Radiometric correction for each band. Possibility to use geometric calibration parameters of the optics (i requested) in other software.
5	✓ YES	✗ NO	✓ YES	✓ YES	GEOM+RADIO+RADIAL	✗ NO	✗ NO	Photogrammetric and radiometric processing for each band, with undistorted images
6	✓ YES	✓ YES	✓ YES	✓ YES	GEOM+STITCH+RADIO+RADIAL	✓ YES	✓ YES	Creation of models, orthophotos and indices.
7					..._CROPPED			Creation of cropped images. Is added the suffix "_cropped" after the name of source folder.

Table 23. The available combinations of the processing parameters.

8.2.1 RADIOMETRIC CORRECTION THROUGH REFLECTANCE TARGET

The workflow of the radiometric correction through reflectance target is shown in Figure 12.



Figure 23. Options and workflow for radiometric correction through the reflectance target.

1. From the 'Radiometric' menu, select the 'WHITE' option.
2. Select the RAW reference image of the white target (or any other colour) in the 'White paper image' field.
3. Change the default reflectance coefficients (if known), which are editable after the choice 'WHITE', with those reported in the target calibration certificate. If these are not known, and if there is no spectrometer to determine them, keep the default values using a white target.
4. Pressing 'RUN' will launch the process. Within the folder that contains the dataset of RAW images, the software will generate a folder named 'geom+stitch+radio+radial' (the name of the generated folder is based on the enabled corrections; see Table 23) with the corrected multi-TIFF images inside. Furthermore, it will generate a second folder named 'stitch' (if coregistration is enabled; see Table 23) that contains the parameters and the reference image related to the stitching with pixel-by-pixel convergence.

8.2.2 RADIOMETRIC CORRECTION THROUGH REFLECTANCE TARGET WHEN NOT CORRECTLY FRAMED

The workflow to apply the radiometric correction through the reflectance target when this is not correctly framed in the centre of the image with a coverage area of 300×200 pixel, is shown below.

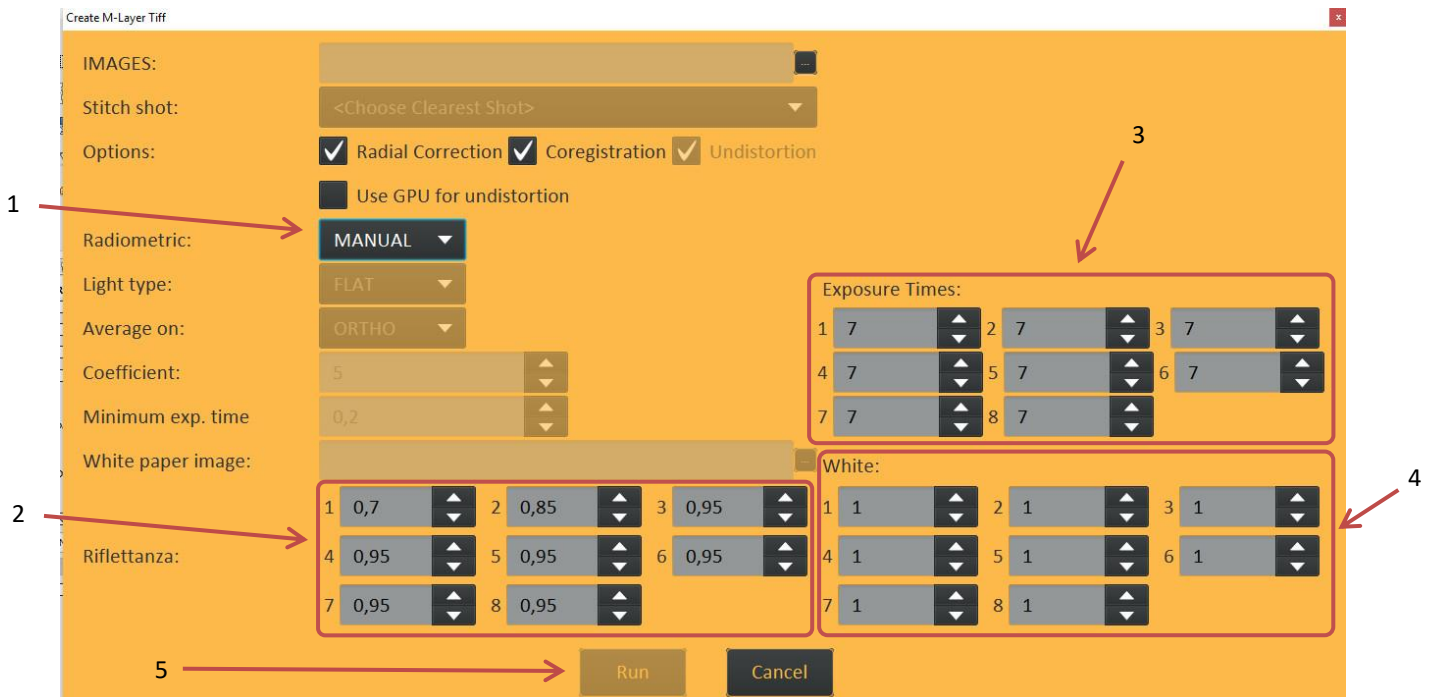


Figure 12a. Options and workflow for radiometric correction with reflectance target when not correctly framed.

1. From the 'Radiometric' menu, select the 'MANUAL' option.
2. Change the default reflectance coefficients (if known), which are editable after the 'MANUAL' option is chosen. Use the ones reported in the target calibration certificate. If these are not known, and if there is no spectrometer to determine them, keep the default values using a white target.
3. Insert the exposure values used for each band of the image that contains the target. These values are on the top right of the visualised RAW image in the function 'Preview' (see section 7.5) or you can export in text file (see section 7.7 section); scroll through all of the bands using the arrows that are situated above the image.
4. For each band, insert a coefficient calculated in this way:
 - Average DN/ 256 for 8-bit images;
 - Average DN/ 1024 for 10-bit images;
 - Average DN/ 4096 for 12-bit images.
5. The average DN is the average value of the digital number measured for all of the pixels that are contained in the reference target. This measure has to be processed for each band of the image where the target is not correctly framed. To carry out this measure, it is necessary to extract the multi-layer TIFF of the image where the target is framed, and then to save it and manage it in some image-processing software (e.g., Photoshop, GIMP). At this point, with the appropriate tools of these software, it is necessary to evaluate the average DN of all of those pixels that are contained in the (not correctly) framed target. This needs to be done for each of the nine bands.
6. Start the compute processing of the image correction for all of the images with the button 'RUN'. The process is applied to all of the RAW images that are contained in the selected folder in the 'IMAGES' slot.

8.2.3 RELATIVE AUTOMATIC RADIOMETRIC CORRECTION

To apply the relative automatic radiometric correction, it is assumed that the acquisition was carried out without references and in a relatively short time, during which the source of light is considered to have been relatively constant.

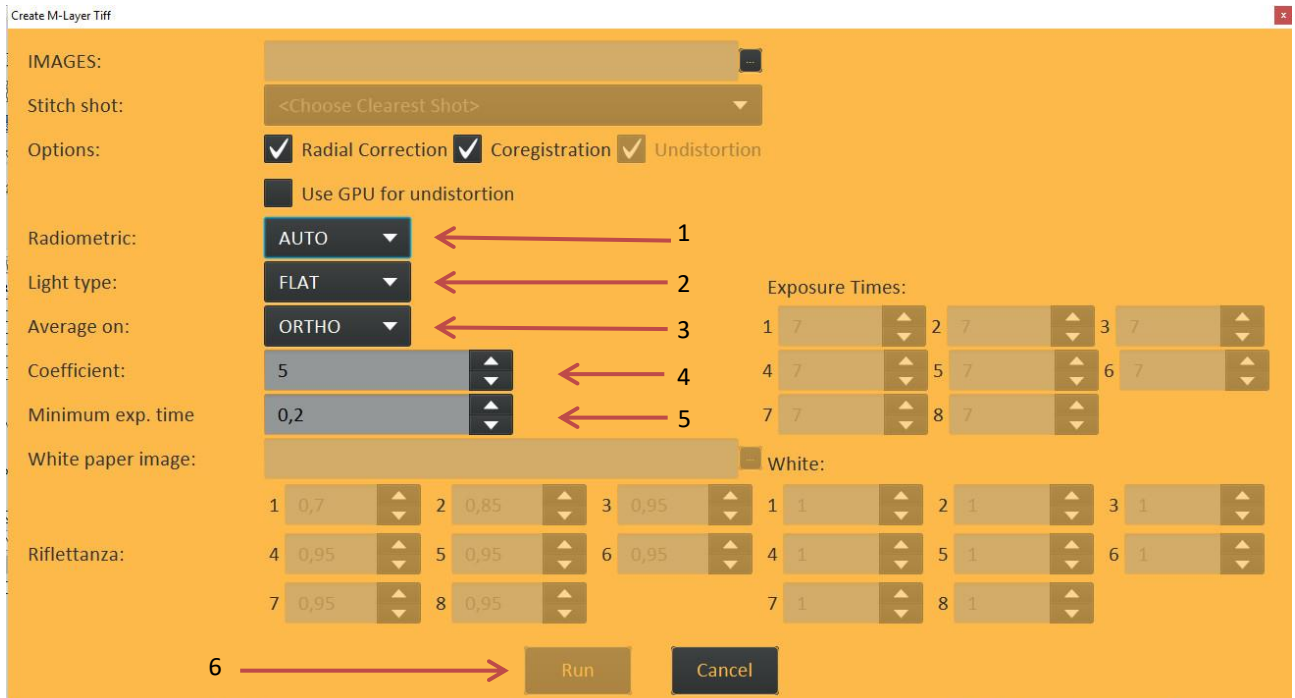


Figure 24. Options and workflow for the radiometric correction with automatic processing.

1. In the 'Radiometric' menu, select the 'AUTO' option.
2. Select 'Light type' as 'FLAT' or 'SUN', depending on the type of light at the moment of acquisition (FLAT, in the presence of white diffuse light or in a laboratory with a flat spectrum source of light; SUN, for sunny days).
3. Select the 'Average on' as 'ORTHO' or 'SINGLE', depending on the type of use of the processed images (ORTHO, the images will be used all together in photogrammetric processing; SINGLE, each single multispectral image will be used for single evaluations).
4. In 'Coefficient', select the multiplicative constant coefficient to apply to the DN of each pixel. This multiplicative parameter is chosen depending on the typology of the object and the coefficient used to generate the automatic exposure. A good compromise for this parameter is the result of the following division: $1 / \text{exposure coefficient}$.

For example:

$$\begin{aligned} \text{coeff_exp} &= 0.2 \\ \text{parameter} &= (1 / 0.2) = 5. \end{aligned}$$

To make the choice of the correct multiplicative coefficient, and to avoid saturation or loss of dynamics in the DN of the images, it is suggested that before launching the radiometric correction, some sample acquisitions can be analysed for the bands that have more reflectance (i.e., less exposure time) for the object to be evaluated.

Example A

Object to evaluate: Corn field

Distribution of the object in the frame: >50%

Band that has most reflectance: B7 (750-820 nm)

Automatic exposure coefficient: 0.2 -> this means that, e.g., for 8-bit images, for each of the nine bands, the sensor shutter remains open as long as the average DN of pixels is $(255 \times 0.2) = 51$.

In the analysis the the DN of the pixels of corn before the correction (**Figure 25**), their value is 60/70, considering that: before the radiometric correction, the noise value of black is subtracted (about 8% for 8-bit images, so $[255 \times 0.08] = 20$); and before the multiplicative parameter, the average DN of the corn object is $60-20 / 70-20 = 40/50$, which is a value that can be multiplied by 5 ($1 / 0.2 = 5$) without risk of saturation (200/250 of 255 maximum for 8-bit images). See the result of the radiometric correction with the multiplicative parameter defined below ([5]; **Figure 25**).

The evaluations for the choice of parameter have to be conducted for the band with the lowest exposure time for the object considered (i.e., more reflectance), because it will be the one that will have the normalisation parameter in the correction closest to 1 (as a result of the quantum efficiency of the sensor, transmittance of the filters, band width, exposure time).

Example B

Object to evaluate: Rice field

Distribution of the object in the frame: <15%

Band that has most reflectance: B7 (750-820 nm)

Automatic exposure coefficient: 0.2

Analysis of the DN of the pixels of the rice before the correction (**Figure 25**) shows that their value is 85/125, considering that: before the radiometric correction, the noise value of black is subtracted (about 8% for 8-bit images, so $[255 \times 0.08] = 20$); and before the multiplicative parameter, the average DN of the rice object is $65/105$, which in order not to saturate the image, allows a maximum multiplicative constant of 2.5 (**Figure 25**).

Taking the vegetation, e.g., as reference, where the bands with more reflectance are those of the infrared (in particular, bands B7, B8), the evaluation for the multiplicative parameter depends on the percentage of vegetational coverage.

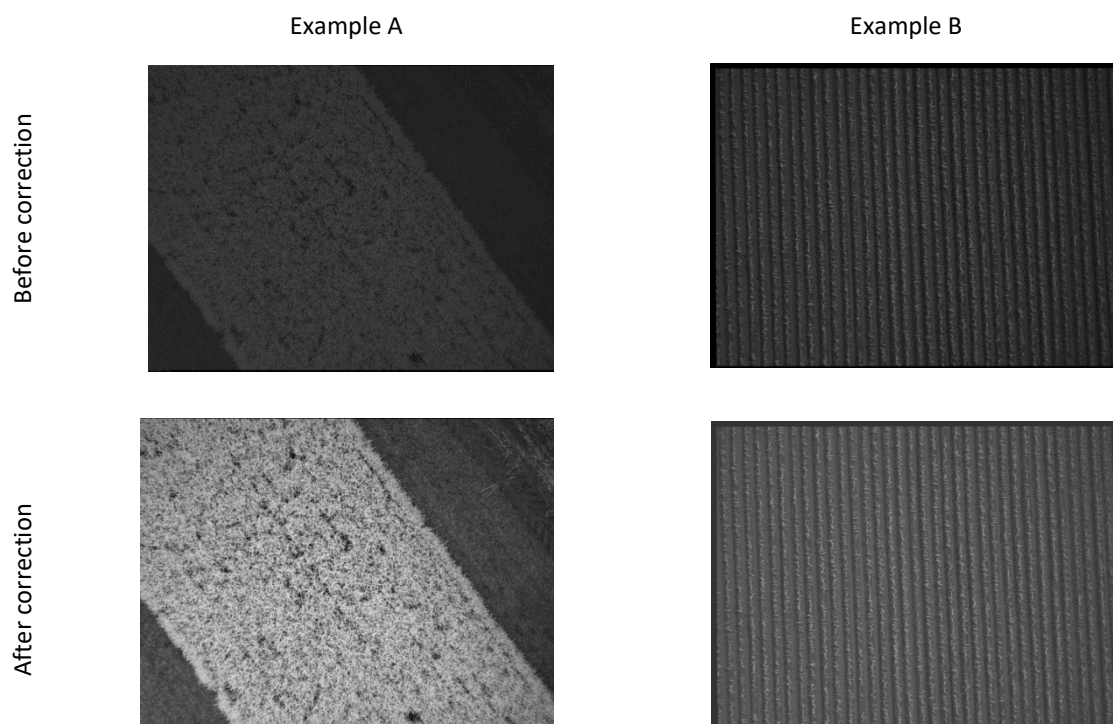


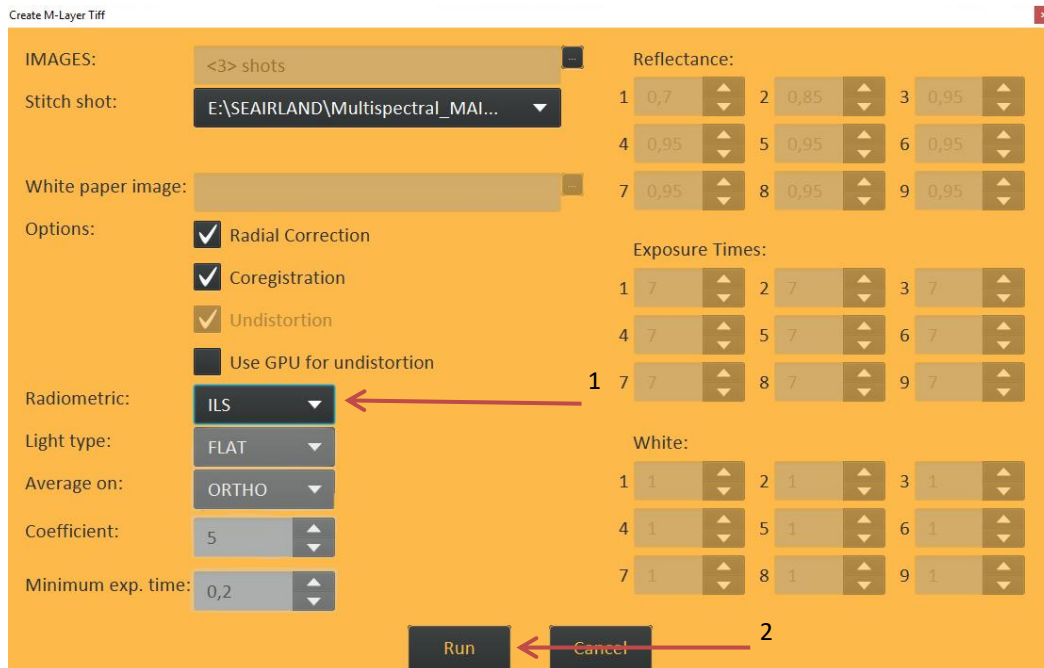
Figure 25. Examples of images with and without radiometric correction (see text).

- In 'Minimum exp. Time', select the minimum exposure time that the acquisition must have for the radiometric correction processing. This is a useful parameter for discarding those acquisitions that might disrupt the dynamics of the remaining dataset, such as those that contain areas with large (in proportion to the image)

- light and bright objects, or parts of the sky due to rapid movements of the aircraft. This would lead the normalization processes to define division values that are too high. The result is that the acquisitions to be discarded will be pushed to saturation, while maintaining the dynamics in the acquisitions that are the object of evaluation in the survey. To estimate the parameter to be inserted here, there is the need to examine some 'previews' of the objects in the nadiral frames at the right operative altitude, and to read off the relative exposure times for each of the bands (e.g., see Figure 19, central panel beside photo name/ sensor: 'Exp = ...' or section 7.7): select the minimum and use this as the parameter.
6. Start the computation processing for the correction of all of the images with the 'RUN' button. The process will be applied to all of the RAW images that are contained in the selected folder in the 'IMAGES' slot.

8.2.4 RADIOMETRIC CORRECTION USING ILS – IRRADIANCE LIGHT SENSOR

To apply the radiometric correction using ILS sensor, it is assumed that the acquisition was carried with ILS sensor, and that the .log file has been downloaded from the MAIA camera along with the .raw images and that it is inside the same folder of the images themselves.



1. In the 'Radiometric' menu, select the 'ILS' option.
2. Start the computation processing for the correction of all of the images with the 'RUN' button. The process will be applied to all of the RAW images that are contained in the selected folder in the 'IMAGES' slot.

8.2.5 EXAMPLE OF CREATION OF MULTI-LAYER TIFF

Figure 26 shows an example of the result of computation of the index NDVI on a real image, using all of the correction combinations in **Table 23**. This shows that the one solution that has no errors is that which uses all of the corrections (i.e., geometric, coregistration, radiometric, radial radiometric; Fig. 15, image 6).

8.2.6 TIPS FOR CORRECT DATA PROCESSING

- Select the datasets and discard the non-significant acquisitions (e.g., take-off and landing images, border zone images).
- For automatic relative radiometric correction, it is suggested to limit the datasets in terms of time, to avoid large differences in the intensity of the light source.
- When using a calibration target, conduct the calibration before every flight to which the relative datasets refer. Note that for the acquisition of the reference target, it is necessary that this is uniformly lit by the light source, without any shadows generated by the operator, by the lifter, or by any other external object. Each sensor needs to have the central part of the frame covered by the target (the processing software computes the average of the values within the central rectangle of 300×200 pixels, respecting a sensor size of 1280×960 pixels).
- For correct pixel-by-pixel convergence and coregistration between the bands, the dataset has to be selected depending on the altitude, which means that if the survey is conducted at different altitudes, maybe due to problems related to the morphology of terrain or other acquisition factors, it is suggested that it is divided into areas that have more or less similar altitudes (e.g., a difference in 15%-20% is not significant). This expedient is because every transformation is valid if the scale of the image remains constant. It is possible to compute a transformation for each image, but the processing time would be intolerable.

(825) RGB image



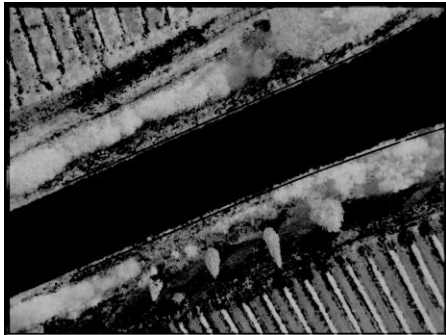
(2) GEOM + RADIAL correction

⊗ Index value not correct



(3) GEOM + STITCH + RADIAL correction

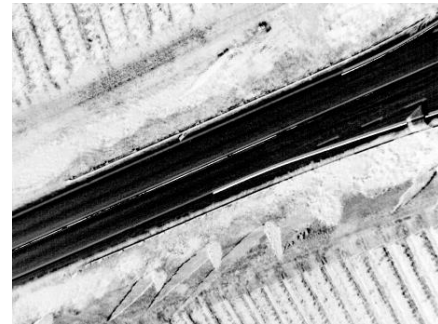
⊗ Index value not correct



(4) RADIO + RADIAL correction

⊗ Overlay band not correct.

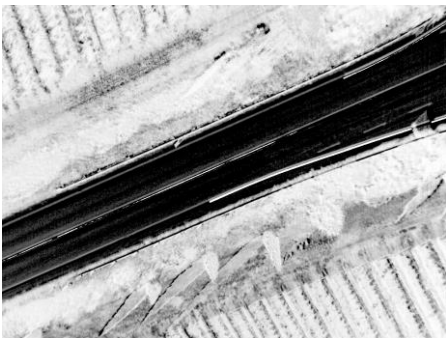
⊗ Generation of lines and shadows that do not exist.



(5) GEOM + RADIO +RADIAL correction

⊗ Overlay band not correct.

⊗ Generation of lines and shadows that do not exist.



(6) GEOM + STITCH + RADIO + RADIAL correction

😊 Indices are geometrically and radiometrically correct.



Figure 26. Examples of the results of multi-layer TIFF creation (see text).

8.3 CREATE VIEW MENU

This menu uses the multi-TIFF images (see section 7.2) to generate false-colour images, multi-channel images with a specific selectable number of bands, and single images in greyscale with a choice of bands.

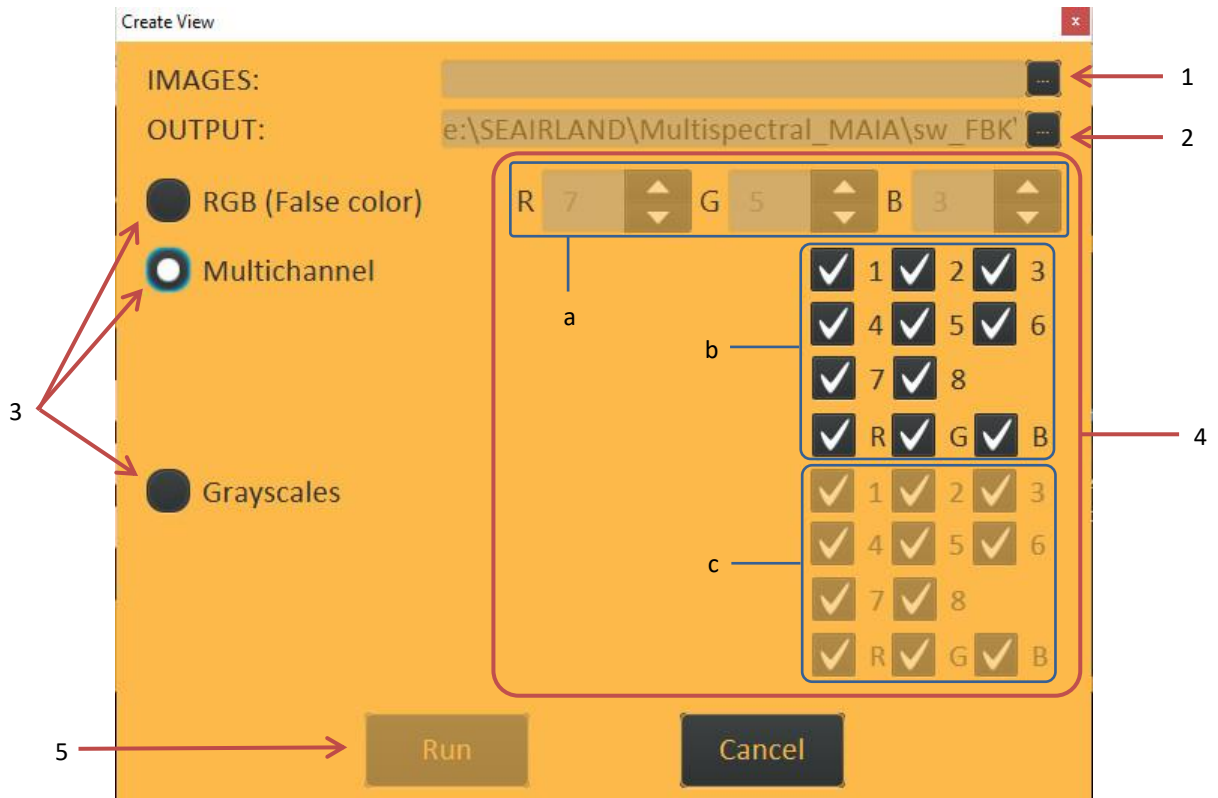


Figure 27. 'Create View' menu.

The workflow for the generation of an image is as follows:

- 1) In 'IMAGES', select the path of the folder that contains the multi-TIFF images.
- 2) In 'OUTPUT', select the path of the folder to store the RGB or greyscale images generated.
- 3) Select between 'RGB (False Color)' or 'Multichannel' or 'Grayscales', by clicking on the relative button.
- 4) Select the specific bands to generate the false-colour image or multichannel or greyscales, as defined in **Table 24**.
- 5) Launch the process by clicking on the 'RUN' button.

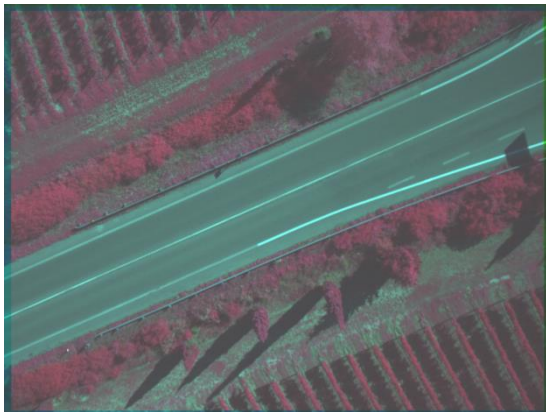
A)

Number	Band (nm)	Colour
1	395-450	Violet
2	455-520	Blue
3	525-575	Green
4	580-625	Orange
5	630-690	Red
6	705-745	Dark red (<i>Red-Edge</i>)
7	750-820	NIR 1
8	825-950	NIR 2
9 – R	RGB sensor	Red
10 – G	RGB sensor	Green
11 – B	RGB sensor	Blue

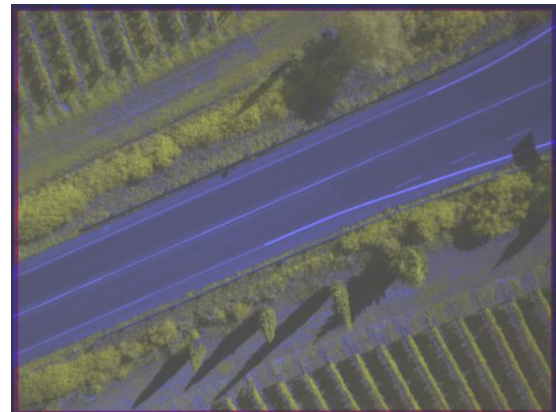
B)

Number	Band (nm)	Colour
1	433-453	Violet
2	457.5-522.5	Blue
3	542.5-577.5	Green
4	650-680	Red
5	697.5-712.5	Red Edge 1
6	732.5-747.5	Red Edge 2
7	773-793	NIR 1
8	784.5-899.5	NIR 2
9	855-875	NIR 3

Table 24. Indices and their relative bands for creation of the images. A) for MAIA WV-2 and B) for MAIA SN-2



R=7, G=5, B=3



R=8, G=7, B=5

Figure 28. Examples of false-colour images.

8.4 CREATE INDEX IMAGE MENU

Starting from multi-TIFF images, this menu provides the generation of both 8-bit and 32-bit content images for each pixel for the corresponding value of the index required (with operations applied through a raster calculator).

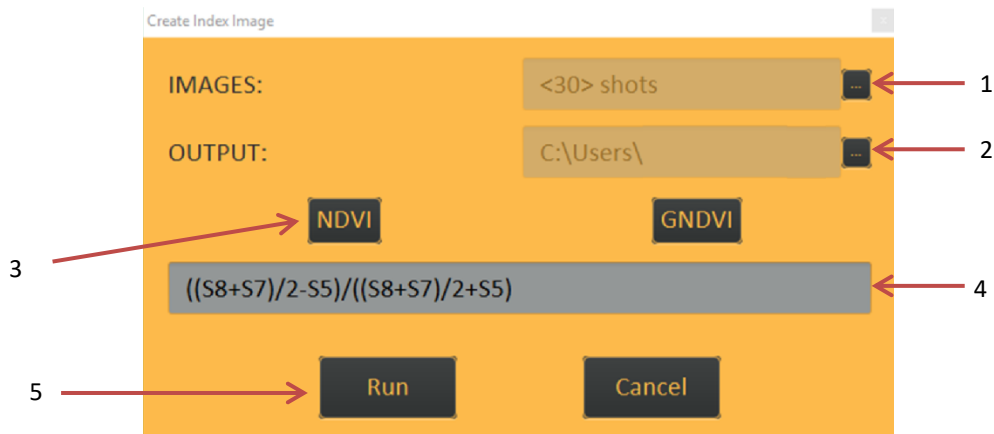


Figure 29. Creation of the index through a raster calculator.

The flow for the creation of the image for the index through a raster calculator is as follows:

- 1) In 'IMAGES', select the path for the folder containing the multi-TIFF images.
- 2) In 'OUTPUT', select the path for the folder to store the 8-bit or 32-bit images generated.
- 3) Click on 'NDVI' or 'GNDVI' to reveal the corresponding editable equation in the window (by default, the NDVI equation appears).
- 4) Modify the equation in the window if needed, to provide the required index if it is different from the default equation, with reference to **Table 25**.
- 5) Start the process by clicking on 'RUN'.

Variable	Band (nm)	Colour
S1	395-450	Purple
S2	455-520	Blue
S3	525-575	Green
S4	580-625	Yellow / Orange
S5	630-690	Red
S6	705-745	Dark red (<i>Red-Edge</i>)
S7	750-820	NIR 1
S8	825-950	NIR 2

Table 25. Variables to use in the formulae (see text).

8.5 MENU PREVIEW

This menu allows real-time direct viewing of the RAW images, and then the screen qualitative analysis of the acquisitions made for the various bands, without the need for further processing. This menu is particularly useful for the initial examination of the acquired dataset and for the correct dimensioning of the minimum exposure time parameter to be used in the related automatic radiometric processing.

- 1) From the main panel shown in **Figure 21**, click on 'Preview'.
- 2) Indicate the folder that contains the acquired RAW dataset.
- 3) The image for the first RAW acquisition of the RGB (S9) band will appear on the screen.
- 4) Navigate through bands S1-S9 (**Table 26**) by clicking the arrows on the screen.
- 5) Navigate through the RAW acquisition using the left/ right arrows of the keyboard.

Sensore	Banda (nm)	Colour
S1	395-450	Purple
S2	455-520	Blue
S3	525-575	Green
S4	580-625	Yellow / Orange
S5	630-690	Red
S6	705-745	Dark red (<i>Red-Edge</i>)
S7	750-820	NIR 1
S8	825-950	NIR 2

Table 26. Correspondence between the indices and the sensor bands.

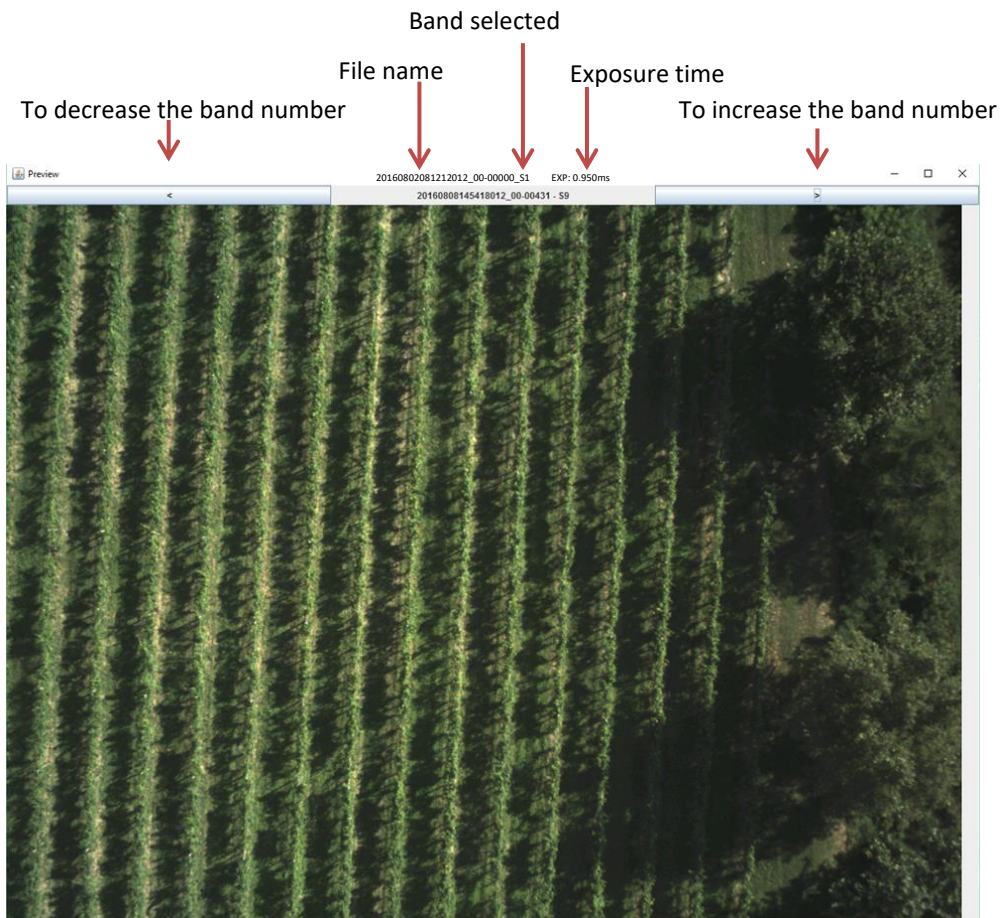


Figure 30. Preview image with the navigation buttons.

8.6 MENU CROP

This menu allows to crop all Multi-tiff images created with the aim to eliminate the “NO DATA” border that is created after the stitching process.

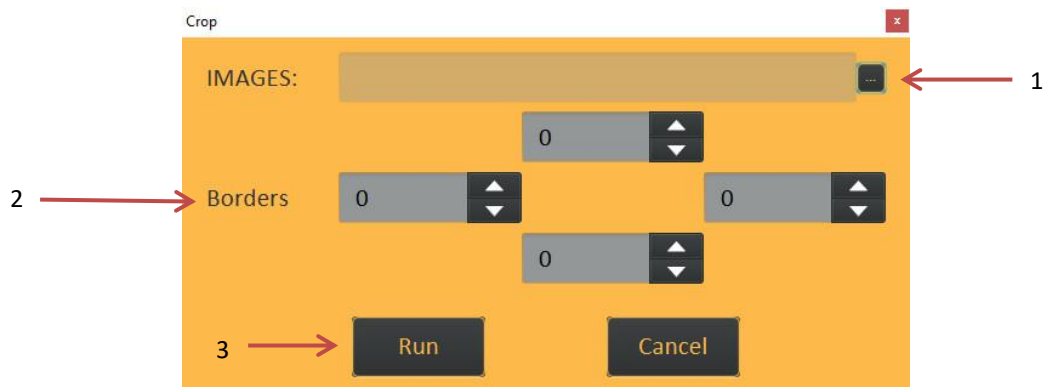


Figure 31. Menu CROP

The flow for the creation cropped images is as follows:

- 1) In 'IMAGES', select the path for the folder containing the Multi-TIFF images.
- 2) In 'Borders', the default values appear in pixel coordinates where the crop (considering the integer more conservative) will be executed in all selected images. These values take into account of all "NO DATA" edges analyzed by the software and are proposed ones that allow you to get all the cropped images in equal measure. The default values are derived from the crop files "border.txt" generated at the time of stitching and located in the same folder of Multi.tiff images. In case you need process different group images located in different folders (eg for reasons of very different flight altitudes), evaluating all the values of pixel coordinates taken from all "border.txt" files, you can manually input the 4 custom values of crop. This in order to have all images with the same pixels size.
- 3) Launch the process by clicking on the 'RUN' button.

8.7 MENU EXPORT

This menu allows to EXPORT all **Exposure Time** values for each band, for each captured .raw image. A text file will be created that, if saved with the .csv extension, allows you to directly open the file in Excel software.

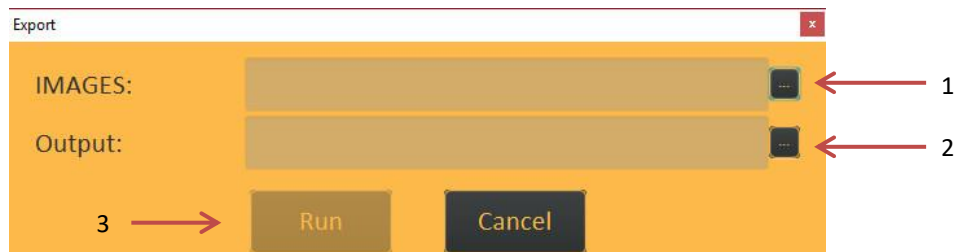


Figure 32. Menu EXPORT

- 1) In 'IMAGES', select the path for the folder containing the RAW images.
- 2) In 'OUTPUT', select the path for the folder to store and insert the name of .csv file
- 3) Launch the process by clicking on the 'RUN' button.

9 TECHNICAL SPECIFICATIONS

9.1 SPECIFICATIONS OF THE MAIA CAMERA

Field	Value			
Optics	Sensitivity interval	VIS-NIR: 390 nm to 950 nm		
		Sensor	Bands for WV-2 set start - stop λ (nm)	Bands for SN-2 set start - stop λ (nm)
		S1	395 - 450	433 - 453
		S2	455 - 520	457.5 - 522.5
		S3	525 - 575	542.5 - 577.5
		S4	580 - 625	650 - 680
		S5	630 - 390	697.5 - 712.5
		S6	705 - 745	732.5 - 747.5
		S7	750 - 820	773 - 793
		S8	825 - 950	784.5 - 899.5
		S9	RGB	855 - 875
	Lens	Fixed focus		
	Focal length	7.5 mm (nominal)		
	Open	f/#2.8		
	FOV	35° HFOV; 26° VFOV; 43° DFOV		
Exposure	Type	Manual Automatic Automatic with maximum exposure time limit		
	Start	Simultaneous for each sensor		
	Exposure time	0.1 ms to 50 ms		
Acquisition	Type	Single shot Continuous with external trigger Continuous at fixed-time interval		
	Max. frame rate	3 frames/second with 10-bit and 12-bit RAW; 5 frames/second with 8-bit RAW		
File format	File format	8-bit RAW 10-bit RAW 12-bit RAW		
	Memory	Type	Internal SSD	
		Capacity	210 GB (net capacity available for image storage)	
	Image size	Format	WV-2 set	SN-2 set
		8-bit RAW	11.8 MB	10.7 MB
		10-bit RAW	21.2 MB	
		12-bit RAW		
	Image storage capacity	Format	WV-2 set	SN-2 set
		8-bit RAW	~18.000	~20.000
		10-bit RAW	~10.000	
		12-bit RAW		
Embedded data	Exposure time for each sensor			
	Timestamp at the shot time			
	Time, position, speed, GNSS fix			
	... continued...			

Field	Value										
Interfaces	<ul style="list-style-type: none"> - Gigabit Ethernet - WiFi in Hot Spot by DHCP server - Serial for GNSS (3.3V LTTL – 5V tolerant) - Synchro input – Trigger (5V CMOS) - Synchro output – Strobe (5V CMOS) - Composite Video-output (NTSC/PAL) - Two-channel PWM input from radiolink (5V CMOS) - IMU/GYRO connection - Three LEDs for events and status + 1 LED in sync with image exposure - Keyboard with eight function buttons 										
Configuration	Web interface from Ethernet or Wifi Video input with on-screen text + keyboard Radiolink input										
RAW image processing software	Professional software for elaborating multispectral images: <ul style="list-style-type: none"> - TIFF multi-layer extraction - geometrical correction (undistorted) - pixel-by-pixel stitching - radiometric correction (manual, auto, white) - radiometric radial correction - index images creation (NDVI, GNDVI, SAVI,...) - band maths (raster calculator) - false-colour images creation - multichannel images creation - mono-chromatic images creation - preview of raw dataset - crop TIFF multi-layer images - export Exposure Time value 										
Physical characteristics	<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%;">Width</td> <td style="width: 30%;">99 mm</td> </tr> <tr> <td>Height</td> <td>129 mm</td> </tr> <tr> <td>Depth</td> <td>47 mm</td> </tr> <tr> <td>Fixing</td> <td>4 fixing holes M3x0.5-6H</td> </tr> <tr> <td>Weight</td> <td>470 g</td> </tr> </table>	Width	99 mm	Height	129 mm	Depth	47 mm	Fixing	4 fixing holes M3x0.5-6H	Weight	470 g
Width	99 mm										
Height	129 mm										
Depth	47 mm										
Fixing	4 fixing holes M3x0.5-6H										
Weight	470 g										
Power	<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%;">Supply</td> <td style="width: 70%;">From +9 V DC to +26 V DC</td> </tr> <tr> <td>Consumption</td> <td>~7.5W typ. 800 mA at 9 V (2 A peak)</td> </tr> <tr> <td></td> <td>Escluding power consumption of the ILS, when connected</td> </tr> </table>	Supply	From +9 V DC to +26 V DC	Consumption	~7.5W typ. 800 mA at 9 V (2 A peak)		Escluding power consumption of the ILS, when connected				
Supply	From +9 V DC to +26 V DC										
Consumption	~7.5W typ. 800 mA at 9 V (2 A peak)										
	Escluding power consumption of the ILS, when connected										
Environmental conditions	<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%;">Operating</td> <td style="width: 70%;">0 °C to 40 °C; 32 °F to 104 °F</td> </tr> <tr> <td>Storage</td> <td>0 °C to 60 °C; 40 °F to 140 °F</td> </tr> <tr> <td>Humidity</td> <td>20%-80%; non-condensing relative humidity</td> </tr> <tr> <td>Protection class</td> <td>IP50 according to IEC-60529</td> </tr> </table>	Operating	0 °C to 40 °C; 32 °F to 104 °F	Storage	0 °C to 60 °C; 40 °F to 140 °F	Humidity	20%-80%; non-condensing relative humidity	Protection class	IP50 according to IEC-60529		
Operating	0 °C to 40 °C; 32 °F to 104 °F										
Storage	0 °C to 60 °C; 40 °F to 140 °F										
Humidity	20%-80%; non-condensing relative humidity										
Protection class	IP50 according to IEC-60529										

Technical specifications are subject to change without notice.

9.2 SPECIFICATIONS OF THE MAIA ILS SENSOR

Field	Value	
Irradiance sensor	<ul style="list-style-type: none"> - True cosine correction of incident light - Light level measured for each band of the MAIA camera, with matched spectra - Accurate irradiance measurement thanks to patented technology 	
GNSS receiver	<ul style="list-style-type: none"> - Standard precision receiver or high precision RTK - Concurrent reception of up to 2 GNSS (GPS, Galileo) - Navigation sensitivity of -165dBm - Better and faster positioning, supporting all satellite augmentation systems - Integrated passive antenna - SMA connector supporting active or passive external antenna 	
6-axis IMU	Gyroscope	+/- 250 deg/s full-scale-range, 0.1 deg/s resolution
	Accelerometer	+/-4g full-scale-range pitch and roll angles with 0.1° resolution
Environmental sensor	Temperature	0-60°C range, ±1°C accuracy (*)
	Pressure	800-1100mbar range, +/-1mbar accuracy
	Humidity	0-100%RH range, +/-5%RH accuracy
Physical characteristics	Width	70 mm
	Height	70 mm
	Depth	40 mm
	Fixing	4 fixing holes M3x0.5-6H
	Weight	160 g
Power	Supply	From +4.5 V DC to +9 V DC provided by the MAIA camera
	Consumption	~2.5W typ. 450 mA at 5 V (700 mA peak)

(*) the thermometer measures the temperature inside the ILS case, which is, in general, higher than the ambient temperature due to several external factors, including the heating caused by the solar radiation and the dissipation feature of the mounting fixture.

Technical specifications are subject to change without notice.

10 TERMS OF LICENCE

The entire software system, both on-board the system and the image-processing software, is not sold but provided with an end-user licence from Eoptis and SAL Engineering, according to the following conditions:

- It is forbidden to disassemble and decompile the software, to join or combine it with other software, to conduct reverse engineering operations on it, to copy it, to translate it, or to adjust it, and it is forbidden to distribute it in any way.
- The software is given as a user licence on a non-exclusive, non-transferable basis, for a single user, and only for the purpose planned for the product.
- The software is given as-is, and although all effort was made in its creation and despite the care taken in its testing, there is no warranty on its correct operation. Eoptis and SAL Engineering are not to be held accountable to customers or to third parties for any direct or indirect damage or malfunction, or loss of income, revenue, profits, contracts, business opportunities, or other commercial advantages related to the use of the software and the MAIA multispectral camera.

Breach of these requirements cancels the right to use the on-board software and the image-processing software.

10.1 CREDITS



The MAIA image-processing software was designed in collaboration with the 3DOM – 3D Optical Metrology research unit in FBK – Fondazione Bruno Kessler (Trento).

11 REVISION HISTORY

The User is recommended to check if this document applies to its camera, according to the Serial Number.

Version	Date	Valid for SN	Notes
Rev.0.01	08.2016	16xxxxxx	Introductory release
Rev.1.00	09.2016	16xxxxxx	Integration of user guide for the image processing software Upgrade of sections and more detailed description of the characteristics Upgrade of the specifications, and terms of the licence
Rev.1.01	02.2017	16xxxxxx	Upgrade of the specifications and upgrade of the descriptions of the software to V. 1.1.3
Rev.1.02	03.2017	16xxxxxx	Upgrade of the specifications and upgrade of the descriptions of the software to V. 1.1.7
Rev.1.03	04.2017	16xxxxxx	Upgrade of the descriptions of the software to V. 1.1.13 - implementation to the LINUX operating system - implementation CROP tool
Rev.1.04	04.2017	16xxxxxx	Upgrade of the descriptions of the software to V. 1.1.14
Rev.2.00	08.2017	17xxxxxx	Major update to almost all sections for new hardware and software release: - Par.1: figure 1 updated - Par.2: acquisition LED added in figure 2 and table 1 - Par.2.1: change in the connectors' pinout, CVBS output added in table 2, table 3 and figure 3 - Par.2.1.1: detailed electrical specs of the IOs added - Par.2.2: "SN-2" filter set characteristics added - Par.2.3: figure 6 updated with new dimensions - Par.2.4: power dissipation section added - Par.3.3.1: gateway settings on the Ethernet interface better detailed - Par.3.3.2: notes about WiFi connection under Windows OS added - Par.3.4: frequency range of PWM updated - Par.3.5: added Par3.5.1 with description of the Acquisition LED - Par.3.6: description of power-up/down sequence added - Par.4.1: screenshots of the web interface added - Par.8: technical specs upgraded
Rev.2.01	02.2018	17xxxxxx	Par.3.3.3 Recommended connection modes added ILS information added to several sections: - Par.1: figure 1 updated - Par.2: figure 2, table 2 and 3 updated - Par.5: added and par.5-10 shifted to 6-11 - Par.9: technical specs added
Rev.2.02	02.2018	17xxxxxx	Upgrade of the descriptions of the software to V. 1.2.0 - Par.8.2.4: radiometric correction using ILS – Irradiance Light Sensor
Rev.2.03	05.2019	17xxxxxx	Par.5 – Incident Light Sensore Several upgrades of the ILS section with new integrated GNSS antenna design and RTK feature added