MAIA M2

The multispectral camera

Quick User Guide

Rev.1.01 - 07/2019

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1 INTRODUCTION

MAIA M2 is the low-cost modular multispectral camera, which can be expanded by adding other modules, thus creating an extremely compact sensors matrix. A very large set of the main multispectral indices can be obtained using only three modules. MAIA-M2 can also operate autonomously and is the smallest and lightest dual-sensor camera available on the market. It is ideal for use on aerial and terrestrial vehicles (APR, drones, rover), particularly suitable for manufacturers, operators and integrators operating in the field of precision agriculture and environmental monitoring.

MAIA is developed in Italy by Eoptis in collaboration with SAL Engineering and Bruno Kessler Foundation.

Each MAIA M2 camera is equipped with two 1.2Mpix CMOS sensors, with global shutter and high sensitivity, which allow you to acquire stable and sharp images up to 1 shot per second. Each sensor is coupled with a higher quality bandpass filter, which precisely defines the range of wavelengths of light that will be detected. The user can draw on a vast portfolio of filters covering the visible (VIS) and near infrared (NIR) region to generate the known agronomic indices and explore emerging applications. One of the two MAIA-M2 sensors can be in color, thus creating a 4-band camera of minimum size.

MAIA M2 is able to capture images in free-run mode with fixed shutter frequency of 1fps or in external trigger mode, based on an electrical signal. To allow an external unit to know the exact moment of tripping, MAIA M2 generates a strobe synchronism signal that can be used for applications with Post Processed Kinematic (PPK).

The optimal exposure time for each sensor is automatically calculated and the user can select the brightness of the images on three levels, through the camera button.

Acquisition images and parameters are saved on the MicroSD card in lossless RAW format with depths of 8 or 12 bits per pixel. The card is removable, but it is also possible to download the images by leaving it inserted and accessing it through the USB interface.

Two or more MAIA M2 cameras can be connected together to create a sensors matrix, increasing the indices that can be calculated exponentially. A serial interface and trigger / strobe signals allow you to synchronize the cameras through the appropriate controller that can be purchased as an accessory, making them operate as a single entity.

The MAIA M2 camera has dimensions of only 34mm x 49mm x 46mm (including lenses and connectors) and weighs only 59g.

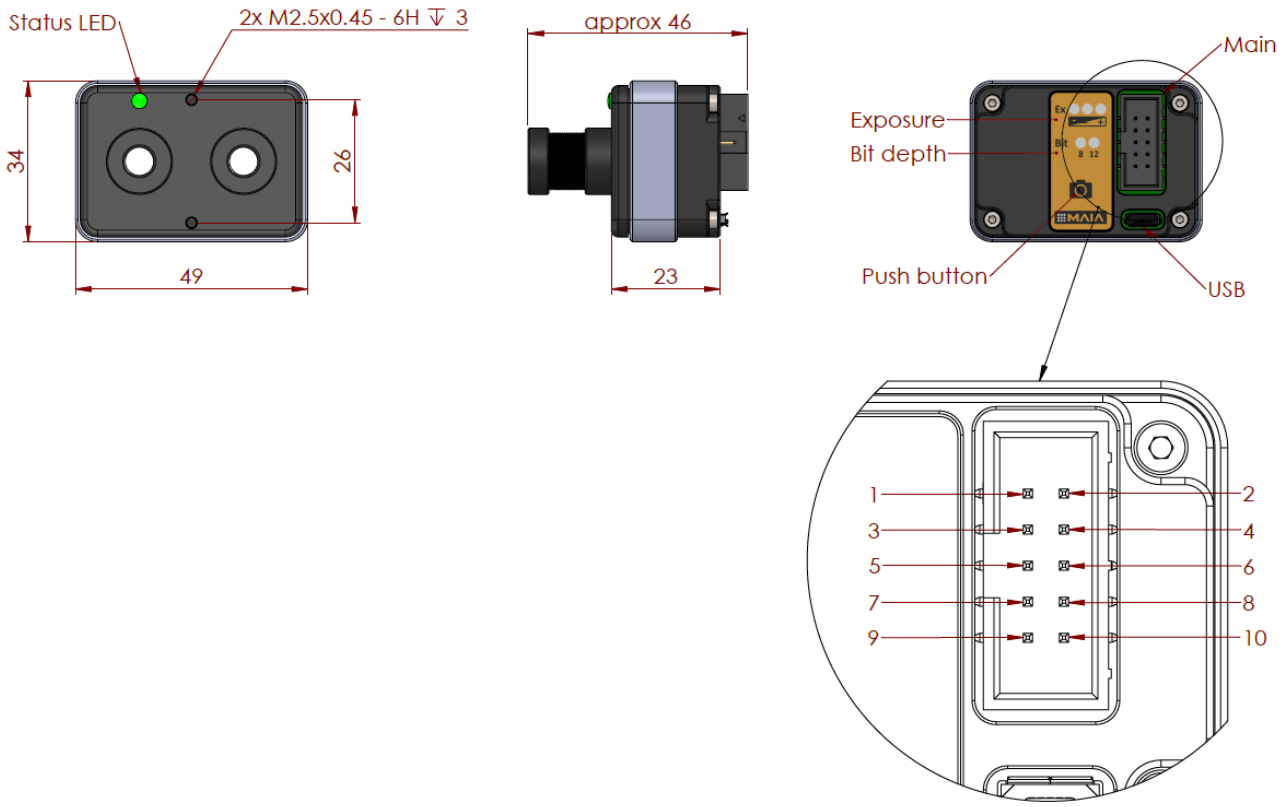


Figure 1: Main elements of the camera with size of mechanics and details of connectors.

2 OPERATION OF THE CAMERA

2.1 OPTICS, SENSORS AND BANDS

The MAIA M2 camera has 2 1280 x 960 (1.2Mpix) sensors with global shutter function. The camera is available with:

- 2 mono sensors, or
- 1 mono sensor + 1 color sensor

The monochromatic sensors are coupled to a band-pass filter that precisely defines the range of wavelengths detected by the sensor (band).

A sensor with 8mm focal length, f / # 2.0, field of view ~ 36º Horizontal, ~ 27º Vertical (full angle) is mounted on each sensor. Depending on availability during production, various types of lenses can be mounted, with similar optical performance but different dimensions. Figure 1 shows a type of lens as an example.

The available bands are listed in Table 1 and shown in Figure 2.

Band		*Start WL (nm)*	*Stop WL (nm)*	*Center WL (nm)*	*Bandwidth (nm)*	*Colour*
	B1	395	450	423	55	Violet
	B2	433	453	443	20	NViolet
	B3	455	520	488	65	Blue
	B4	458	523	490	65	SBlue
	B5	525	575	550	50	Green
	B6	543	578	560	35	NGreen
	B7	580	625	603	45	Yellow
	B8	630	690	660	60	Red
	B9	650	680	665	30	NRed
	B10	698	713	705	15	H RedEdge
	B11	705	745	725	40	RedEdge
	B12	733	748	740	15	L RedEdge
	B13	773	793	783	20	H NNIR
	B14	750	820	785	70	H NIR
	B15	785	900	842	115	W NIR
	B16	855	875	865	20	L NNIR
	B17	825	950	888	125	L NIR
	RGB	-	-	-	-	RBG

Tabella 1. Bands available for MAIA M2.

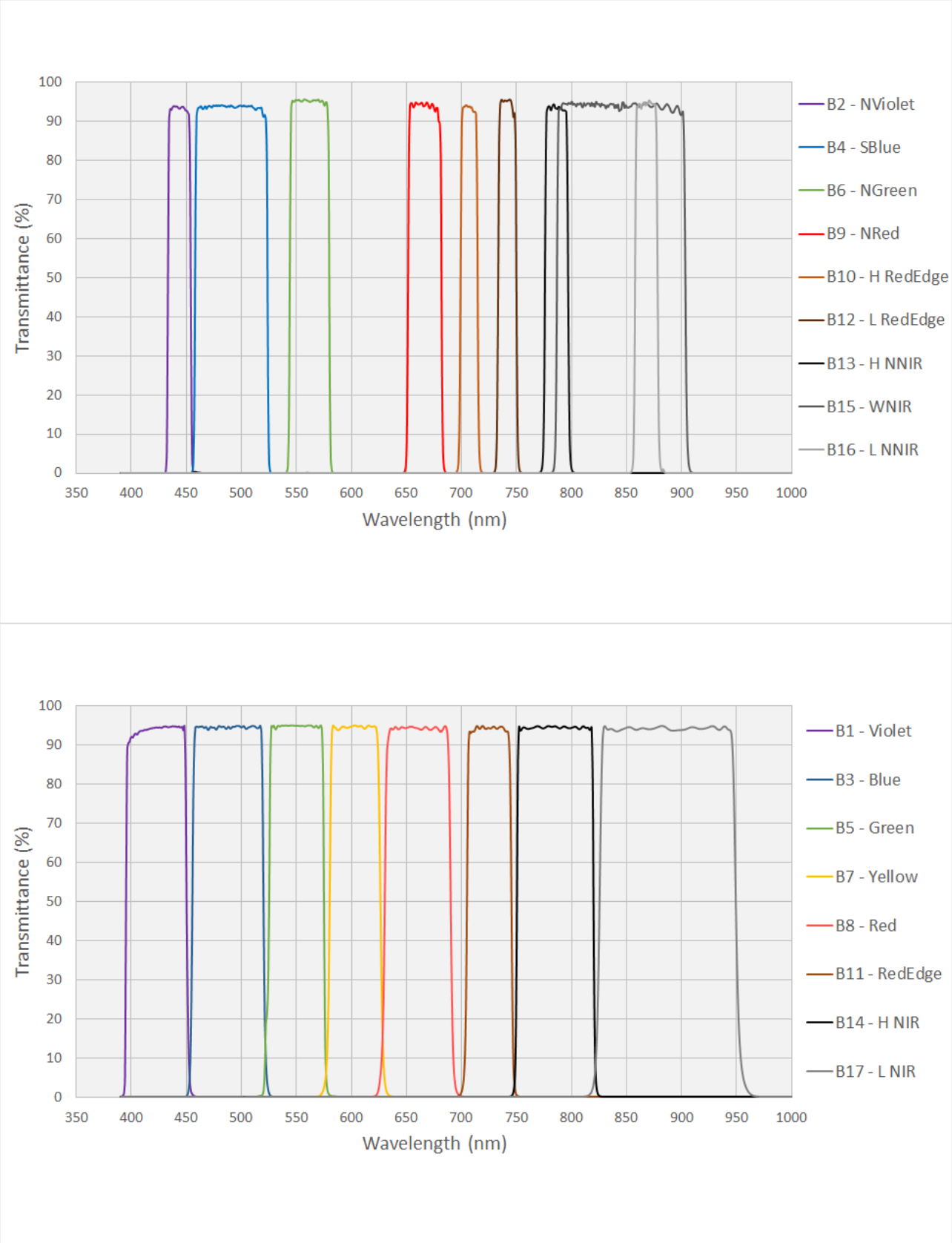


Figure 2. Bands available for MAIA M2.

The choice of the pair of filters for the MAIA M2 camera is usually related to the type of indices to be calculated according to the type of application. The models offered with the relative obtainable indices are described in Table 2.

Model	*Bands*				*Main indices*		*Other indices*
M2-V01			B1	B5	PPR	Plant Pigment Ratio	CTR6
M2-V02			B1	B8	NPCI	Normalized Pigment Chlorophyll Index	IO, CTR1, LIC2, SRPI
M2-V03			B1	B11	WV-BI	Worldview Built-Up Index	WV-NHFD
M2-V04			B1	B15	BWDRVI	Blue-Wide Dynamic Range Vegetation Index	WV-VI
M2-V05			B3	B5	PRI	Photochemical Reflectance Index	BGI, CRI1
M2-V06			B3	B8	BRI	Blue Red Pigment Index	IOR
M2-V07			B3	B11	CRI2	Carotenoid Reflectance Index 2	
M2-V08			B3	B15	BNDVI	Blue Normalized Difference Vegetation Index	PSSRC1, PSSRC2, PSNDC1
M2-V09			B5	B8	PVR	Photosynthetic Vigour Ratio	NGRDI, DSWI-4, GI
M2-V10			B5	B11	ARI	Anthocyanin Reflectance Index	
M2-V11			B5	B15	GNDVI	Green Normalized Difference Vegetation Index	PBI, GOSAVI, GSAVI, RARS, GRVI, GCI
M2-V12			B7	B15	CTR3	Simple Ratio Carter 3	
M2-V13			B8	B11	NDVIRedEdge	Normalized Difference Vegetation Index Red Edge	FR, FR2, CTR4
M2-V14			B8	B15	NDVI	Normalized Difference Vegetation Index	RDVI, TDVI, WDVI, WDRVI
M2-V15			B11	B15	NDRE	Normalized Difference Red Edge Index	NDCHL, RRI
M2-V16			RGB	B15	NDVI* GNDVI* BNDVI* SAVI* Immagine a colori	*con Rosso/Verde/Blu a banda larga	

Table 2. MAIA M2 models with realted combinations of bands and multispectral indices.

2.2 EXPOSURE

The camera works in self-exposure trying to keep the average image value constant at target value despite environmental variations. To do this, the exposure times are setted independently for each sensor. The exposure target, common to the two sensors, can be set between three predefined values using the button on the camera. The default values are 0.15, 0.20 or 0.25, with 0.20 set by default. These values are to be considered as the average brightness of the image on a scale from 0 to 1, where in 0 there is a completely dark image and in 1 there is a completely saturated image (all pixels with value 255 if in 8 bits or 1024 if in 12 bit). In the case of 0.20, for example, the average value of the image will be around 51 codes (8 bits) or 205 codes (12 bits). The image will appear visually underexposed in its entirety but this allows you to keep information even for any particularly bright areas that should appear in the image, occupying only a marginal part.

The exposure algorithm requires a certain number of images to converge, depending on scene. In external trigger mode the images are acquired only in the presence of triggers and therefore the first ones may not be correctly exposed.

2.3 MAIN CONNECTOR

The main connector supplies power to the camera and contains connections for I / Os and communication with the controller.

The main connector on the board is a 5x2 pole 2.54mm pitch (CNCTech 3020-10-0300-00). For the flat cable connector, it is recommended to use the IDC socket of the CNCTech 3030-10-0103-00 with retention. Alternatively, it is also possible to use component 3030-10-0102-00 without retention.

The main connector pinout, shown in Figure 1, is described in Table 3.

Pin	*Net*
1	VDC
2	VDC
3	Out 1 - STROBE
4	Out 2 - Reserved
5	Serial TX – Reserved
6	Serial RX - Reserved
7	In 1 - FREERUN
8	In 2 - EXTTRIG
9	Gnd
10	Gnd

Table 3. Pinout of the main connector.

2.3.1 POWER SUPPLY

When the camera is mounted on a drone it is powered at 5VDC, from the main connector via the VDC and GND pins. The 4-9V range is tolerated. The average consumption of the camera is 450-500mA at 5V. The power supply unit must guarantee at least 1A inrush.

It is appropriate to leave plenty of free space around the camera and ensure an air flow for dissipation.

In the laboratory, for SD access and image transfer, the camera can be powered directly from the USB port. To guarantee compatibility with the 500mA max of the USB standard, in this mode it is only possible to access the SD card and the other camera functions are inhibited.

There is no power button, when the camera is powered, it starts automatically.

2.3.2 I/OS AND SYNCHRONISM

The camera can be synchronized with external devices using the following pins:

- 1 FREERUN input: when high, the acquisition starts in free-run mode at 1fps or the camera saves an image every second. In this state the pressure of the ACQ button is ignored and the acquisition stops only by lowering the pin. When low, you are in external trigger mode, i.e. the camera is sensitive to pulses on the EXTTRIG pin. If it is not driven by an external device, this pin is low by default.
- 1 EXTTRIG input: the camera acquires an image at each rising edge on this pin, up to a maximum of 1fps. This pin is ignored if the acquisition is started with the ACQ button or when the FREERUN pin is high. If you do not intend to use this signal, leave the pin disconnected.
- 1 STROBE output, which emits a high pulse of 100ms duration each time an image is acquired. The rising edge coincides with the start of integration by the sensors. The pin is driven by a push-pull driver and no external pull-up resistance is needed.

All I / Os have 3.3V voltage and are tolerant for 5V at the input. The thresholds for the high level inputs are at 2.0V and the low one at 1.3V. The outputs can supply or absorb a current of max 20mA.

See also section 2.6 Image acquisition for more details on the use of EXTTRIG and FREERUN signals.

2.3.3 SERIAL PORT FOR COMMUNICATION WITH CONTROLLER

On the main connector there is a serial port, which allows you to communicate with the controller via point-to-point connection. The use of this interface is reserved.

2.4 MICROSD CARD AND IMAGE FORMAT

The camera saves the images in proprietary RAW format, at max 1fps on a microSD card. The color sensor saves 16 bit RGB 4:6:4 already debayered. The monochrome sensor can be set to 8 or 12 bits.

The SD card must be removed and inserted ONLY with the camera turned off, i.e. the camera must not be connected via USB to a PC or other external device nor must there be power from the main connector.

The camera supports 32GB microSD, with FAT32 formatting and 64k clusters (it is the default value used by Windows for formatting this type of media). The card must be class 10 U3. The following models have been validated:

- Kingston Gold 32GB
- SanDisk Extreme Pro 32GB
- Samsung Pro Plus 32GB.

Operation with other cards of similar or higher specifications is generally possible but not guaranteed. The use of capacities beyond 32GB is not recommended.

2.5 USB CONNECTORS

The camera has a USB2.0 connector for transferring the images saved on the SD to the PC, which will see the SD as an external drive. Access to the card is made by connecting the camera to the PC with a USB A / Micro-B cable. It is not recommended to power the camera simultaneously from USB and the main connector. The content of the SD is made visible to the PC when connected. With the USB connection active, the other camera functions are inhibited.

When the camera is powered by USB, two LEDs, indicating the exposure level, flash.

2.6 IMAGES ACQUISITION

There are two ways of acquiring images, alternatives to each other:

- Continuous (or Freerun): the camera acquires 1fps images
- With external trigger: the camera acquires an image at the rising edge of the EXTTRIG trigger signal. The time separation between two successive triggers must be greater than or equal to 1s. The exposure of the image begins typically within 0.3ms from the trigger front.

In both cases, the acquisition takes place simultaneously from the two sensors. The two modes are managed through the button and the FREERUN and EXTTRIG pins of the connector.

2.7 *ACQ* E LEDS BUTTONS

The ACQ button allows you to:

- Start and stop the Freerun acquisition mode
- Adjust the bit depth of monochrome images (8 or 12 bits)
- Adjust the exposure target between three levels (0.15, 0.20, 0.25)

To start the freerun acquisition, press the button quickly. When the freerun acquisition has been started with the button, it is necessary to press the button again to stop it. Any events on the EXTTRIG and FREERUN inputs are ignored. To set the parameters, keep the button pressed for 3s, until the Bit LED flashes. Press the button to move the led to the desired setting. Confirm by holding the button for 3s. The configuration moves to the exposure level and the Exp LED flashes. Set to the desired level by pressing the button. Exit the configuration mode by holding the button down for 3s.

The settings for the bit depth and the exposure target are kept when the camera is restarted and are visible on the LEDs next to the button. During the setting of the parameters, the image acquisition is suspended. In order to set the parameters it is necessary that there are no acquisitions in progress, i.e. that the FREERUN pin is low and that no triggers are sent.

2.8 FRONT LED

The two-color LED visible on the front part of the camera indicates the presence of the power supply, the acquisition status and any errors.

Camera status	LED status
Camera OFF	OFF
Camera ready to acquire images	GREEN
Red pulse at any image acquired	RED PULSE
Memory full	RED
Error. Ex.: starting acquisition without SD card or camera receiving too frequent triggers.	RED FLASH

Table 4. Front LED status.

2.9 INTERNAL CLOCK

The camera has an internal clock, powered by battery, which is used to attribute the time of saving the images on the SD card. The clock is factory adjusted to UTC time. Battery life is estimated to be over 10 years from the moment of production and its replacement requires the camera to return to the factory.

2.10 NAMES AND FEATURES OF THE IMAGE FILES

The camera saves the image captured by the two sensors on the SD card in a single uncompressed file, with the ".Raw" extension. The file format is a proprietary raw file, for which decoding it is recommended to use the supplied software.

The file name is constructed differently depending on whether the acquisition takes place in freerun mode or with external trigger and a part of the name can be attributed by any external controller to synchronize the images with the GPS logger. The files are placed in a folder named yyyymmdd (year, month, day), created when a new acquisition session is activated.

An acquisition session begins with one of these events:

- The freerun mode is activated (by pressing the ACQ button or the FREERUN signal goes high)
- The camera receives the first trigger while the FREERUN signal is low (= external trigger mode enabled)

A subfolder with the name hhmmss (hours, minutes, seconds) is created in the session folder, which contains a maximum of 1000 files. Exceeding 1000, another is created with new hhmmss.
The file name is in 8.3 format with the syntax yyyyyxxx.raw, where:

- xxx is a progressive 000-999 assigned by the camera to each save
- yyyyy is a value that in external trigger mode can be set by the controller by sending it to the serial line immediately after each trigger pulse (from 00001 to 65535). If not received within the set times, it is set to 00000. In freerun mode it is fixed at 00000.

When the camera operates in freerun mode in the absence of controllers and the acquisition takes particularly long (over 16 minutes) to exceed 1000 files, the names of the files contained in the subfolders into which they are divided are the same folder by folder. It is therefore necessary to be careful when copying the files to the PC and maintaining the folder structure to avoid overwriting.

The size of the file varies according to the configuration of the sensors and the bit depth chosen.

Camera configurations	*8 bit*	*12 bit*
2 mono-chromatic sensors	2.5MB	4.8MB
1 mono-chromatic sensor + 1 RGB	3.7MB	4.8MB

Tabella 5. File size according to the cmaera configuration and bit depth.

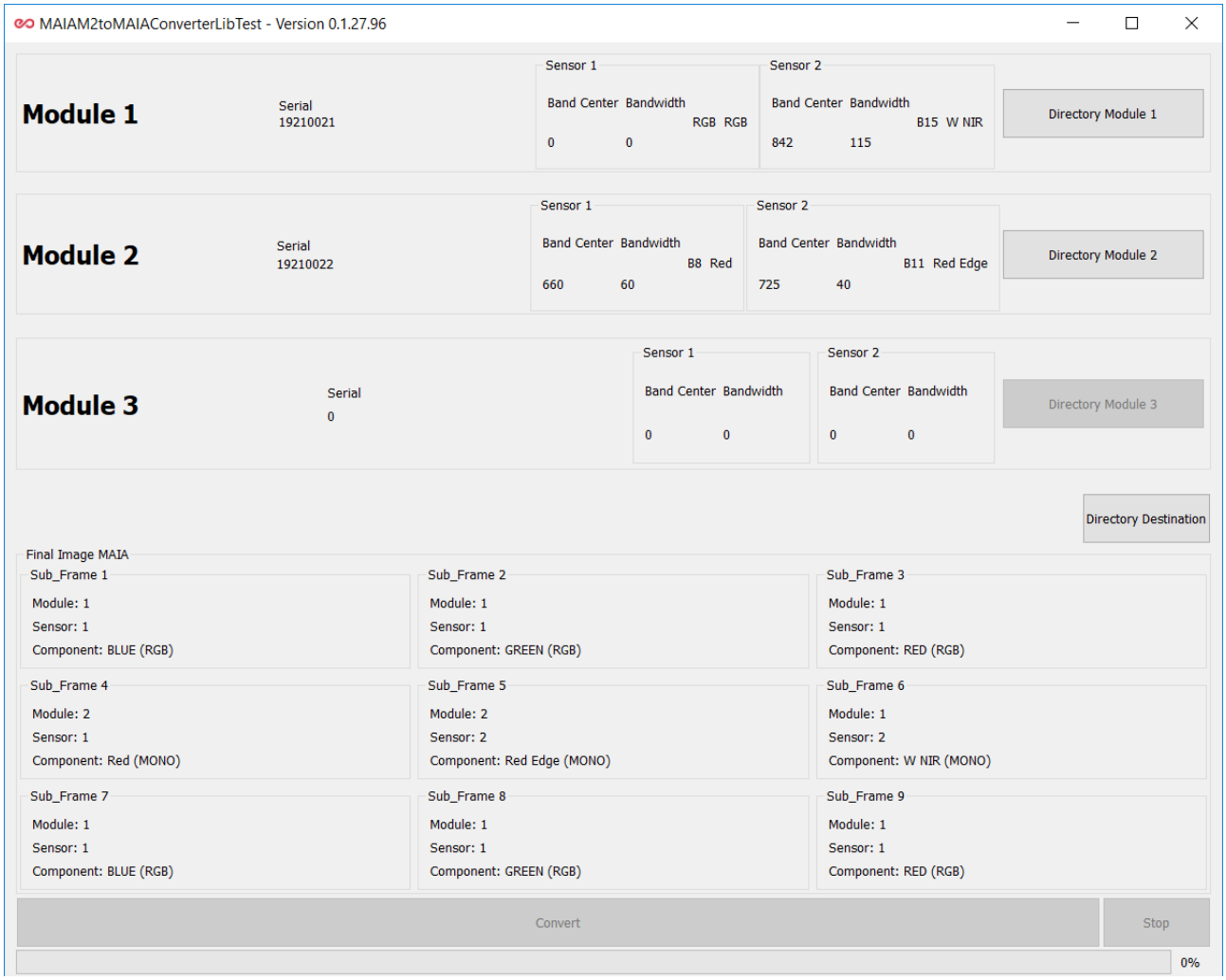
2.11 MECHANICS AND FIXING

On the front of the camera there are 2 M2.5 holes, 3mm deep to fix the camera to a support. The support must ensure adequate air circulation to allow heat dissipation.

If several modules are used side by side, it is important to align the modules in the best way so that they frame the same scene and it is essential that the support ensures a rigid coupling that keeps the relative position between the modules and the orientation of the view axes fixed. In the absence of this requirement, the image co-registration cannot be completed.

3 IMAGE PROCESSING SOFTWARE

Image processing can take place with *MultiCam Stitcher Pro* software of the 9-band MAIA camera, which allows you to generate the image recorded on the various bands, also acquired from different MAIA M2 modules. For the functionality of the software, please refer to the User Guide of 9-band MAIA. Radiometric correction features are not currently supported.
The use of the *MultiCam Stitcher Pro* software with images of the MAIA M2 requires an adaptation of the file, through the use of the *MAIA M2 Converter software*. This software loads the images of up to 3 MAIA M2 modules and combines them into a file compatible with the *MultiCam Stitcher Pro*. The change requires the presence of the geometric calibration file of the various modules (.cal) and the .ini file containing the allocation rules . It is recommended not to modify these files. To use, follow these steps:
1. Copy the images from the SD card to the PC, preserving the folder structure. It is recommended to process one acquisition session at a time.
2. Run the software.
3. Choose the folder containing the files of each module. The characteristics of each module will be highlighted in terms of serial number and bands and it will be possible to operate on the modules defined by the .ini file.
4. Choose the destination folder for the files.
5. Process the files in the destination folder, as required by the *MultiCam Stitcher Pro* software.



4 TECHNICAL FEATURES

Campo	*Valore*
Sensors	2 sensors CMOS 1.2Mpix (1280x960) with high sensitivity global shutter 2 mono-chromatic sensors or 1 mono-chromatic + 1 RGB sensor
Optics	Geometric calibration of each lens Focal lenght 8.0mm, f/# 2 Aperture: 36° horizontal, 27° vertical, 44° diagonal Ground sampling distance (GSD): 3 cm* Field of view (FOV): 45m x 34m * * at height above ground level of 75 m
Exposure	Automatic, with possibility to set brightness on 3 levels
Acquisition	Single shot or continuous, with external trigger or at fixed frequency Simultaneous shot for the two sensors up to 1fps
Images	RAW 8 - 12bits per pixel File size: 2.5MB to 4.8MB, based on image format Multi-layer / multi-band TIFF post-processing
Storage	Micro-SD class 10 U3 up to 32GB Up to 12.000 images, equivalent to 3h acquisition
Interfaces	USB2.0 for downloading images Trigger input and Strobe output for synchronism Button or pin for input to start or stop the acquisition Button to sett bits for pixels and image brightness Serial port for connection of external controller
Size and weight	49mm x 34mm x 23mm (~46mm including lenses and connectors) 59g
Power supply	5-9VDC, 1A peak, ~2.5W typical
Ambient conditions	Operaional temperature 0-40°C Operationl humidity 20-80% RH without condensation Protection IP50

With a view to continuous product improvement, we reserve the right to change the specifications at any time without notice.

5 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.1.00	08.2018	1826xxxx	Introductory release
Rev.1.01	07.2019	All	Global update of content for public release