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Hyperspectral core-logger image acquisition

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1 *Works for me* This protocol is published without a DOI.

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ABSTRACT

The following protocol describes how to acquire hyperspectral images with Specim's Single Core Scanner (SCS) with two hyperspectral cameras (VNIR, SWIR). It was developed thanks to the expertise of many people within the M2C laboratory, as well as the Specim manual and a Butz publication.
This protocol also highlights important properties (exposure time and pixel overlap) on which it is necessary to take time to obtain the most informative hyperspectral image with an optimal signal-to-noise ratio.

Butz, C., Grosjean, M., Fischer, D., Wunderle, S., Tylmann, W., Rein, B., 2015. Hyperspectral imaging spectroscopy: a promising method for the biogeochemical analysis of lake sediments. J. Appl. Remote Sens. 9, 1–20. https://doi.org/10.1117/1.JRS.9.096031

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KEYWORDS

Hyperspectral imaging, sediment cores, Specim

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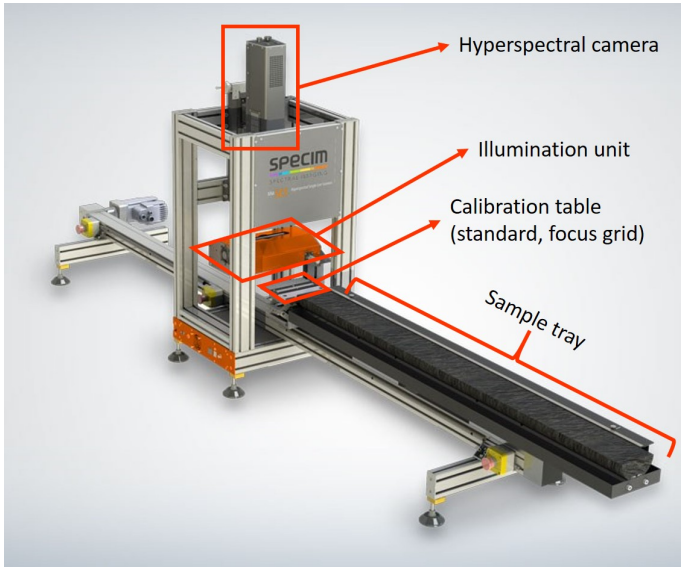
SAFETY WARNINGS

- The white reference panel is fragile. Do not touch its surface.
- Do not touch the lens.

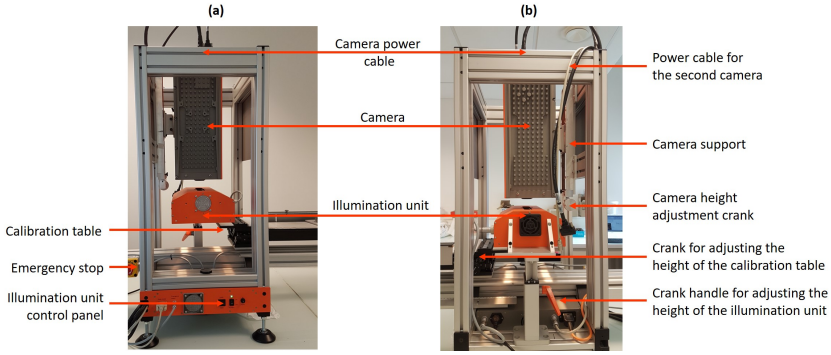
General description of the acquisition bench

1



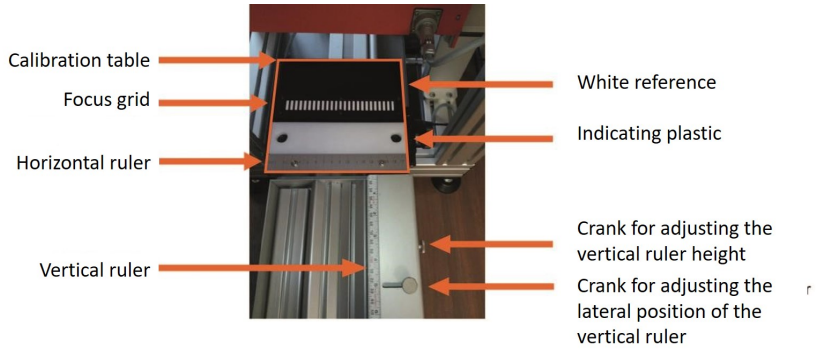
General description of the hyperspectral core-logger (Specim)

2



Description of camera support: (a) front, (b) back

3

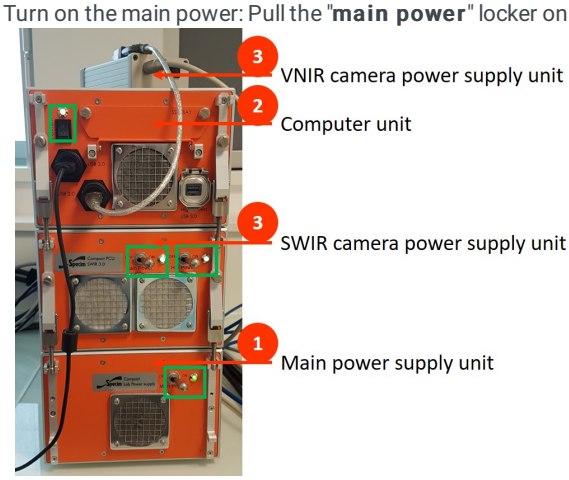


Description of the calibration table

Core logger set-up

4 Check that the 4 **emergency stop buttons** placed along the core logger are unlocked. To do this, press and turn at the same time to unscrew the buttons.

5 Turn on the main power: Pull the "**main power**" locker on the block at the base of the computer.



Power supply units constituting the hyperspectral core logger

6 Turn on the computer: **O/I "power"** button at the top left of the computer.

7 Check which camera is positioned on the acquisition bench. Depending on the problem related to the sample, the choice of the camera is important. Switch on the corresponding camera:
- For the **VNIR camera**: Turn on the small grey **"VNIR power supply"** unit located on the top of the computer.
- For the **SWIR camera**: Pull the "**main power**" and "**HSI POWER**" lockers on the central unit of the computer.

8 Turn on the **illumination unit** at the base of the camera support, check that the position of the lamp is on "**VNIR**" or "**SWIR**" depending on the camera used.

9 Turn on the **air conditioning** to maintain a constant temperature in the room, as the temperature affects the signal.

10 Close the **blinds** on the room windows to keep the room dark. The **lights** should be turned off before acquiring the sample.

11 Take the **white reference** and place it (the smoothest part towards the camera) on its location on the calibration table.

⚠ The white reference is very delicate. Handle it by touching only the slices and dust its surface once placed in the calibration table with the **brush**.

12 Remove the **shutter** from the camera.

⚠ Hold the lens with one hand and point the shutter with the other hand do not touch the lens !

Sediment core preparation

13

It is very important to keep the core out of the freezer as little time as possible. It should be based on a maximum time of 1 hour and a minimum of 15 minutes. Beyond 1 hour, the sample may crack. Below 15 minutes, the sample may be too humid, which will induce important absorptions with the SWIR camera, and reflection for the VNIR camera. These times vary from one sample to another depending on the properties of the sedimentary matrix.

The surface of the core should be as smooth as possible, because the depth of field of the cameras is small, in the order of a few millimetres. And any variations in the surface have an impact on the signal. Biofilms may also be present on the surface of the sample, which will partially mask the sediment signal. Similarly, oxidation of the sample surface may mask underlying sedimentary structures. Therefore, it is important to take the time to "clean" (shave the surface with a **spatula** or **knife**).

In areas with shells or sand, "cleaning" can very easily leave marks on the surface. To avoid this, it is recommended to "clean" these shell areas with very little pressure and then smooth the surface with your finger by wearing a **latex glove** slightly moistened (the smoothest part on the sediment). Very light finger pressure should be applied to the sediment. If the sediment is very clayey and very wet, avoid using the finger with the glove but use only the spatula with very little pressure.

It is also important to remove elements that are not part of the sediment (mould, small pieces of plastic...).

Sample placement

14 Place the **cleaned core** on the **sample tray**. Place the TOP of the core towards the camera, butting against the calibration plate.

When acquiring multiple cores, it is important to keep the same software parameters and heights (samples, light and camera) to be able to compare data with each other. Tip: calibrate the calibration tray and ruler heights on the sample that has the greatest height, so it will just have to compensate the difference for the others with the addition of pieces of cardboard.

15 Adjust the height of the **calibration table** with the worm screw located at the back under the tray. The height must correspond to the height of the sample (not necessarily the height of the container).

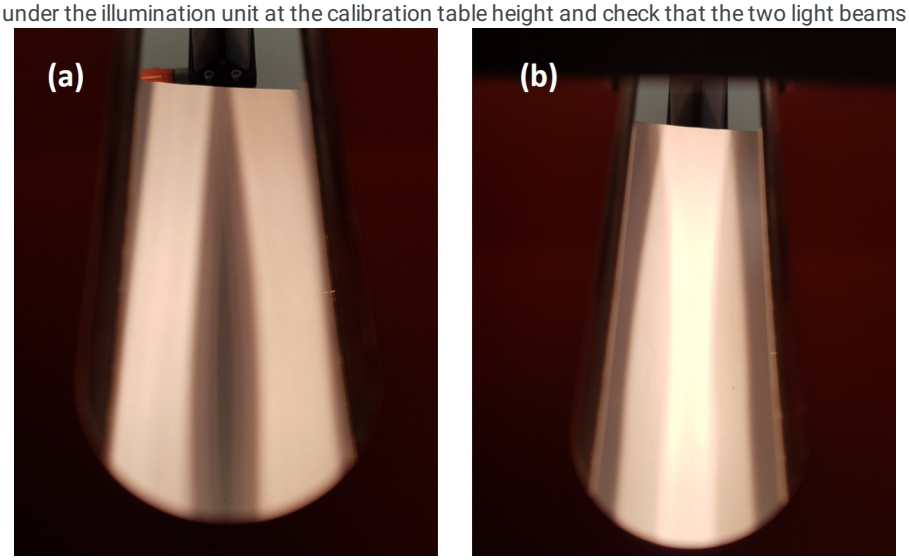
16 Adjust the **ruler** against the core and to the height of the calibration table by turning the adjustment screw. The purpose of this point is to position the ruler and sample as horizontally as possible using a spirit level.

17 Using this ruler, adjust the horizontality and height of the **sample** by placing objects (pieces of cardboard, polystyrene) between the tray and the sample.

Illumination unit adjustment

18 Adjust the height of the **illumination unit** with the orange handle. To check the correct height, place a white paper

under the illumination unit at the calibration table height and check that the two light beams overlap.



Alignment of the light beams as seen through the aperture provided for the camera. (a) bad, (b) good alignment

The illumination unit must be held with one hand when handling the orange handle. The illumination unit may be hot!

Adjusting the camera height

19

The camera height adjustment has an influence on the resolution, but also on the depth of field (range of "sharpness" of the image). Therefore, depending on the sample and the interests of the study, a compromise will have to be made when adjusting the camera height.

Reduce or increase the height of the **camera** with the crank at the back above the camera support and lock the rack with the brake screw (small and black).

We usually work at a height of 20 cm for both cameras.
The height is measured between the underside of the camera and the calibration table.

	VNIR	VNIR	SWIR	SWIR
Focal length	14 cm	35 cm	14 cm	35 cm
Pixel size	50 µm	120 µm	150 µm	370 µm
Time of analysis	20 min	12 min	20 min	12 min
Volume of data	8 Go	3 Go	2,5 Go	0,8 Go

Choice of camera height and influence on pixel size, analysis time and data volume for a 1.5m sample length

Adjusting the focus and determining the acquisition parameters

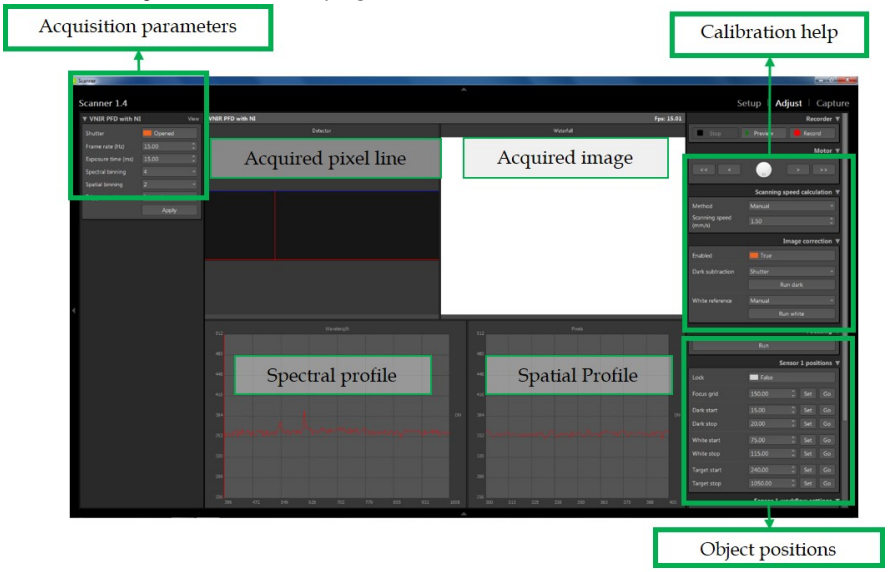
20 Open the **LUMO** software to control the core logger.

21 Connecting the **camera** to the **computer:**
In the "**Setup**" tab at the top right, select **Sensor 1** and **connect** the camera "**VNIR PFD with NI**" or "**SWIR3 with NI**", then **connect** "**Motor 1**" as well.

In the tab " **Sensor 1** " in " **Capture folder** ", you can choose the folder where the different acquisition files will be saved. Check that the disk where the data will be saved has enough space available.

22 Focus Adjustment :

22.1 Click on the "**Adjust**" tab at the top right to see the interface:

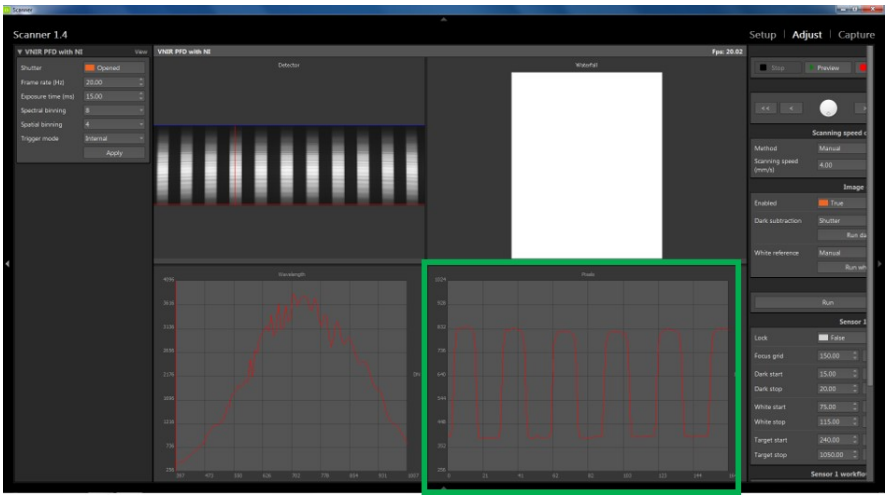


LUMO user interface

22.2

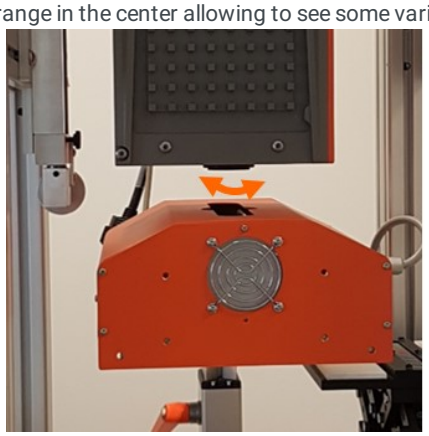
Adjusting the focus is an important step and one on which it is necessary to take time to achieve the optimal setting to obtain sharp images.

To do this, first place the sample tray on the focus grid. In the "**Adjust**" tab, you must define its position in the "**Sensor 1**" - "**Focus grid**" box, it is at 150 (if this is not the case, change it, click on **Go**, wait for the sample tray to be placed, and validate with **set**). And **set** the **exposure time** (top left) to **13 ms** for the **VNIR** camera and **1.5 ms** for the **SWIR** camera. At this point, the spatial profil show in the software interface:



Focus grid adjustment

22.3 Rotate the **lens** (below the camera) so that the ripples on the profile in "**spatial view**" look likes **slots** as much as possible. To do this, you can use the dark grey grid in the graph to find your way around. It is also possible to zoom, with a right click, in autoscale uncheck autoscale x, then in option choose a range in the center allowing to see some variations.



Focusing the focus by rotating the lens

22.4 An optimization can be made in the "**Adjust**" tab, then "**Focusing**", press **Run**. This tool will help you find the optimal focus setting. Then, turn the **lens** to scan different focus settings (slots (optimal) or sinusoids (non-optimal) in "**spatial view** "). Finally, rotate the lens until you reach a value close to 100%. If the percentage remains at 0%, redo manually and keep this adjustment.

23 Data correction:
In order to view images with colors close to what is observed, it is necessary to calibrate them with **black** (automatic shutter closing) and **white** (with the white reference positioned on the calibration table). To do this, go to the "**Adjust**" tab, then to "**Image correction**" :

- Dark substraction": Select **Shutter** and press **Run Dark**
- White reference": Select **Scanner**, press **Run White**

This correction may not have the desired effect. There may also be a difference between viewing in "**Adjust**" and "**Capture**".

24 Acquisition parameters:
In the "**Adjust**" tab, in the top left square, you will find the main parameters to be adjusted to perform the acquisition.

- Shutter: Which must always be with an orange square (Opened)
- Trigger mode: Who should mark: "Internal".
- **Spectral binning**: Binning allows to cumulate intensities of neighbouring wavelengths. In the case of a binning of 2, we combine 2 neighboring wavelengths. This also allows to reduce the number of wavelengths and thus the size of the output data file, but this can hide important spectral information. (Usually set to 8 for the VNIR camera and 1 for the SWIR camera).
- **Spatial binning**: Here too, binning allows you to average the intensities of neighbouring pixels. In the case of a binning of 2, we combine 2 neighboring pixels. This also allows to reduce the number of pixels and thus reduce the resolution and size of the output data file. (Usually set to 1 for both cameras).

	VNIR	VNIR	SWIR	SWIR
Spectral Binning	8	1	2	1
Spatial Binning	1	1	1	1
Number of data	970.000	7.760.000	345.600	691.200
Volume of data	2,8 Go	22,4 Go	415 Mo	830 Mo

Impact of the binnings for a 60cm sample

Fill in these chosen values in the acquisition software, validate with **Apply**

24.1 Spectral quality (exposure time):
Exposure time: Adjusts the recorded light intensity that affects the signal-to-noise ratio. If the time is too long, there is a risk of signal saturation, and if the time is too long, the signal may be masked by noise.

- VNIR: minimum: 0.1 ms, maximum: 100 ms
- SWIR: minimum: 0.1 ms, maximum: 20 ms

To increase the spectral quality of the data (signal-to-noise ratio), it is interesting to take some time to define this parameter. To do this, place the sample tray on an area that can have the maximum signal (the brightest area). With "**Target stop**" define the position and move the tray with **Go**. Adjust the **Exposure time** to find out when the signal is saturated (plateau at maximum values) and choose a value corresponding to 75% of it.

In the case of multiple samples, make sure that the brightest areas do not saturate.

Fill in this chosen value in the acquisition software, validate with **Apply**

24.2 Spatial quality (overlap):

Overlap is the amount of a pixel that is found in the next pixel. In the perfect case, it would be 0%. In the case of our images this is not the case, so we try to approach it with some of the acquisition parameters that will constrain the value of the overlap.
An Excel spreadsheet (**Parameters.xlsx)** has been created to estimate the **frame rate** and **scan speed** values from the previous acquisition parameters (**focal length, binning, exposure time**). The frame rate and scan speed can be estimated either from the overlap or from the analysis time.

- **Frame rate** (Hz): Represents the number of acquisitions per second. (maximum: 150 fps VNIR, 450 fps SWIR)
- **Scan speed** (m/s): Speed of the traveling bench

Fill them in in the acquisition software (validate with **Apply**).

Step		VNIR OLE23			Step		SWIR OLE22,5		
1	Focal distance	20		cm	1	Focal distance	20		cm
	Pixel size	69,59		µm		Pixel size	212,96		µm
	Ground Sample Distance	605,15		µm		Ground Sample Distance	1893,00		µm
	Depth of field	3,38		mm		Depth of field	4,02		mm
2	Spatial binning	1			2	Spatial binning	1		
2	Spectral binning	8			2	Spectral binning	1		
3	Exposition time	12,7		ms	3	Exposition time	3,5		ms
4a	Pixel overlapping	0,00	19,54	%	4a	Pixel overlapping	0,00	-11,54	%
	Frame rate	7,72	21,60	nb line / s		Frame rate	35,70	6,85	nb line / s
	Scan speed	0,60	1,67	mm/s		Scan speed	8,69	1,67	mm/s
4b	Sample length	1,5		m	4b	Sample length	1,5		m
4a'	Acquisition time	41,96	15,00	min	4a'	Acquisition time	2,88	15,00	min
	Data size	5,10	5,10	Go		Data size	1,39	1,39	Go
	Fill in the grey cells.								
	Apply in Lumo software the selected frame rate and scan speed.								
	Reference the grey and green cells.								

Spreadsheet for the choice of acquisition parameters

Parameters.xlsx

The **Parameters.xlsx** includes formulas for the calculation of the overlap using the different acquisition parameters. Thanks to a design of experiment, it is possible to relate focal length, frame rate and scan speed to the overlap or the acquisiton time.

Optimization of the values or manual selection of the frame rate and scan speed:

1. Place the **sample tray** at the dark level with "**Sensor 1** " - " **Dark start** " then **Go**.
2. Place a **round coin** on the **indicator plastic**.
3. In "**Sensor 1 positions**", check that the "**Target start**" is at 180 and the "**Target stop**" at 220 (if not, change it, click **Go**, wait for the measuring bench to be placed, and validate with **set**).
4. In "**Adjust**", "**Scanning speed Calculation**", select **Aspect ratio**, then **Run**. The software will then offer you speed or frame rate values close to those previously estimated. Select the **speed** change. Then select Manual to see the new speed.

Acquisition of hyperspectral images

25 In "**Sensor 1 positions**", define "**Target start**" and the "**Target stop**" corresponding to positions on the sample tray that cover the entire length of the core to be passed. Also be sure to click "**Set**" each time you change these numbers. (Start at 180, end less than 2,000)

26 Turn off the **lights** in the room.

27 Check that the **illumination unit** is turned on according to the **camera** used ("VNIR" or "SWIR"). Check one last time that the **acquisition parameters** are correct and validate them with **Apply**.

28 Make a final correction to the image. To do this, go to the "**Adjust**" tab and then to "**Image Correction**" :

- Dark substraction ": Select **Shutter** and press **Run Dark**
- White reference": Select **Scanner**, press **Run White**

29 Write the name of the core on a piece of paper and place it on the **indicating plastic** between the core and the focus grid in order to have a mark of the name of the core on the acquired image.

In the " **Capture** " tab, give the name of the sample (dataset name) and put some comments if necessary. Launch the

30 capture, by clicking on "**Record** ".

It is not advisable to place heavy objects on the table so as not to alter the horizontality of the sample tray.

Data standardization

31

Normalize the image using Dark and White acquisitions to remove instrumental noise and obtain calibrated reflectance.

Open the software: **ENVI classic+IDL**.

32 Click on "**Specim**," "**Scan Normalization**". Return to the acquisition folder and select the file: **manifest**.

33 In the new windows, select the files that are requested, for example the "white" or "dark reference". These files are located in the **Capture folder**.

34 Once all the files are selected. A new window will appear with a blue bar: "Normalization".

35 As soon as normalization is complete, new windows will be opened that can be closed. A new file is also created during normalization (_refl.dat). This file will be used for all future processing.

36 Then close **ENVI classic+IDL**. Then repeat the previous steps for a new acquisition or continue this protocol.

For the acquisition of multiple cores, it is also possible to complete all acquisitions before doing all normalization.

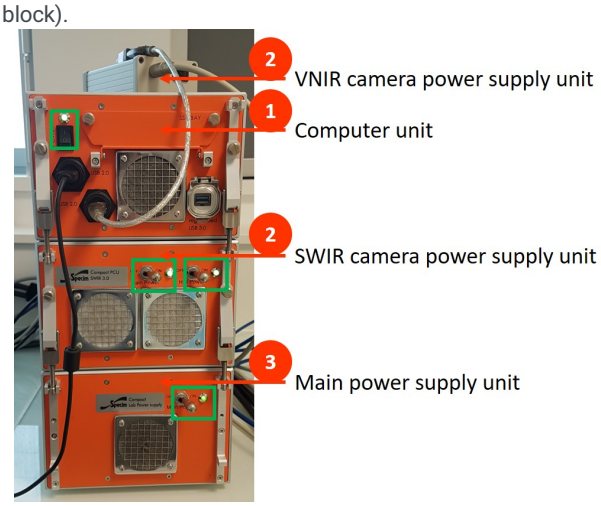
When acquiring multiple cores, try to keep the same software settings and heights (samples, illumination and camera) to be able to compare data with each other. For this, it is advisable to always work at the same focal length, so the other acquisition parameters are the same.

Switching off the hyperspectral core logger

37 In the **LUMO** acquisition software, go to "**Setup**" in the upper right-hand corner, then click on "**Disconnect**" in the tab "**Sensor 1**" (upper left-hand corner).

38 On the left in the "**Moto**r 1" tab, click on "**Disconnect**".

39 Close the **LUMO** software, switch off the **computer** in a conventional way, and with the **O/I "power"** button (top block).



Switching off the hyperspectral core logger

40 Turn off the **illumination unit** at the base of the **camera support**.

41 Switching off the **camera**
- For the VNIR: Turn off the small grey "**VNIR power supply**" box located on the top of the computer.
- For the SWIR: Pull the "**HSI POWER**" and "**main power**" lockers on the central block of the computer.

42 Pull the lockers "**Main power**" at the base.

43 Turn off the **air conditioning** in the room.

44 Store the **white reference**.

45 Clean the various components of the room (tray, benches, tools) and put them away.