

EnMAP Field Guide - In-Situ Measurements for Validation Purposes

Version 1.3 rev 1; 27.09.2023

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Recommended citation of the report:

Brell, M.; Milewski, R.; Neumann, C.; Ong, C.; Lau, I.; Hank, T.; Foerster, S; Chabrillat, S. (2023) EnMAP Field Guide - In-Situ Measurements for Validation Purposes. V.1.3. EnMAP Field Guide Technical Report. GFZ Data Services. DOI: <https://doi.org/10.48440/enmap.2023.002>

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https://www.enmap.org/data_tools/flights/

Imprint

EnMAP Consortium

Helmholtz Centre Potsdam

GFZ German Research Centre

for Geosciences

Publisher

GFZ Data Services

Telegrafenberg

D-14473 Potsdam

September 2023

DOI: <https://doi.org/10.48440/enmap.2023.002>



Document Signature Page

Project:	Environmental Mapping & Analysis Program (EnMAP)
Document:	EnMAP Field Guide - In-Situ Measurements for Validation Purposes (<i>Guide for Field Spectroscopy Measurements v1.0</i>)
Datum:	12. July 2023
Doc. Nr.:	EN-GFZ-FG-002
Version:	1.3 rev 1

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The document was discussed, and the measurement procedures were optimized together with Cindy Ong and Ian Lau (CSIRO), Tobias Hank (LMU) and Raymond Kokaly (USGS)

Acknowledgments to Ray Kokaly (USGS), Todd Hoefen (USGS), and John Meyer (USGS) for improving the protocol based on their experience with the protocol in supporting several EnMAP validation campaigns.

Table of Contents

1	Introduction	4
2	Selection of Ideal Site for Spectral Ground Control Points (SGCPs)	5
3	Tools and Preparation	5
3.1	Tools.....	5
3.2	Setting-up Measurement Transects/Pattern	6
3.3	Setting up ASD device.....	8
3.4	Data Format and Post-processing	10
4	Detailed Data Acquisition Procedure Using an ASD FieldSpec.....	8
4.1	Preparing the ASD Fieldspec at the site:	8
4.2	Configuring the instrument	8
4.3	Measurement	9
5	Bibliography.....	11
6	Quick Field Guide for In-Situ EnMAP Validation Measurements	12
6.1	General Preparation preparation for field measurements	12
6.2	Day before field measurements	12
6.3	Day of field measurement	12
6.4	Post-processing of the Field Data.....	12
7	Items checklist for spectroradiometric field measurements	13

1 Introduction

In support of the Environmental Mapping & Analysis Program (EnMAP) mission [1], the acquisition of accurate and comparable spectroradiometric in-situ measurements is crucial for vicarious validation of the official EnMAP data products [2].

This document provides a guide on properly conducting spectroradiometric field measurements within the scope of EnMAP. It is a summary of the detailed technical handbook developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) [3], the approach established by the Remote Sensing Laboratories (RSL, University of Zurich) [4], on the bases of “Progress in field spectroscopy” [5], “Field and airborne spectroscopy cross validation - Some considerations” [6] and the experience gained throughout numerous validation efforts for air- and spaceborne sensors by the Remote Sensing and Geoinformatics section at the GFZ Potsdam that have been specially adapted for EnMAP purposes.

The following procedure should be used when conducting in-situ measurements of terrestrial surfaces to obtain consistent measurements by applying a repeatable approach throughout the validation phase of the EnMAP mission.

2 Selection of Ideal Site for Spectral Ground Control Points (SGCPs)

The choice of the site where the spectroradiometric ground measurements are to be carried out is a crucial first decision that has to be made. For validation of EnMAP L2A BOA reflectance data, the target areas should be spatially and spectrally as homogenous as possible. They should also be relatively temporally invariant and can be efficiently covered by ground measurements efficiently.

The validation area to be sampled should be:

- at a minimum 90x90 m (3x the size of the 30 m EnMAP Ground Sampling Distance (GSD)) (Figure 1)
- spatially and spectrally as homogenous as possible
- temporally invariant, as much as possible
- not in the proximity of large water bodies
- a flat terrain and flat surface
- lacking any shadowing effects
- an area that has low adjacency influence from the surroundings (ensure there is a sufficient buffer to the validation area)
- of a surface material that experiences little alteration due to the measurement activities
- easy and legally accessibility

Not all the points above can be considered to weigh equally on the selection of the validation area and are dependent on the validation site specifications. The best intermediate solution should be chosen to achieve the most suitable result. All deviations from the relevant parameters should be documented in the measurement protocol. Please consider the validation sites center coordinates (Latitude/Longitude), orientation of the measurement pattern, site specifications during the acquisition tasking to optimize for specific acquisition parameters.

3 Tools and Preparation

3.1 Tools

Once the validation sites have been chosen, the necessary equipment for the in-situ spectroradiometric measurements can be prepared.

Several items, outlined in Table 1, are used for the field acquisitions. To minimize mishaps, it is best to prepare and test all the necessary equipment the evening before the field measurements. An Items checklist for spectroradiometric field measurements of all the tools needed to conduct fieldwork can be found later in the document (page 13).

We recommend conducting in-situ measurements in a team of two and that dark and non-reflective clothing (preferably made from natural fibers) is worn on the day of measurement to reduce unwanted effects caused by the clothing.

The primary tool needed is, of course, a radiometrically and especially spectrally well-calibrated field spectroradiometer, of which there are a few different manufacturers available (e.g., Malvern Analytical ASD, Spectral Evolution, Spectra Vista Corporation, etc.).

A calibrated Spectralon (or equivalent) panel is also necessary and basic requirement to measure absolute reflectance.

There are differences in handling the instruments and attachments that are available for each. At their core, they remain similar, and therefore a more generic approach is described in the following section which is based on the operation of an ASD FieldSpec instrument.

All batteries for electronic devices should be fully charged. Hence, one of the important preparations the day before the fieldwork includes the charging all of the spare batteries for the instruments. In the case of an ASD field spectroradiometer, these are:

- Field Spectroradiometer batteries (2x)
- Laptop battery (2x)
- Camera (or mobile phone)
- GPS

It is also important to gather all the essential logistical information the day before the fieldwork. Proximity and access to the site should be evaluated, and potential landowners should be informed about the field fieldwork. The preparation of maps and notes help to facilitate the planning and execution of the measurement.

Table 1. Essential items needed for Spectroradiometric Field Measurements; underlined items require preparations the day before the fieldwork

1	Field spectroradiometer (recently radiometrically and wavelength calibrated) (spectral range 350 – 2500 nm)
<u>2</u>	<u>Fully charged</u> battery for spectroradiometer (+ one spare = 2 in total)
3	Battery cable
4	Pistol grip preferable with bubble level attached
<u>5</u>	<u>Charged</u> laptop & spare laptop battery
6	Laptop carrier and instrument backpack
<u>7</u>	<u>Clean</u> , not scratched, preferably recently calibrated white reference (Spectralon or equivalent) panel (the larger, the better, preferably 250x250 mm as a minimum), if possible, with bubble level attached (How to properly clean a white reference panel see: [7])
8	Adjustable tripod with adequate mount for the white reference, preferably with bubble level [3]
9	Logging sheet, already prefilled
10	GPS (+batteries and PC cable if not wireless)
11	Camera (smartphone is fine, charged)
12	Fore optic (FOV 8° preferable; instrument must be radiometrically calibrated for the actual physical foreoptic that is being used)
13	(optional) Monopod to operate pistol grip with a bubble level to indicate horizontal positioning (min 1m length) [3]
14	(optional) Dust blower [3]
15	(optional) Square meter quadrat for taking standard perpendicular photos of the target surface [3]
16	(optional) calibrated Microtops II Sun Photometer (and Ozonemeter)

3.2 Setting-up Measurement Transects/Pattern

Transects should be aligned to the orientation of the EnMAP swath to maximize the overlap of the validation area and the coverage of the pixels (this may not be possible, e.g., for vegetated sites). The EnMAP path is not directly north-south but has an orientation of approximately 8° degrees from true North (please check the current and accurate orientation before a particular acquisition measurement; consideration of the magnetic declination should be applied based on the location). Minimum transects should cover an area representing a 3x3 pixel (90x90 m) neighborhood. It is recommended to divide the area into 6 transects, each 12.8 meters apart, with a continuous measurement at a walking distance every 30 meters. For a 90-meters transect, 3 continuous

measurements are needed while walking the transect (see sampling scheme in Figure 1).

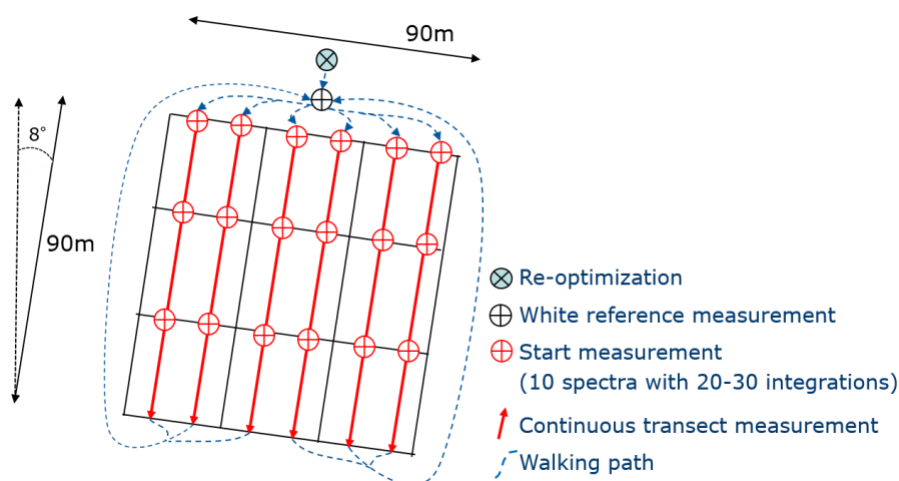


Figure 1. Example of the recommended sampling layout in the Northern Hemisphere that divides a 3x3 EnMAP pixel neighborhood into the 6 x 90 m transects, with transects and measuring points spaced ~12.8 m apart. Measurements are conducted walking into the sun (walking south).

Summary of the sampling layout:

- Transects should cover an area that represents a 3x3 pixel (90x90 m) neighborhood (sensor geometry)
- Orientation congruent to orbit inclination (8° degrees)
- Divide the area into 6 transects (each ~12.8 meters apart)
- Before every single transect, a re-optimization and a white reference panel measurement must be performed
- The white reference measurement should be saved at the start of the transect (as well as the end if time permits)
- A single transect consists of the collection of 3 measurements with 10 spectra respectively, each with 20-30 integrations per spectra
- Transects and white reference panels should be measured by walking/standing perpendicular to the sun alongside the transect/panel (to avoid and minimize shadowing and adjacency effects)
- Walk at a constant pace along the transect, which fits with the duration of a single measurement (10 spectra with 20-30 integrations) and the distance of 30 m (representing a single EnMAP pixel)
- If time permits a white reference panel measurement should be performed after a transect measurement to track the variation of the instrument or the atmospheric conditions during.

To meet all these requirements, the test field should be prepared for a fast and smooth measurement by dividing it sufficiently in advance. Not all points can be considered equally depending on the validation site specifications and atmospheric conditions. The best intermediate solution should be chosen to achieve the best possible result. For example, if the orientation of the transect parallel to the orbit inclination transect orientation is not feasible, the transect length, starting, and endpoints must be adapted to meet the 3x3 pixel neighborhood requirement. If site characteristics require alterations to the sampling method then, the overall pattern should be changed, and deviations shall be noted on the logging sheet.

3.3 Setting up ASD device

The following settings are required have to be set up for the ASD device before measurement:

- Reflectance mode
- Dark current averaging: 20-30 (if the unit has a mechanical shutter)
- Spectrum averaging: 20-30
- White reference averaging: 30
- Absolute reflectance (if possible process out the panel reflectance factor/calibration to give absolute reflectance or supply the spectral response of the white reference)
- Number of files to save: 10
- Time between saves: 0 sec
- New file format
- UTC Time should be accurately set on the laptop controller
- GPS should be connected (wirelessly or by cable) to the laptop controller and the setting activated
- Fore optic set to e.g. 8°
- Filename and file path (see 4.3)

4 Detailed Data Acquisition Procedure Using an ASD FieldSpec

Carry out measurements as fast as possible and close in time (maximal +/- 1 hour) to the overpass of EnMAP (Local time descending node: 11:00 h \pm 18 min). If trampling of the surface material (e.g., vegetation, soil) is an issue, consider starting the measurement shortly after the overpass of EnMAP (as long as the illumination changes and atmospheric/conditions allow it). Ideally, a helper should be in constant communication with the operator to assist in maintaining the transect, pace, height, and orientation of the measurement as well as taking notes.

The following measurement procedure should be applied to every validation site:

4.1 Preparing the ASD Fieldspec at the site:

1. Switch on the ASD first and allow for a warm-up time of at least 30 min - 1h (a two-hour warmup is optimal; swap battery quickly to a fresh one 10 minutes before starting collection)
2. Switch on the laptop (necessarily only after the ASD) and GPS
3. Establish/check successful laptop connection to the ASD and GPS
4. Wear dark clothing.
5. Set up your instruments: Mount the white reference panel on the tripod without touching the panel's surface. The panel should be mounted at least at the same height as the measured surface, a maximum of 1 meter above it, and leveled with care using the attached bubble level. Note: the setup of the white reference panel is a sensitive step. If not properly leveled, uncertainty on the measurements up to 0.8% per degree (see [8]) is introduced. Choose a spot not affected by adjacency effects (no objects nearby) and keep the setup the same throughout the before finishing the whole sampling process. Place the fibre optic in the pistol grip and make sure it is securely seated before putting on the foreoptic. Place the pistol grip on the end of monopod.
6. Start filling in the logging sheet

4.2 Configuring the instrument

For setting up the ASD Instrument device, see section 3.3

4.3 Measurement

The measurement process for each validation target:

1. Set-up of the spectrum save (Menu: Control → Spectrum Save):
 - a. Create a folder for today's acquisition in the structure:
"SiteName_DDMMYYYY_LAT_LON"
The root folder structure for the spectra is: *\EnMAP_val\[today's_acquisition]
 - b. Set the base filename according to your nomenclature of the validation site or type (e.g., if you are measuring grass → "t1_grass" t1 = target1, then if you measure sand → "t2_sand")
 - c. Set the number of files to save to 10
 - d. Ensure the checkbox "Save As New File Format" is checked.

2. Switch to **Reflectance mode and 8-degree foreoptic**: Make sure that it says 'Reflectance' and not 'Digital Numbers' or 'Radiance' in the scroll-down menu (RS3 GUI, see figure 2). Also make sure that the appropriate foreoptic is set.

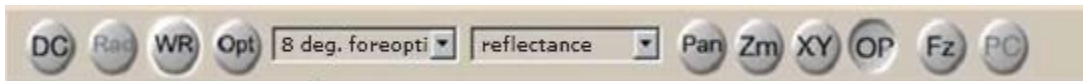


Figure 2: RS³ GUI

The measurement process for each transect:

3. Before the actual measurements start, make sure to minimize the following potential operator errors:
 - The operator's position should be perpendicular to the sun azimuth (sun principal plane)
 - The sensor entrance fore optic must point nadir (help by using bubble level)
 - Operate using the monopod or at least an arm's length (as far away from the panel as possible)
 - The distance of the sensor entrance (fiber fore optic cable tip) to the panel should be determinable and be the same for each white reference measurement (shadowing and reflection of your pistol grip must be avoided; make sure that the projected footprint is sufficiently smaller than the size of the white reference).
 - The non-operator/note taker should assist the operator with sighting up the positioning and horizontal orientation of the foreoptics via verbal communication as much as possible
4. Place the fore optic sensor entrance above the white reference.
5. **Optimize the instrument (Press OPT button)** over the white reference panel (unless your target is brighter than the WR). **Take note that an optimization was collected on the log sheet.**
6. **Acquire the white reference panel (Press the WR button):**
 - In relative reflectance mode wait until a horizontal line (except for the water bands) is displayed for the white reference measurement (y-axis = 1 → 100% reflectance).
 - In absolute reflectance mode, it won't be a flat line. It will have the spectralon feature at ~2200 nm in it and trailing off in the 2500 nm region.

After a successful WR measurement, the axis scale should have changed from DN to reflectance [0, 1]. **Press the space button to save the WR calibration** (10 spectra should be saved). Check that the name of the next spectra will be numbered 010). **Take note that a white reference measurement was performed and the collected spectrum numbering on the log sheet.**

7. Acquire a transect:
 - During a single measurement (space bar push or remote trigger), the operator should cover 30 meter of a transect. A single complete transect of 90 m is thus covered with 3 measurements (pushes of the spacebar/remote trigger)
 - Acquire measurements at approximately 1 m distance: projected footprint of bare fiber (25°) from 1 m distance is approximately 40 cm in diameter (or 14 cm using the 8° fore optic)
8. Take a return track outside the transect area. If time is critical, return to the white panel along the same path to minimize foot prints within the scene and collect measurements of the white panel.
9. The operator should communicate with the note taker the numbers and sequences of spectra they have collected as well as missed spectra or measurement errors at the end of the transect and after measuring the white reference. This should be noted down on the log sheet along with any changes in the atmospheric and environmental conditions.
10. Starting again at point 5 above until all transects are completed.

The measurement process for each validation target:

11. Take **pictures** of the target (from the side and one picture nadir), environment, sky, etc. (all as indicated on the logging sheet).
12. Write down the file name.
13. Take a general **GPS** reading of the target center
14. Complete the Campaign Protocol Document of this site for the current target
15. Shutting down the equipment:

!! IMPORTANT NOTE !!

When closing the RS³ software, wait until it closes completely (takes a couple of seconds), wait another 5 seconds, and then switch off the ASD.

→ Failing to follow this procedure, the ASD's internal memory can go corrupt since RS³ is writing a small log file onto the ASD upon closing the program. Alternatively, switch off the ASD first and then close the RS³ software. In this case, the software skips writing the log file.
16. Post-processing (see 4.4)
17. Hand over data and logging sheet to GFZ (enval@gfz-potsdam.de).

4.4 Data Format and Post-processing

The measured data should be processed with, e.g., ViewSpec Pro software. The acquired spectral validation data should be delivered in a *.txt with the file name convention: "SiteName_DDMMYYYY.txt". In addition a *.csv file with spectra name, Well Known Text (WKT) coordinate (Lat/Lon in WGS 84), Aerosol optical thickness (AOT), and column water vapor (WV in cm) (if available and measured by a helper with a Microtops II Sun Photometer) of every spectrum should be written in the same order as included in the spectral library should be delivered. The *.csv should follow the name convention and the structure shown in Figure 3.

```
spectra names;wkt;AOT;WV
AP1;Point (35.3714588 31.0681266);0.2;2.0
AP2;Point (35.3714588 31.0681266);0.2;2.0
AP3;Point (35.3714588 31.0681266);0.2;2.0
AP4;Point (35.3714588 31.0681266);0.2;2.0
```

Figure 3. *.csv file with spectra names, Well Known Text (WKT) coordinates, and, if available, AOT and WV

In addition, all ASD raw data (*.asd), the GPS log file (*gps.log), and calibration files of the instrument and the white reference named after the mentioned name convention should be made available to enable reprocessing of the data if necessary.

The post-processing should include the visual and statistical inspection, consistency, and plausibility check of the measured spectra and the assigned Latitude/Longitude (WGS 84) coordinates. Incorrect spectra, including the corresponding GPS measurement, should be sorted out. Any GPS offsets/inaccuracies should be corrected based on high-resolution reference data. These steps are essential for the validity of the reference measurement and should be done by someone familiar with the measurements and the respective site. The EnMAP Box spectral library capabilities can help with these tasks by supporting advanced metadata handling.

Please compress the data in the following structure: "SiteName_DDMMYYYY" --> Logging sheet + spectral library + Subfolders (RAW, PICTURE) and send the zip file to enval@gfz-potsdam.de.

5 Bibliography

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6 Quick Field Guide for In-Situ EnMAP Validation Measurements

6.1 General Preparation preparation for field measurements

1. Read the guide and logging sheet.
2. Choose a validation site and check its accessibility.
3. Check the EnMAP overpass date and time for your area of interest.

6.2 Day before field measurements

1. Gather equipment (see Section 3.1).
2. Charge the batteries of the laptop, field spectroradiometer, GPS & camera (also spare batteries).
3. Make sure the white reference panel is clean. It may just need a blow with clean air, or a gentle wash with clean (demineralized) water. However, if heavily soiled, it may not be suitable to use without the proper sanding under running clean (demineralized) water.

6.3 Day of field measurement

1. Depending on your field spectroradiometer, let it warm up sufficiently (minimum of 30-60 minutes).
2. Carry out measurements max+/- 1h of the satellite overpass.
3. Wear dark clothing.
4. Start with filling in the logging sheet.
5. Set up your appliance instruments and field spectroradiometer:
 - a. Mount the white reference panel on the tripod without touching the panel's surface.
 - b. The clean panel should be mounted at the same height as the measured surface and maximal 1m above it and leveled with care using the attached bubble level.
 - c. Choose a spot not affected by adjacency effects (no objects nearby).
 - d. (optional) Attach the monopod to your pistol grip and, optionally, the fore optic.
6. Acquisition of a transect:
 - a. Set up the ASD device (see Setting up ASD device for Parameters)
 - b. Acquire the spectral data in the **reflectance** mode of your instrument (not radiance).
 - c. Before the actual measurements start, make sure to minimize the following potential operator errors:
 - i. The operator's position should be perpendicular to the solar principal plane.
 - ii. The sensor aperture must point nadir (help by using bubble level).
 - iii. (optional) Operate the monopod standing as far away from the panel as possible. The person not operating the ASD should help with positioning the operator over the panel and give verbal instructions so it is positioned in the center, looking nadir and at the correct height.
 - iv. For white reference measurements, the distance of the sensor aperture to the panel should be the same for each white reference measurement (preferably between 10 and 20 cm distance to the panel).
 - d. Before every transect, perform a re-optimization and a white reference panel measurement
 - e. Acquire **6 Transects (every transect with 3 single continuous measurements) → walk at a constant pace along the transect which fits with the duration of a single measurement (10 spectra with 20-30 integrations) and the distance of 30m (representing a single EnMAP pixel)**
 - f. For every single transect, make sure:
 - i. The operator's position should be perpendicular to the solar principal plane.
 - ii. The sensor aperture must point nadir (help by using bubble level).
 - iii. Acquire measurements at approximately 1 m distance to the target (according to sensor FoV).
 - iv. Make sure only intended, and representative information gets into the stored spectra.
7. Take a **picture** of the target, environment, etc. (all as indicated on the logging sheet).
8. Estimate and describe (or measure) the atmospheric conditions.
9. Write down the file name (logging sheet).
10. Take a **GPS** reading representing the target center.

→ complete the logging sheet document of this site for the current target.

6.4 Post-processing of the Field Data

1. Renaming, quality assessment, removal of bad spectra and zipping up
2. Hand over data and logging sheet to GFZ.

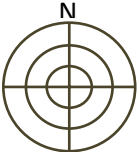
7 Items checklist for spectroradiometric field measurements

- Field spectroradiometer (recently calibrated) (350 – 2500 nm)
- Charged Battery for Spectroradiometer (+ one spare = 2 in total)
- Charged Laptop (+ one spare Laptop battery = 2 in total)
- Battery cable

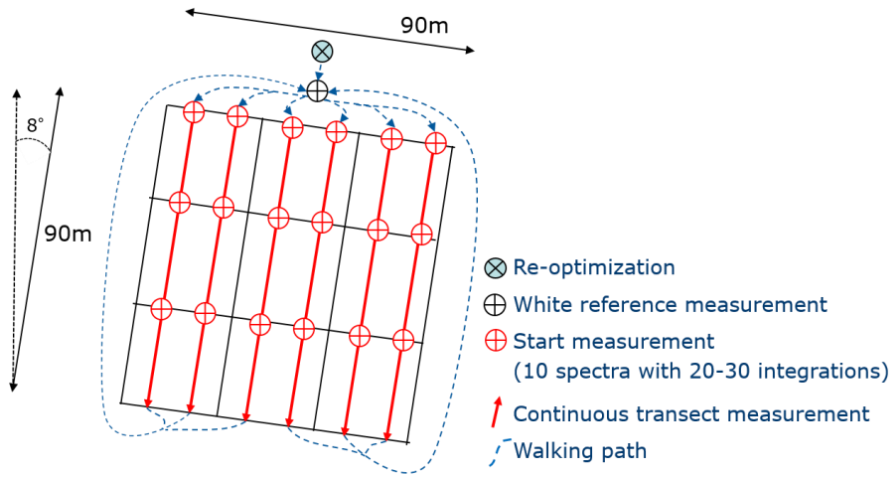
- Shielded LAN cable if not using wireless connection to the ASD
- Pistol Grip preferable (with bubble level attached)
- Laptop carrier table (“belly board”)
- Backpack for spectroradiometer
- Clean, non-scratched, recently calibrated white reference panel. If if possible, with bubble level
- Tripod with an adjustable head, with bubble level. A mount for the panel to the tripod may need to be constructed.
- Logging sheet
- Pen + spare
- GPS (and cable to PC if not wireless)
- Camera (Smartphone is fine)
- Wear dark clothing preferably of natural fibers (and not reflective)
- Fore Optic (e.g. FOV 8°)
- (optional) Monopod (1 m) to operate pistol grip with a bubble level to indicate horizontal positioning
- (optional) dust blower
- (optional) Square meter quadrat for taking standard photos of the target surface

Logging sheet

Date [DDMMYYYY]		Start Time	
Team		End Time	
Site Name		<input type="checkbox"/> Local time	<input type="checkbox"/> UTC
Latitude/Longitude		Weather at start	
File Name		Photo Nr.	
Instrument Type/Name:		<input type="checkbox"/> Absolute reflectance	<input type="checkbox"/> Relative reflectance
Serial number		Calibration number	

Target Details:	<p>Target Type:</p> <p>File Name:</p> <p>Target Condition:</p>
Weather:	<p>Sky conditions: <input type="checkbox"/> 0% (clear sky) <input type="checkbox"/> 10% <input type="checkbox"/> 20% <input type="checkbox"/> 30% <input type="checkbox"/> 40% <input type="checkbox"/> 50% <input type="checkbox"/>[%]</p> <p>Visibility: [km] AOT: [] CWV:[] Cloud position: </p> <p>Cloud types: <input type="checkbox"/> [Ci] <input type="checkbox"/> [Cb] <input type="checkbox"/> [Cu] <input type="checkbox"/> [St] Cirrus Cumulonimbus Cumulus Stratus</p>
Setup:	<p>Sensor:</p> <ul style="list-style-type: none"> • Warmed up time: [min] • <input type="checkbox"/> 8° or <input type="checkbox"/> 25° Fore Optic / <input type="checkbox"/> Bare Fibre • Sensor monopod mount? <input type="checkbox"/> Yes → length: [cm] <input type="checkbox"/> No • Averaging: Dark current White reference Spectrum <p>White reference:</p> <ul style="list-style-type: none"> • Tripod mounted and leveled once? <input type="checkbox"/> Yes <input type="checkbox"/> No • Sensor – panel distance: [cm] • Panel size: [cm] • Condition of white reference: <input type="checkbox"/> like new <input type="checkbox"/> traces of use <input type="checkbox"/> heavily used <p>Transects:</p> <ul style="list-style-type: none"> • Sensor – surface distance: [cm] • Recommended sampling pattern applied? <input type="checkbox"/> Yes <input type="checkbox"/> No → Please specify on page 2 • Congruent to orbit inclination (8° degrees)? <input type="checkbox"/> Yes <input type="checkbox"/> No → Azimuth: [deg]
Notes:	

Sampling pattern:



Notes:	
--------	--

Transect num.	Base file name (SiteName_DDMMYYYY):		Comment
	Start (file count)	End (file count)	
1			
2			
3			
4			
5			
6			