User's Guide
Mars™ Soiling Sensor

Document Number 880060 Rev. D1, November 2021

ATONOMETRICS

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1 Product Overview

The Atonometrics Mars™ Soiling Sensor, shown in **Figure 1-1**, is a revolutionary product that provides simplified measurement of soiling losses for PV installations. Patented Mars™ technology detects accumulated soiling on a soil collection window using an internal camera. The Mars™ unit requires no water, has no moving parts, is compact and easy to install, and does not require site-specific dust calibration or technician service visits. It is specifically designed to be suitable for a wide range of PV installation types, including small commercial and industrial projects.

The Mars™ unit has two options for digital communication. An M12-connectorized Ethernet port provides for simple setup, configuration, and status checks using a networked PC with a web browser, as well as output data via Modbus TCP. An M12-connectorized RS-485 port is also provided which may be used for output data via Modbus RTU.

The Mars™ unit and cable connections are IP67-rated for weather protection and the product is built in a cast aluminum enclosure that provides for solid mounting.

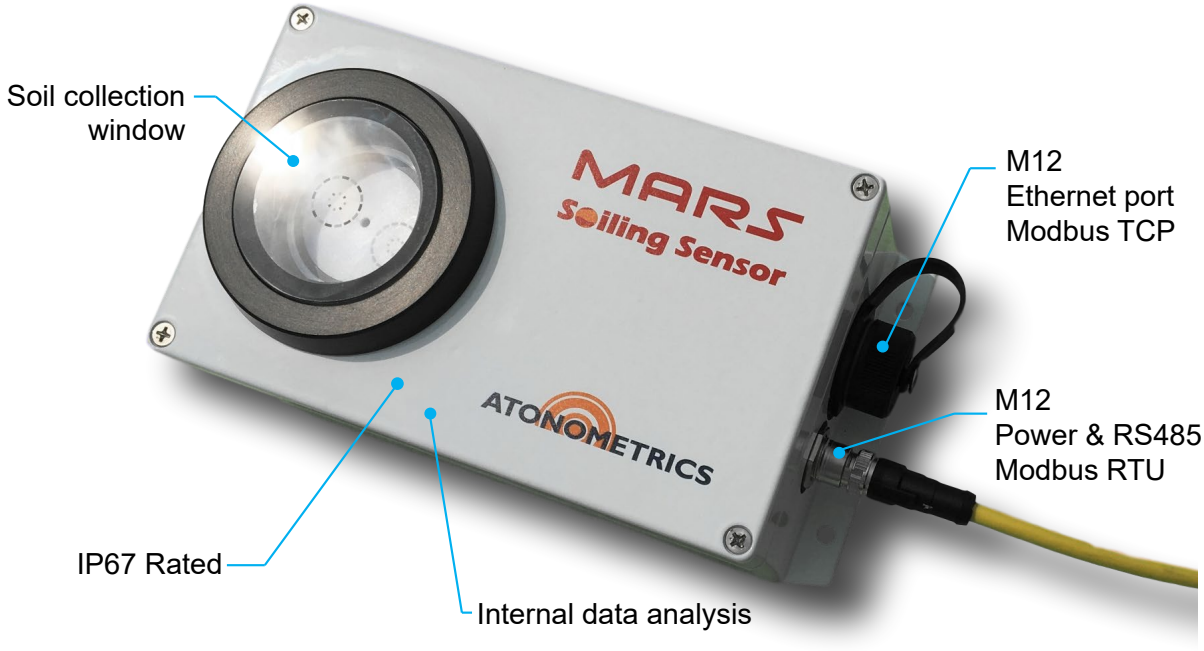


Figure 1-1: Mars™ Soiling Sensor (810230)

2 Configuration

2.1 Get the Latest Firmware

Before starting configuration, visit the Atonometrics support website (support.atonometrics.com) and download the latest version of the Mars™ firmware corresponding to your Mars model number and the latest User Guide (this document).

2.2 Configuration Kit

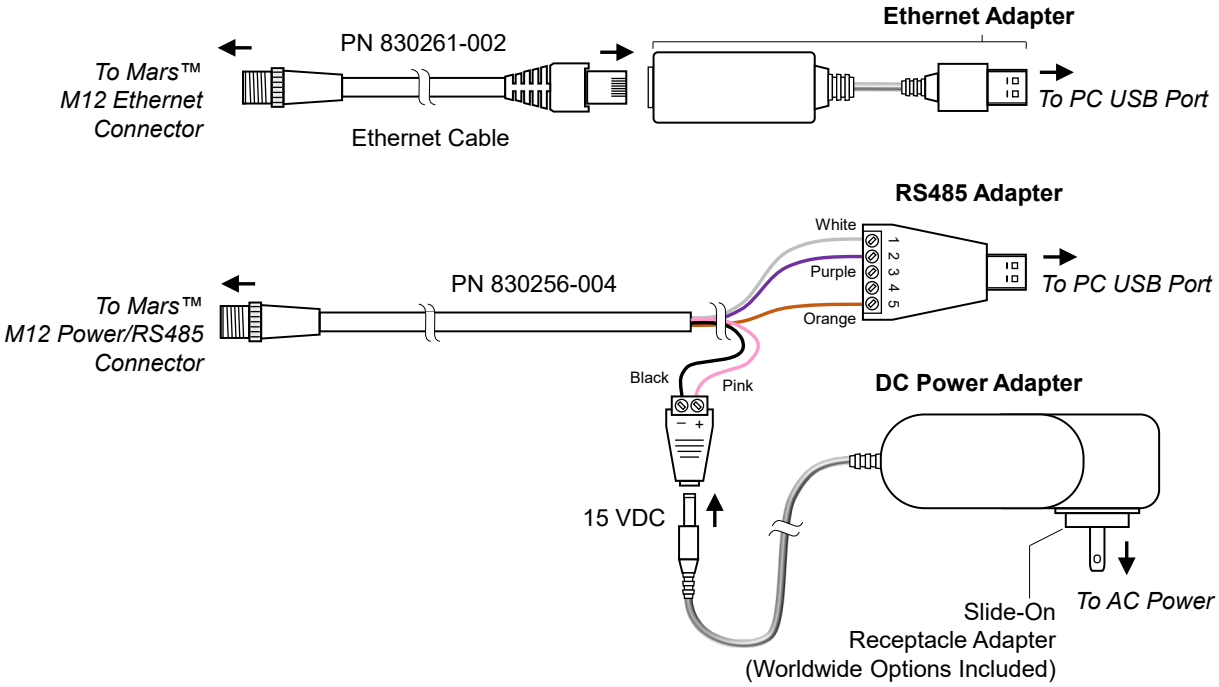
The optional Configuration Kit (810235-01, sold separately) allows you to conveniently power your Mars™ unit while you perform configuration via Ethernet and, if desired, test communication over the RS-485 port. The kit, shown in **Figure 2-1**, contains everything needed to connect your PC to the Mars™ unit, including a power adapter (AC to 15 VDC) with slide-on worldwide receptacle adapters, an Ethernet-to-USB adapter, an Ethernet cable, an RS-485 to USB adapter, and a cable for connecting power and RS-485 to your Mars™ unit. An M12 to RJ45 Ethernet cable is also included with each Mars™ unit for connection to the M12 Ethernet port (on SN15000 and higher).

To assemble and install the kit:

- Select and install the receptacle adapter appropriate for your country
- Insert the 15 VDC plug into the Mars™ cable assembly
- Connect the Mars™ cable assembly to the Mars™ unit
- Connect the M12/RJ45 Ethernet cable to the Ethernet-to-USB adapter and to the Mars™ connector; insert the adapter into one of your PC's USB ports; allow Windows to detect the adapter and automatically install its driver; configure the adapter address to 10.244.69.1
- If desired, insert the RS-485-to-USB adapter into one of your PC's USB ports; allow Windows to detect the adapter and automatically install its driver, or install the driver from the CD included in the kit
- Connect the power adapter to AC power

Note: The Configuration Kit is optional. You may duplicate the functions of the Configuration Kit with user-supplied equipment, or using cables prepared for your installation site.

Note: Installing the RS-485-to-USB adapter is only needed for testing Modbus RTU over RS-485. The configuration kit does not include software for this purpose. Use your own or third-party Modbus software.



The 830261-002 cable is provided with each Mars unit, not with the 810235-01 configuration kit.

Figure 2-1: Configuration Kit 810235-01 (sold separately)

2.3 Accessing the Web Interface

After power up, the Mars unit's soil collection window will light up for a short time and then will go dark. Wait 2-5 minutes for initialization to complete.

Configuration is performed by accessing the unit's internal web interface from your PC using a web browser, such as Chrome, Firefox, or Internet Explorer.

Launch the web browser on your PC and enter the Mars™ IP address (default = 10.244.69.66). You will then see the Mars™ web interface shown in **Figure 2-2**.

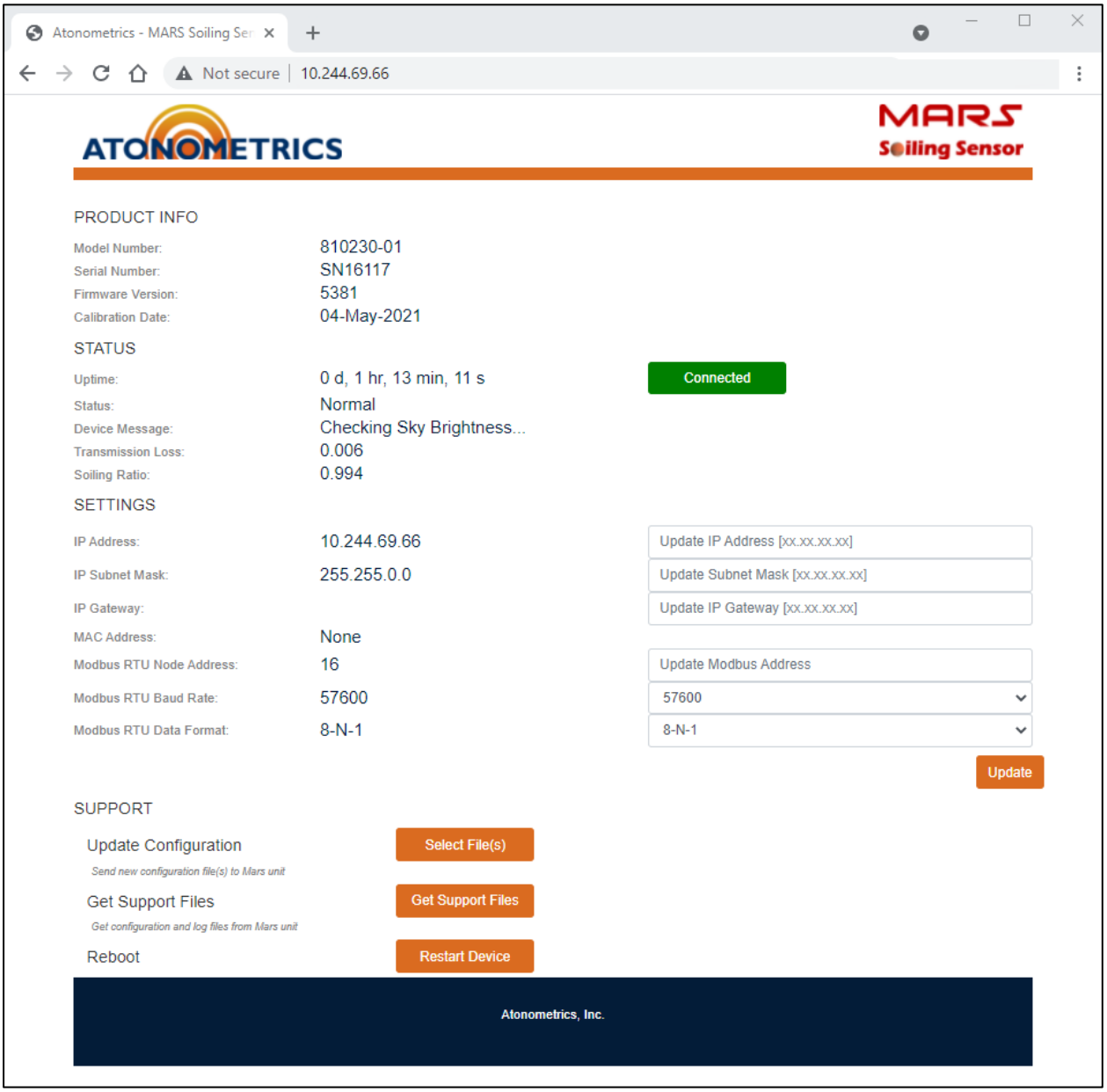


Figure 2-2: Web interface

Note: If needed, configure the Ethernet adapter (either the USB-Ethernet adapter supplied with the Configuration Kit, or the Ethernet adapter on your PC) to operate on the same subnet as the Mars™ unit. The unit's default IP address upon shipment from Atonometrics is 10.244.69.66. Therefore, set your Ethernet adapter to 10.244.69.XX, where XX is any unused node (not .66). For instructions, consult Windows documentation or related help. When configuration is complete, return your PC's IP settings to their previous values.

Note: If the IP address of your Mars™ unit has been changed from the factory default, use the appropriate subnet and address corresponding to the Mars™ unit on your Ethernet adapter.

Note: If the IP address of your Mars™ unit is unknown, visit support.atonometrics.com and download the Mars IP Address Discovery Tool. Instructions are provided with the software tool to help you recover the unit's IP address.

2.4 Configuration Steps

2.4.1 Updating the Firmware

Your unit's current installed Firmware Version number is shown near the top of the web interface (**Figure 2-2**). If the version you downloaded in Step 2.1 is newer, update the firmware before proceeding.

To update the firmware, press "Select File(s)" next to "Update Configuration" near the bottom of the web interface. Following the prompts that will appear, select the previously downloaded firmware update file and transmit it to the Mars™ unit.

Note: The firmware file is transmitted directly to the Mars™ unit and is not user-openable, even if it has a .zip format.

Note: On firmware version R5381 and higher, it is no longer required to enter Latitude or Longitude or to set a Clock on the unit. If your unit is displaying entries for these parameters, update your firmware to the latest version.

2.4.2 Setting IP Address, Subnet Mask, and Gateway

Your Mars™ unit's default IP address upon shipment from Atonometrics is 10.244.69.66.

To change your Mars™ unit's IP address, enter the new address, as well as any desired subnet mask and gateway, using the web interface (**Figure 2-2**), then press "Update".

After setting the new IP address:

- Adjust the subnet of the Ethernet adapter on your PC, if required, to match
- Update the Mars™ IP address entered into your web browser
- Refresh your web browser to confirm that the new address is properly set.

2.4.3 Setting Modbus RTU Settings

If you will be using Modbus RTU for communication over RS-485, configure the Modbus RTU settings. Otherwise, you may leave these settings at their default values.

Modbus Node Address

- The unit's default node address for Modbus RTU upon shipment from Atonometrics is 16.
- To change the node address, enter the new address using the web interface (**Figure 2-2**), then press "Update".
- Node addresses from 1 to 247 are allowed.

Baud Rate and Data Format

- From the web interface you may also select the serial communication parameters for baud rate and data format.
- Supported baud rates are 9600, 19200, 38400, 57600, and 115200.
- Supported data formats are 8-N-1, 8-N-2, 8-E-1, and 8-O-1.
- To change the settings, select the new values and press "Update".

2.4.4 Checking Status

Check the Status field on the web interface (**Figure 2-2**) and confirm it reads "Normal". If an error condition is shown, confirm all configuration settings. If the error persists, contact Atonometrics for support.

The "Device Message" portion of the web interface will indicate current operations of the unit, including checking sky brightness, waiting, and acquiring data.

Note: Upon initial shipment, the Transmission Loss and Soiling Ratio fields will read the last measured values recorded during factory test; these will correspond to clean glass with near 0 loss. These fields will update once the unit is deployed outdoors in its installation location overnight.

2.5 Checking Communication

For an example and guidance on checking Modbus communication using third-party software in your data logger or SCADA system, see the Atonometrics application note document 880084 "Testing Modbus Communication on the Mars™ Soiling Sensor", available at support.atonometrics.com.

Note: Reading a value of NAN for Transmission Loss and Soiling Ratio is not a communication error condition. This value confirms that communication is correct but indicates that a measurement value is not available. The measurement value should update once the unit is deployed outdoors in its installation location overnight.

3 Wiring

3.1 Power

The Mars™ unit requires 10-30 VDC and draws ~2.5 W of average power. However, it may draw up to 6W on a transient basis.

Note: When using long power cables, consider the effect of voltage drop along the cable and ensure that the Mars unit will receive at least 10 VDC at up to 6W of power draw.

3.2 Cable Options

Each Mars™ unit is supplied with the following:

- An M12 connector (160375-02) for user assembly of the power/RS-485 cable using user-supplied wiring material.
- A two-meter RJ45 to Mars™ M12 Ethernet cable (830261-002) for configuration and testing.

Complete cable assemblies are available from Atonometrics, sold separately. See Section 3.3.

Instructions for making user-supplied cables are provided in Section 3.4.

Note: **Use only Atonometrics-supplied connectors or cable assemblies.** Although other connectors may appear to fit, use of non-approved components may result in water penetration

Note: **Atonometrics recommends using Ethernet vs. RS-485 when possible,** since Ethernet enables remote configuration and status checks via the web interface, in addition to data acquisition via Modbus TCP.

Note: Units with serial number less than 15000 have a sealed RJ45 Ethernet connector on the Mars™ unit instead of an M12 connector.

WARNING: **Check all wiring before turning on power. Incorrect wiring may damage the unit and/or your other equipment.**

3.3 Atonometrics-Supplied Cables

Options for Atonometrics-supplied cable assemblies are listed in **Table 3-2**, with wire colors for the 830256 M12 power and RS-485 cable shown in **Figure 3-1**.

Note: Atonometrics-supplied 830256 M12 power and RS-485 cables include additional wires that are not used for the Mars™ product. See Section 3.5.

Note: Atonometrics-supplied 830261 Ethernet cables will have **one sealed M12 connector** for connection to the Mars™ unit. The other end of the cable will include a **non-sealed RJ45** for cable testing purposes. Remove this and use a user-supplied cable gland or sealed connector for installation to your outdoor equipment cabinet.

Table 3-1: Atonometrics-supplied cables (sold separately)

Length	M12 Cable Power & RS485	M12 Cable Ethernet
4 m	830256-004	830261-004
10 m	830256-010	830261-010
25 m	830256-025	830261-025
50 m	830256-050	830261-050
100 m	830256-100	n/a

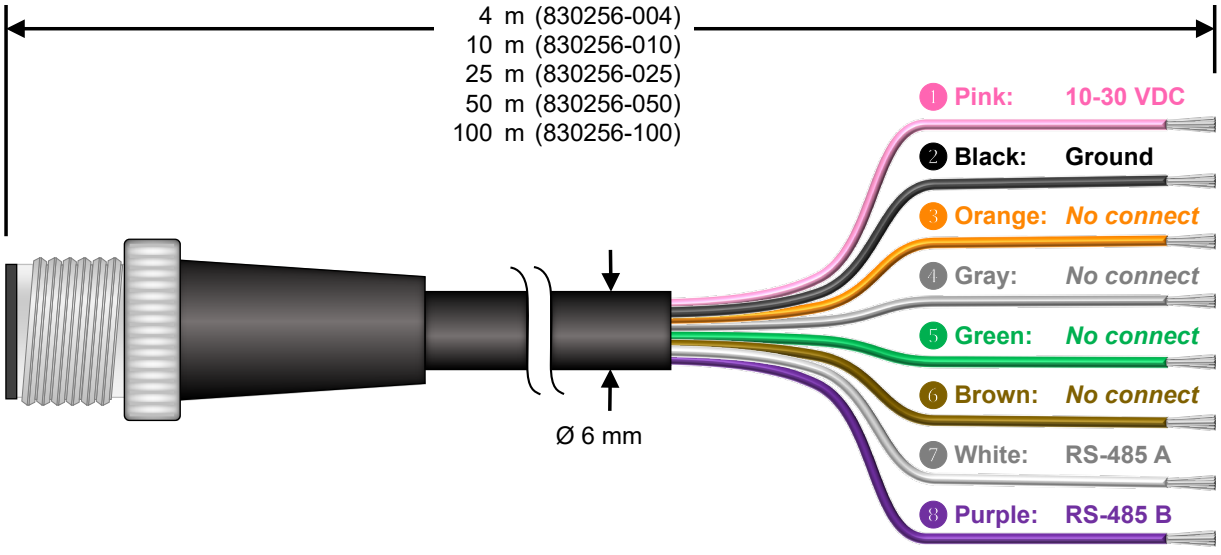


Figure 3-1: Wire colors for 830256 M12 power & RS485 cable

3.4 User Assembly of Power & RS-485 Cable

In place of purchasing a complete power & RS485 cable from Atonometrics, you may optionally assemble this cable using user-provided wiring materials as listed in **Table 3-2** and **Figure 3-2**.

Note that each Mars unit is shipped with a 160377 connector for user wiring.

Table 3-2: Materials for user-assembled power & RS485 cable

Item	Atonometrics Part Number	Cable Requirements
Power & RS485 M12 Connector 8 pins (Sealed, IP67)	160375-02	2 conductors (power only) or 4 conductors (power & RS485) Outer diameter 6-8 mm 20-24 AWG / 0.20-0.52 mm^2 *Example: Belden 5502G1*

For wiring the power & RS-485 M12 connector, use the pinout shown in **Figure 3-2**. Note that the view is facing the connector on the Mars™ unit from the outside.

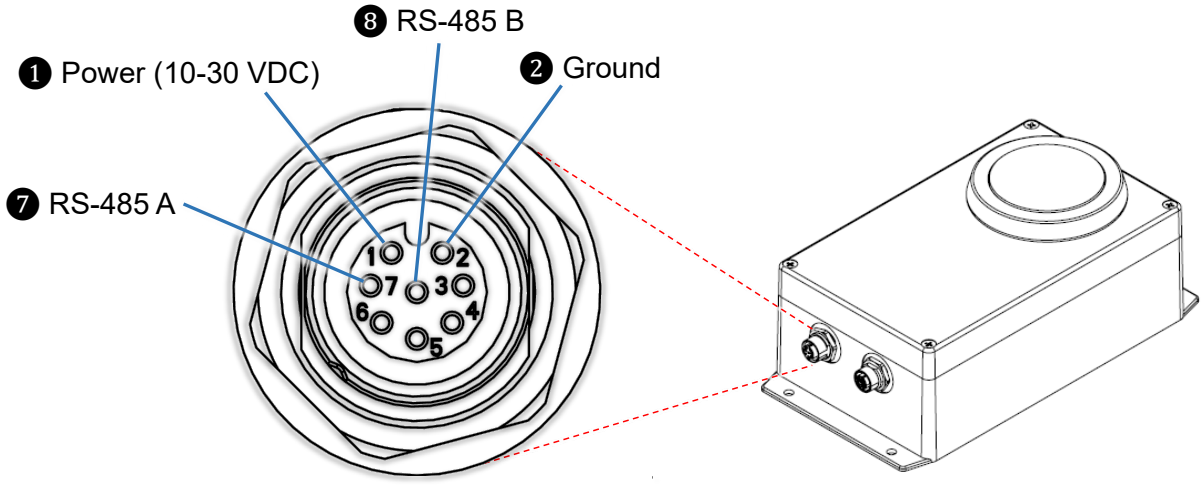


Figure 3-2: Pinout of Power & RS-485 M12 connector

3.5 Protecting Unused Wires

Protect any unused wires from accidental contact by cutting to unequal lengths, folding back, and insulating, as shown in **Figure 3-3**.

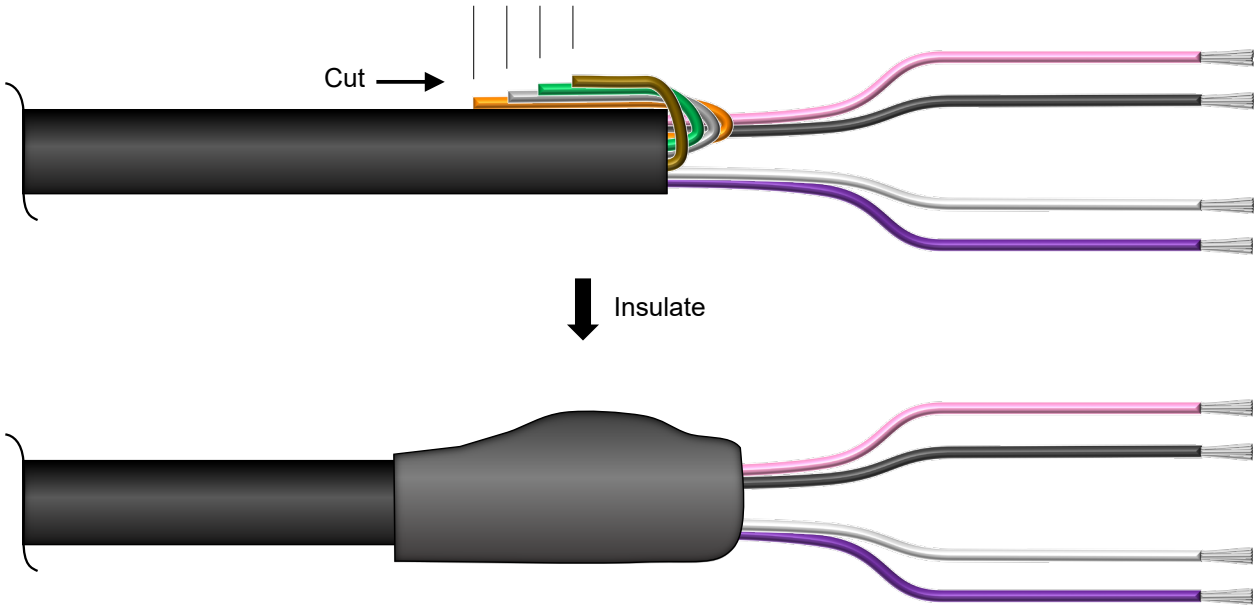


Figure 3-3: Protecting unused wires from accidental contact

4 Mounting

4.1 Mounting Requirements

Mount the Mars™ unit in the plane of array of your PV modules, choosing a location where the unit will have a clear view of the sky within a cone at least ± 30° from the normal, as shown in **Figure 4-1**

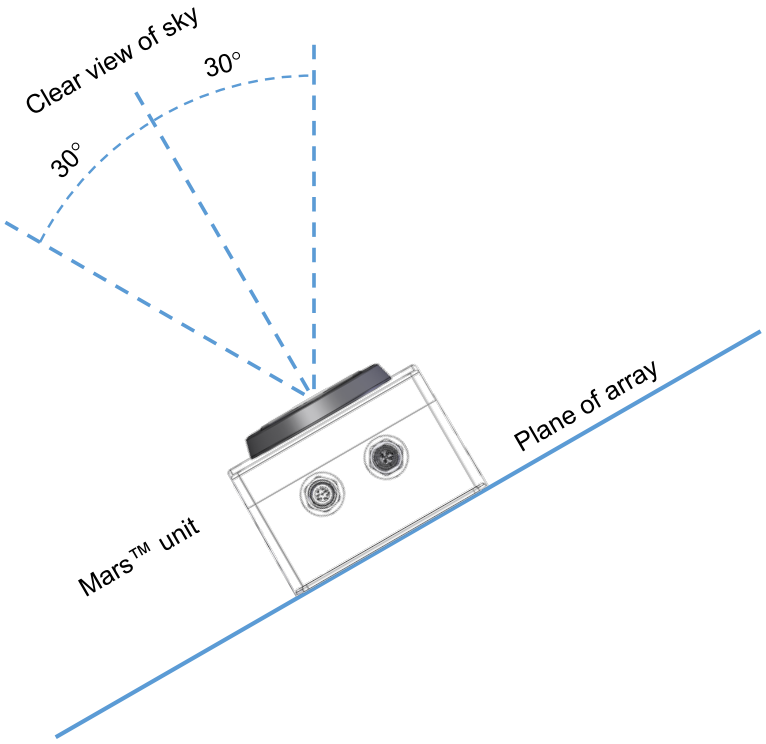


Figure 4-1: Mounting requirements and view of sky

To mount the Mars™ unit, use the four mounting holes on the flange of the unit shown in **Figure 4-2.**

To minimize the potential for water entry to the sealed housings, always mount the Mars™ unit with the cables facing down or to the side, as shown in **Figure 4-3**, and never with the cables facing up.

See **Figure 4-4** for dimensions.

Note:	Do not remove the screws on the top cover of the unit, as this may compromise the weather-proof seal. Removing the screws will void the warranty.

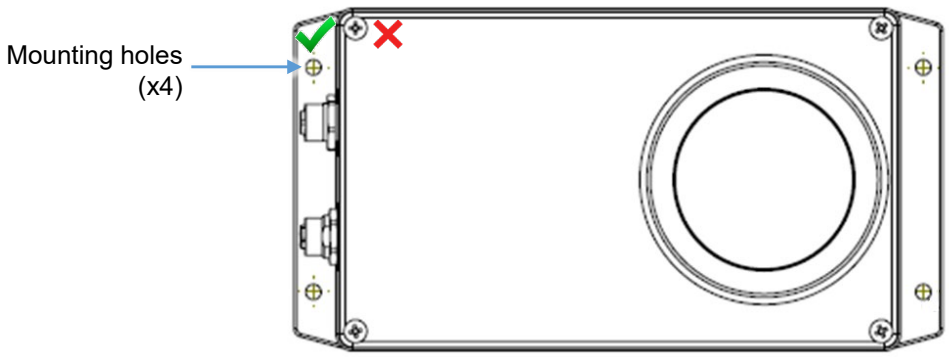


Figure 4-2: Mounting holes

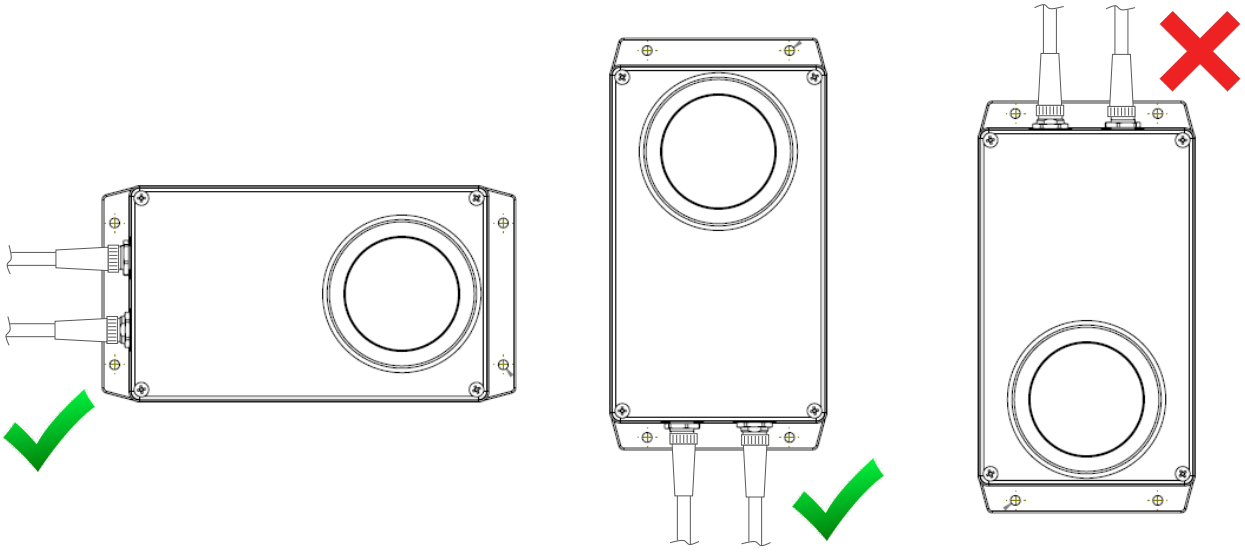


Figure 4-3: Mount with cables down or to the side

4.2 Dimensions

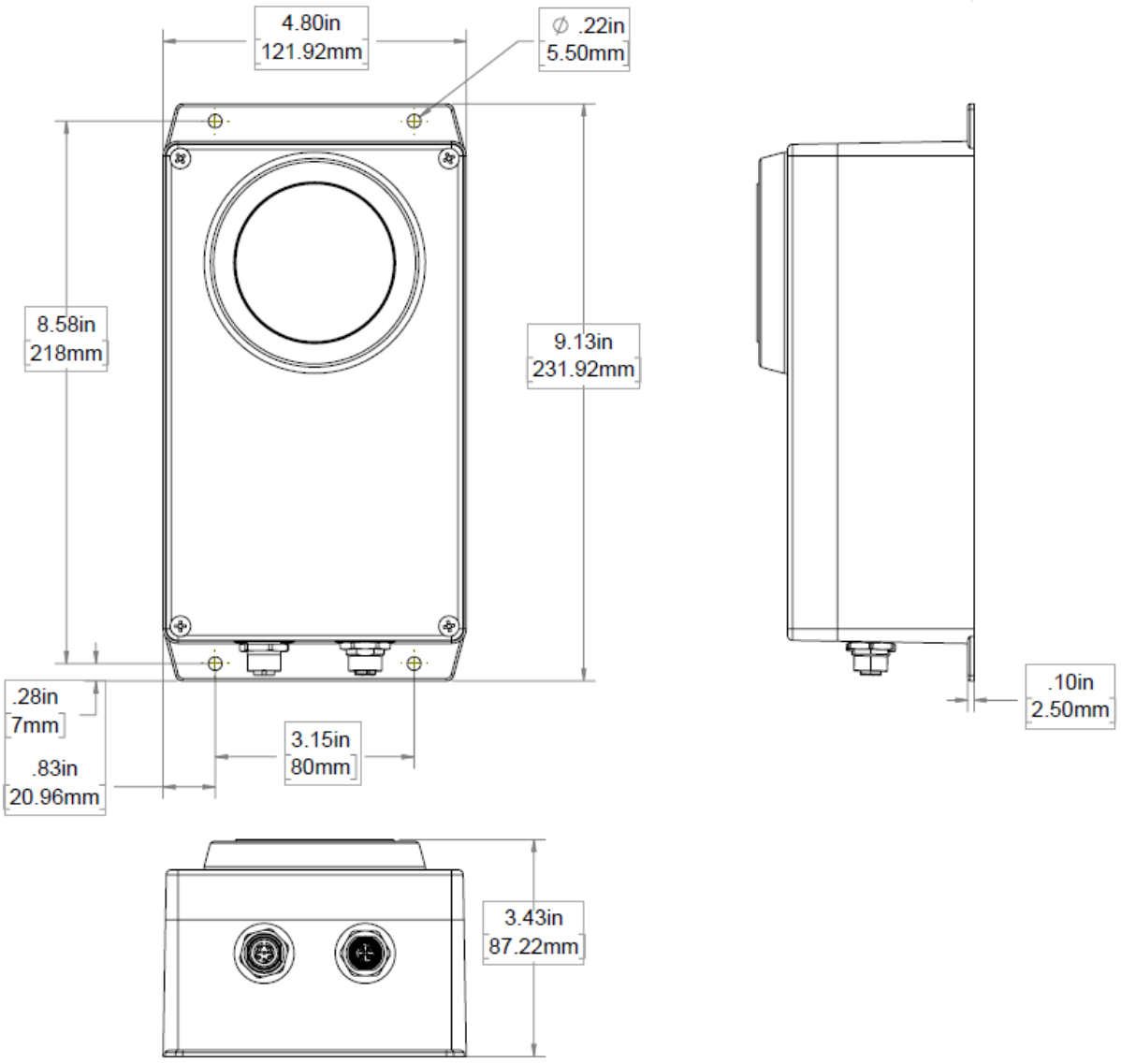


Figure 4-4: Mars™ dimensions

4.3 Mounting Accessories

Optional flat plate, right-angle, and pole-mountable adjustable-angle mounting accessories are shown in **Figure 4-5**, **Figure 4-6**, and **Figure 4-7**.

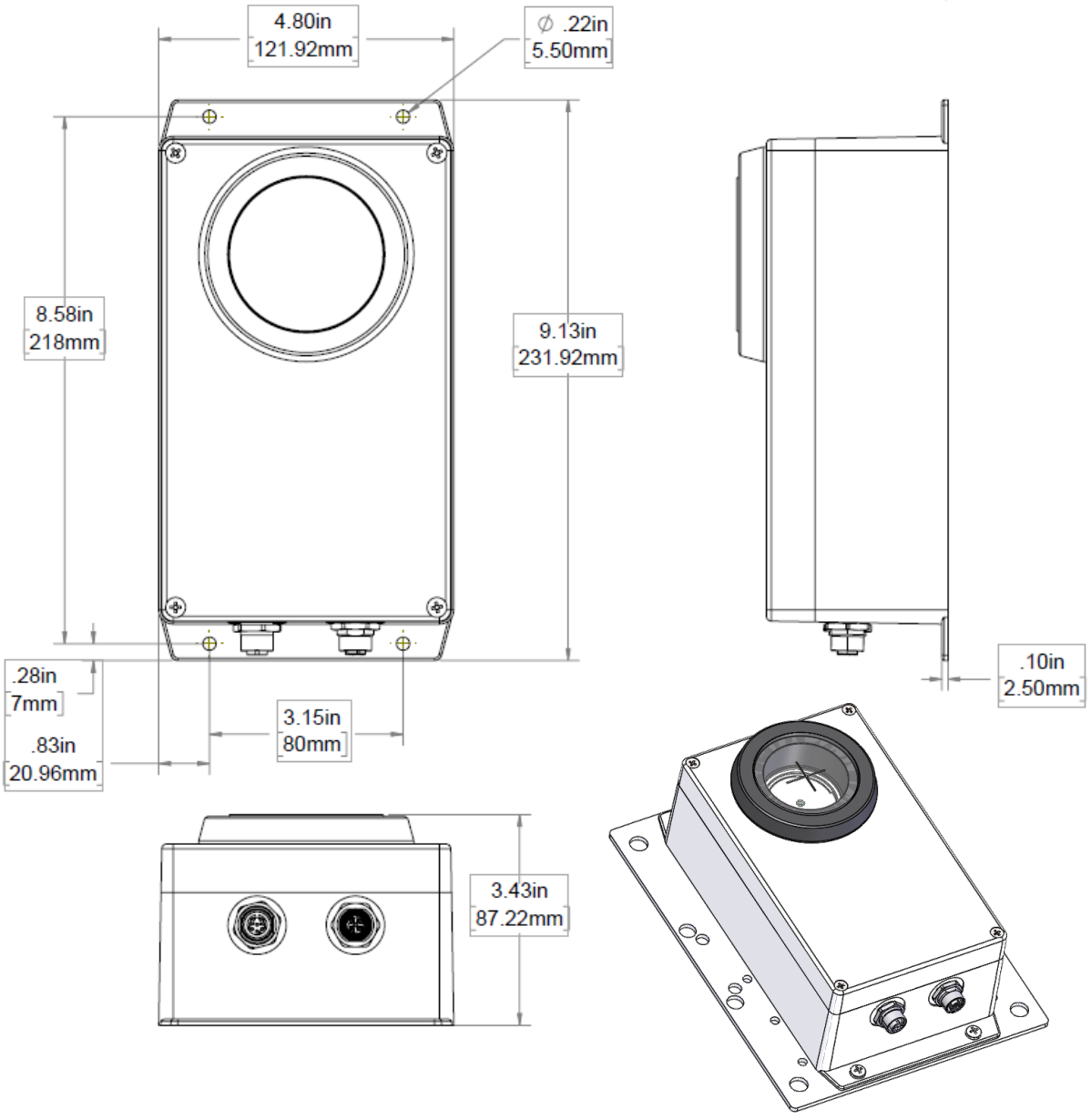


Figure 4-5: Optional flat mounting plate 610449 (sold separately)

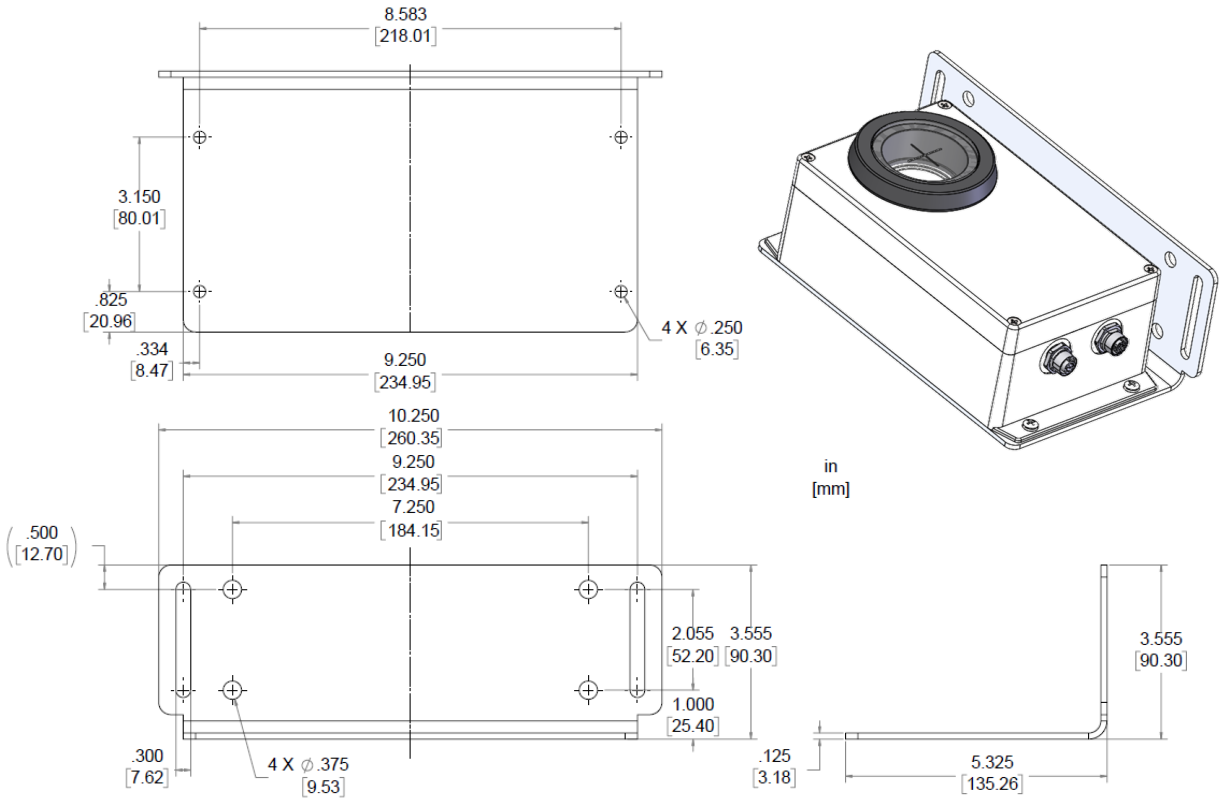


Figure 4-6: Optional right-angle mounting bracket 610451 (sold separately)

Figure 4-7: Optional adjustable bracket kit 810241 for pole mounting (sold separately)

5 Network Setup

To configure your Mars™ unit for use on an Ethernet network, set IP addresses and related communication parameters as directed in section 2.4.2.

In addition, you may need to open ports in your network firewall or set port forwarding on your cellular modem. See **Table 5-1**.

Table 5-1: Mars IP ports

Port Number	Protocol	Function
22	TCP	Atonometrics technical support, if needed
80	TCP	Access to web interface for configuration and status
2018	UDP	IP address recovery using Atonometrics Mars™ IP discovery tool

6 Modbus

Table 6-1 lists the registers available for your client software to read data from the Mars™ unit.

Each numbered register in the table is a 16-bit (2-byte) register. Parameters requiring more than two bytes must be read from sequential registers as indicated by the Register Start and Register End columns. For a 4-byte value with bytes in the order *ABCD*, from most to least significant, the first register reads out bytes *AB* and the second reads out bytes *CD*.

For detailed information on Modbus protocols, please reference the specifications published by Modbus.org.

Note: On some user data acquisition devices, it is necessary to add 1 to all the register values shown in **Table 6-1** to determine the Modbus address.

Note: Recommended parameters for Modbus communication are scan period ≥ 1 s, timeout ≥ 500 ms, delay between polls ≥ 30 ms. Do not poll the unit more than once per second. Using shorter timeouts may result in communication errors.

Table 6-1: Modbus map

Register Start	Register End	Parameter	Data Type	Bytes	Notes
1	2	Transmission Loss	Float(1)	4	Fractional loss of transmission due to soiling particles
3	4	Soiling Ratio	Float(1)	4	1 - Transmission Loss
200	200	Modbus RTU Node Address	Uint16	2	1-247
203	206	IP Address	Uint16 x 4	8	4 registers: XX.XX.XX.XX
207	216	Part Number	Char x 10	20	String: 10 registers, 1 char each
217	224	Serial Number	Char x 8	16	String: 8 registers, 1 char each
225	225	Software Version	Uint16	2	Software version number
228	233	Calibration Date	Uint16 x 6	12	6 registers: Y, M, D, H, M, S
501	502	Uptime	Uint32	4	Seconds
503	503	Status Code	Uint16	2	0 = Normal

(1) Float32 denotes single-precision 32-bit floating point per IEEE 754

7 Troubleshooting

Issue	Solutions
• No communication, unit not responsive during configuration attempt	• Confirm power wiring and power supply voltage range (Chapter 3) • Turn power off, then on again; confirm Mars™ window lights up for a short time and then turns dark • Wait 2-5 minutes after power-up for initialization to complete • Confirm correct IP address (p. 6) • Confirm PC's subnet and other IP settings are correct for Mars™ unit's IP address (p. 6) • Check firewall settings and ports (p. 18)
• Lost the IP address of Mars™ unit	• Download Mars™ IP address discovery tool from support.atonometrics.com, and use tool to determine IP • Check firewall settings and ports (p. 18)
• Modbus communication for logging unsuccessful	• Confirm Modbus register numbers (p. 19) • Verify whether register addresses require +1 offset for your client device (p. 19) • Confirm byte order (p. 19) • Confirm timeouts and polling rate (p. 19)
• Soiling ratio values out of expected range	• Confirm your Mars™ unit has the latest firmware (p. 7) • Confirm Mars™ unit is installed outdoors in desired plane of array with clear view of sky (p. 13) • Allow Mars™ unit to operate through at least one sunset and night and check the readings the next day (Chapter 8) • If needed, visually inspect unit for damage or fouling

8 Theory of Operation

Mars™ soiling sensor technology is designed to simplify soiling measurement. The sensor requires no water, has no moving parts, is compact and easy to install, and has no site-specific dust calibration requirements. The sensor is designed to be operated unattended without service visits and is suitable for a wide range of PV installation types, including small commercial and industrial projects.

Mars™ technology is covered by patents US 10,171,029, US 10,715,081, US 10,886,876, US 10,937,139 and EP 3590187. Other patents may be pending.

The Mars™ technology is illustrated in **Figure 8-1.** The soiling sensor is exposed to soiling just the same as nearby PV modules in your PV array, causing soiling particles to accumulate on the sensor window over time, just as they accumulate on the PV modules. Sunlight illuminates the sensor window, and a camera system, consisting of an image sensor and microscope lens, captures an image of the shadows cast by the soiling particles on the window. An example image is shown on the right in **Figure 8-1.** A processor inside the Mars™ unit analyzes the image to determine the transmission loss (the soiling loss) due to the soiling particles. A series of self-calibration marks inside the window provides reference features in the image which aid analysis.

The Mars™ sensor works best in diffuse lighting. Therefore, the sensor automatically operates each day at sunset. The sensor's outputs for soiling measurements will update each day after sunset.

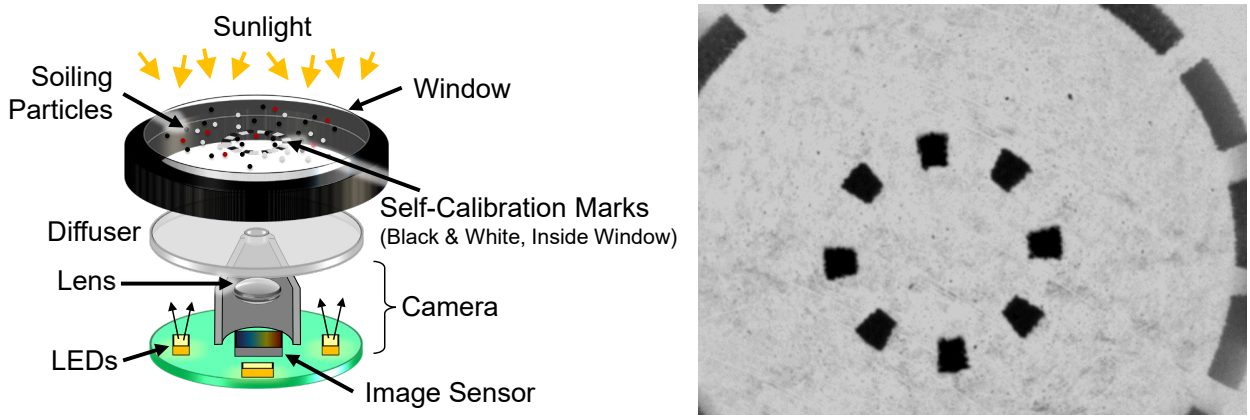


Figure 8-1: Mars™ technology

9 Specifications

CE

Table 9-1: Specifications

General	Model name	Mars Soiling Sensor™
	Ambient working temperature	-20 to +60 °C
	Input power	10 to 30 VDC
	Power consumption	~2.5 W average (up to 6 W transient)
	Transmission loss accuracy	± 1%
	Local dust calibration	Not required
	Communication protocols	Modbus TCP (Ethernet) Modbus RTU (RS-485)
Enclosure	Material	Powder-coated cast aluminum housing
	Outdoor rating	IP67
	Dimensions	9.13 x 4.80 x 3.43 in. / 231.92 x 121.92 x 87.22 mm
	Weight	3.00 lb / 1.35 kg
	Mounting	4 mounting holes, dia. 0.22 in. / 5.50 mm Mounting accessories available
Cables	Power & RS485	Shielded, weather resistant, UV-rated 24 awg / 0.2 mm^2 M12 circular connector, IP67
	Ethernet	Shielded, weather resistant, UV-rated M12 circular connector, IP67