

# NRG Lidar Spidar

USER'S MANUAL



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## TABLE OF CONTENTS

<b>I.</b>	<b>INTRODUCTION .....</b>	<b>5</b>
<b>A.</b>	<b>NRG Spidar Vertical Profiler .....</b>	<b>5</b>
<b>B.</b>	<b>Direct Detect Lidar and the Cross Correlation Method .....</b>	<b>5</b>
<b>II.</b>	<b>SAFETY AND WARNINGS.....</b>	<b>7</b>
<b>A.</b>	<b>Laser Safety.....</b>	<b>7</b>
<b>B.</b>	<b>Laser Safety Warnings.....</b>	<b>7</b>
<b>C.</b>	<b>Laser Safety Requirements.....</b>	<b>7</b>
<b>D.</b>	<b>Electrical Safety.....</b>	<b>7</b>
<b>E.</b>	<b>Ergonomic Safety .....</b>	<b>8</b>
<b>III.</b>	<b>SYSTEM OVERVIEW .....</b>	<b>9</b>
<b>A.</b>	<b>Optimal Installation Dimensions .....</b>	<b>9</b>
<b>B.</b>	<b>Minimum Installation Dimensions .....</b>	<b>10</b>
<b>C.</b>	<b>Maximum Installation Dimensions.....</b>	<b>11</b>
<b>IV.</b>	<b>SPIDAR SPECIFICATIONS.....</b>	<b>12</b>
<b>A.</b>	<b>System Verification .....</b>	<b>12</b>
<b>B.</b>	<b>Verified Wind Measurement Performance.....</b>	<b>12</b>
<b>C.</b>	<b>System Geometry.....</b>	<b>12</b>
<b>D.</b>	<b>Hardware Specifications.....</b>	<b>12</b>
<b>E.</b>	<b>Electrical Specifications.....</b>	<b>12</b>
<b>F.</b>	<b>Data Specifications.....</b>	<b>12</b>
<b>G.</b>	<b>Environmental Specifications .....</b>	<b>13</b>
<b>H.</b>	<b>System Options .....</b>	<b>13</b>
<b>I.</b>	<b>Service Options .....</b>	<b>13</b>
<b>V.</b>	<b>UNPACKING.....</b>	<b>14</b>
<b>A.</b>	<b>Spidar Installation Flow Chart .....</b>	<b>14</b>
<b>B.</b>	<b>Package Integrity + Visual Inspection .....</b>	<b>14</b>
<b>C.</b>	<b>Opening the Crate .....</b>	<b>15</b>
<b>1.</b>	<b><i>Removing the Upper Cover .....</i></b>	<b><i>15</i></b>
<b>2.</b>	<b><i>Removing the Protective Beam.....</i></b>	<b><i>16</i></b>
<b>3.</b>	<b><i>Removing the Front Panel.....</i></b>	<b><i>16</i></b>



- D. Unpacking the Crate..... 17
  - 1. *Removing the Spidar Main Body*..... 17
  - 2. *Removing the Internal Boxes* ..... 19
- E. Spidar Tripod Assembly..... 21
  - 1. *Leg Assembly*..... 21
  - 2. *Tripod Mounting*..... 22
- VI. INSTALLATION + COMMISSIONING ..... 26
  - A. Siting..... 26
  - B. Elevation + Leveling ..... 27
    - 1. *Remove Surface Obstructions* ..... 27
    - 2. *Set Tripod Leg Length* ..... 28
  - C. Anchoring ..... 31
  - D. Orientation ..... 32
    - 1. *Determining Azimuth Angle*..... 32
  - E. Meteorological Sensor ..... 33
  - F. Spidar Power Controller ..... 34
    - 1. *AC Power Connections*..... 34
    - 2. *DC Power Connections*..... 35
    - 3. *Power Controller to Spidar Connections*..... 37
    - 4. *Installing SIM Card in Spidar Power Controller PC*..... 38
    - 5. *Connect and Confirm Spidar Power Controller Operation* ..... 41
    - 6. *Setting SIM Card APN* ..... 42
    - 7. *Confirm Power Controller PC Configuration* ..... 43
  - G. Spidar Setup and Operation ..... 44
  - H. Powering on the Spidar ..... 44
  - I. LED Status Indicator ..... 44
  - J. Filling Wiper Fluid Reservoirs ..... 45
    - 1. *Reservoirs Filling Process* ..... 45
  - K. Configuring the Spidar..... 48
  - L. Finalizing Spidar Installation ..... 50
- VII. SYSTEM MAINTENANCE ..... 53



- A. Maintenance Schedule..... 53
- B. Wiper Replacement Instructions ..... 54
- C. Wiper Fluid Nozzle Service ..... 55
- D. Power off Spidar ..... 56
- VIII. DATA ANALYSIS..... 57
  - A. Introduction..... 57
  - B. Spidar File Structure..... 57
    - 1. File Name ..... 57
    - 2. File Format ..... 58
    - 3. Data File Contents ..... 58
    - 4. Time Stamp ..... 59
    - 5. Met Measurements ..... 59
    - 6. Wind Measurements ..... 60
  - C. Spidar Data Filtering..... 60
    - 1. Data Quality Indicator Inputs ..... 61
    - 2. Setting a Data Quality Threshold ..... 61
    - 3. TI Filtering ..... *Error! Bookmark not defined.*
- IX. SPIDAR TO METEOROLOGICAL TOWER CORRELATION GUIDELINES..... 63
  - A. Introduction..... 63
  - B. Positioning the Spidar near the Meteorological Tower..... 63
  - C. Data Filtering Procedure ..... 63
    - 1. Spidar Data Filtering..... 63
    - 2. Met Mast Data Filtering ..... 63
    - 3. Time Stamp Alignment ..... 64
  - D. Data Correlation Methods..... 64
    - 1. System Availability ..... 65
    - 2. Post-Processed Data Availability ..... 65
    - 3. Wind Speed Correlation Methods ..... 65
    - 4. Average Wind Speed Comparison ..... 65
    - 5. Average Wind Direction Comparison ..... 66
    - 6. Wind Rose Comparison ..... 66



## I. INTRODUCTION

### A. NRG Spidar Vertical Profiler

NRG Spidar is a vertical profiling pulsed direct detect Lidar specifically designed for wind measurement within the wind energy industry. Spidar remains the only direct detect Lidar in use by wind energy professionals globally for early stage prospecting, wind shear validation, horizontal uncertainty reduction, and as a permanent met mast replacement on operating wind farms.

### B. Direct Detect Lidar and the Cross Correlation Method

Laser pulses from one Spidar beam sample the atmosphere. The reflected intensity of these pulses are received, analyzed and sampled in time. The sampled time-series represents the aerosol density in the line of sight of the transmitted pulse.

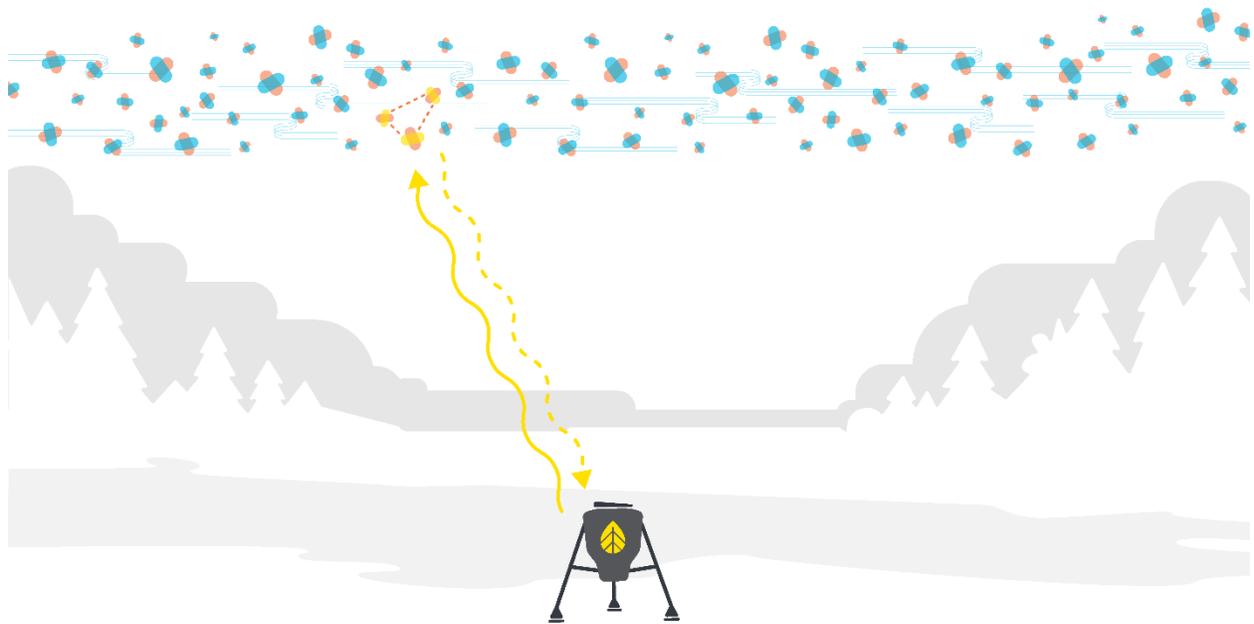


Figure 1: Spidar Pulsed Sampling

Aerosol density structures persist over time and travel with the wind.

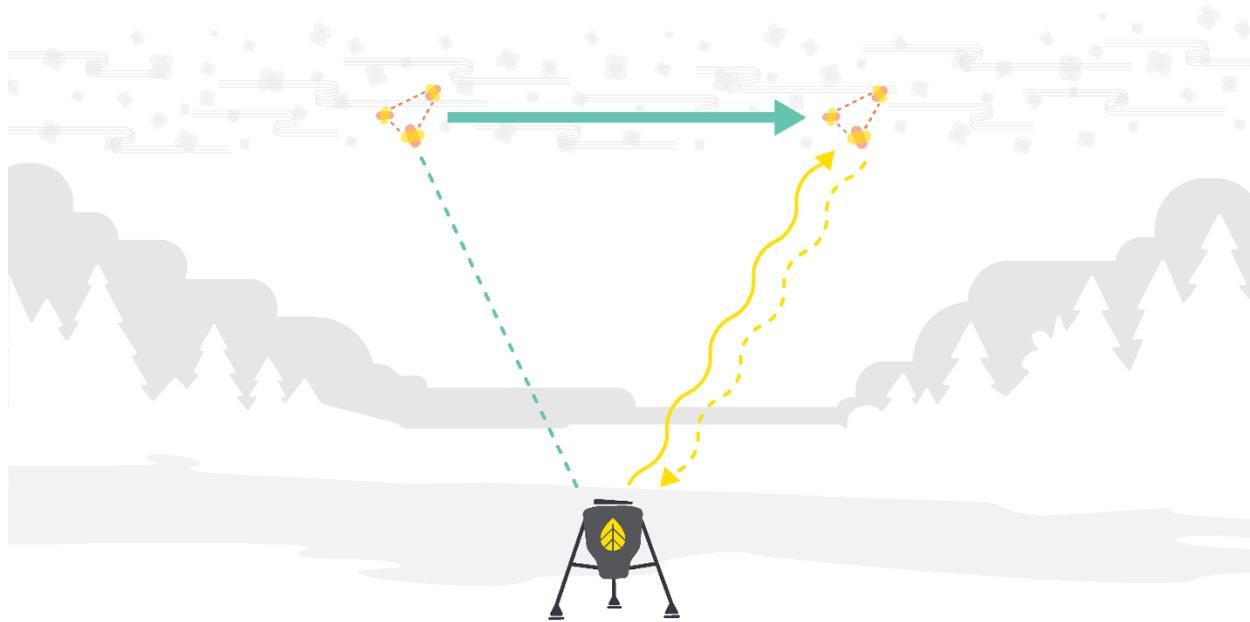


Figure 2: An Identifiable Aerosol Density Structure Moving with the Wind



## Spidar User Manual

Laser pulses from the downwind Spidar beam sample the atmosphere. The same aerosol density signature is identified. This establishes the time of flight between the two beam locations. Combined with the known distance between the two locations, Spidar is able to determine both wind speed and direction.



*Figure 3: Spidar Pulsed Sampling at a Second Beam Location*



## II. SAFETY AND WARNINGS

This section details the standards and classifications to which the Spidar system is manufactured and also highlights potential hazards and handling requirements. These are for guidance purposes only. The customer should take all necessary care to ensure safe use of the equipment.

### A. Laser Safety

The Spidar utilizes a 1550nm fiber-laser source.

The Spidar contains a Class 4 laser source, but the product is equipped with all the laser safety means needed for the assignment as a Class 1M laser product to comply with the IEC/CE 60825-1 standard, as well as the CDRH (FDA) Title 21 CFR 1040.10 standard.

Class 1M is eye-safe for naked eye, but may be hazardous if using optical viewing instruments, such as eye loupes or binocular. Therefore, the product carry a Class 1 M label mentioned, "Do not Stare directly with Optical Instruments".

### B. Laser Safety Warnings



**Never look directly into the Spidar window.**



**Never cover the Spidar window.**



**Only certified NRG technicians are authorized to open a Spidar system. The Spidar internal laser is class 4, and therefore is hazardous to direct eye exposure. Diffused reflections such as those from paper or other matte surfaces are not harmful.**

### C. Laser Safety Requirements

The Spidar laser source classified as class 4, is assembled inside a metal protective housing and an additional external envelope that is enclosing the Laser beam inside the protective housing. The only laser beam is the Class 1M Laser beam that is projected by the housing on the top of the product.

### D. Electrical Safety

The Spidar input voltage is 24VDC (low voltage with low risk).

The Spidar is designed in full compliance with the European Safety Directive for electrical equipment for measurement, control and laboratory use EN601010-1:2001.



DC input voltage for the Spidar is 24V DC. Use only the supplied power cable.



Input voltage rating is 110V to 220V AC (50/60 Hz).

Spidar AC/DC power supply installation ONLY to electrician or certified NRG technician.



Before servicing the Spidar, ensure turning off the power to the system by switching the ON/OFF key to the OFF position.

### E. Ergonomic Safety

Please review the following ergonomic safety instructions and warnings.



Each Spidar has a case to enable safe transportation of the system. It is recommended that at least two people are used to lift and carry them due to their size and weight: 75kg (165lb).

Use the red handles when lifting and moving the Spidar.



Safety shoes must be worn when installing the Spidar.



### III. SYSTEM OVERVIEW



Figure 4: NRG Spidar System Overview

#### A. Optimal Installation Dimensions



Figure 5: Optimal Installation Height

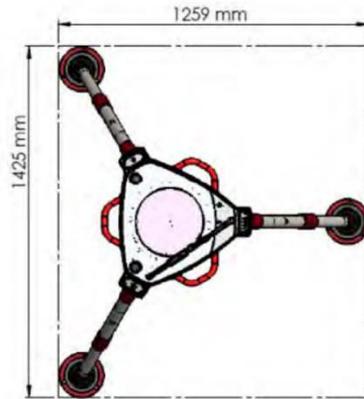


Figure 6: Optimal Installation Footprint

## B. Minimum Installation Dimensions



Figure 7: Minimum Installation Height

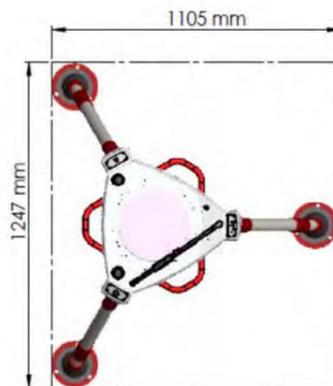


Figure 8: Minimum Installation Footprint



### C. Maximum Installation Dimensions



Figure 9: Maximum Installation Height

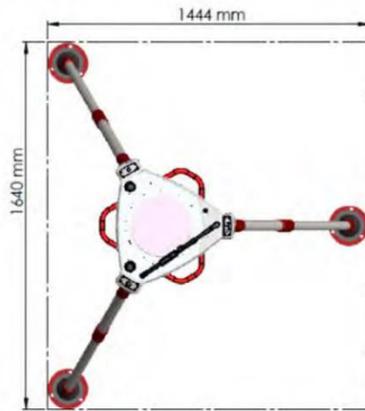


Figure 10: Maximum Installation Footprint



## IV. SPIDAR SPECIFICATIONS

### A. System Verification

Calibration	<ul style="list-style-type: none"> <li>All units are factory verified against IEC calibrated reference Lidar</li> <li>IEC calibration available upon request.</li> </ul>
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### B. Verified Wind Measurement Performance

Applicable Measurement Height Range	100m
WS Forced Fit Slope	.996
WS Correlation R <sup>2</sup>	.979
WS Deviation ( $\pm$ m/s)	0.04 @ 10 m/s
WS Deviation (%)	0.40%

### C. System Geometry

Full Cone Angle	10°
Measurement Height Range	20 – 200m
Number of Range Gates	10
Range Gate Heights	Configurable

### D. Hardware Specifications

Warranty	2 years – see NRG warranty statement
Maximum Site Slope	20°
Dimensions	Typical footprint: 1,092mm x 1,259mm x 1,425mm (43" x 49.6" x 56.1")
Weight	Shipping Crate: <ul style="list-style-type: none"> <li>136kg (300lbs)</li> <li>1,118mm x 889mm x 1,041 (44" x 35" x 41")</li> </ul>

### E. Electrical Specifications

Power Consumption	<ul style="list-style-type: none"> <li>&gt;0°C: 35W</li> <li>&lt; 0°C: 50 to 100W</li> </ul>
Supply Voltage	23 – 32VDC

### F. Data Specifications

Data Sampling Rate	14 Hz
Averaging Interval	Configurable



Storage File Format	ASCII
Storage Capacity	~3 years
Data Output Options	<ul style="list-style-type: none"> <li>.csv files delivered via email at configurable interval</li> <li>Continuous delivery to SCADA networks via Modbus</li> </ul>

### G. Environmental Specifications

Operating Temperature Range	-40° to 50°C
Operating RH Range	0 to 100%
Ingress Protection	IP65
Eye Safety Classification	IEC Laser Class 1M

### H. System Options

Spirit Level	Included
Communications, User Interface, and Power Control Module	Included
Power Supply (Trailer, PV, Fuel Cell, Genset, Storage, etc.)	Available
Temperature, Barometric Pressure + Precipitation Sensors	Included
Cellular Communications	Available
Satellite Communications	Available
Location + Clock Synchronization (GPS)	Included
Wiper Fluid Reservoir (4.2L)	Included

### I. Service Options

Technical Support	Included
User Interface (via webserver)	Included
Validation (vs reference Lidar, traceable to IEC met mast)	Included
Field Services (Installation, Logistics, etc.)	Available
Training (Installation, Operations, etc.)	Available
Remote Monitoring	Available
Email Data Delivery (.CSV attachments)	Included
Web Data Portal	Available



## V. UNPACKING

This section describes removing the Spidar from its crate and inspecting its contents.

### A. Spidar Installation Flow Chart

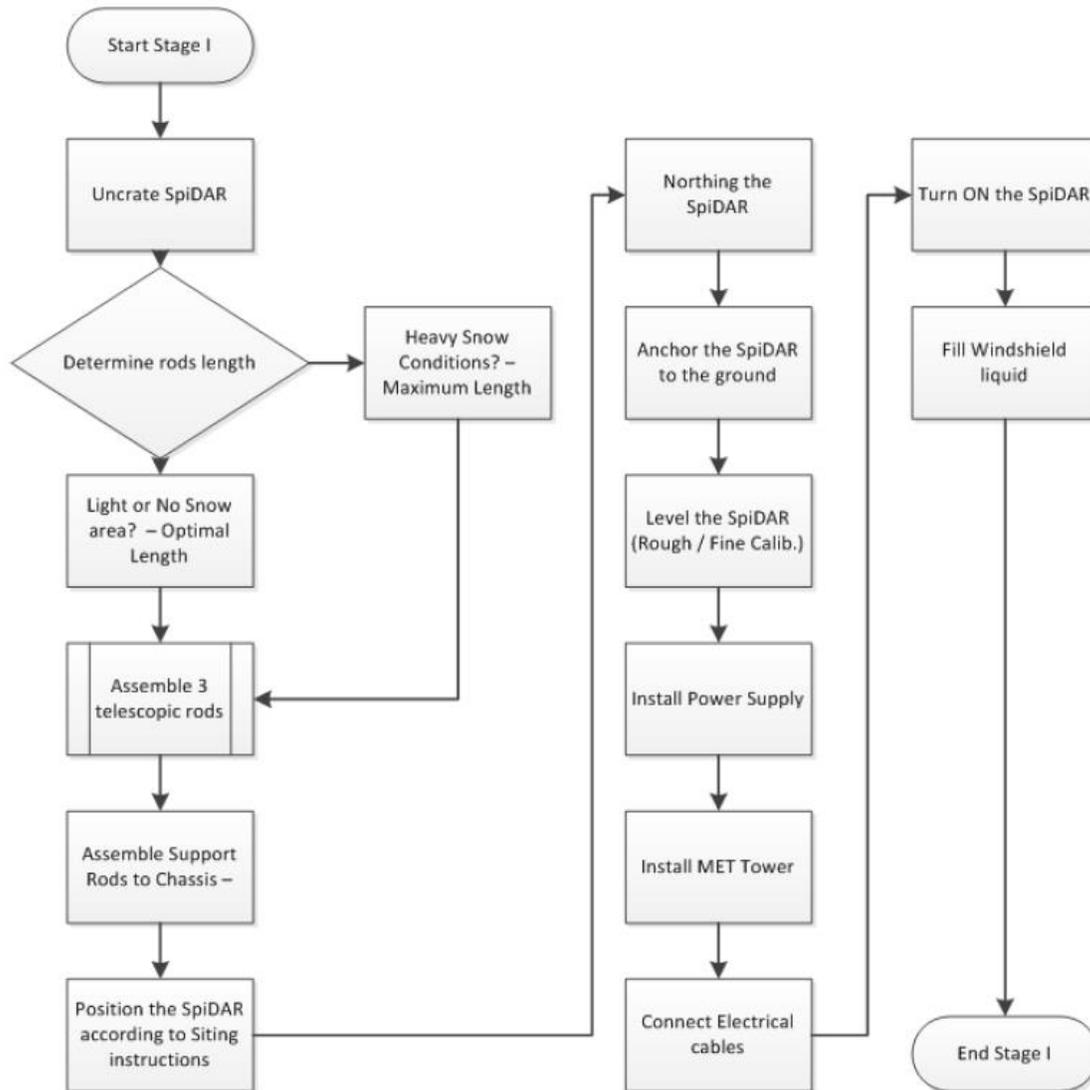


Figure 11: Spidar Installation Flow Chart

### B. Package Integrity + Visual Inspection

Before unpacking the Spidar from its shipping crate, verify the crate integrity, stickers, documents and markings. Verify that the TiltWatch™ tilt indicator and the Shockwatch™ shock indicator are not colored red. Red indicates that the crate has been tilted or has undergone an excessive impact. If any damage has occurred during shipping please contact NRG Technical Services as soon as possible.



Figure 12: Tilt and Shock Indicators

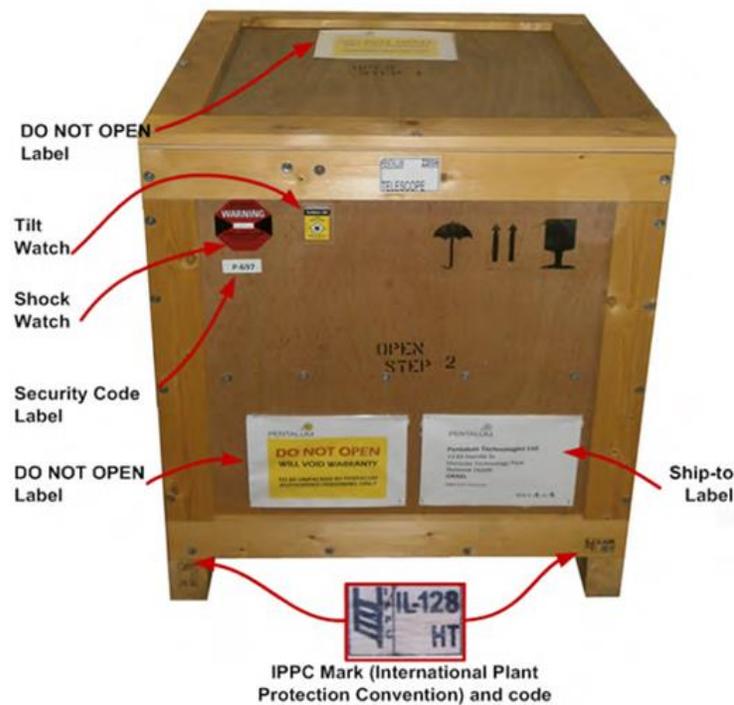


Figure 13: Crate Shipment Integrity Features

## C. Opening the Crate

### 1. Removing the Upper Cover

Unscrew the four screws located on the upper cover side boards using a Posidrive head screwdriver. Remove the upper cover carefully and place it to the side.



Figure 14: Shipping Crate Upper Cover

## 2. Removing the Protective Beam

Unscrew the four screws located either side of the protective beam using a Posidrive head screwdriver. Remove the crossbar carefully and place it to the side.



Figure 15: Shipping Crate Protective Beam

## 3. Removing the Front Panel



To remove the front panel, marked with Step 2, unscrew 20 screws. Remove the side panel carefully and place it to the side.



Figure 16: Shipping Crate Front Panel

## D. Unpacking the Crate

### 1. Removing the Spidar Main Body

Remove the Spidar main body, lifting carefully by its red handles.



Only lift the Spidar by its red handles.

Safety shoes must be worn when installing the Spidar.



Figure 17: Spidar Main Body + Accessory Boxes



Figure 18: Removing Spidar Main Body from Crate



**2. Removing the Internal Boxes**

Remove the three cardboard boxes from the main crate, please see Figure 12.

- Box #1 – size 75×30×15 cm
- Box #2 – size 28×22×12 cm

Open the three boxes and verify that all parts are present.

Description	QTY	Box #	Picture
Spidar Main Body	1	NR	
<b>Box 1</b>			
Tripod Leg Subassembly	3	1	
Tripod Base Subassembly	3		
Anchor Pins	3		
Wiper Blade	1		
External Wiper Fluid Pump	1		



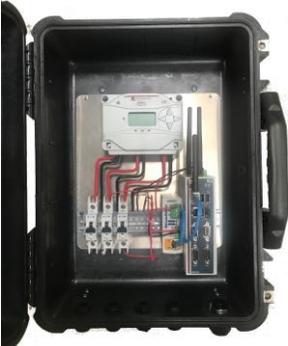
Tool Kit	1		
Screw Set	1		
<b>Box 2</b>			
Met Sensor	1	2	
<b>Box 3</b>			
Spidar Power Controller	1	3	

Figure 19: Spidar Components



## E. Spidar Tripod Assembly

### 1. Leg Assembly

- a) *Remove leg subassemblies from the shipping crate.*
- b) *Cut the zip ties securing the support rod on each telescopic tripod leg assembly.*



Figure 20: Tripod Leg Subassembly



Figure 21: Tripod Base Subassembly

- c) *Assemble the three tripod subassemblies legs, as seen in Figure 16. The tripod leg inner sleeves are marked (engraved) indicating optimal and max extension leg lengths. Set all legs according to the area condition and snow feasibility. In heavy snow condition it is recommended to extend the legs to max.*

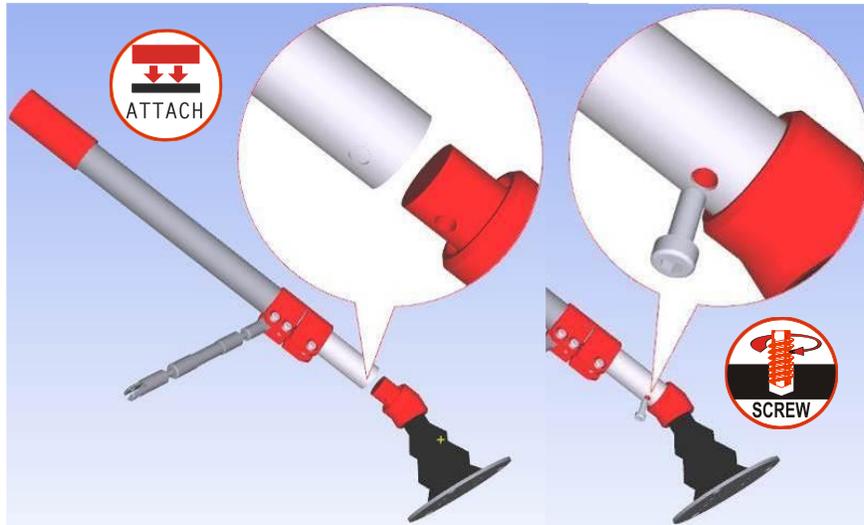


Figure 22: Tripod Leg to Base Assembly

## 2. Tripod Mounting

This section describes how to mount the telescopic tripod legs to the Spidar main body. Each of the tripod legs should be inserted into the leg sleeves and screwed on tight.



**The Spidar weighs approximately 50kg. Use two technicians to remove and maneuver the Spidar from the shipping crate and during assembly.**

- a) *Slightly tilt the Spidar to insert an assembled telescopic legs into a sleeve by gripping the leg support rod to enable free rotation for screwing the leg tightly into position.*

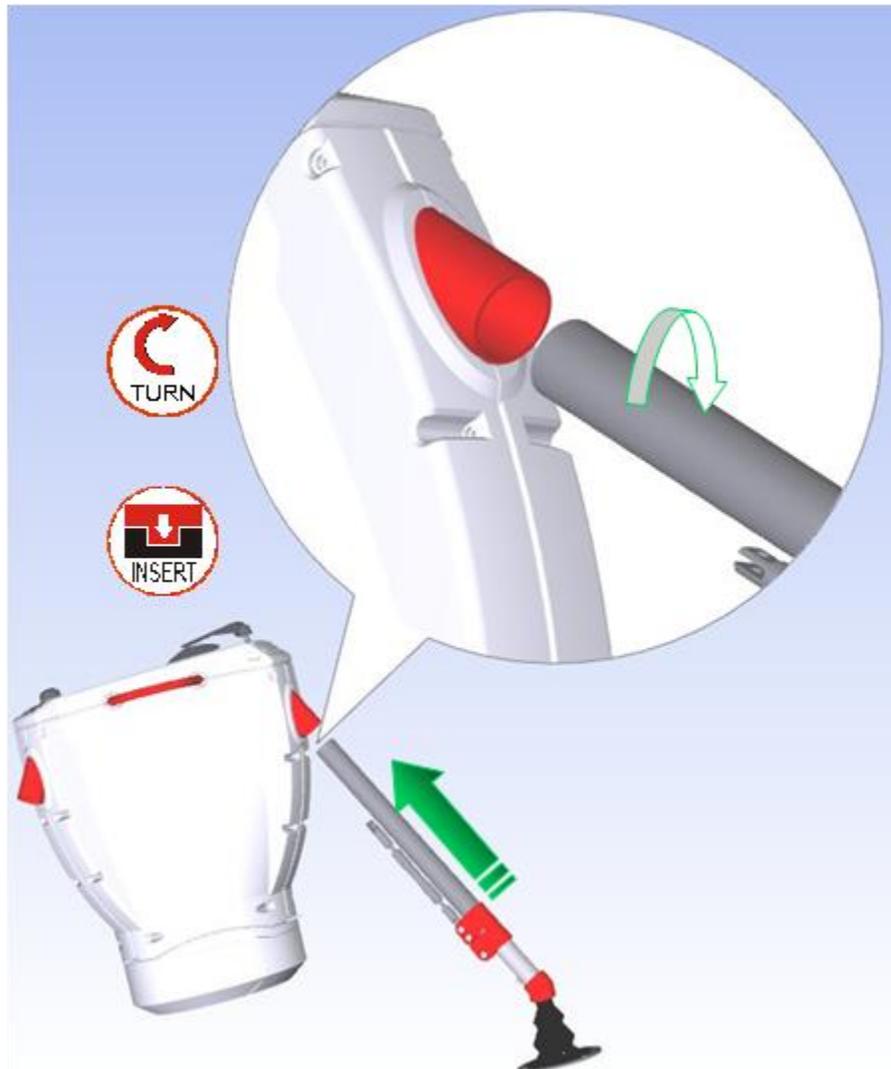


Figure 23: Tripod Assembly

**b)** Repeat for all 3 legs. Two people are needed: one should hold and tilt the Spidar while the second connects the legs.

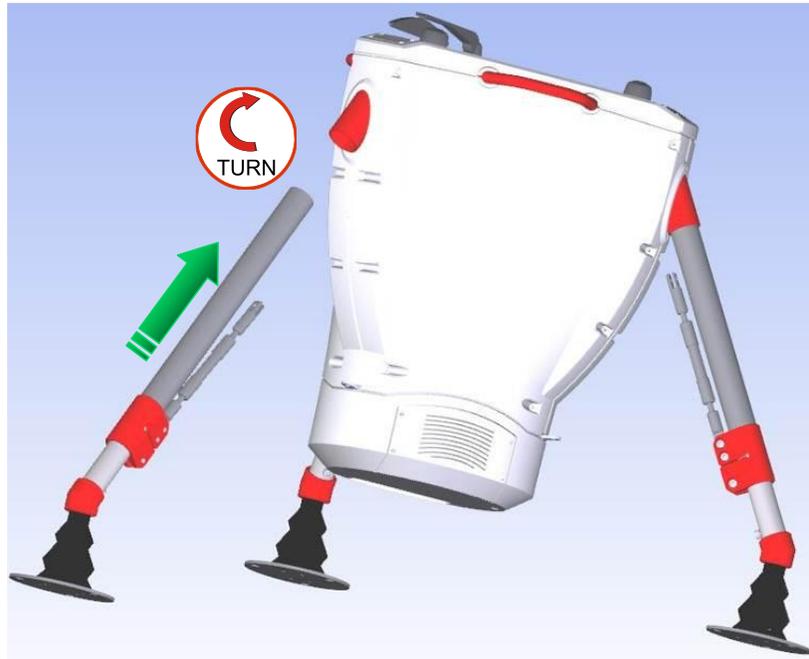


Figure 24: Final Leg of Tripod Mounting

c) **Remove the Allen screw from a support rod.**



Figure 25: Remove Support Rod Screw



- d) **Position the support rod between the chassis and the telescopic leg and insert and tighten the Allen screw. Rotate the tightening nut for proper tension in order to reduce stress from the chassis.**



Figure 26: Connect and Adjust Support Rod

- e) **Repeat steps C + D for all 3 support rods.**



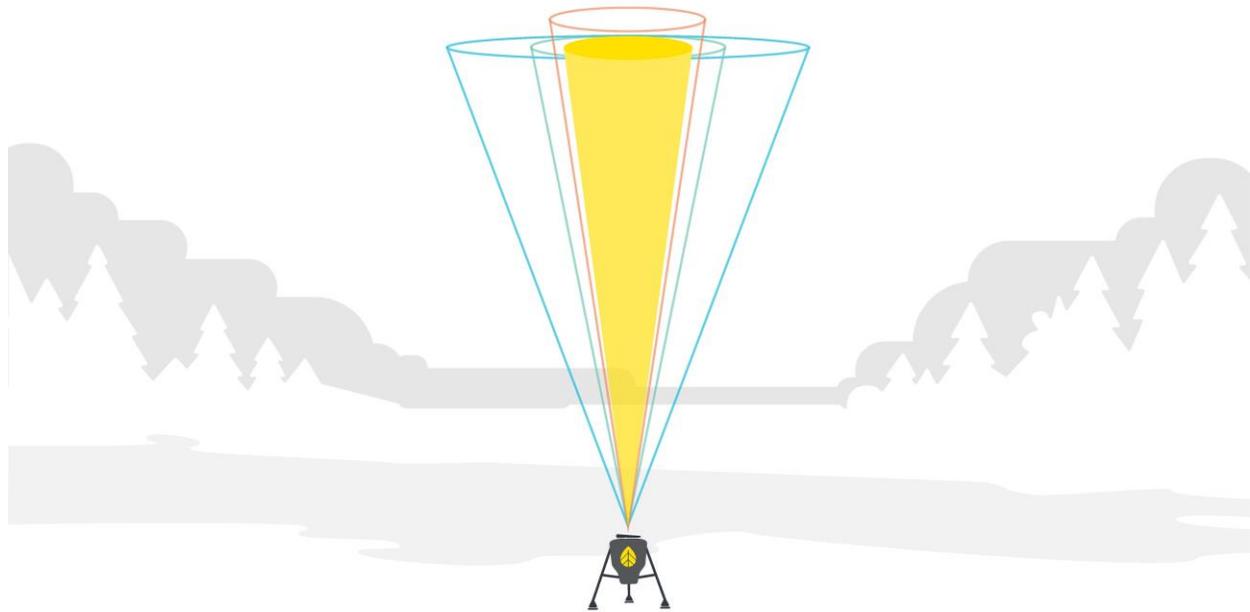
## VI. INSTALLATION + COMMISSIONING

### A. Siting

The Spidar must be sited far enough away from possible obstructions to avoid interference.



**Ensure the location complies with the recommended distances from objects known to cause interference.**



*Figure 27: Spidar has Narrowest Beam Angle of All Wind Energy Remote Sensors*

The table below shows proper horizontal offset distances given the height of a potential obstruction, such as a met tower, buildings, or trees. The offset distances shown are based solely on the cone angle of each device. Note that additional setbacks are required for sodars in order to prevent echoes from fixed objects from interfering with measurements.

Spidar has the smallest cone angle of any remote sensor in the wind industry, allowing it to be sited closer to potential obstacles than any other device.



Minimum Horizontal Distance from Met Tower (m)	Obstruction Height (m)
13.1	150
12.2	140
11.4	130
10.5	120
9.6	110
8.7	100
7.9	90
7.0	80
6.1	70
5.2	60
4.4	50
3.5	40
2.6	30
1.7	20
0.9	10

*Table 1: Spidar Offset Distances*

## **B. Elevation + Leveling**

This section describes how to set the height of the Spidar above level ground. The Spidar can be installed with a range of total system heights, from 912mm up to 1,305mm. The best height for your installation will depend on site conditions, particularly how level it is and the expected snowfall.

### **1. Remove Surface Obstructions**

Roughly level the Spidar and ensure that the bases of each tripod leg are clear of surface obstructions.

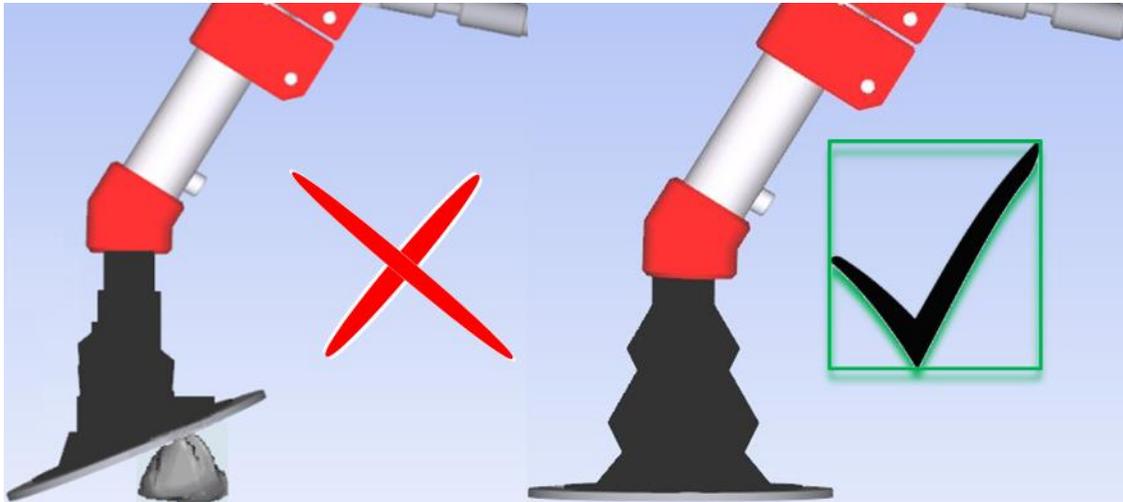


Figure 28: Remove Surface Obstructions

## 2. Set Tripod Leg Length

The Spidar can reach a maximum of 500mm ground clearance for normal operation by extending its telescoping legs. For installations in areas likely to experience heavy snowfall, the Spidar should be installed with maximum possible ground clearance to minimize potential obstruction by snow and ice.

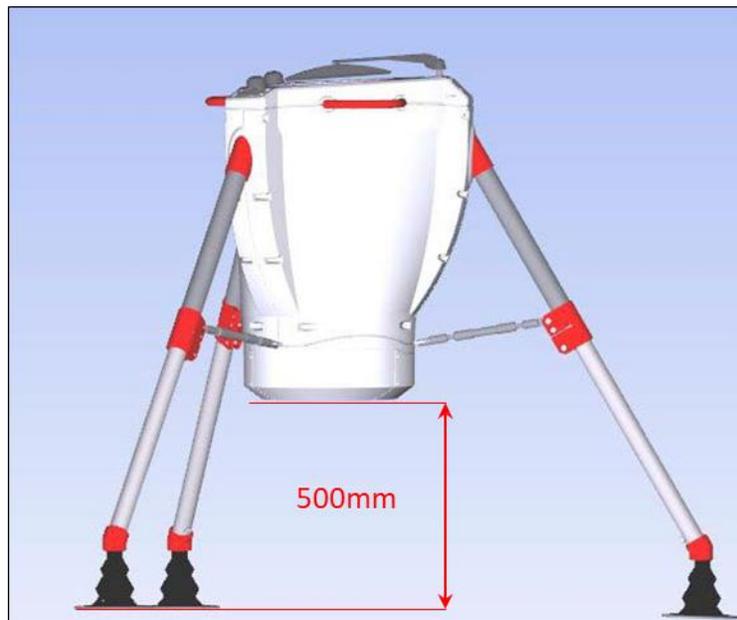


Figure 29: Maximum Ground Clearance

The tripod leg inner sleeves are marked (engraved) indicating optimal and max extension leg lengths to aid this process.

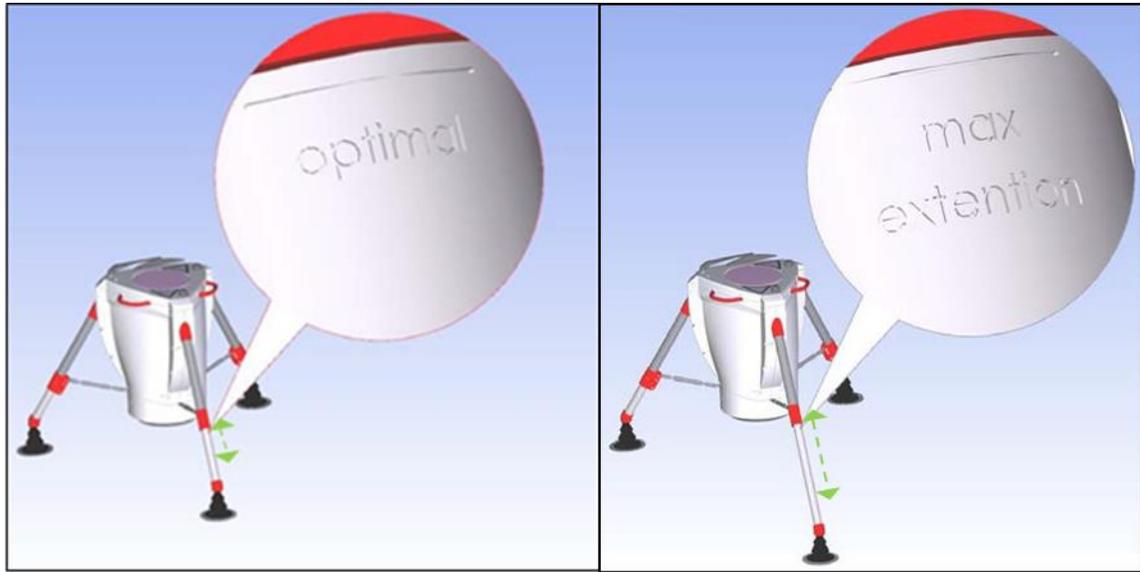


Figure 30: Spidar Leg Engraving

The Spidar has a built-in spirit level to enable precise leveling. The Spidar is plumb when the spirit level air bubble is within the red circle.



Figure 31: Spirit Level and Spirit Level Cover

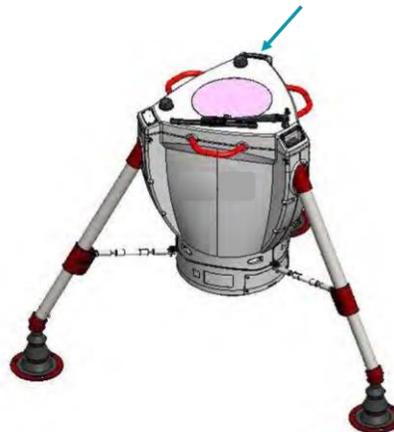


Figure 32: Spirit Level Location



- a) *Loosen the leg sleeve Allen screws and lengthen the telescopic tripod legs as necessary to achieve rough leveling. The three legs should be different lengths when installing on an uneven surface to achieve rough leveling.*



Figure 33: Adjusting Leg Length

- b) *After roughly leveling the Spidar, tighten with an Allen key.*
- c) *Tighten the Allen screws affixing the support rods.*



Figure 34: Tightening Support Rod Screw



- d) *Using the built-in Spirit Level, determine which tripod leg(s) require fine adjustment to bring the Spidar into plumb. Spidar is plumb when the spirit level air bubble is within the red circle.*
- e) *To make an adjustment, fold up the rubber 'sock' on the appropriate leg and rotate the base assembly on the fine adjustment nut to bring the Spidar to plumb. The Fine Adjustment nut must remain aligned flush and perpendicular to the Upper Angler Joint.*



Figure 35: Fine Adjustment Nut Location

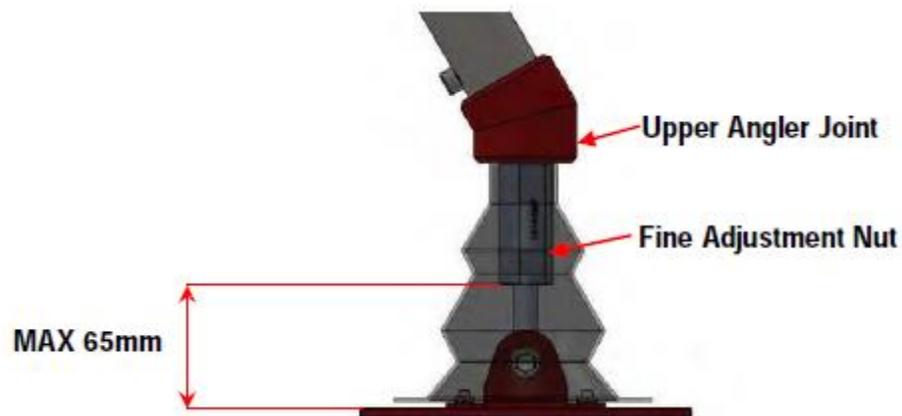


Figure 36: Spidar Foot Assembly

- f) *Check your spirit level to confirm the Spidar is plumb. Repeat steps D and E as needed.*

### C. Anchoring

Anchor the Spidar is important to ensure that the system remains fixed in position and plumb during your measurement campaign. Insert an anchor rod through the outer hole of each foot pad and force the anchor into the ground.



*Figure 37: Inserting Anchors*

## D. Orientation

This section describes how to determine the Spidar's orientation relative to north, which is important to enable accurate wind direction measurements. The azimuth angle is the angular difference between compass north and the Spidar's orientation, and should be measured during commissioning and recorded in the system's configuration information. A custom jig is provided to aide in this process.

### 1. Determining Azimuth Angle



*Figure 38: Orienting the Spidar*



- a) *Stand at least 5 meters back from the Spidar. The further away from the Spidar you are, the more accurate the result achieved.*
- b) *Position yourself to clearly observe the protruding rods vertically aligned, while observing the jig aligned with a compass.*
- c) *Extend an imaginary line between two notches in the upper ring of the Spidar optical head to measure the azimuth angle using a handheld compass.*
- d) *Take note of the compass azimuth value.*
- e) *The northing calibration procedure is very significant for accurate wind direction measurements. It is highly recommended to verify the results by having a second person repeat steps A through D (above) for confirmation.*

## E. Meteorological Sensor

This section describes the installation of the combined temperature and precipitation sensor (“met sensor”) that comes with each Spidar system.

- a) *Unscrew four Allen screws fastening the brackets located at the back of the converter and open the brackets.*
- b) *Position the met sensor sideways onto the tripod leg upper section on the wiper side to avoid droplets being thrown onto it from the wiper arm movement.*
- c) *Close the brackets and screw the Allen screws back into place, leaving the screws slightly loose for now.*
- d) *Plug the Met Mast into P4 in the connections panel (see below).*

**NOTE:** *This connection may be shared with the RS232 Y-cable connection to the Power Controller.*



Figure 39: Installation of Met Sensor



## F. Spidar Power Controller

This section describes how to configure the Spidar Power Controller for use with AC or DC power and connect the Power Controller with the Spidar. It also explains how to use the Power Controller PC and where to install the SIM card.

### 1. AC Power Connections

When using AC power, the AC/DC converter at the bottom end of the Power Controller needs to be terminated with a cable and plug that will be compatible with the regional power outlets.



**CAUTION:** The following instructions require working with AC and DC electricity. Only trained technicians with the proper experience should work with these power supplies. Please use caution when working with the Power Controller.

#### Required cable specifications:

- Max rating 16A 250V AC
- Minimum 5m cable length with local electrical plug on one end (most quality extension cords will work) Cut one end off and prep the bare wires to the specifications shown below:

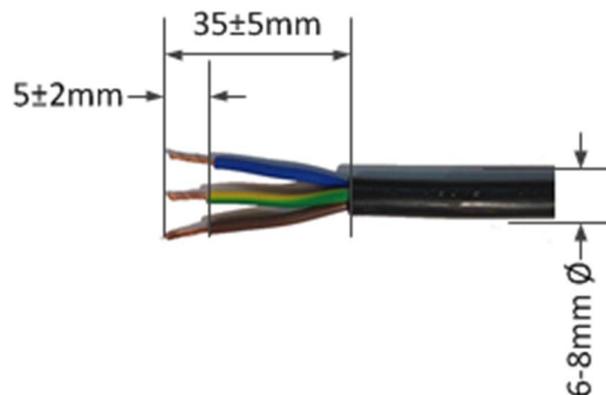


Figure 40: Cable preparation before assembly

1. Remove unwired side of the AC power cable connector
2. Unscrew nut and strain relief
3. Place nut and strain relief over the AC power cable end
4. Wire the AC plug cable into the terminal strip
  - Blue = Neutral
  - Brown = Phase
  - Green/Yellow = Earth Ground

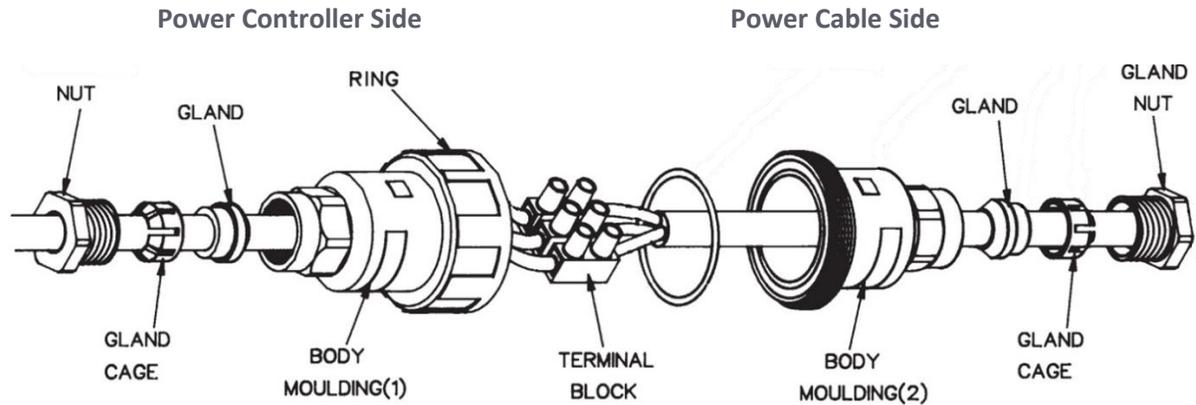
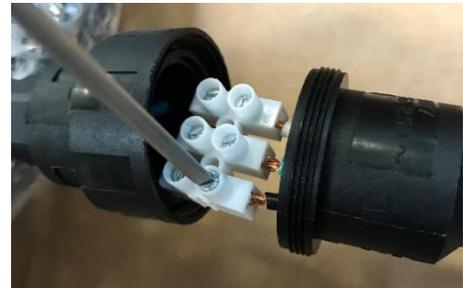


Figure 41: Main cable connection to the power supply

5. Tighten the nut to secure the cable in place
6. Plug in AC power cable into 110 -240 VAC power source
7. Connect the Spidar power cable with the orange protective cap on the end into port P1 in the Spidar's connection panel.

Skip to section ADD SECTION for the next steps.



## 2. DC Power Connections

When using a Photovoltaic (PV) and Battery power supply the Spidar Power Controller needs to be wired differently. The following instructions explain how to wire the Power Controller:

1. Unscrew the second strain relief port from the left and push the gasket out
2. Cut four slices in the gasket to allow the PV and Battery wires to fit through
3. Place the wires in the holes, making sure the screw cap is on the cables before feeding the wires into the case



Figure 42: Cut gasket, place wires in gasket, secure with nut

4. Locate the AC/DC adapter cable that comes through the first strain relief port from the left and remove the positive and negative leads from the terminal blocks. Tape the ends and secure the wires out of the way to make room for the PV and battery leads.
5. Wire PV leads into the first terminal block on the left (PV Input)
6. Wire Battery leads into the middle terminal (Battery Input)

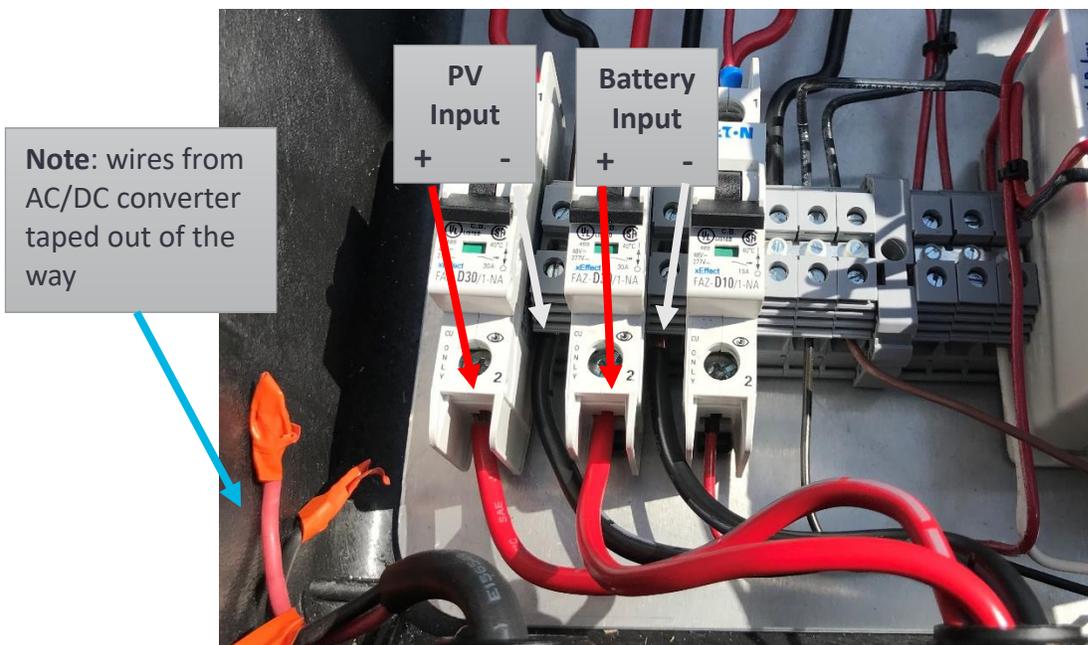


Figure 43: Wiring of battery and PV inputs (negative wire highlighted with gray arrow for contrast)

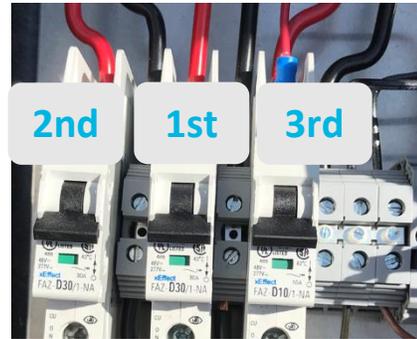
7. Tighten strain relief and make sure everything is secure



## Spidar User Manual

8. When powering a DC system ON, follow this order to protect the Charge Controller:

- 1<sup>st</sup> - battery circuit breaker, middle.
- 2<sup>nd</sup> - PV circuit breaker, left
- 3<sup>rd</sup> - load (Spidar) circuit breaker, right



### 3. Power Controller to Spidar Connections

To access the connection panel, locate it along the base of the Spidar and unscrew the four Allen screws, using a 3mm Allen Screwdriver. This will release the cover and allow you to lower it, exposing the connections underneath.



Figure 44: Opening Electrical Connection Panel

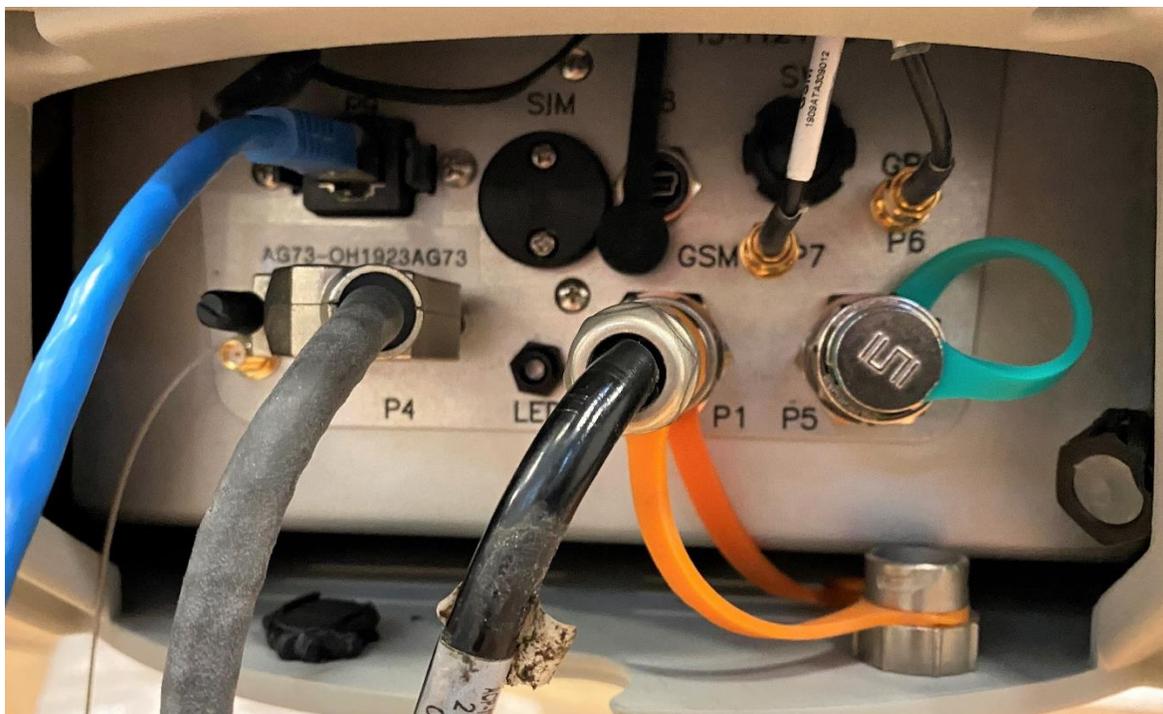


Figure 45: Electrical Connections

Ethernet Cable (P9)	Connected to Power Controller PC LAN 2
Main Power Cable (P1 - Orange Label)	Connects to Power Controller Power Cable
RS232 (P4)*	Used for Met Mast and monitoring and upgrading OS
Power Cable (P5 - Green Label)	Not used with the current configuration
SIM Card Slot	Not used with the current configuration

Table 2: Electrical Connections

\*RS232 Y-cable can be plugged into P4 with the Met Sensor and RS232 to USB cable connected to it. With this configuration the RS232 to USB cable must be installed inside the electrical connection panel and the USB cable run from connection panel into the Spidar Power controller and plugged into one of the USB ports. This will allow Technical Services to update software and troubleshoot via RS232 if needed.

#### 4. Installing SIM Card in Spidar Power Controller PC

The Spidar Power Controller comes with a modem embedded in the Power Controller PC. The following instructions show how to remove the PC from the pelican case and access the SIM card holder. This process is best done in the office before installing the Spidar and Power Controller in the field.

**Tools required:** small electronics flat head and Philips screwdrivers (preferably with a magnetic tip).

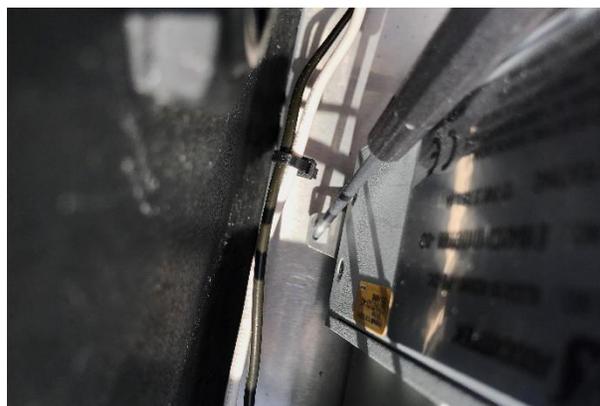
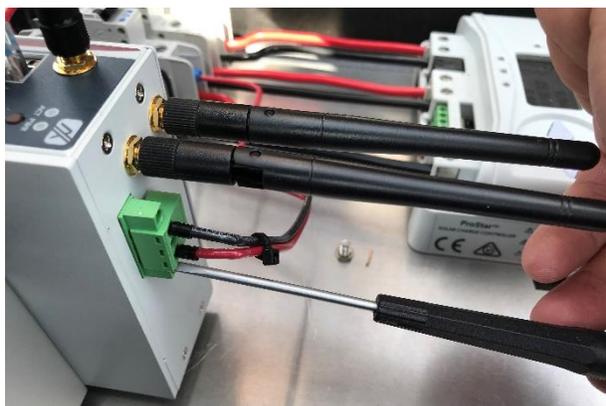


**CAUTION:** It is recommended to use an ESD ground strap when handling electronics to prevent accidental electrostatic damage to the Spidar Power Controller PC.

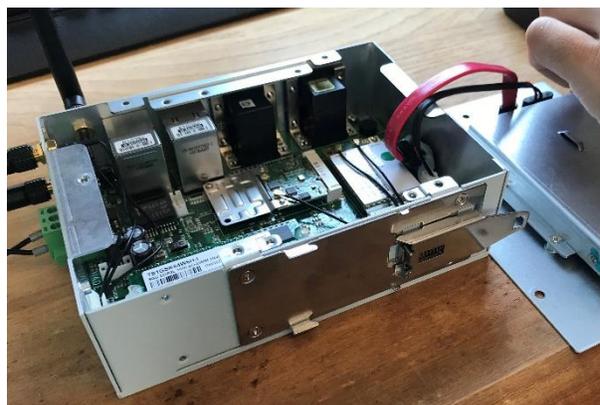


## Spidar User Manual

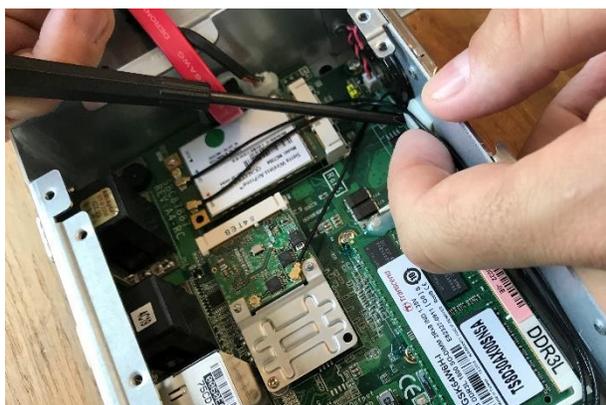
1. Disconnect all cables from the Spidar Power Controller PC
  - Undo the flat head screws on the green connector behind the two antennas on the PC to remove the green power adapter (no need to undo the red and black wires)
2. Remove the PC from the DIN rail by locating the latch at the bottom of the PC and using a screwdriver to pull it towards the bottom of the pelican case.



3. Place the PC upside down and undo the 6 Phillips screws that hold the cover down.
4. Remove the cover **slowly** because it is still connected to the inside to the PC.

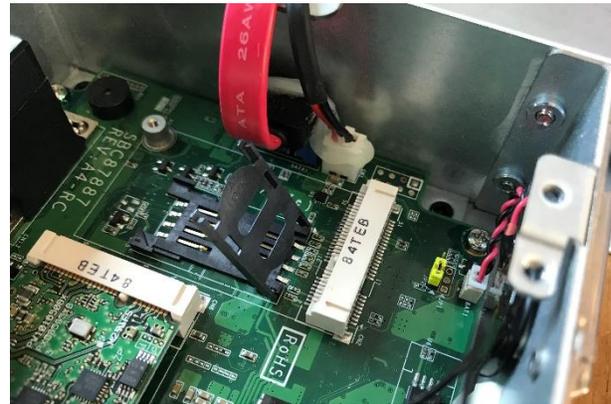


5. Unclip the modem wires from the side of enclosure
6. Remove the single screw holding the modem down

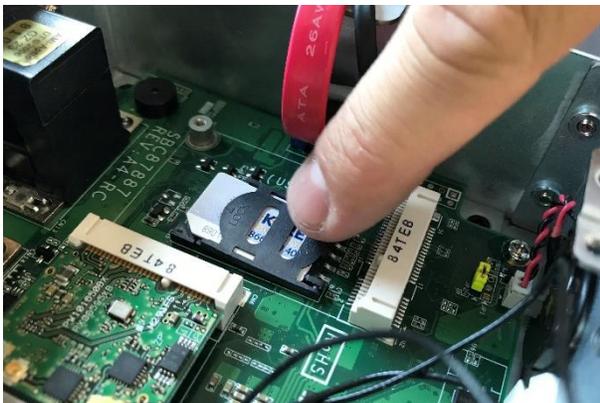




7. Gently remove the modem by lifting it slightly and then gently pull/wiggle it out.
8. Slide the SIM card tray back to release it and pull it out



9. Insert the SIM card with the contacts down and the notch in the upper left corner.
10. Lay the SIM card tray flat and slide it forward to lock it into place
11. Insert the modem back into its slot and secure it with the screw



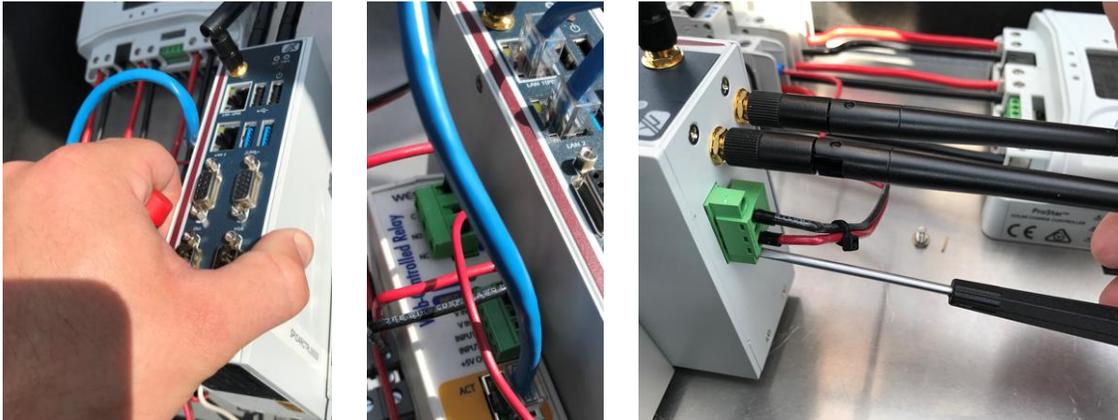
12. Clip the modem wires back into the wire holder
13. Place the cover back onto the PC and secure it with the 6 screws.



14. Install the PC into the Pelican case. Align top of PC with DIN rail, click in the bottom



15. Attach the Ethernet cables (web-relay into LAN1, Spidar into LAN2) and the power adapter.



### 5. *Connect and Confirm Spidar Power Controller Operation*

Once the Spidar Power Controller has been connected to a power source and the SIM card installed, it is ready to be used. Before leaving the site the Power Controller PC should be logged into to verify the functionality of the following apps:

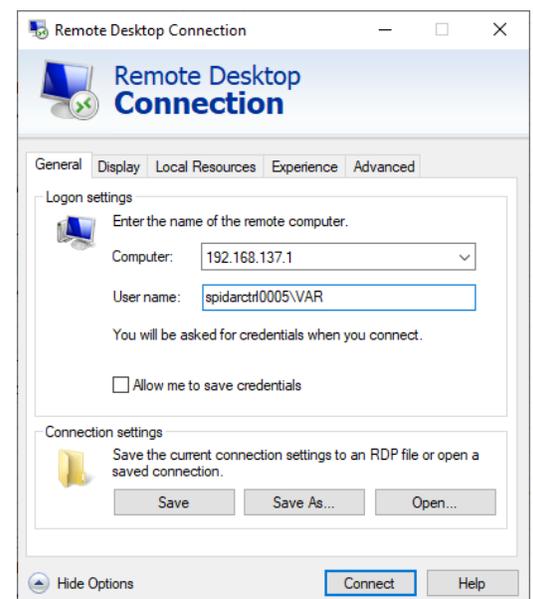
- **Skylight** – used to configure the SIM card's APN
- **FUSE.exe** – used to retrieve data from the Spidar and uploaded it to NRG's cloud server
- **FileZilla** – used to set the Spidar's configuration and manually retrieve data files and LOGs
- **TeamViewer** – used to connect to the Power Controller and Spidar remotely

There are a handful of other applications loaded on the Spidar Power Controller PC for troubleshooting.

There are two ways to connect to the Spidar Power Controller PC – via Wi-Fi and via Direct Connect:

#### Connect via Wi-Fi:

1. Look for a wireless network SSID called **SPIDARCTRL00xx** and click on it
2. Enter the password **direct-detect!**
3. Use Remote Desktop to connect to the Power Controller PC:
  - Computer = **192.168.137.1**
  - User = **spidarctrl1234\VAR**
  - Password = **direct-detect!**



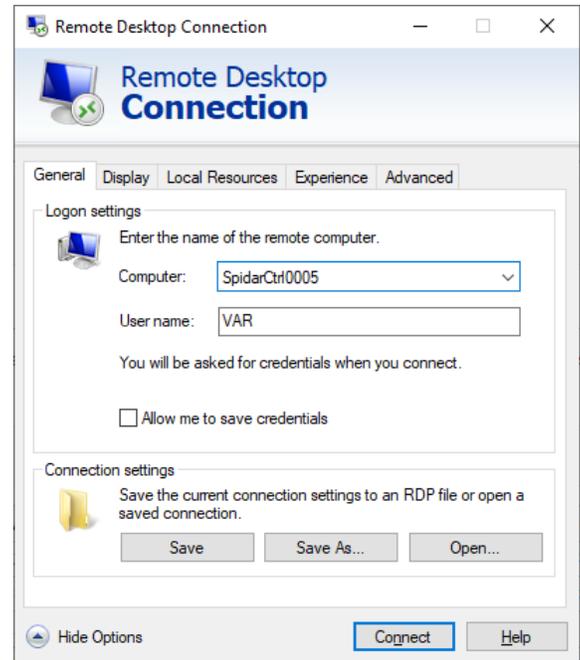


**Connect via direct connection:**

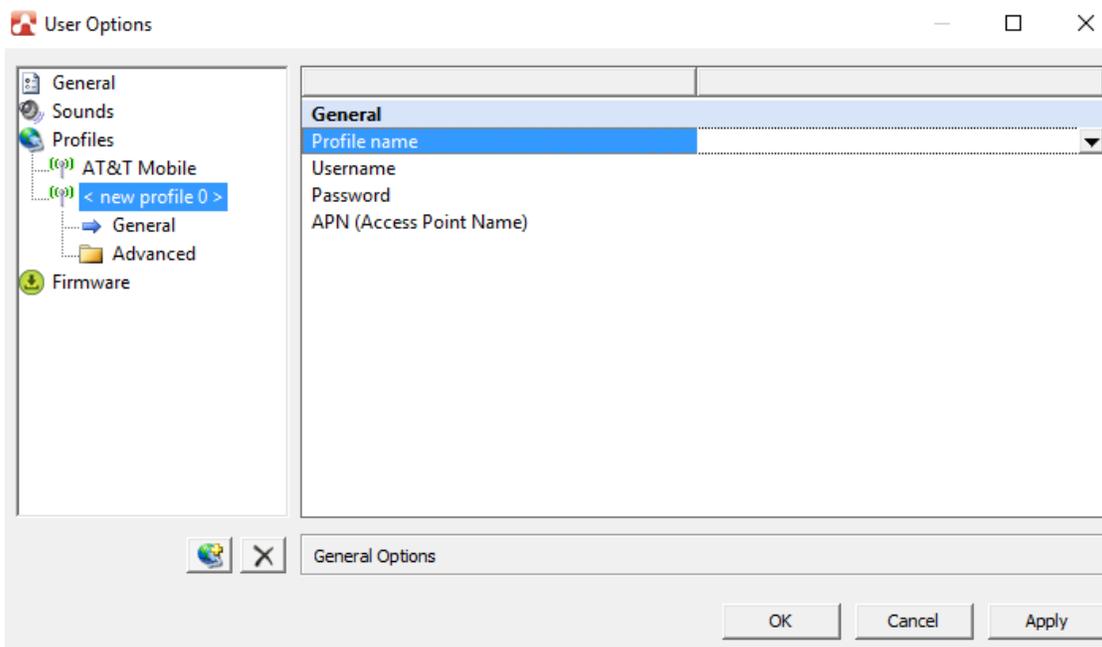
1. Open the Spidar Power Controller pelican case and plug an Ethernet cable into the Ethernet port being used by the remote power switch (LAN 1).
2. Use Remote Desktop to connect to the PC:
  - Computer = **SpidarCtrl00xx** (see serial number sticker on the Power Controller case)
  - User = **VAR**
  - Password = **direct-detect!**

**6. Setting SIM Card APN**

Once connected to the Spidar Power Controller, the SIM card’s APN information need to be entered in the Skylight App.



1. Locate the Skylight App on the Power Controller PC’s desktop and double click on it. 
2. Click on the wrench icon to access the settings. 
3. Right click on “Profiles” and choose “Add new profile”. Add a profile name and enter the APN Username, APN Password and APN. Click Save when complete.





## Spidar User Manual

4. The modem should now be able to connect to the network and should give the option to Connect/Disconnect for the network.

**NOTE:** by using the modem in the embedded Spidar Power Controller PC, it is not necessary to use the SIM card tray in the Spidar Connection Panel. If for some reason the modem inside the Spidar needs to be used, please contact Technical Support for instructions on programming the APN for the SIM.

### **7. Confirm Power Controller PC Configuration**

#### **FUSE**

The application folder can be found here: C:\FUSE

1. Click on the FileUpload.exe. If the fields are blank, choose “LOAD CONFIGURATION”
2. Choose the “DEFAULT.fus.config.json” file and click Open. All of the boxes should be filled in.
3. Press “EXECUTE” and watch the bottom window to verify that the program works properly.

**NOTE:** The Spider Power Controller will need to be connected to the Spidar via Ethernet and the Spidar will need to be powered on in order for it to work properly.

#### **TeamViewer**

Locate the TeamViewer shortcut on the desktop or at C:\Program Files (x86)\TeamViewer.

1. Double click on the icon to open the application (a pop-up might say it’s already running – this is okay).
2. When the application opens it should show “YOUR ID” and “PASSWORD” – these are the credentials needed to access the computer remotely. If these are not present, contact Technical Support.
3. Leave TeamViewer running to allow remote access if needed.

#### **Power Relay**

The power relay to disconnect and reconnect power to the Spidar remotely is accessed via Firefox. There should be a shortcut saved to the Desktop. Double click the link to navigate to the site.

1. Open FireFox and navigate to 192.168.1.7.
2. Click OFF to cycle power off. Click ON to enable power.

**NOTE:** Always wait 1+ minute before turning the power back on to allow the unit to fully reset.

#### **Spidar Admin Tool**

Information on the Spidar Admin tool can be found in **Section L - Finalizing Spidar Installation**.



## G. Spidar Setup and Operation

This section describes powering on and launching the Spidar. Once powered on, it is necessary to calibrate the device and test for accurate wind data readings. This section includes the following procedures:

- Powering on the Spidar
- Filling Water
- Configuring the Spidar
- Using the Spidar Admin Tool application

## H. Powering on the Spidar

After all power and communication cable connections have been established, the Spidar can be powered on by a switch located in the Electrical Connection Panel.



Figure 46: Spidar Power Switch

## I. LED Status Indicator

The Spidar has a three-color LED status indicator. Use this indicator mechanism to quickly confirm system status.



Figure 47: LED Status Indicator



Red + Green	Startup Process
Amber + Green	Finalizing Startup
Green	Running
Amber	Alert
Red	Critical Error

Table 3: LED Status Key

**J. Filling Wiper Fluid Reservoirs**

For a proper functioning of the Spidar, the top filter Lens must be cleaned. An automated cleaning system including a wiper and a sprinkler are installed for this purpose. Wiper fluid is held in an internal 1.1 gallon (~4 liters) reservoir within the Spidar.

As part of the of the Spidar maintenance, it is necessary to verify sufficient Anti-Freeze liquid and proper function of the wiping system every two months to six months.

While anti-freeze can be used in cold climates, we recommend using a mixture of water and isopropyl alcohol to lower the freezing point of the water. The table below provides a rough guideline:

Minimum Temperature	Percent Water	Percent Isopropyl
-3°C	90%	10%
-7°C	80%	20%
-20°C	60%	40%

Table 4: Water to Isopropyl Ratios

**1. Reservoirs Filling Process**

1. Locate the pump provided with the Spidar and set aside.
2. Remove the reservoir panel by unscrewing the four screws and pull the reservoir tube out:



3. Remove the black plug by pushing the blue ring down while pulling the plug out of the tubing.



## Spidar User Manual

4. Insert the blue tubing from the external pump and push it securely into the black connector:



5. Place the blue pump into the water or washer fluid container.
6. Connect the gray power cable to the lose connector on the right hand side inside the Connection Panel. The pump will start as soon as the electrical connection is made (with the Spidar powered on).



7. The pump will continue pumping until power is removed (i.e. the gray cable is disconnected from the Spidar).
8. Once the reservoir is fill the excess liquid will drain out of the bottom of the Spidar.
  - a. Verify that the blue tubing is visible from the bottom of the Utility Panel (opposite side from the Connection Panel where the pump is plugged in – see image on next page).
  - b. If the blue tube is not visible from the bottom of the Spidar, open the Utility Panel and make sure the blue tube is fitted through the drain hole.



9. When water starts leaking out of the bottom drain tube, disconnect the power wire from the Spidar. Remove the pump, dry it and store the pump in the Spidar transport case.
10. With a full reservoir the LED Status Indicator should turn green, indicating the Spidar is ready for operation.



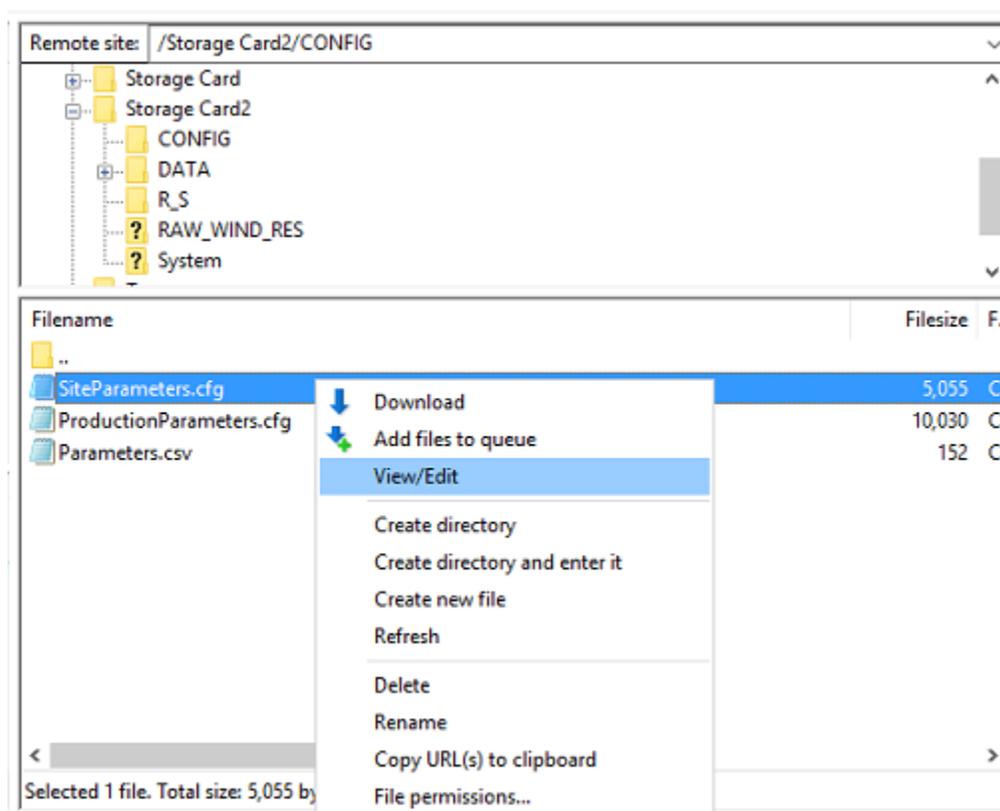
## K. Configuring the Spidar

To program the Spidar's settings and measurement heights use the FileZilla application installed on the Spidar Power Controller PC. Locate the shortcut on the desktop of the PC and follow these instructions:

1. Enter the Host (192.168.1.1), Username (Pentalum), Password (xphhsr) and Port (21) in FileZilla and click "Quickconnect":



2. The right section of the screen (labeled 'Remote Site') refers to the file structure inside the Spidar. Navigate to Storage Card/CONFIG/SiteParameters.cfg
3. Right click on the SiteParameters.cfg file and choose "View/Edit"



**NOTE: DO NOT EDIT THE SiteParameters.cfg OR ANY OTHER FILE WITH WORD OR EXCEL – THIS WILL CORRUPT THE SETTINGS AND WILL AFFECT THE SPIDAR'S OPERATION. Only use Notepad or Text Editor!**



## 4. Set the Customer, Site and Location Names:

```
#
# Customer, Site and Location Names
# CustomerName - 4 letters MUST (EXAMPLE: PENT)
# SiteName - 3 letters MUST (EXAMPLE: REH)
# LocationName - 3 letters MUST (EXAMPLE: GAG)
#
CustomerName,PPPP
SiteName,PPP
LocationName,PPP
```

**NOTE:** these names are alphanumeric, so numbers can be used as needed.

## 5. Set the number of range gates and measurement heights:

```
#
# Number of heights and Heights Vector
# NumHeights - possible values: 1-10
# HeightVector - up to 10 values separated by comma (,). Must have NumHeights values.
# EXAMPLE: "{30,40,50,60,70,80,90,100,110,120}"
#
NumHeights,10
HeightVector,"{40,60,80,90,100,120,130,160,180,200}"
```

## 6. Set the direction offset (if the unit is not aligned north).

```
#
# Reference Azimuth ---- possible values: 0-360
#
ReferenceAzimuth,0
```

## 7. NRG strongly recommends NOT changing the "Time Reference for output files" to be at the end of the 10 minute interval.

```
#
# Time Reference for output files
# Possible values: 0(default) or 1
# 0(default) - start of 10min
# 1 - end of 10min
#
TimeReferenceForOutputFiles,0
```

## 8. Spidar units are programmed to create 10 minute averages by default. The averaging interval can be modified but the minimum averaging interval should be 5 minutes (300).

```
#
# AverageDataRefreshRate - The average wind resolution.
# possible values: 30,60 or 600
# 30 - 30 seconds average wind resolution.
# 60 - one minute of average wind resolution.
# 600 - ten minute of average wind resolution.
#
AverageDataRefreshRate,600
```

## 9. If using Modbus set the parameters to the following:





- a. Here you can see the four Spidar Beam Signals. The beams should have a similar pattern to each other and should fall within the blue dots.

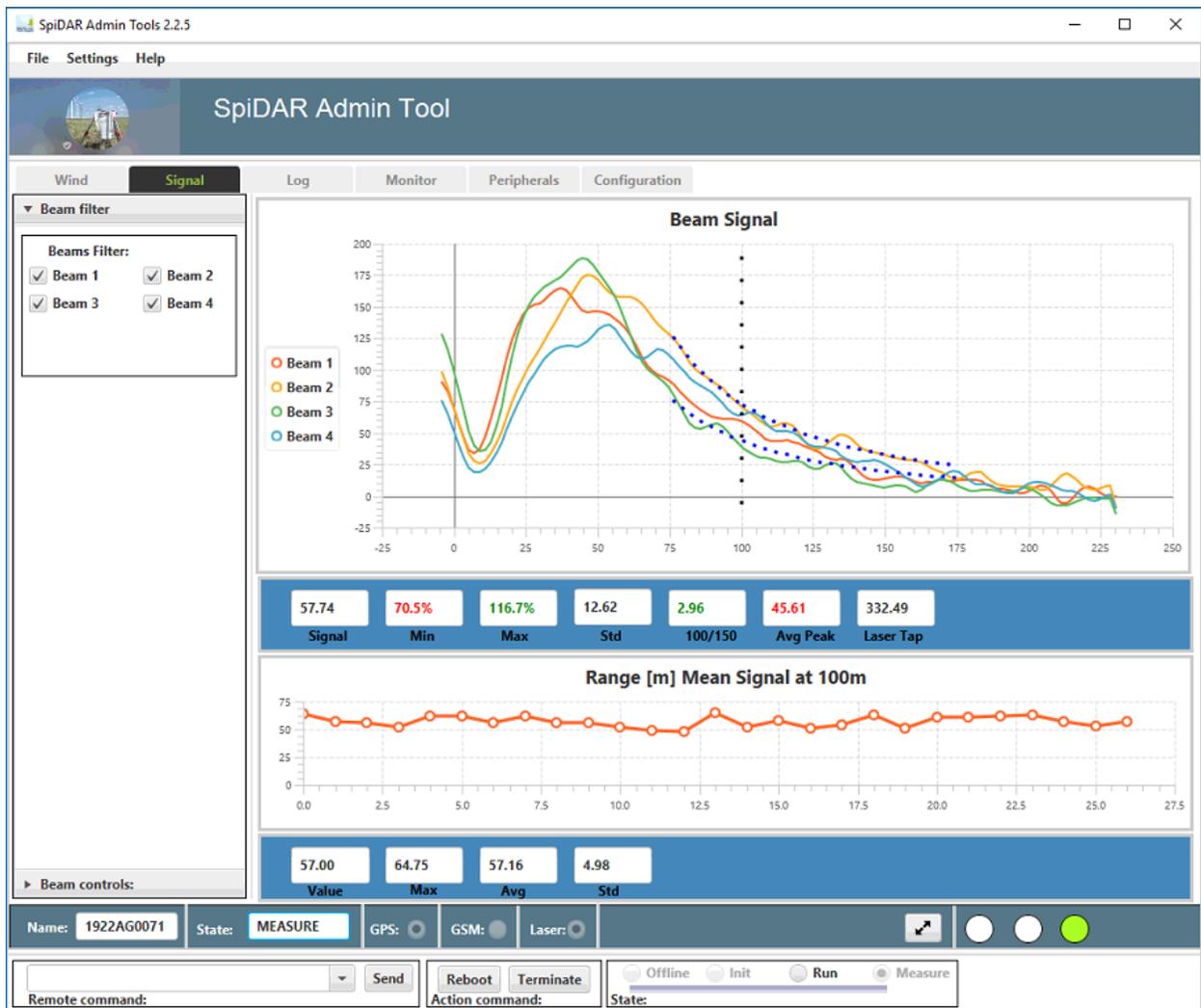


Table 5: Spidar Admin Tool 'Signal' Tab

**NOTE:** the above image shows a typical Spidar Beam Signal. Contact NRG Technical Services with questions or if the beams are falling outside of the dotted lines – if this is the case the Spidar likely needs a mirror adjustment.

- b. If using 10 minute averages, the “Wind” tab will provide average data points every 10 minutes (with AVG” selected instead of “RAW”).
- c. **DO NOT CHANGE OTHER VALUES OR CLICK OTHER BUTTONS INSIDE THE APP AS THEY MAY AFFECT THE SPIDARs SETTINGS.**

**Check Data Files:**

After 10+ minutes the Spidar will write data to the storage cards. Before leaving the site it is good practice to pull the latest data file to make sure the data files are being written to the Spidar properly.

1. Current data files cannot be read, so it is necessary to fist cycle power to close the current file.
  - a. Turn off the Spidar for 1+ minutes, and then re-power.
2. Using the Spidar Power Controller PC, connect to the Spidar with FileZilla.
3. Navigate to the Storage Card/DATA folder, which contains the data files.
  - a. Right click and choose View/Edit to review the file in Notepad.
  - b. Or, choose the files you want to move over to the Power Controller PC and choose the location you want to download them to in the left (Local site) window. Drag the files from the right screen to the left or right click on the data files and choose Download.
4. There will only be a couple 10-minute average entries (depending on how long the Spidar was running before being rebooted). If the right range gates are visible and the wind speed/direction readings are reasonable then the Spidar is ready to be left to measure!

**Notify NRG Systems:**

Once the Spidar has been configured send an email to NRG Technical Services to confirm that the Spidar has been installed. Please include the Spidar serial number (AG00XX) and the names and email addresses of the people that want to receive the Spidar data files.



## VII. SYSTEM MAINTENANCE

### A. Maintenance Schedule

The Spidar requires periodic maintenance to ensure reliable continuous operation. We recommend the following maintenance schedule:



#### Check Spidar Glass

The top of the Spidar should be clear of any debris and dirt. If dirty, make sure the Spidar has wiper fluid and clean the glass with water and a soft cloth. Use isopropyl alcohol for stubborn stains.

#### Check Spidar Leveling

Proper leveling is critical to taking accurate measurements. Undo the protective cap and verify that the spirit bubble is still in the middle of the circle. If misaligned, re-level the Spidar.

#### Check Power Supply

Verify on the charge controller that the batteries are at a healthy level 24.5+ VDC. Clean the PV panels off if they are directly, check the battery bank to verify that they are secured and connected properly.

#### Check Cables

Make sure all cabling/wires are protected against the environment and animals and that they are not damaged.

#### Fill Wiper Fluid

The Spidar's status lights will change to Yellow when the reservoir is 1/3 full. Refill as needed. It is recommended to start with monthly inspections to see how much liquid the Spidar is using at the current site. Once consumption is known then the schedule can be reduced.

#### Review Data Files

Looking at the data files and LOG files will help verify that the Spidar is operating normally.

**Maintain Site Vegetation**

Check to see if vegetation is growing up around the Spidar or Power Supply. Cut vegetation back and take preventative measures to keep it from interfering with the equipment.

**Adjust PV Angle**

If the PV panels are adjustable, change their orientation in the summer and winter to maximize PV gain.

**Replace Wiper Blade**

The wiper blade should be replaced preemptively to avoid it wearing down and scratching the glass. A yearly change of the wiper is a general suggestion and therefore close attention should be paid to see if it should be replaced more frequently.

**B. Wiper Replacement Instructions**

The Spidar wiping system that consists of wiper arm and water nozzle which is used to clean the top window. The wiping system is controlled by an algorithm based off the precipitation sensor and the Lidar beam strength. To replace the wiper blade:

1. Lift the wiper into the upright position.
2. Firmly hold the wiper arm with one hand and the wiper blade with the other.
3. Slide the wiper blade downwards to release it from the wiper arm.



4. Place the new wiper blade under the hook and slide it upward until it clicks into place:



### C. Wiper Fluid Nozzle Service

The Wiper Fluid Nozzle clips onto the wiper arm and can require maintenance to remove clogs.



If the nozzle gets clogged, clear it with compressed air or a pin.



#### D. Power off Spidar

To power the Spidar off:



Power Switch for Newer  
Spidar systems

1. Remove Connection Panel cover
2. Flip the power switch to OFF

NOTE: When rebooting the Spidar, wait at least 1+ minutes before turning back on.



## VIII. DATA ANALYSIS

### A. Introduction

These guidelines are provided to facilitate the analysis of NRG Spidar Vertical Profiler wind measurement data. They are especially intended for Spidar owners or third-party evaluators who are analyzing the Spidar measurements to learn important information about the wind resource at their site.

Our recommended analysis methodology is not only targeted at wind assessment experts but to all those interested in understanding the valuable insight that the use of Spidars can provide when assessing a site’s wind resources.

An explanation of how the Spidar calculates wind speed and direction over a range of heights and some key terminology are presented.

The main section of this document provides information about the 10-minute average file generated by the Spidar and a step-by-step procedure for filtering the Spidar data. It also outlines methods to analyze the results in various ways and guidelines for correlating the Spidar to a met mast.

### B. Spidar File Structure

The Spidar sensor measures and records average wind speed and direction every 10 minutes. These measurements are stored in a CSV format wind data file in the following location in the sensor's storage card: \Storage Card\DATA

This chapter describes the data structure of these wind data files.

#### 1. File Name

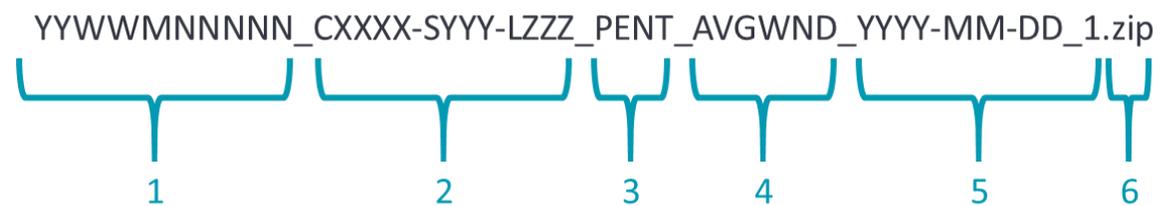


Table 6: File Naming Convention

#	Field Name	Description
---	------------	-------------



1	Sensor Serial Number	A unique number belonging to a single Spidar, designated during production.
2	Notes	<p>A collection of short notes recorded during installation. If notes are not provided, the field will fill with default letters ('0'). Note examples include:</p> <ul style="list-style-type: none"> <li>• Customer identification. "C" character followed by customer name. 4 alphanumeric characters.</li> <li>• Site identification. "S" character followed by site name. 3 alphanumeric characters.</li> <li>• Location identification. "L" character followed by 3 alphanumeric characters.</li> </ul> <p>A '-' character delimits the fields.</p>
3	Company Name	A fixed string denoting the company name (eg. NRGs)
4	File Type	A 6 letters string denoting the type of the file. The following options apply: AVGWND
5	Date	<p>Format: YYYY-MM-DD_#</p> <p># - sequential number of a specific file within a day (starting from 1)</p>
6	Extension	CSV / ZIP depending on file format

## 2. File Format

The format of the file is CSV (Comma Separated Delimiter) and can be easily opened with Microsoft Excel, a text editor, or wind analysis software. The file is encoded in UTF-16.

## 3. Data File Contents

The daily wind data files are laid out in the following format:

	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6 through 18 - 1st Measurement Height (13 columns)	Column 19 through 31 - 2nd Measurement Height(13 columns)	
Row 1	Column Headers							
Rows 2 - 145 (for a 24 hour period)	Timestamp	pressure[mmHg]	temperature[C]	humidity[%]	precipitation[0-1]	spd_40_horz_min[m/s] spd_40_horz_max[m/s] spd_40_horz_mean[m/s] spd_40_horz_std[m/s] spd_40_vert_min[m/s] spd_40_vert_max[m/s] spd_40_vert_mean[m/s] spd_40_vert_std[m/s] dir_40_min[Deg] dir_40_max[Deg] dir_40_mean[Deg] dir_40_std[Deg] wind_measure_40_quality[%]	spd_60_horz_min[m/s] spd_60_horz_max[m/s] spd_60_horz_mean[m/s] spd_60_horz_std[m/s] spd_60_vert_min[m/s] spd_60_vert_max[m/s] spd_60_vert_mean[m/s] spd_60_vert_std[m/s] dir_60_min[Deg] dir_60_max[Deg] dir_60_mean[Deg] dir_60_std[Deg] wind_measure_60_quality[%]	Etc....



The daily data files include:

- (1) **Time stamp – determined by GPS satellite link**
- (2) **Barometric pressure – 1m above ground level (AGL)**
- (3) **Temperature – 1m AGL**
- (4) **Humidity – 1m AGL**
- (5) **Precipitation – 1m AGL**
- (6) **Wind speeds – up to 10 different user-defined heights**
- (7) **Wind directions – up to 10 different user-defined heights**

#### 4. Time Stamp

Time format according to the ISO-8601 standard.

**YYYY-MM-DD hh:mm:ss.mmm**

Table 7: Timestamp Structure

YYYY	Year using 4 digits (Range - 0000-9999)
MM	Month within a year using 2 digits (Range - 01-12)
DD	Day within month using 2 digits (Range - 01-31)
hh	Hour within a day using 2 digits (Range - 00-23)
mm	Minutes within an hour using 2 digits (Range - 00-59)
ss	Seconds within a minute using 2 digits (Range - 00-59)
mmm	Milliseconds within a second using 3 digits (Range - 000-999)

#### 5. Met Measurements

**Barometric pressure** values represent the average pressure readings as received from the pressure sensor for the current time period at 1m above ground level. Table 1 summarizes the barometric pressure sensor parameters.

**Temperature** values represents the average external temperature at 1m above ground level as received from the temperature sensor for the current time period.

**Relative Humidity** values represent the external relative humidity at 1m above ground level as received from the humidity sensor for the current time period.

**Precipitation** values represent the external precipitation reading as received from the precipitation sensor for the current period. The precipitation sensor detects rain drops at 20Hz. The reading in the file is the sum of these detections, normalized to 1

See section IV. Spidar Specifications for measurement specifications.



## 6. Wind Measurements

Every measured height produces 13 values (expressed as columns) and divided into:

- **4 columns - Horizontal speed**
- **4 columns - Vertical speed (not provided currently)**
- **4 columns - Horizontal direction**
- **1 column - Measurements quality**

The first 4 columns are the horizontal speed measurement results.

*Table 8: Horizontal Wind Speed Data Structure*

spd_h_horz_min[m/s]	horizontal minimum speed in meters/second for height h
spd_h_horz_max[m/s]	horizontal maximum speed in meters/second for height h
spd_h_horz_mean[m/s]	horizontal average speed in meters/second for height h
spd_h_horz_std[m/s]	horizontal standard deviation speed in meters/second for height h

The next 4 columns are reserved for vertical speed measurement results, which are not currently available. Data is filled with 0's. The next 4 columns are the horizontal wind direction measurement results.

*Table 9: Wind Direction Data Structure*

dir_h_horz_min[m/s]	horizontal minimum direction in degrees for height h
dir_h_horz_max[m/s]	horizontal maximum direction in degrees for height h
dir_h_horz_mean[m/s]	horizontal average direction in degrees for height h
dir_h_horz_std[m/s]	horizontal standard deviation direction in degrees for height h

Finally, the last column of wind measurement data is the measurement quality factor.

*Table 10: Wind Measurement Quality Factor*

wind_measure_h_quality[%]	The quality is a number between 0-100
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## C. Spidar Data Filtering

Each Spidar wind speed measurement is accompanied by a quality score (Q value). This is a number between 0 (lowest confidence) to 100 (highest confidence) that is determined based on a combination of several parameters.



## 1. Data Quality Indicator Inputs

- (1) Percentage of raw real time results used to calculate the 10 minute average.*
- (2) Correlation level of the current measurement to other 10 minute measurements in close measurement heights/ranges and close time stamps.*
- (3) Signal or equipment problems leading to quality = 0.*

## 2. Setting a Data Quality Threshold

Setting a quality threshold (Qth) is an efficient mechanism to throw out low quality data from the measurements results and leave only high-quality data that give useful results to the user. Qth affects both the quality of the results and data availability. The higher Qth is, the better the remaining results are, but also more data is being filtered out and the data availability is lower. It is therefore important to choose the optimal Qth value that will give the best accuracy with the best data availability for each test site and test conditions. In general, it is recommended to implement Qth to each measurement height separately based on the following suggested procedure:

- (1) As a rule of thumb – we recommend to use Qth of 20 (use data with Quality score  $\geq 20$  – i.e. filter out data when the quality is less than 20). This is a good starting point in the process of finding an optimal quality threshold.*
- (2) If this Qth results with data availability of  $>85\%$ , it is recommended to keep it as is and use it for the rest of the analysis done on this set of data.*
- (3) If the resulted data availability is lower than 85% - it is recommended to reduce the value of Qth until the user gets data availability of 85%. However, this data set may contain singular points of low quality wind speeds so it is crucial in this case to check the quality of the data by comparing wind speed results of two close heights by drafting the correlation ( $R^2$ ) graph between the two close heights. If the correlation coefficient is strong ( $R^2 > 0.96$ ) then keep this new value.*
- (4) If not, follow the next phase: Filter humidity to  $<97\%$  - as high humidity sometimes results with fog that disrupt the measurements. That may eliminate singular points that were not removed by Quality 0 of the system.*
- (5) Filter strong rain out of the data by throwing out data with Rain value  $>0.5$ .*
- (6) If filtering through Humidity and Rain parameters doesn't improve the correlation values, then go back and select higher Qth values until the correlation value is strong, and use the new Qth value that results from this process for the rest of the analysis. In this case the new Qth value is a compromise that gives lower data availability but keeps the proper accuracy and value of the original measurements unbiased.*
- (7) The above process should be repeated in general for each measurement height or range of the system.*

Please note:



- *The quality score does not correspond directly to data availability (i.e. when using filter of quality score  $\geq 20$  it does not mean that you have filtered out 20% of the data!)*
- *An optimal quality threshold is both site and customer dependent – so there is not a standard value that is optimal in all cases.*



## IX. SPIDAR TO METEOROLOGICAL TOWER CORRELATION GUIDELINES

### A. Introduction

It is best practice to install the Spidar close to a met tower for conducting a correlation study before starting the measurement campaign. Typically, 2 to 4 weeks of data is sufficient to ensure that the Spidar is operating correctly and agrees with met tower measurements. In the following section, the recommended data analysis procedure for a Spidar to meteorological tower correlation study is given. The advised filtering algorithm is explained and various ways of comparing the Spidar and tower data are demonstrated. Several recommended measures of Spidar performance are given and these include:

**(1) Spidar Reliability (Operational Uptime)**

**(2) Percent of Valid Spidar Data vs. Height**

**(3) Correlation of Spidar to Tower Data**

- (a) Wind Speed
- (b) Wind Direction

**(4) Wind Rose Comparison**

### B. Positioning the Spidar near the Meteorological Tower

It is strongly recommended to position the Spidar as close as possible to the meteorological tower while remaining clear of known obstructions or obstacles such as guywires, trees, or other vegetation. An easy rule of thumb to remember is 10:1. The Spidar needs to be 1m horizontally clear from an object for each 10m in height of the object.

See IV.A. Siting for a table of obstacle offset distances by height, and comparisons to other types of remote sensing devices.

### C. Data Filtering Procedure

Whenever the Spidar is operating it is collecting data. Therefore, the unfiltered data capture rate is equivalent to the system's reliability or up time. However, before conducting a correlation study or using Spidar data to characterize a site's wind resource, the wind data should be filtered to ensure high quality measurements. Several factors can cause invalid readings such as icing events for anemometer data or low atmospheric reflectivity and heavy fog for Spidar.

**1. Spidar Data Filtering**

**(1) Follow procedure described in VIII.C. Spidar Data Filtering.**

**2. Met Mast Data Filtering**



- (1) Filter time stamps with wind speeds < 2 m/s.**
- (2) Filter data from sectors where anemometers are in tower shadow.**
  - (a) If there is only one anemometer at a given height, determine the boom orientation of each anemometer and remove data when the wind direction was from the opposite side of the tower (with a width of 30°). For example, if an anemometer's boom orientation is 90° then the wind speed measurements should be omitted when the wind direction was from 255 – 285° .
  - (b) If there are two anemometers at a given height, plot the ratio of the anemometer measurements as a function of wind direction, determine the wind direction sector affected by tower shadow for each anemometer and omit the corresponding data. (Typically, tower shadow affects a ~30° wide sector and can be identified as large spikes in the ratio plot.)
- (3) Filter data from sectors where the Spidar is shadowed by the meteorological tower or other obstacles such as wind turbines or trees.**
- (4) Filter data from time periods where the met mast experienced icing. Freezing temperatures can cause cup anemometers to stick or freeze and underreport wind speed. Icing events can be identified by examining the standard deviation of mechanical wind direction vanes. Periods where ambient temperatures are near or below 0°C and the standard deviation of vanes remains at a fixed value are likely icing events. Data acquired during such periods should not be included in a correlation analysis.**

### **3. Time Stamp Alignment**

It is very important to ensure that the Spidar and tower data sets are using the same time stamps before beginning a correlation analysis. The Spidar default reports in UTC time while met tower data loggers often use local time. Furthermore, the Spidar's time stamp corresponds to the end of the ten-minute average, while many loggers use the time stamp at the beginning of the interval. It may therefore be necessary to adjust the time stamp to account for these differences.

A simple way to check that the Spidar and tower data are aligned is to examine a time series plot of the wind speeds.

### **D. Data Correlation Methods**

After the Spidar and tower data have been filtered and the time stamps have been aligned, the two data sets can be compared and the performance of the Spidar can be evaluated. The following performance measures are recommended and are demonstrated in the following section:



- a) *System Availability*
- b) *Post-Processed Data Availability*
- c) *Wind Speed Correlation to Anemometer data*
- d) *Average Wind Speed Comparison*
- e) *Wind Direction Correlation to Vane data*
- f) *Wind Rose Comparison*

### 1. **System Availability**

System availability is defined as the percent of time that the system was up and running and collecting data. This does not distinguish between valid and invalid data. To calculate this number use the following equation:

$$UpTime = \frac{\# \text{ of Averages}}{Max \# \text{ of Averages}}$$

### 2. **Post-Processed Data Availability**

Spidar data filtering is discussed in VIII.C. Spidar Data Filtering. The post-processed data availability metric is defined as the percent of ten-minute averages remaining at the end of this process divided by the maximum number of averages possible for the campaign duration.

### 3. **Wind Speed Correlation Methods**

One measure that quantitatively describes the agreement between two data sets is the correlation coefficient,  $R^2$ . This value ranges from -1 to 1 and denotes how well two sets of data track one another. A correlation coefficient of -1.0 implies a perfect inverse correlation while a value of +1.0 is indicative of perfectly synced data.

One method to determine the correlation coefficient is to use Excel's built-in function CORREL. This function calculates the correlation coefficient between the two series of data.

### 4. **Average Wind Speed Comparison**

An important aspect of a Spidar-tower correlation study is the average wind speed comparison. While the correlation coefficient is an excellent measure of how well the two data sets track one another, the agreement in average wind speed is also a key factor in assessing the quality of the Spidar-tower comparison.



### **5. Average Wind Direction Comparison**

The correlation between the Spidar and tower wind direction data can be examined in the same way as the wind speed data as long as the north wind direction data is dealt with correctly.

When the wind is from the north, the wind direction value transitions between 360° and 0° and this causes problems when calculating the correlation coefficient. To resolve this, sort the data by direction and either add or subtract 360° from one data set in the northern direction sector.

Once this is complete, the correlation coefficient can be calculated correctly.

### **6. Wind Rose Comparison**

The wind rose is a common method of representing wind direction data. It allows the prevailing wind directions to be easily determined and they provide information about how variable the wind direction is at the site. In this section, the wind rose as determined by the Spidar and met tower wind vane are compared.

To generate a wind rose, each data set is separated into 16 wind direction sectors (22.5° wide) and the number of data points in each bin is counted.