Ver V1 (Jan 2022)

SAGE

A Software-Defined Sensor Network

Cyberinfrastructure for AI at the Edge


# GETTING STARTED

## WILD SAGE NODE – VERSION 1

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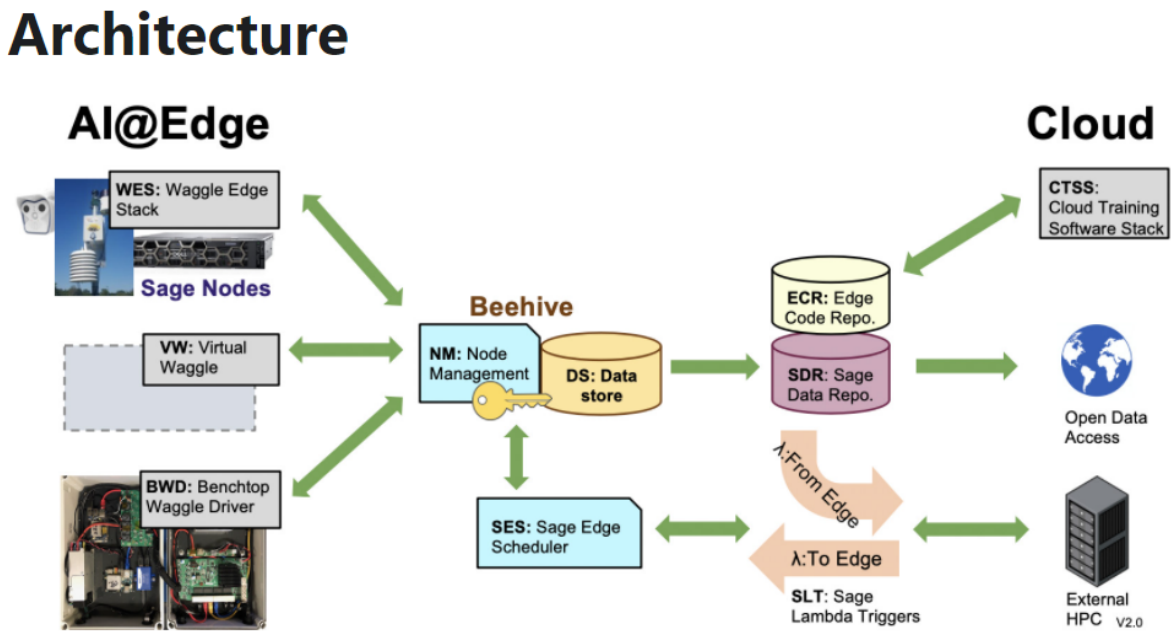
# Introduction

## Sage Vision

**The goal of Sage CI is to design and build a new kind of national-scale reusable cyberinfrastructure to enable AI at the edge.**

From early detection of wildfire smoke plumes to identifying ultrasonic calls of bats or the patterns of pedestrians in a busy crosswalk, Sage's artificial intelligence-enabled sensors will give scientists a new tool to understand our planet. Sage explores new techniques for applying machine learning algorithms to data from such intelligent sensors and then builds reusable software that can run programs within the embedded computer, and transmit the results over the network to central computer servers. Sage developed computer code and hardware design is open source and available on GitHub.  The data from sensors is hosted in the cloud to facilitate easy data retrieval and analysis.



## Why Sage?

Distributed, intelligent sensor networks that can collect and analyze data are essential for scientists seeking to understand the impacts of global urbanization, natural disasters such as flooding and wildfires, and climate change on natural ecosystems and city infrastructure. Sage will deploy sensor nodes that support machine learning frameworks in environmental testbeds in California, Colorado, Oregon, Texas, Oklahoma, and Kansas, and in urban environments in Illinois and Texas. The reusable cyberinfrastructure running on these testbeds will give climate, traffic, and ecosystem scientists new data for building models to study these coupled systems. Sage will also extend the current educational curriculum used in Chicago and will inspire young people – with an emphasis on women and minorities, to pursue science, technology, and mathematics careers – by providing a platform for students to explore measurement-based science questions related to the natural and built environments.

Some of the science applications targeted through Sage are listed below. Please follow the links to find out more:

- WildFire Detection: WildFire Detection Science
- Snowflake Classification: Snowflake Classification Science
- Water Segmentation: Water Segmentation Science
- Water Level Detection: Water Level Detection Science
- Vehicle Tracking: Vehicle Tracking
- Lightning Science: Lightning Science
- Social Distancing: Social Distancing
- Characterizing Clouds: Characterizing Clouds
- Nowcasting Weather: Weathernet: Nowcasting Net Radiation at the Edge
- Bandwidth Aware Learning: Bandwidth Aware Learning

## WSN Features and Capabilities

As a cloud enabled software-defined sensing instrument, a wild sage node derives its capabilities through a combination of hardware sensors and actuators, and the edge-applications that work closely with the sensors and the connected cloud infrastructure. The following table briefly describes the various features and capabilities in this generation of WSN.

| Feature | Capabilities / Details |
|---|---|
| **Hardware** | |
| *Sensing* | Environmental TPH Sensor (BME680), up to three Cameras (XNV-8081Z and/or XNF-8010RV), Optical Rain Gauge (RG-15), Condenser Microphone (Max SPL 120db, 20-18khz response, –50db Sensitivity) |
| *Edge Processing* | Upto two Nvidia Volta GPUs each with 8 GB LPDDR4 RAM, 1TB shared storage, and capable of running machine learning (ML) models. Multiple Raspberry Pi4s with 8GB RAM, 32GB shared storage and capable of running light-weight applications |
| *Expansion* | New sensors, actuators, and computing components can be added through USB (1x) and POE (upto 2, depending on the node configuration) interfaces |
| **Measurements, Inference, and Data** | |
| *Temperature, barometric pressure, and relative humidity measurements* | Default frequency of 2 per minute. Can be configured for higher rates upto 1Hz |
| *Rain accumulation measurements* | Default frequency of 2 per minute. Can be configured for higher rates upto 1Hz |

| | |
|---|---|
| *Image / Video / Audio Data Collection for AI/ML training* | Variable and location dependent. By default no continuous collection |
| *Video data stream for Edge Applications* | 5 megapixel RGB H.264 frames @ 2560x1920 and 30 FPS, RTSP Stream |
| *Audio data stream for edge applications* | 48KHz mono audio, Pulse Audio Stream |
| *AI/ML applications* | 12 pre-loaded applications, ready for deployment out of the box. New applications can be added by submitting them to the Edge Code Repository (ECR) (portal.sagecontinuum.org) |

More information and details are provided in the Sage Cyberinfrastructure for AI at the Edge Overview.

## Data Access

A growing number of sensor data and inference results from the nodes are collected and published by Sage. In addition to data captured by the sensor nodes, data useful for training new AI/ML models are also collected and published. Up to date information on data availability, access methods, and metadata are described in the Access & Use Data page. Sage data can be obtained through two methods -

**1. Downloadable Data Archives**: A daily updated archive containing all sensor and inference data produced by the Sage nodes can be downloaded from the SAGE Data Archive site.

### 2. Data API

All reported data, inferences results and training data can also be accessed in near real-time via a REST API.

- https://data.sagecontinuum.org/api/v1/query (REST interface)
- SAGE Data Client (API interface python library)

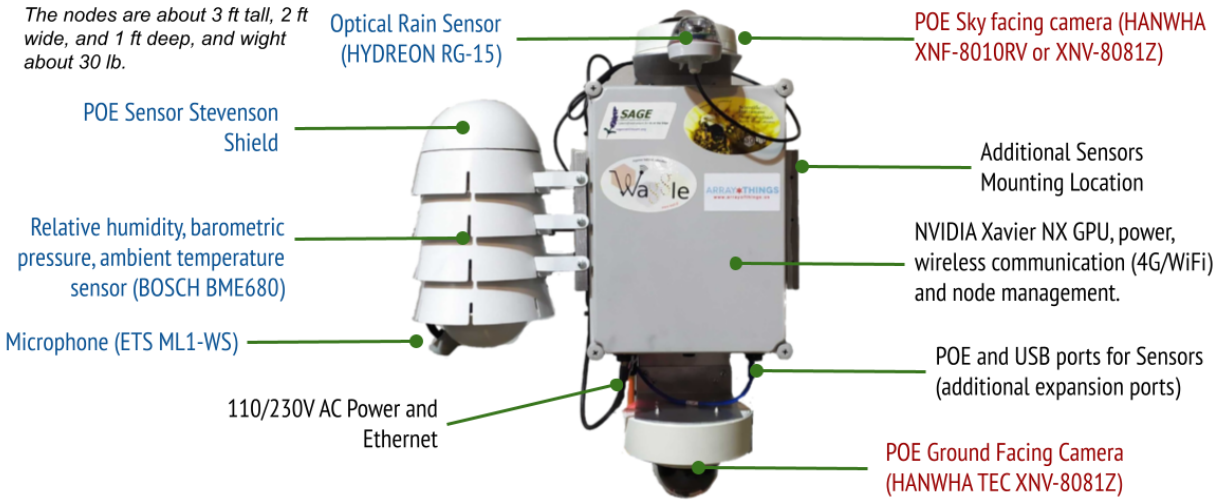
The following is an example of using the REST API to access all the BME680 (gas sensor) data produced in the last 10 seconds:

```
curl -H 'Content-Type: application/json'
https://data.sagecontinuum.org/api/v1/query -d '
{
    "start": "-10s",
    "filter": {
        "sensor": "bme680"
    }
}
'
```

# Sage Instrument

## WSN Overview

The Wild Sage Node (WSN) integrates several sensors, computing, and expansion capabilities in the default configuration (Figure 1). Additional sensors can be mounted on the side sensor mount-plate (with custom drill holes) and connected to the system through USB/POE Sensor interface ports in the bottom.




The Wild Sage Nodes may feature one or both of the following cameras:

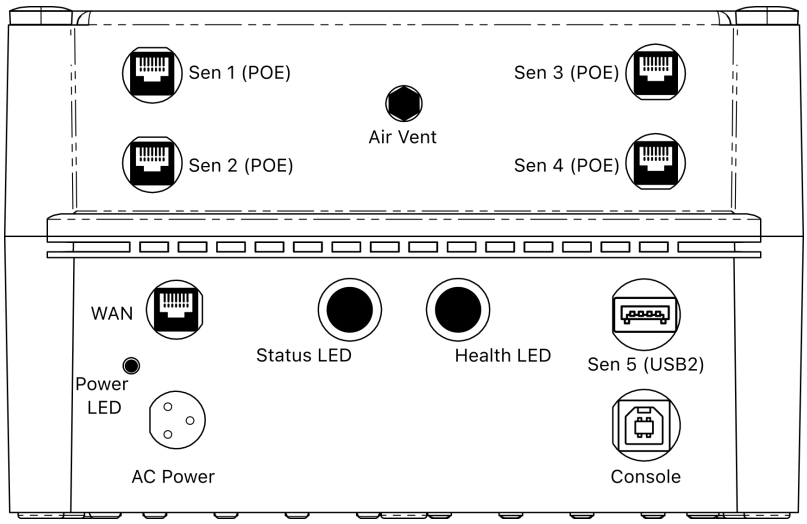
- XNF-8010RV with simple focus for Wide Angle / Fisheye View.

- XNV-8081Z with motorized varifocal lens, field positioning and zoom capability.

The ground (and optional horizon) facing camera is XNV-8081Z, and the Sky facing camera is either XNF-8010RV or XNV-8081Z depending on the use case and deployment location.

## Sensor Connectivity

Several sensors can be connected to the WSN node through the weather-proof boundary connectors on the bottom of the main processing box. The figure below highlights the various sensor connectivity options on the node .




| Port | Description | Use |
|---|---|---|
| Sen 1-4 (POE) | Interface port with POE capability. 30W max power, DHCP addressing. Sensors connected here are accessible by all processing modules in the node. | Cameras and stevenson shield that are part of the standard node use these ports. One or more ports may be available for interfacing additional sensors |
| Sen 5 (USB2) | Interface port with USB2 support. Sensor connected to this port is only available to the 1st processing module in the node. | Generally available to interface a legacy USB sensor. The POE is the recommended interface to add new sensors to the instrument. Compatible cable can be obtained here. |

## Technical Specification

| Wild Sage Node | |
|---|---|
| **Base Weight:** | 13.5 kg / 30 lb |
| **Dimensions:** | 75x57x32 cm / 9.5x22.5x12.5 in |
| **Power Input:** | 50/60 Hz, 85-264 VAC*, 80W average |
| **Mounting height:** | City Street installation - 5.5 m / 18 ft from ground level. For all other installations please discuss with the Sage team. |

** The WSN internally uses DC power upto 48V only, supplied by a modular AC/DC converter (Model: RCB600). The AC power fed to the node through the boundary connector is directly fed to the RCB600 power converter.*

# Site Preparedness

The WSN is an internet connected research instrument that incorporates sensitive electronics to sense and analyze the environment around it. For proper functioning, the instrument needs proper site selection and preparation ahead of deployment.

## Communications

Each WSN comes with the ability to connect to the internet over WiFi (802.11 AC/N/G) and Ethernet (GigE). Nodes may *optionally* also be fitted with 4G LTE modems and SIM cards depending on the deployment and use case.

### Ethernet Connectivity

The WSN node has a Gigabit Ethernet WAN CAT6 port. The node in the default configuration expects a DHCP issued IP address, and the DHCP DNS option (6) should be offered. For installations using a static IP assignment, please contact the Sage team for configuration at the factory. Only a *non-POE network cable* should be connected here.

### WiFi Connectivity

The nodes are fitted with a dual band 5GHz/2.4GHz 802.11AC WiFi card. To program the ESSID and Password, the node has to be initially connected to the Internet over Ethernet for remote configuration. Alternatively,  please contact the Sage team to set the WiFi profiles at the factory.

### 4G/LTE Cellular Connectivity (Optional)

Nodes with the optional 4G/LTE modem come pre-installed with ATT SIM cards. Please make sure the selected deployment location has good ATT 4G/LTE cellular connectivity.

## Mounting Considerations

There are 3 main considerations for mounting the nodes:

1. For city street deployments, the recommended mounting height is 5.5 meters / 18 ft. from ground level. For all other installations please discuss with the Sage team.
2. The location should ideally be free from artificial sources of heat and particulates.
3. The cameras should be as unobstructed as possible.

## Installation Requirements

The WSN nodes are outdoor deployment ready, and fitted with 3 mounting brackets. The node can be strapped to a pole or a meteorological tower using mounting bands/straps.

**Provided**

- 10.6 meters / 35 ft. long AWG 16/3 power cable

**Suggested Mounting Parts**

- Stainless steel bands, 3/4" x .44" Recommended: 150 Stainless steel band, Part #BA430 or equivalent.
- 3 Stainless steel crimp buckles, 3/4" Recommended: Part # BU440 or equivalent, tensioning and crimping installation tools.
- *Optional:* Power Drill, 19 mm / 3/4" hole saw, rubber grommet, appropriate for hole size and pole wall thickness.

## Ethernet and WiFi Network Requirements

WSN nodes that are connected to the Internet through Wired and WiFi need outbound access to the following IP addresses to operate correctly:

| Server Address | Purpose | Port | Protocol |
|---|---|---|---|
| 192.5.86.5 | SSH | 49190 | TCP |
| 192.5.86.3 | AMQP (RabbitMQ) | 49191 | TCP |
| 192.5.86.4 | SSH/rsync | 49192 | TCP |
| 0.pool.ntp.org<br>1.pool.ntp.org<br>0.fr.pool.ntp.org | NTP | 123 | UDP |
| {docker-auth,registry}.sagecontinuum.org<br>docker.io* | Docker images | 443 | TCP |
| github.com* | Software updates | 443 | TCP |
| nmcheck.gnome.org* | Network interface check | 80 | TCP |

For installations using Ethernet and/or Wi-Fi networking with a DHCP issued IP address, the DHCP DNS option (6) should be offered.

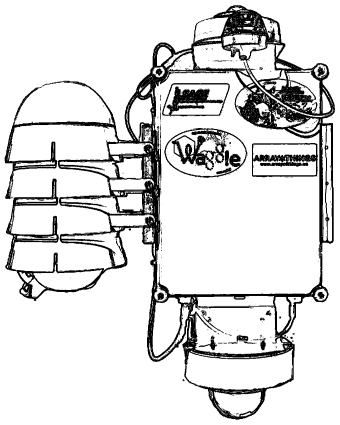
For installations using Ethernet and/or Wi-Fi networking with a static IP assignment, please contact the Sage team for configuration.

* A future software update will limit/eliminate the need for access to non-Sage infrastructure IP addresses from the nodes.

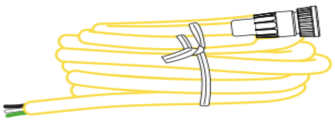
# What is included in the box?

The following two items are included in the box:

**Wild Sage node**



**Power Cable**

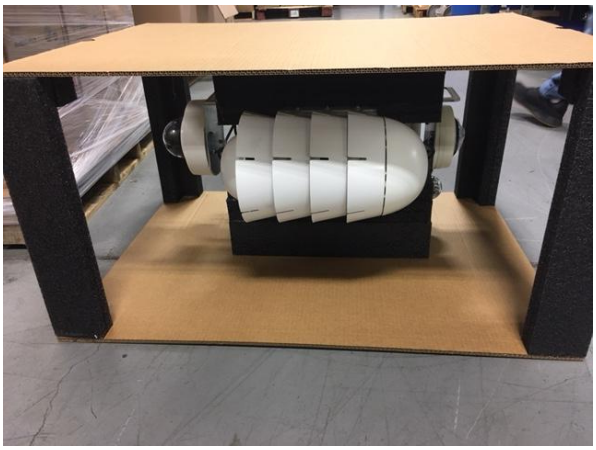


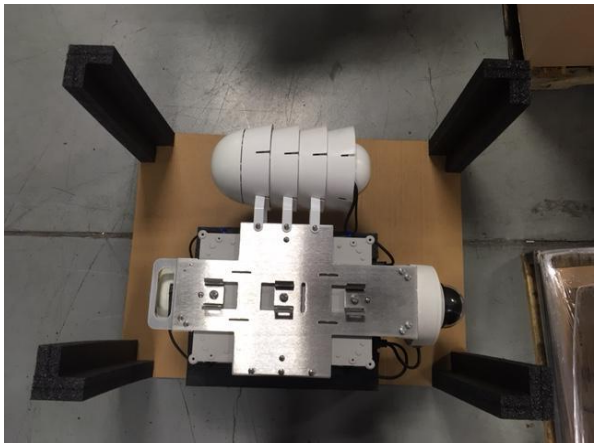
## Power Cable

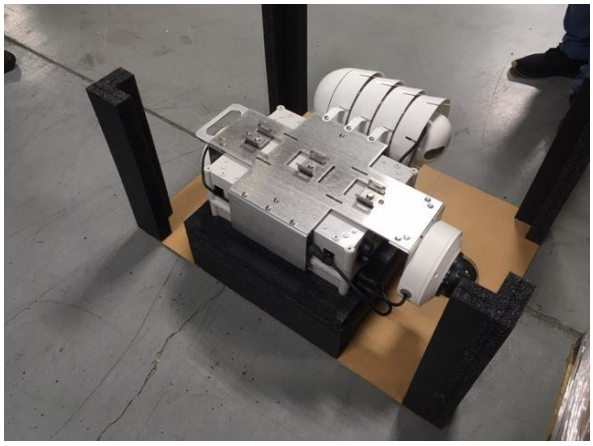
The power cable included in the shipment is outdoor ready. The cable has a IP-66 female connector on one end that connects to the node. The other end can either be spliced directly into the power-line or fitted with an appropriate AC wall plug. The power cable follows standard US single-phase AC electrical wire coloring -

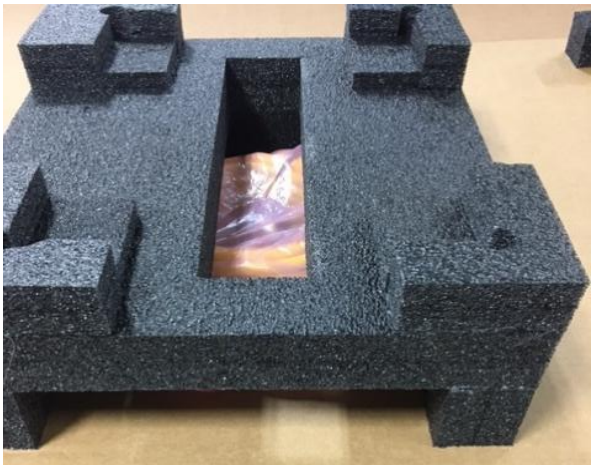
- **Black**: Line, Single Phase
- **White**: Neutral
- **Green**: Protective Ground

## Packaging Details







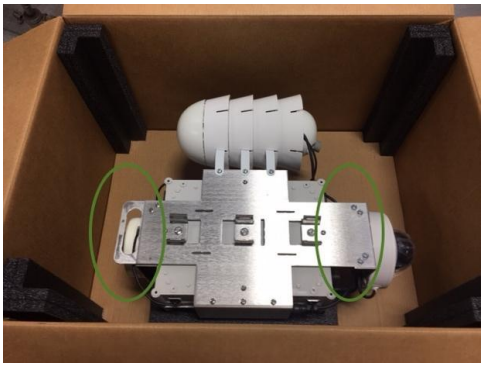


## Unpacking Instructions

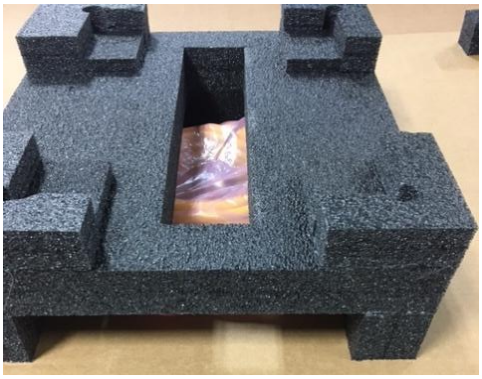
1. Ensure the shipping box is top side up before opening it. From the suggested side, lift the top cover using the two side finger cutouts.


2. Once the top cover is removed, the node can be safely lifted by holding it by the **handle** (on the left) **and** the **camera support** (on the right). The node can be safely set on a table on its back on the stainless-steel mounting brackets (the shiny surface in the image on the right).

*The two green ovals in the picture show the safe lifting locations*.



3. Verify that the top foam padding has the power cable.



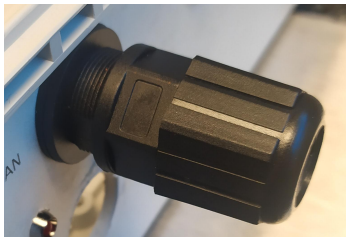
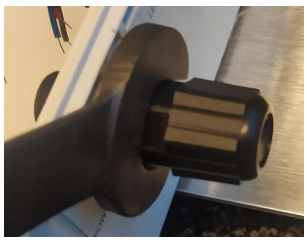
4. Carefully remove the power cable from the packaging.

***The shipment box and packaging are reusable. Please save them for any future transport of the node.***

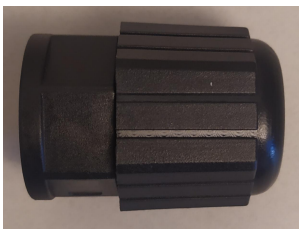
# WAN ETHERNET CABLE INSTALLATION (OPTIONAL)

The WSN WAN ethernet port comes installed with a weatherproof cap. This cap has to be fitted over the network cable to make a water-tight connection to the node. The method below should also be used to connect any additional sensors to Sen 1-4 ports.

1. Carefully remove the cap by unscrewing it with a hex spanner.

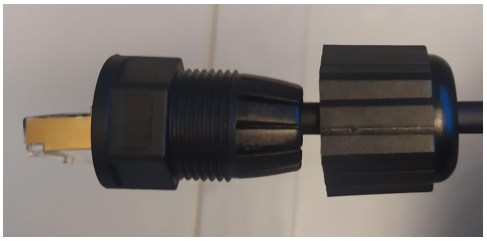



2. Separate the compression cap from the rest of the weatherproof cap assembly.



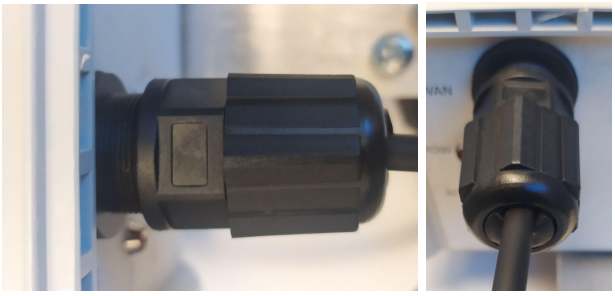
3. Extract the rubber grommet from the base of the cap assembly.

4. Insert the compression cap and the base into the Ethernet cable such that the threaded end is on the same side as the RJ45 jack.



5. Plug the jack into the boundary connector and screw the base on the boundary connector. Fit the rubber grommet around the ethernet cable and push into the flexible portion of the base. The grommet may have to be reduced in length to accommodate cables with large strain relief areas.

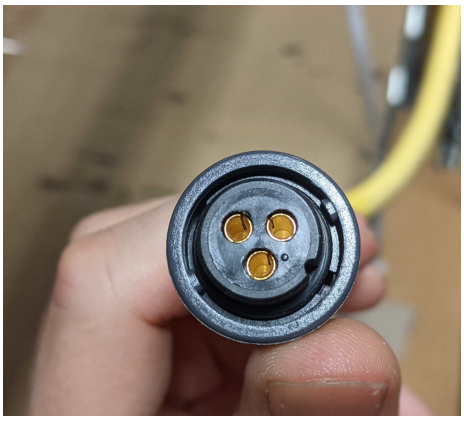
6. Tighten the compression cap on the base, to make a strong seal around the cable.



# NODE POWER ON

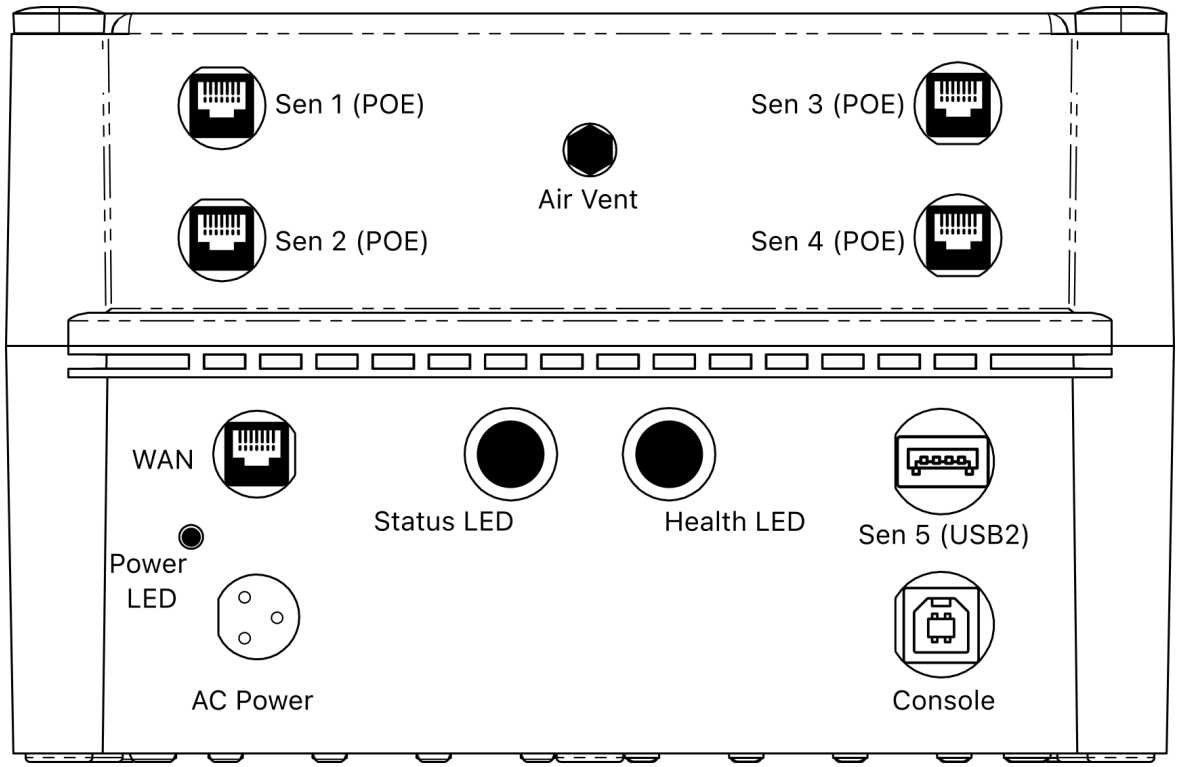
- Locate the AC power boundary connector on the bottom of the node.

- Locate the notches on the female end of the power pigtail. Align them with the depressions in the AC power boundary connector, press in and lock into position by screwing in the twist lock.



- Connect the other end to mains and turn power on to the node. After approximately 16 seconds, the Power LED should turn on. Shortly the Status LED will start blinking blue, showing operation of the node. The Health LED should turn Green in about 70 min if the node is healthy, indicating a successful install.

# BOUNDARY CONNECTIONS AND COMPONENTS




| Port | Description | Use/Notes |
|---|---|---|
| **AC Power** | 3 pin single phase 50/60 Hz, 85-264 VAC power input. | |
| **Power LED** | Red LED that indicates power to the Node. | The LED turns on about 12-16 seconds after applying power. |
| **Status LED** | Multicolored LED that shows the status of the Node. | Blinking blue: the WSN is booted and running. Solid red: the WSN is shutdown and power can safely be removed. |

| | | |
|---|---|---|
| **Health LED** | Multicolored LED that shows the health of the node. | Solid green: Healthy state.<br>Solid Orange: Warning state - one or more minor issues.<br>Solid Red: Failed state - one or more major issues.<br><br>*LED should transition from off to solid green about 10 min after power ON.*<br><br>*If the LED is not green, check back after approximately 1 hour.* |
| **WAN** | Gigabit Ethernet RJ-45 port. | Default network interface for the node. Its use may be called for initial provisioning and post-install debugging. |
| **Sen 1-4 (POE)** | Interface port with POE capability. 30W max power, DHCP addressing. Sensors connected here are accessible by all processing modules in the node. | Cameras and stevenson shield that are part of the standard node use these ports. One or more ports may be available for interfacing additional sensors |
| **Sen 5** | Interface port with USB2 support. Sensor connected to this port is only available to the | Generally available to interface a legacy USB sensor. The POE is the recommended |

| | | |
|---|---|---|
| | 1st processing module in the node. | interface to add new sensors to the instrument. Compatible cable can be obtained here. |
| **Air Vent** | Gore-tex vent for venting moisture safely. | This vent should not be covered. It keeps the main processor box free of moisture and condensation. |
| **Console** | Debugging Serial Console. | Easy access serial console used for debugging by the devOps team. |

## CARE AND MAINTENANCE

- When possible Keep the node free of debris and obstruction post install. Check the stevenson shield and microphone for insect nests. They are warm and attract bugs and insects.
- Wipe the camera off with a microfiber glass cleaning cloth and water.
- Check for fraying wires, and weathering damage on the node from time to time.
- Check for any errors / warnings indicated by the node, and report issues to the Sage team.

# TROUBLESHOOTING

If you believe the node is not functioning properly, or the node indicates issues - Power LED off, Status LED off, or Health LED is red, then please see the table below to identify symptoms and solutions to common problems. If you are unable to resolve your issue, please contact the Sage technical team support@sagecontinuum.org.

| Symptom | Solution |
|---|---|
| Power LED is off after applying power | Please check that the power cable is properly connected to the mains. Disconnect and reconnect the power cable to the node and twist-lock into position. If the node does not power on, contact the Sage team. |
| Status LED is off | Please leave the node on, with the network connected and contact the Sage team. |
| Health LED is red | The Health LED updates about 70 min after initial power up. If the LED continues to be red, please visually inspect the node sensors, enclosures, boundary connectors, and wires for any damage. Please report any damage to the Sage team, preferably with pictures. Next proceed to check that all connectors are properly locked into position. Tighten any connectors and if that does not resolve the error state in 70 min, please contact the Sage team. |

| | |
|---|---|
| Grinding or whining noise from the node | The node has several fans to cool the devices in it. A grinding noise indicates a failing fan. Please contact the Sage team. The team will benefit from knowing where exactly the noise is originating (main box, stevensor shield, other parts). |
| No Data on Sage Portal | Check that the sensors are properly connected, and contact the Sage team. |

## CONTACT US

For any general technical or node-related assistance, please contact support@sagecontinuum.org. For specific questions please contact -

- **Software:** Joe Swantek **-** jswantek@anl.gov
- **Planning and Logistics:** Helen Taaffe - htaaffe@anl.gov
- **System and Deployment:** Raj Sankaran - rajesh@anl.gov

For a digital version of this getting started guide click here!

# Appendix

## Quick Links

**Sage Nodes Dashboard**
https://admin.sagecontinuum.org/status

**Edge Code Repository (ECR)**
portal.sagecontinuum.org

**Sage Science Applications Descriptions**
https://sagecontinuum.org/science/

**Sage Data API Client**
https://github.com/sagecontinuum/sage-data-client

**Access and Data Use**

https://docs.sagecontinuum.org/docs/tutorials/accessing-data

**Sage Data Archive**

https://web.lcrc.anl.gov/public/waggle/sagedata/SAGE-Data.tar

**Sage Data API:** https://data.sagecontinuum.org/api/v1/query

# Safety and Compliance

## Electrical Safety

The core electronics and sensors of the WSN were tested against CENELEC EN 61000-6-2: 2019, CENELEC EN 61000-6-4: 2011, IEC 61000-4-2: 2008, IEC 61000-4-3: 2006 +A1:2007 +A2:2010, IEC 61000-4-4: 2012, IEC 61000-4-5: 2014, IEC 61000-4-6: 2013, IEC 61000-4-11: 2004+A1:2017, CENELEC EN 55011: 2016, FCC Part 15 CFR Title 47: 2020, ICES-001: 2014 (Canada), CENELEC EN 61326-1: 2013 and 2014/30/EU EMC Directive. A detailed report on the test results is available on request.

**Emissions Tests Results**

| Environmental Phenomena | Frequency Range | Basic Standard | Test Level | Test Result |
|---|---|---|---|---|
| Conducted Emissions, AC Mains | 0.15-30 MHz | EN 55011<br>FCC Part 15<br>ICES 003 | Class A | Pass |
| Conducted Emissions, Telecommunication Lines | 0.15-30 MHz | EN 55011 | Class A | Pass |
| RF Radiated Emissions | 30-2000 MHz | EN 55011<br>FCC Part 15<br>ICES 003 | Class A | Pass |

**Immunity Tests Results**

| Port Tested | Environmental Phenomena | Test Level | Basic Standard | Performance Criteria Met | Test Result |
|---|---|---|---|---|---|
| Enclosure | ESD | 8 kV Air 4 kV Contact | EN 61000-4-2 | A | Pass |
| Enclosure | RF EM Field | 10 V/m; 80-1000 MHz<br>3V/m; 1-6 GHz | 61000-4-3 | A | Pass |
| AC Power | Fast Transients | 1.0 kV 5/50 nSec | 61000-4-4 | A | Pass |
| Ethernet | Fast Transients | 0.5 kV 5/50 nSec | 61000-4-4 | A | Pass |
| AC Power | Surges | 1 kV Diff.; 2kV Comm. | 61000-4-5 | A | Pass |
| Ethernet | RF Conducted | 10 V; 0.15-80 MHz | 61000-4-6 | A | Pass |
| AC Power | RF Conducted | 10 V; 0.15-80 MHz | 61000-4-6 | A | Pass |
| AC Power | Voltage Dips and Interruptions | 0% 10 mSec.<br>40% 200 mSec.<br>70% 500 mSec.<br>0% 20 mSec.<br>0% 5 Seconds | 61000-4-11 | A<br>A<br>A<br>A<br>C | Pass |

**IEC 17025 Decision Rule:**
The declaration of pass or fail is based on the specifications listed above. The declaration of pass or fail did not consider measurement uncertainty.

**CE Product-family Test Specifications and Results**

| Document | Date | Title | Test Results |
|---|---|---|---|
| CENELEC EN 61000-6-2 | 2019 | Electromagnetic compatibility (EMC) Part 6-2 - Generic standards - Immunity for Industrial Environments | Complied with All Applicable Tests |
| CENELEC EN 61000-6-4 | 2007 + A1:2011 | Electromagnetic compatibility (EMC) Part 6-4 - Generic standards - Emission standard for industrial environment | Complied with All Applicable Tests |
| CENELEC EN 61326-1 | 2013 | Electrical equipment for measurement, control and laboratory use – EMC requirements | Complied with All Applicable Tests for Class A and Industrial immunity |

## Environmental Testing and Certification

The tests were performed in accordance with IEC 60068 2-30, IEC 60068 2-2, IEC 60068 2-1, and MIL STD 810G. A detailed report on the test results is available on request. No modifications were made to the WSN during the testing. A deviation was made to the specification during the salt fog and blowing dust tests in which the WSN was operated continuously during the testing. The acceptance criteria required proper operation upon completion of the testing and no damage that would interfere with proper operation.

| Test Description | Specification Section | Test Results | S/N | Date Tested |
|---|---|---|---|---|
| Cyclic Damp Heat | IEC 60068-2-30 | Compliant | 001 | 2/17/21-2/19/21 |
| Dry Heat | IEC 60068-2-2 | See Results Section 12.2.4 | 001 | 2/21/21-2/22/21 |
| Cold Temperature | IEC 60068-2-1 | Compliant | 001 | 2/22/21-2/23/21 |
| Wind Blown Rain | MIL-STD-810G, Method 506.6, Procedure I | Compliant | 001 | 2/24/21 |
| Blowing Dust | MIL-STD-810G, Method 510.6, Procedure I | Compliant | 001 | 2/25/21 |
| Icing/Freezing Rain | MIL-STD-810G, Method 521.3 | Compliant | 001 | 3/1/21-3/2/21 |
| Salt Fog | MIL-STD-810G, Method 509.6 | Returned to Customer for Further Evaluation | 001 | 3/3/21-3/7/21 |