Ver V1 (Feb 2022)

Sage

A Software-Defined Sensor Network

Cyberinfrastructure for Edge Computing

www.sagecontinuum.org

GETTING STARTED

WILD SAGE NODE – VERSION 1

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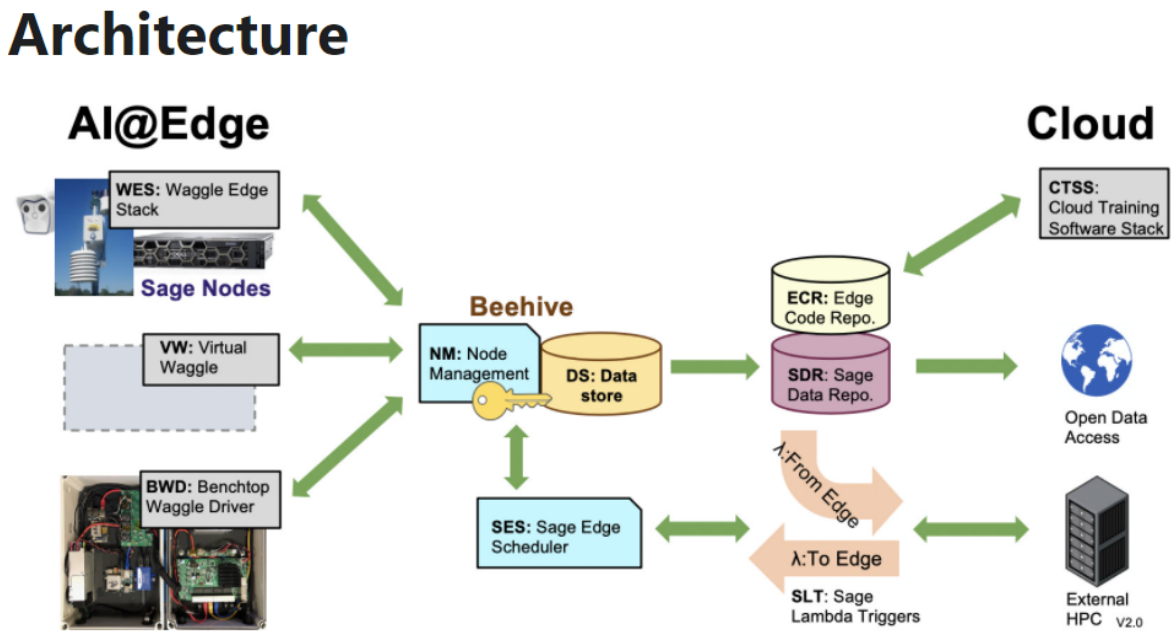
1. Getting Started

1.1 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 are open source and available on GitHub. The data from sensors is hosted in the cloud to facilitate easy data retrieval and analysis. See the figure below.



1.2 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

1.3 Wild Sage Node Features and Capabilities

As a cloud-enabled software-defined sensing instrument, a Wild Sage Node (WSN) derives its capabilities through a combination of hardware sensors and actuators and edge applications. The edge applications interface with the sensors and the connected cloud infrastructure. The following table briefly describes the various features and capabilities available out of the box 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 120 db, 20-18 kHz response, –50 db sensitivity)
Edge Processing	Up to two Nvidia Volta GPUs each with 8 GB LPDDR4 RAM, 1 TB shared storage, and capable of running machine learning (ML) models. Multiple Raspberry Pi4s with 8 GB RAM, 32 GB storage, and capable of running light-weight applications
Expansion	New sensors, actuators, and computing components can be added through USB (1x) and POE (up to 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 up to 1 Hz
Rain accumulation	Default frequency of 2 per minute; can be

measurements	configured for higher rates up to 1 Hz
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	48 kHz mono audio, pulse audio stream
AI/ML applications	12 preloaded 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.

1.4 New Sage Edge Applications

The Sage platform is designed to be hardware and software extensible. The versalite infrastructure is built from the ground up to support new edge applications from the science community following industry standard processes for software development and deployment (Docker, K3S, GitHub etc.). The Sage programming model is out of scope for this document, and more information on getting started with new Sage applications can be found in the compute at the edge guide.

1.5 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 commissioned 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)

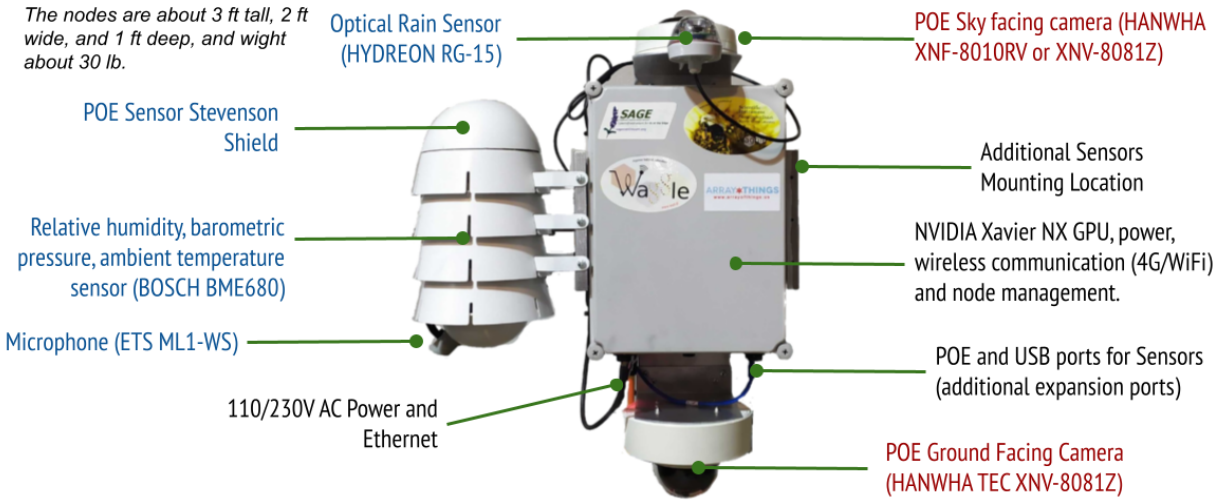
The following is an example of using the REST API to access all the BME680 (gas sensor) data produced in the past 10 seconds:

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

2. Wild Sage Node Instrument

2.1 WSN Overview

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



The WSN may feature one or both of the following cameras:

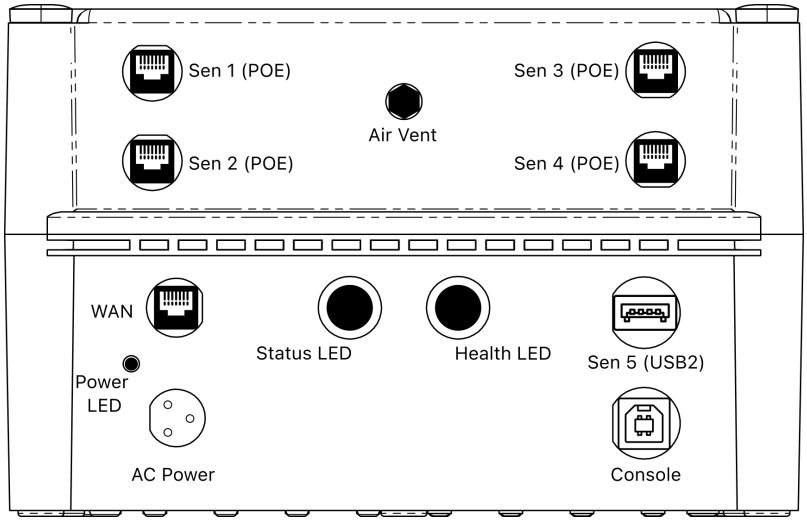
- XNF-8010RV with simple focus for wide angle / fisheye view.

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

The ground-facing (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.

2.2 Sensor Connectivity

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



The table below lists the interface ports and their use with the sensors.

Port	Description	Use
Sen 1-4 (POE)	Interface port with POE capability. 30 W 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(s) connected to this port are available only to the main 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.

2.3 Hardware Technical Specification

The following table lists the basic hardware specifications of the WSN.

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 up to 48 V 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.*

2.4 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 diligent site selection and preparation ahead of deployment.

2.4.1 WSN Connectivity Options

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. WSN nodes use about 6 GB of data every month.

Ethernet Connectivity

The WSN has a Gigabit Ethernet RJ45 WAN port. The node in the default configuration expects a DHCP- issued IP address, and the DHCP DNS option (6) and NTP option (42) 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 to this port.

WiFi Connectivity

The nodes are fitted with a dual-band 5GHz/2.4GHz 802.11AC WiFi card. In order 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.

The nodes are designed to store data when there is a loss in connectivity and to transmit when online again. However, the nodes expect to be connected at all times and take recovery actions to debug and retry to reach a connected state. These actions over prolonged periods of time may lead to time windows of no sensing and computing. If a communication outage is expected or if a mostly unconnected operation is desired, please contact the Sage team for proper configuration.

2.4.2 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 1.pool.ntp.org 0.fr.pool.ntp.org	NTP	123	UDP
{docker-auth,registry}.sagecontinuum.org docker.io*	Docker images	443	TCP
github.com*	Software updates	443	TCP
nmcheck.gnome.org*	Network interface check	80	TCP

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

2.4.3 Installation

The WSN is outdoor-deployment ready and fitted with 3 mounting brackets. The node can be strapped to a pole or a meteorological tower by using mounting bands or 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.

Mounting Considerations

There are 3 main considerations for mounting the nodes:

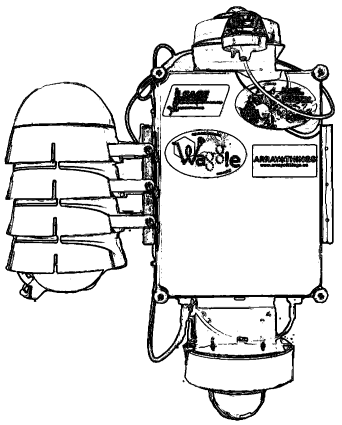
1. For city-street deployments, the recommended mounting height is 5.5 meters / 18 ft. from ground level. For all other installations please discuss with the Sage team.
2. The location should ideally be free from artificial sources of heat and particulates.
3. The cameras should be as unobstructed as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

2.5 Unboxing and Installation Instructions

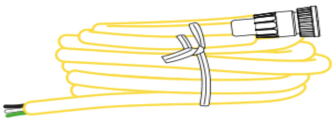
2.5.1 Box Contents

The following two items are included in the box:

Wild Sage node



Power Cable



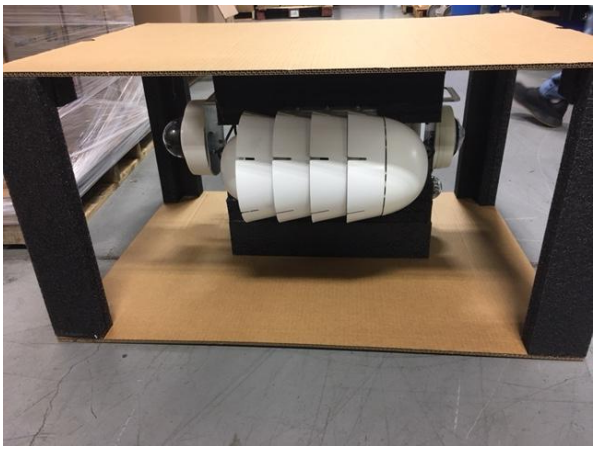
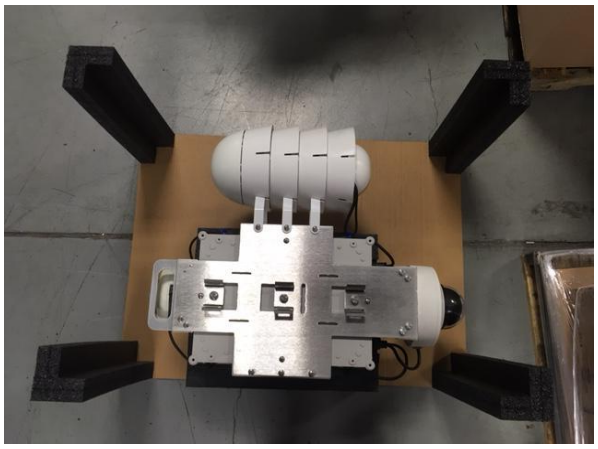
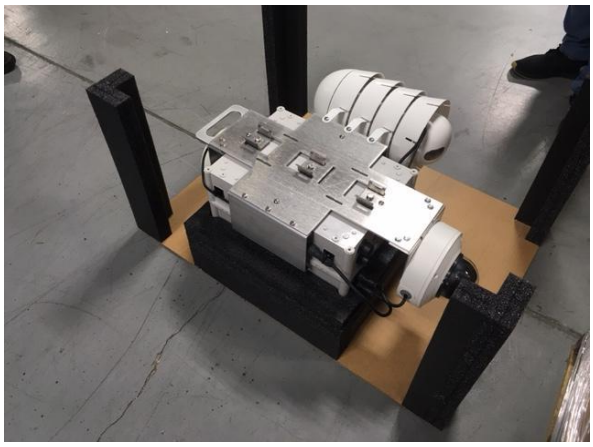
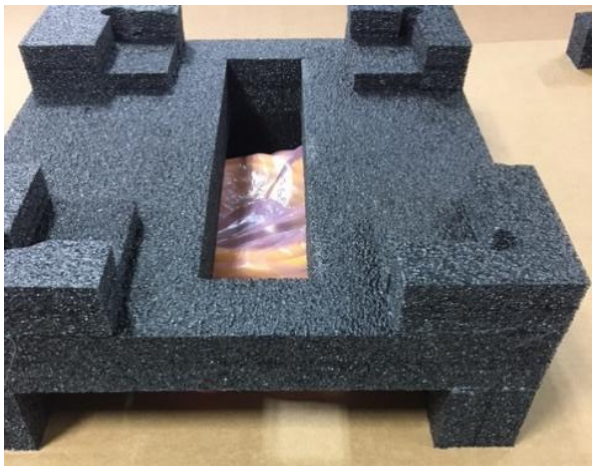
Power Cable

The power cable included in the shipment is rated for outdoor use. 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 U.S. single-phase AC electrical wire coloring –

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

2.5.2 Node Packaging

The node and power cable are shipped in a custom box with protective lining. The top layer of the packaging holds the power cable.

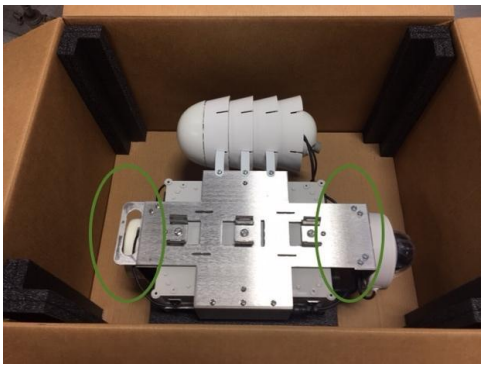







2.5.4 Unpacking Instructions

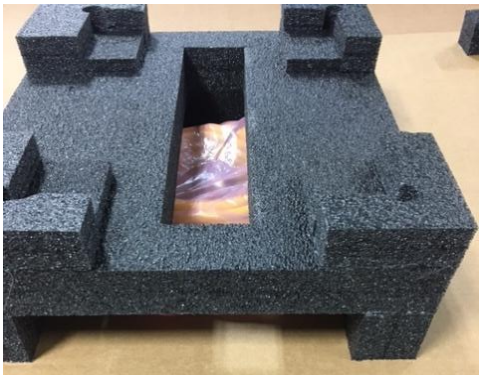
1. Ensure that the shipping box is top side up before opening it. From the top side, lift the top cover using the two side finger cutouts.

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.



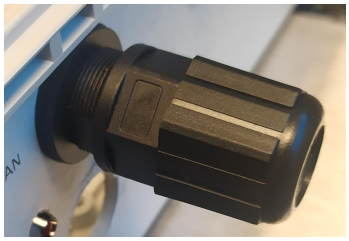
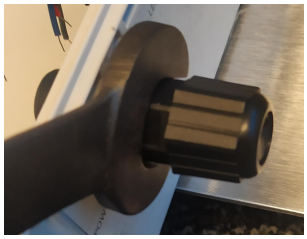
4. Carefully remove the power cable from the packaging.

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

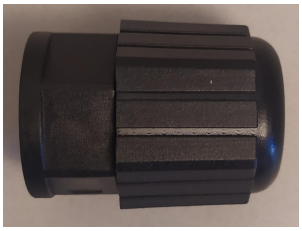
2.5.5 WAN Ethernet Cable Installation (Optional)

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.

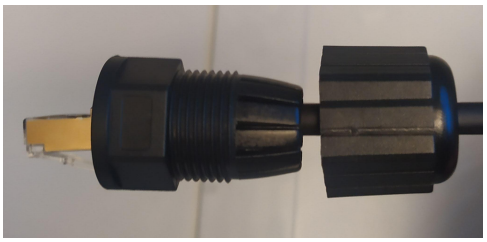



2. Separate the compression cap from the rest of the weatherproof cap assembly.



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

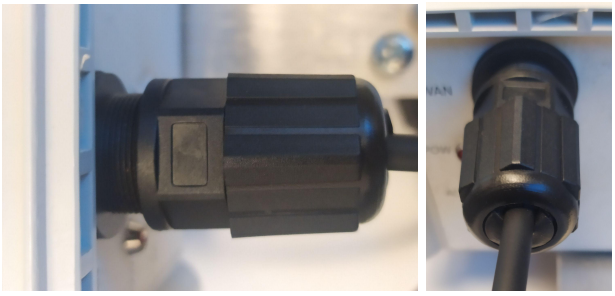
4. Insert the compression cap and the base into the Ethernet cable such that the threaded end is on the same side as the RJ45 jack.



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.

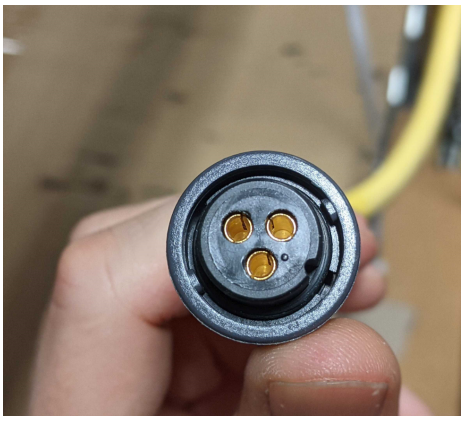
6. Tighten the compression cap on the base, to make a strong seal around the cable.



2.5.6 Node Power On

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

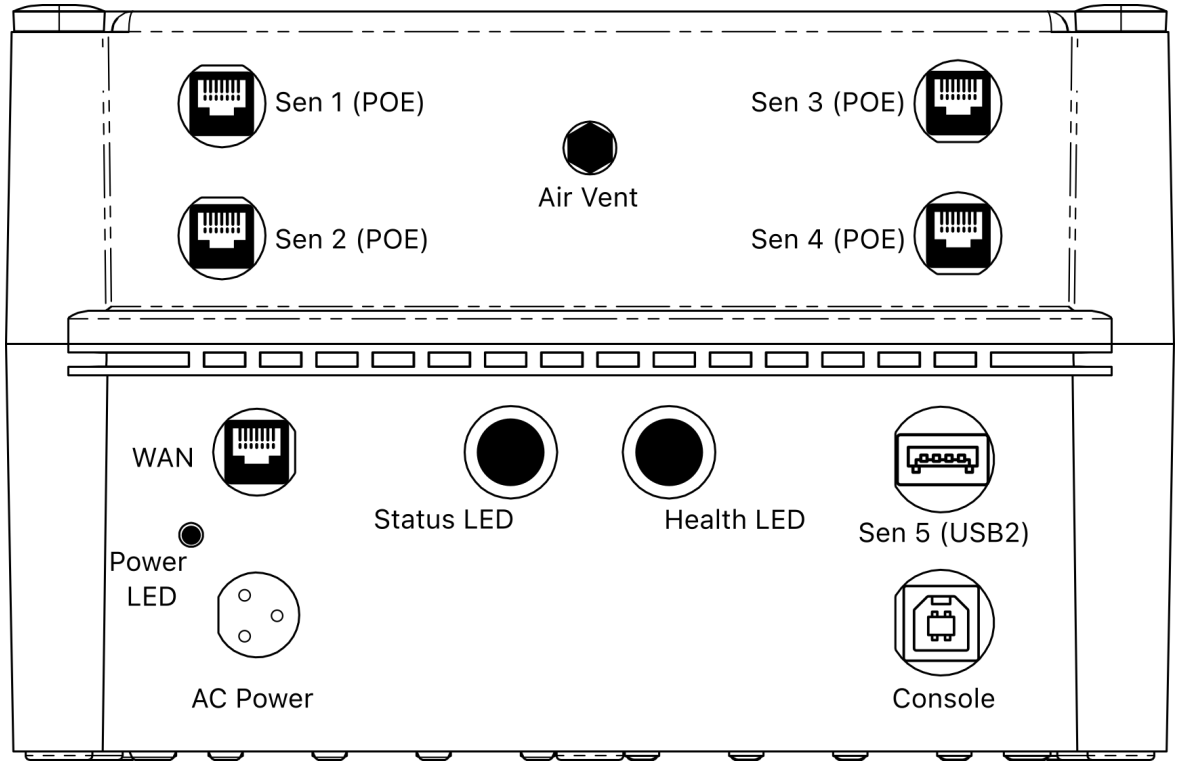
- Locate the notches on the female end of the power pigtail. Align them with the depressions in the AC power boundary connector, press in, and lock into position by screwing in the twist lock.



- Connect the other end to the mains, and turn power on to the node. After approximately 16 seconds, the Power LED should turn on. Shortly thereafter, the Status LED will start blinking blue, showing operation of the node. The Health LED should turn green in about 10 min if the node is healthy, indicating a successful install.

3. Additional Information

3.1 Boundary Interfaces 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 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 shut down, and power can safely be removed.
Health LED	Multicolored LED that shows the health of the node.	Solid green: Healthy state. Solid Orange: Warning state -- one or more minor issues. Solid Red: Failed state-- one or more major issues. *LED should transition from off to solid green about 10 min after power ON.* *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 needed 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 available only 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.
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.

3.2 Care and Maintenance

- When possible, keep the node free of debris and obstruction after 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.

3.3 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), please see the following table 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 power connected to the node, with the network connected, and contact the Sage team.
Status LED is red	Remove and reapply power. If the LED remains red or does not come back on, please contact the Sage team.
Status LED is blue but no data on the Sage repository	Check that the sensors are properly connected, the device has network connectivity, and please contact the Sage team.
Health LED is red	The Health LED updates about 5 min after initial power up and every 60 min thereafter. 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).
Node reboots often (Status LED transitions between blue and red)	Ensure that the node has Internet connectivity, and please contact the Sage team.

3.4 Contact Us

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

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

Appendix

A.1 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

A.2 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 FCC Part 15 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 FCC Part 15 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 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. 40% 200 mSec. 70% 500 mSec. 0% 20 mSec. 0% 5 Seconds	61000-4-11	A A A A 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

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