Sage

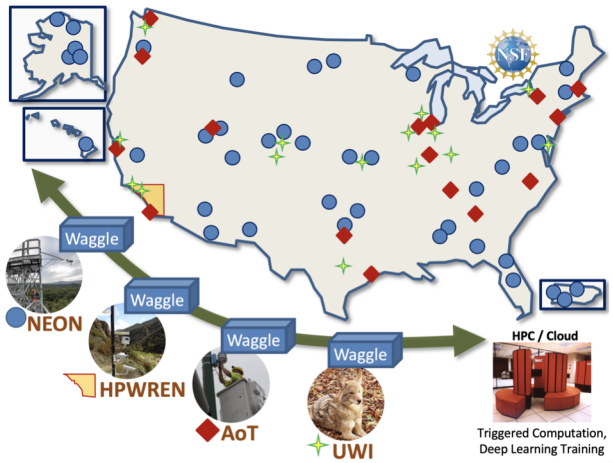
A Software-Defined Sensor Network

Cyberinfrastructure for Edge Computing

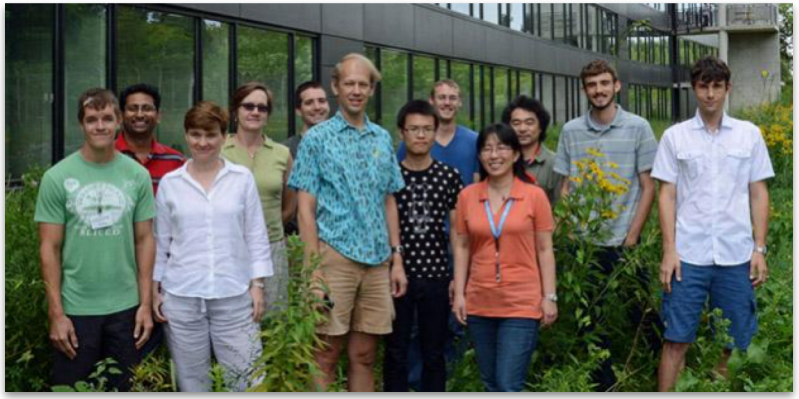
www.sagecontinuum.org

SAGE High-level Architecture

Pete Beckman
Northwestern University & Argonne National Laboratory

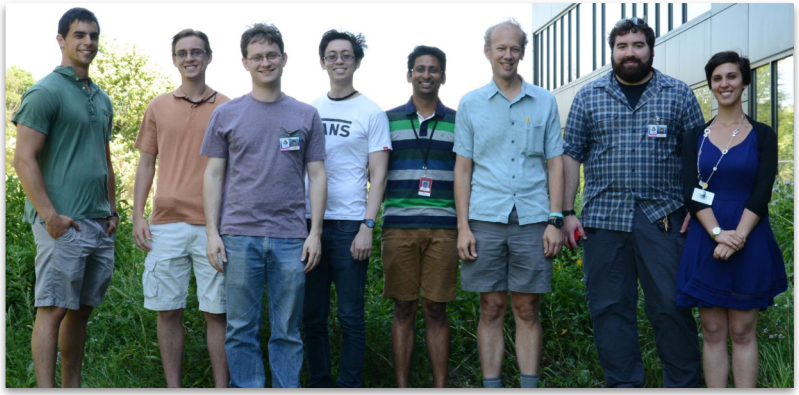


Northwestern University
THE UNIVERSITY OF CHICAGO
Northern Illinois University
Argonne NATIONAL LABORATORY
Colorado State University
UC San Diego
GEORGE MASON UNIVERSITY
ARRAY of THINGS
ARM
neon National Ecological Observatory Network
HPWREN
SDSC SAN DIEGO SUPERCOMPUTER CENTER
LINCOLN PARK ZOO. FOR WILDLIFE. FOR ALL.

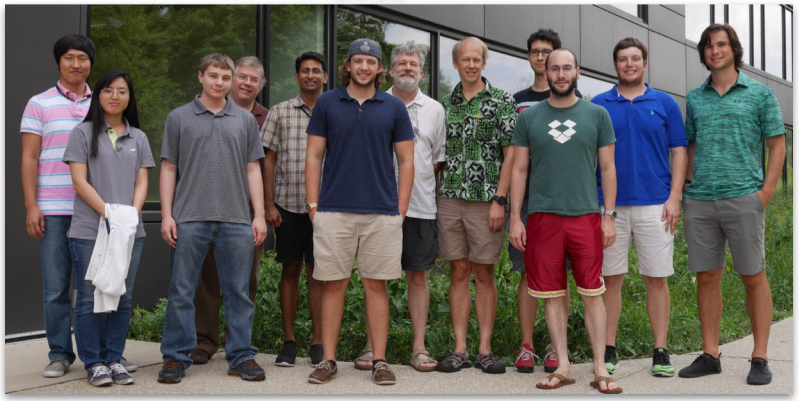


2013

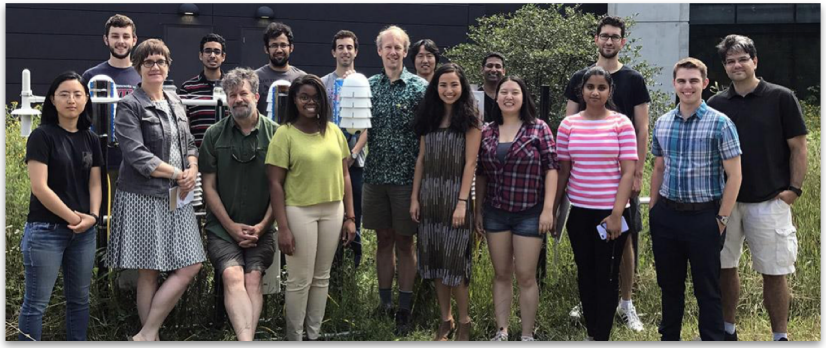
2014



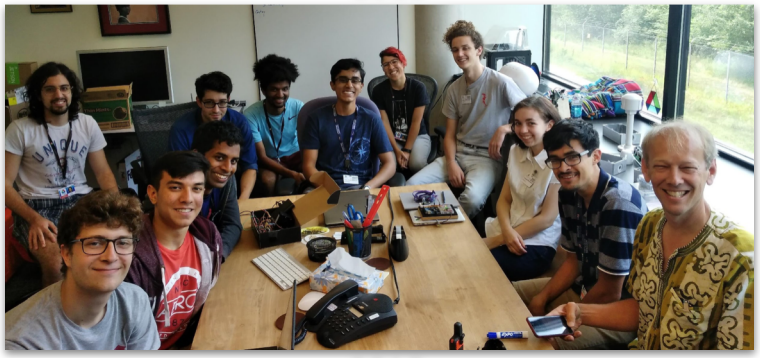
2015



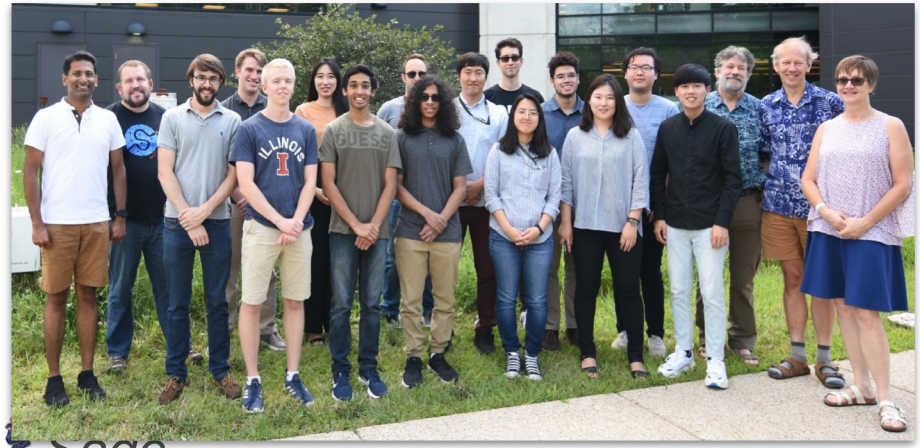
2016



2017



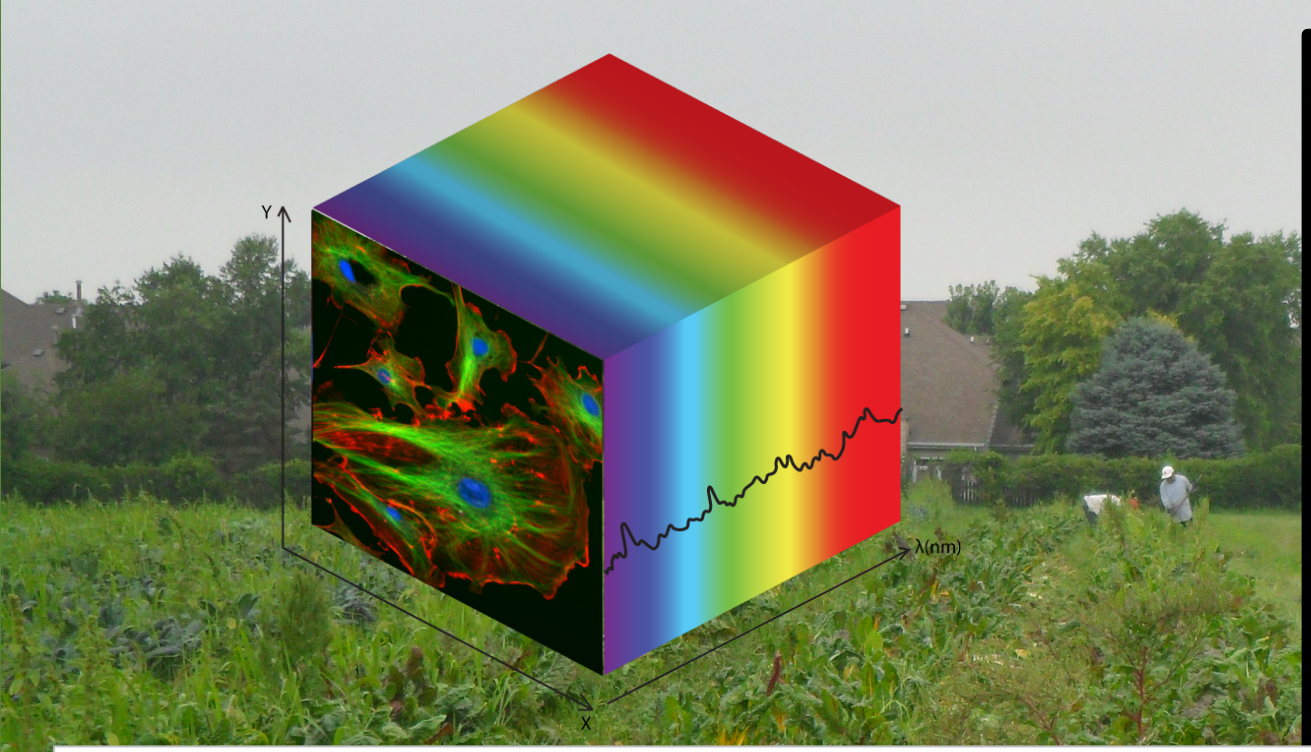
2018



2019

2020

Sage



Example: Hyperspectral SPECIM Camera:
PFD VNIR with 768 bands
(2734 x 1312) x 768 x 2bytes = **5.1GB image**

1 sample every 5 min
Twilight to twilight on June 21 = **1TB**

We need a parallel computer with each sensor!

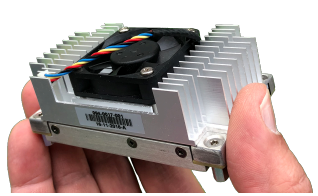
"A supercomputer is a device for turning compute-bound problems into I/O-bound problems."
(Ken Batcher)

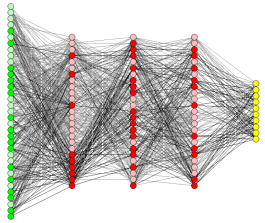
Larry Smarr at NCSA, 1986

"An edge computer is a device for turning I/O-bound problems onto compute-bound problems.

AI@Edge

Parallel Computing



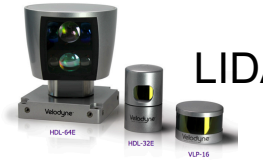


- Artificial Intelligence
- Deep Learning Inference
- Lightweight Edge Learning

Sage

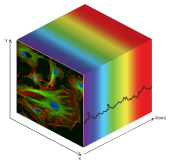
AI@Edge

Sensors



LIDAR

Software Defined Radios



Hyperspectral Imaging

Facilities

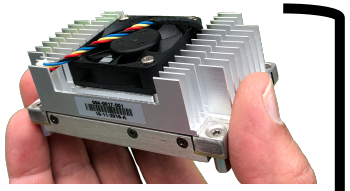
Actuators

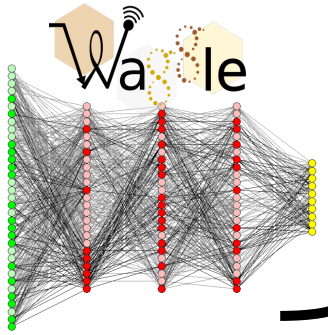
Servos

Dynamic adaptation

Powerful

Parallel Edge Computing





Artificial Intelligence
Deep Learning Inference
Lightweight Training

Edge computing and deep learning with feedback for continuous improvement

Reduced, Compressed data

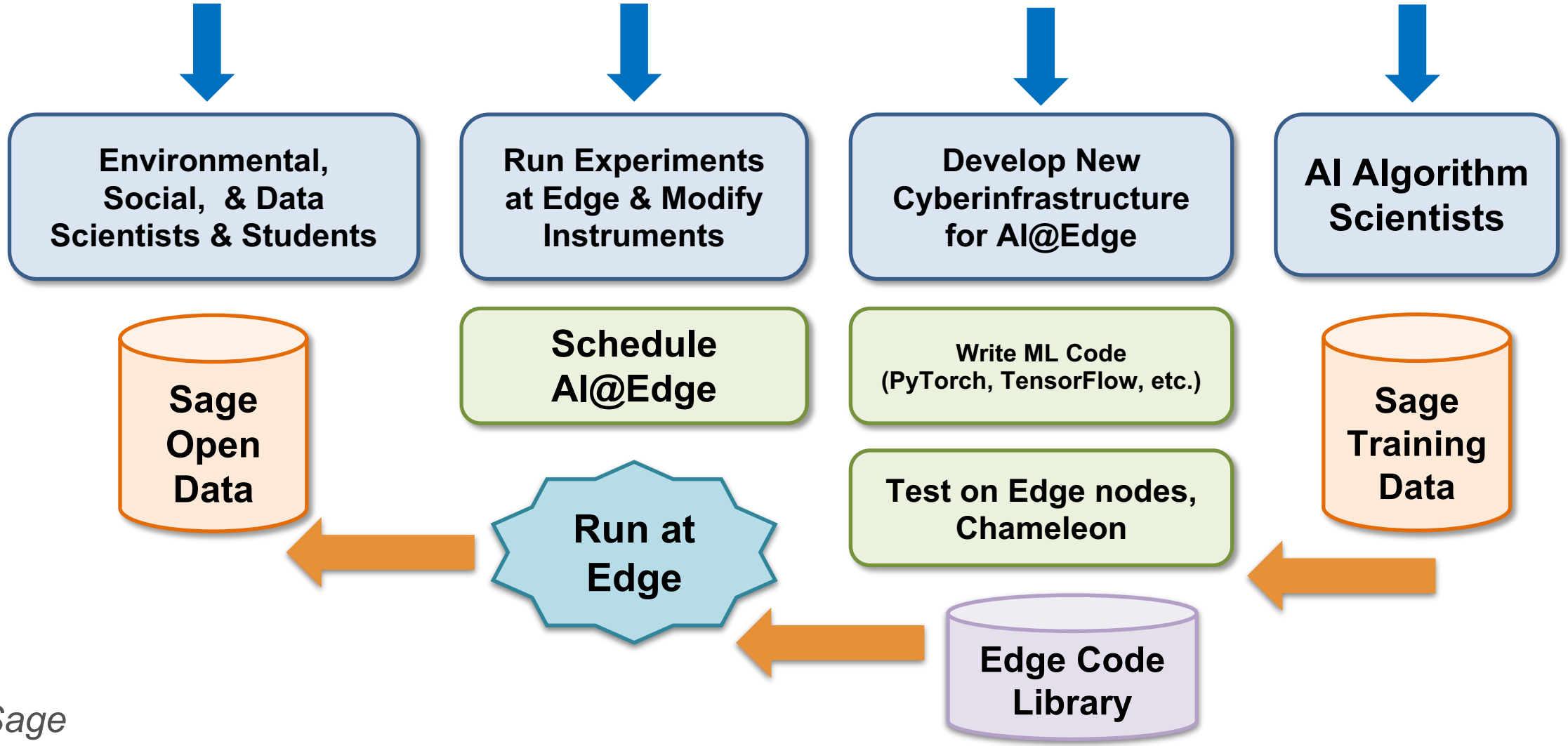
New inference (model)
Adaptive steering

HPC

Deep Learning Training
Simulation / Forecast

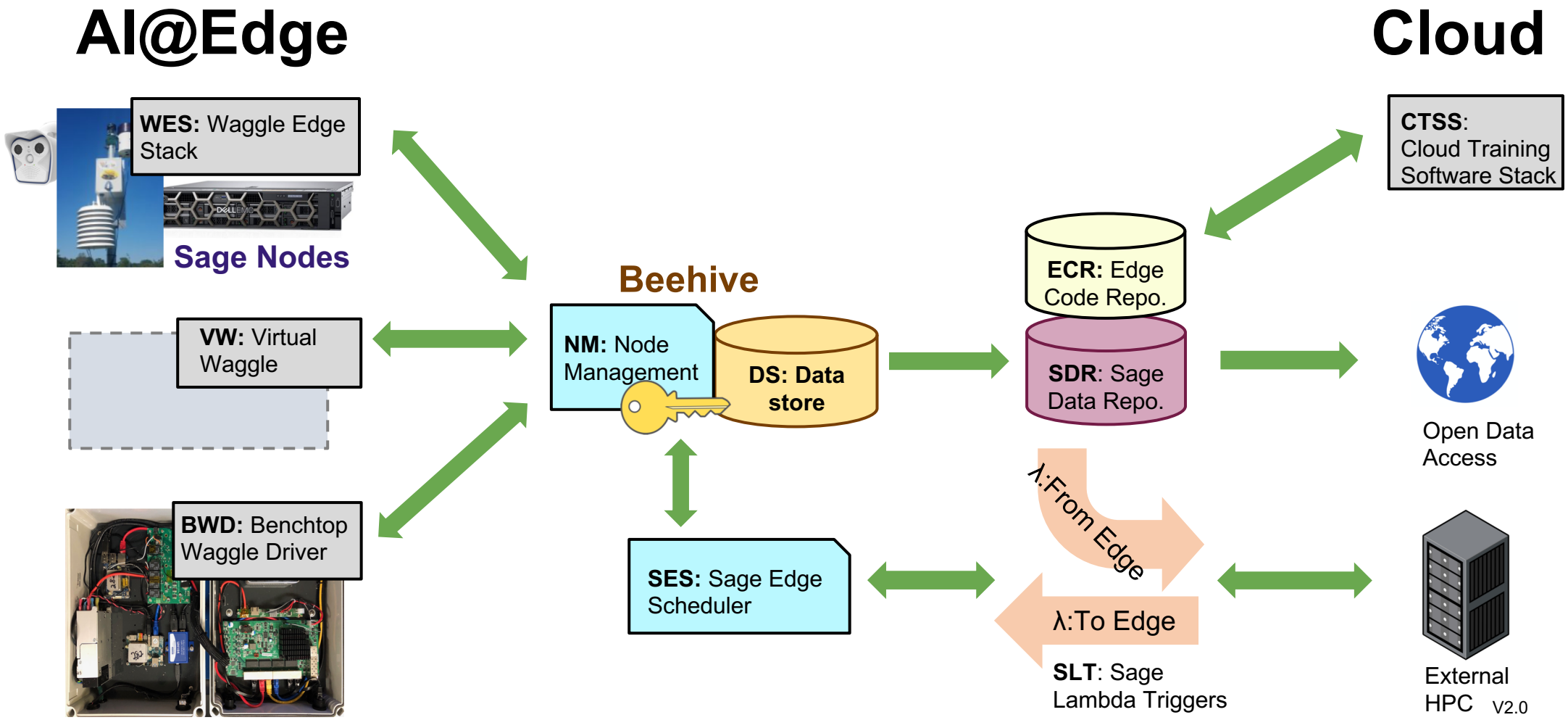
What does AI@Edge Cyberinfrastructure need?

A User-Driven, Science Architecture:



Sage

SAGE Technical Architecture



Sage

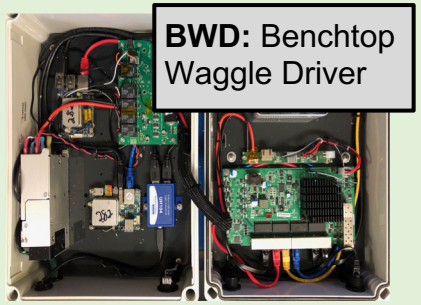
Starting at the Edge… Hardware

AI@Edge

WES: Waggle Edge Stack

Sage Nodes

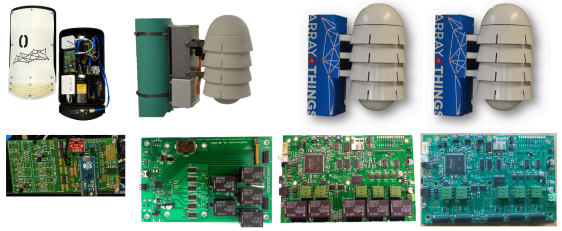
VW: Virtual Waggle

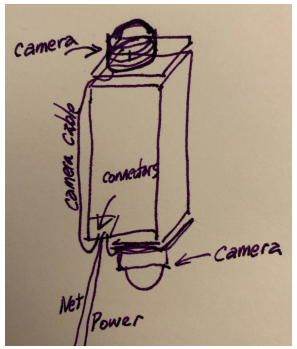


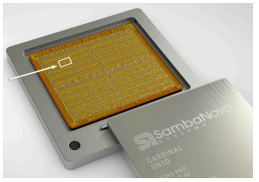
BWD: Benchtop Waggle Driver

1) Sage Blade

2) Wild Sage







Testbed for latest AI@Edge Hardware

Sage

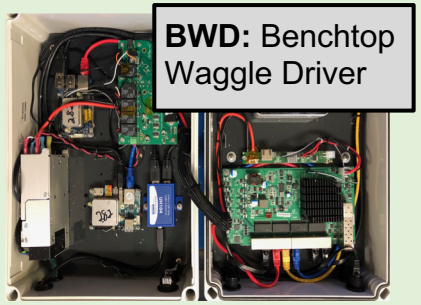
Starting at the Edge… Software for a Sage Node

AI@Edge

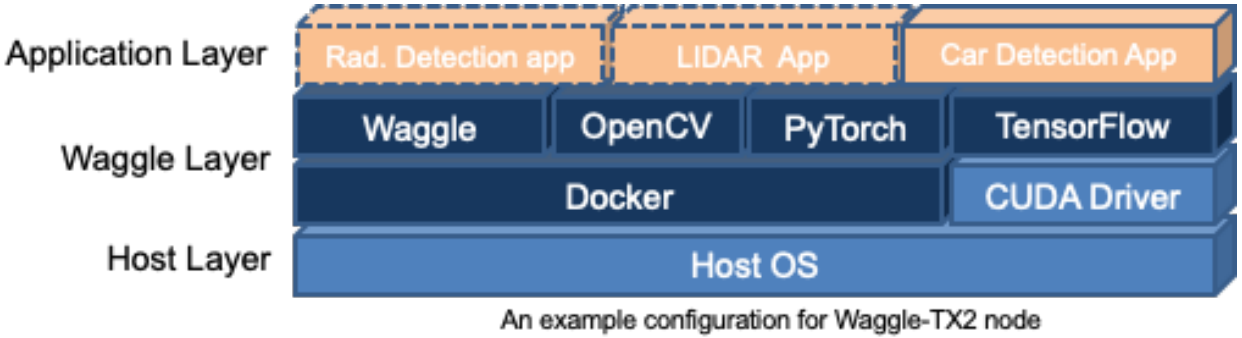
WES: Waggle Edge Stack

Sage Nodes

VW: Virtual Waggle



BWD: Benchtop Waggle Driver



An example configuration for Waggle-TX2 node

Key Functions:

- AI@Edge Environment
- Configuration Management
- Resilience and robustness management
- Secure messaging and certificates
- Resource management for multi-tenancy & scheduling

TensorFlowLite

docker + kubernetes

PYTORCH

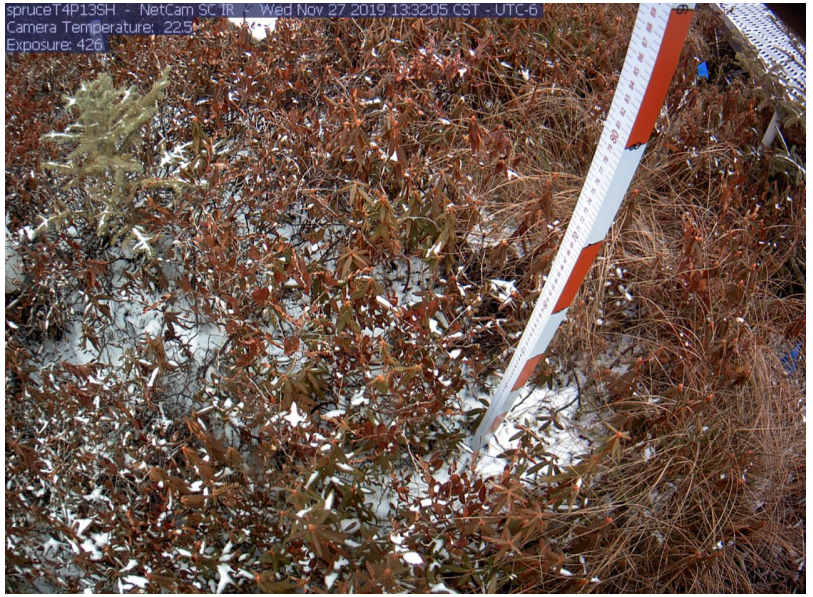
OpenCV

Sage

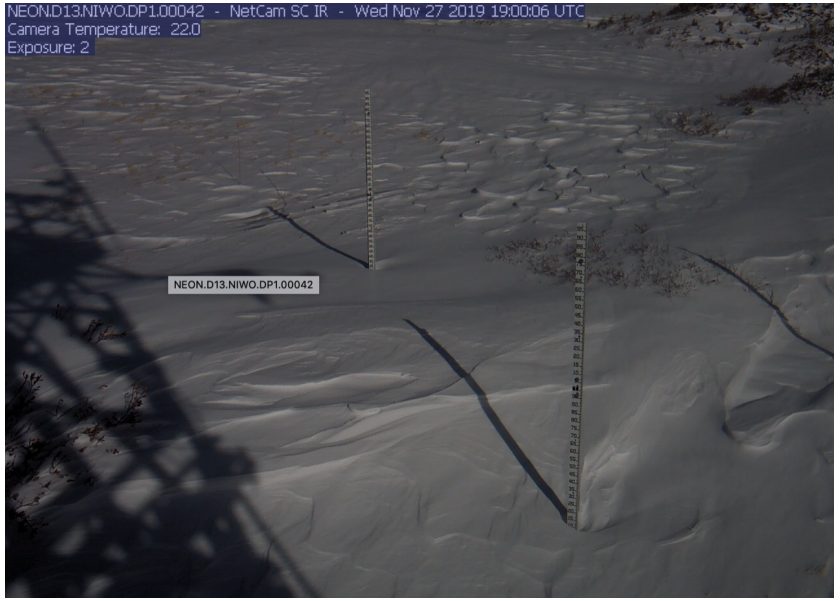
Tomorrow's Deep Dive….


NEON.D16.MART.DP1.20002 - NetCam SC IR - Thu Nov 21 2019 17:00:06 UTC
Camera Temperature: 28.5
Exposure: 1995


NEON.D11.BLUE.DP1.20002 - NetCam SC IR - Wed Nov 27 2019 19:00:05 UTC
Camera Temperature: 39.5
Exposure: 54
NEON.D11.BLUE.DP1.20002


spruceT4P13SH - NetCam SC IR - Wed Nov 27 2019 13:32:05 CST - UTC-6
Camera Temperature: 22.5
Exposure: 426


NEON.D16.MART.DP1.20002 - NetCam SC IR - Tue Nov 19 2019 16:00:06 UTC
Camera Temperature: 36.0
Exposure: 1037


NEON.D13.NIWO.DP1.00042 - NetCam SC IR - Wed Nov 27 2019 19:00:06 UTC
Camera Temperature: 22.0
Exposure: 2
NEON.D13.NIWO.DP1.00042


NEON.D18.TOOL.DP1.00042 - NetCam SC IR - Fri Nov 15 2019 01:00:05 UTC
Camera Temperature: -1.5
Exposure: 1532

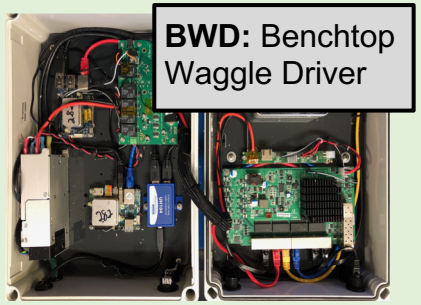
Starting at the Edge… Software but no Node

AI@Edge

WES: Waggle Edge Stack

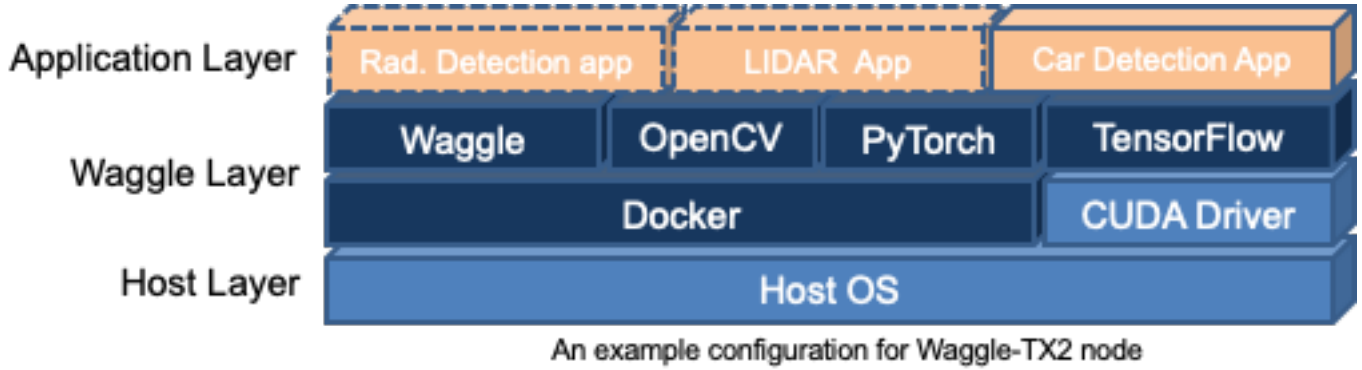
Sage Nodes

VW: Virtual Waggle



BWD: Benchtop Waggle Driver

Test and explore AI@Edge code at home or on Chameleon



An example configuration for Waggle-TX2 node

Sage

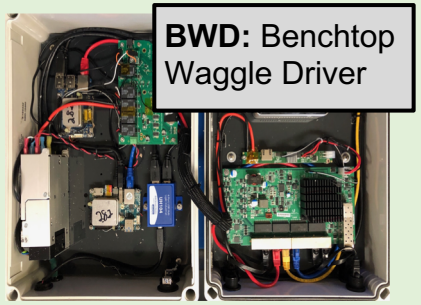
Starting at the Edge… Software

AI@Edge

WES: Waggle Edge Stack

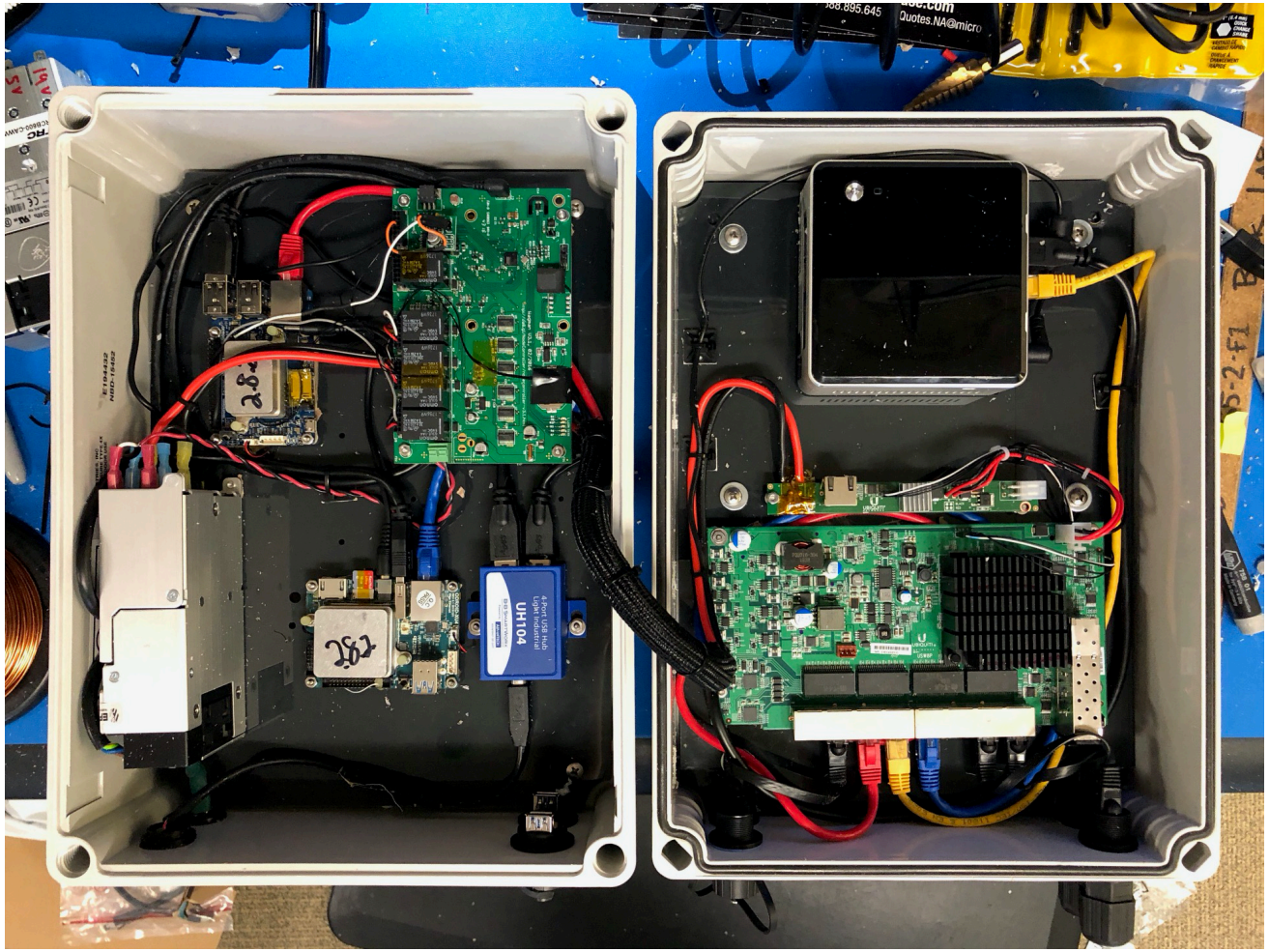
Sage Nodes

VW: Virtual Waggle



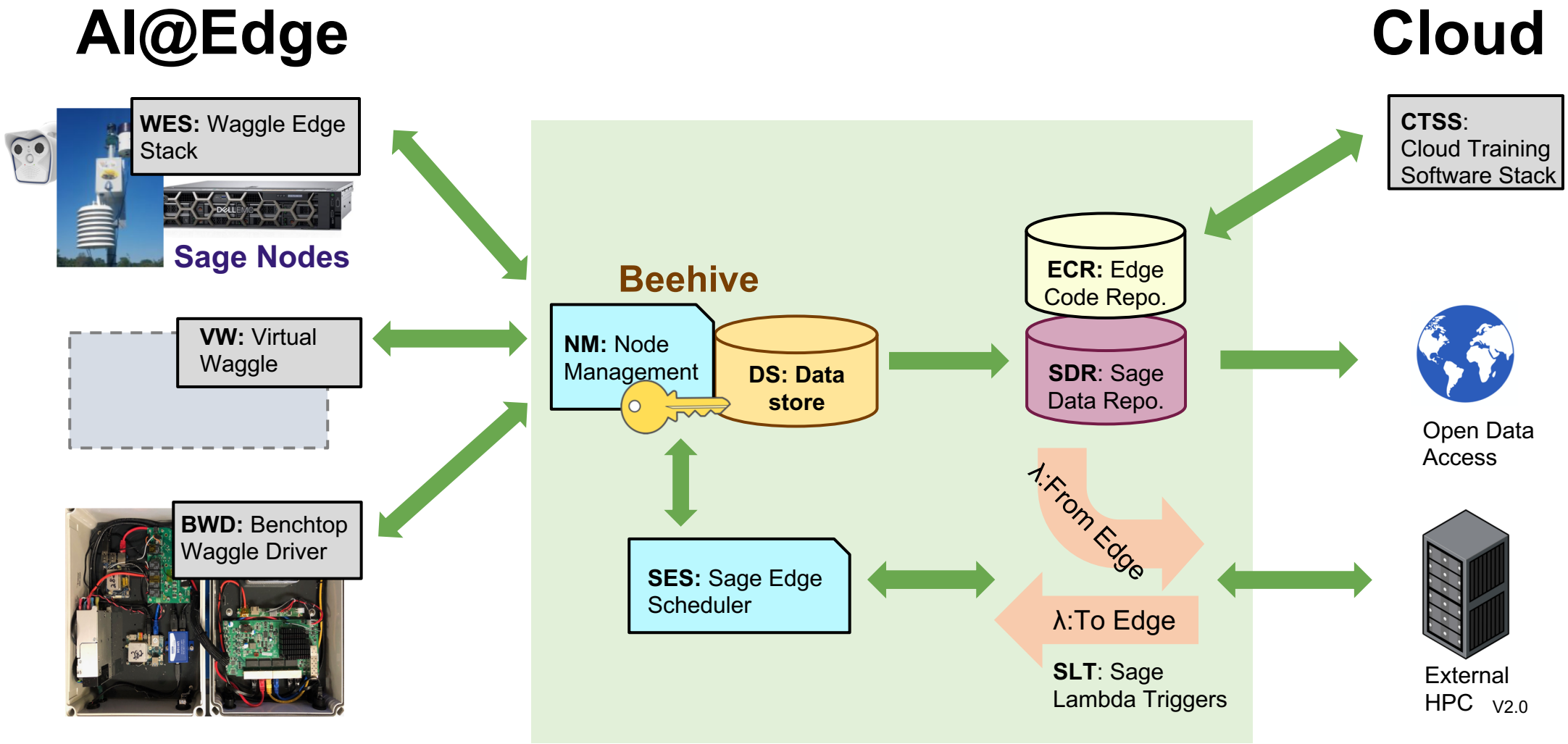
BWD: Benchtop Waggle Driver

If you have a Sage Node on your Desk…



Sage

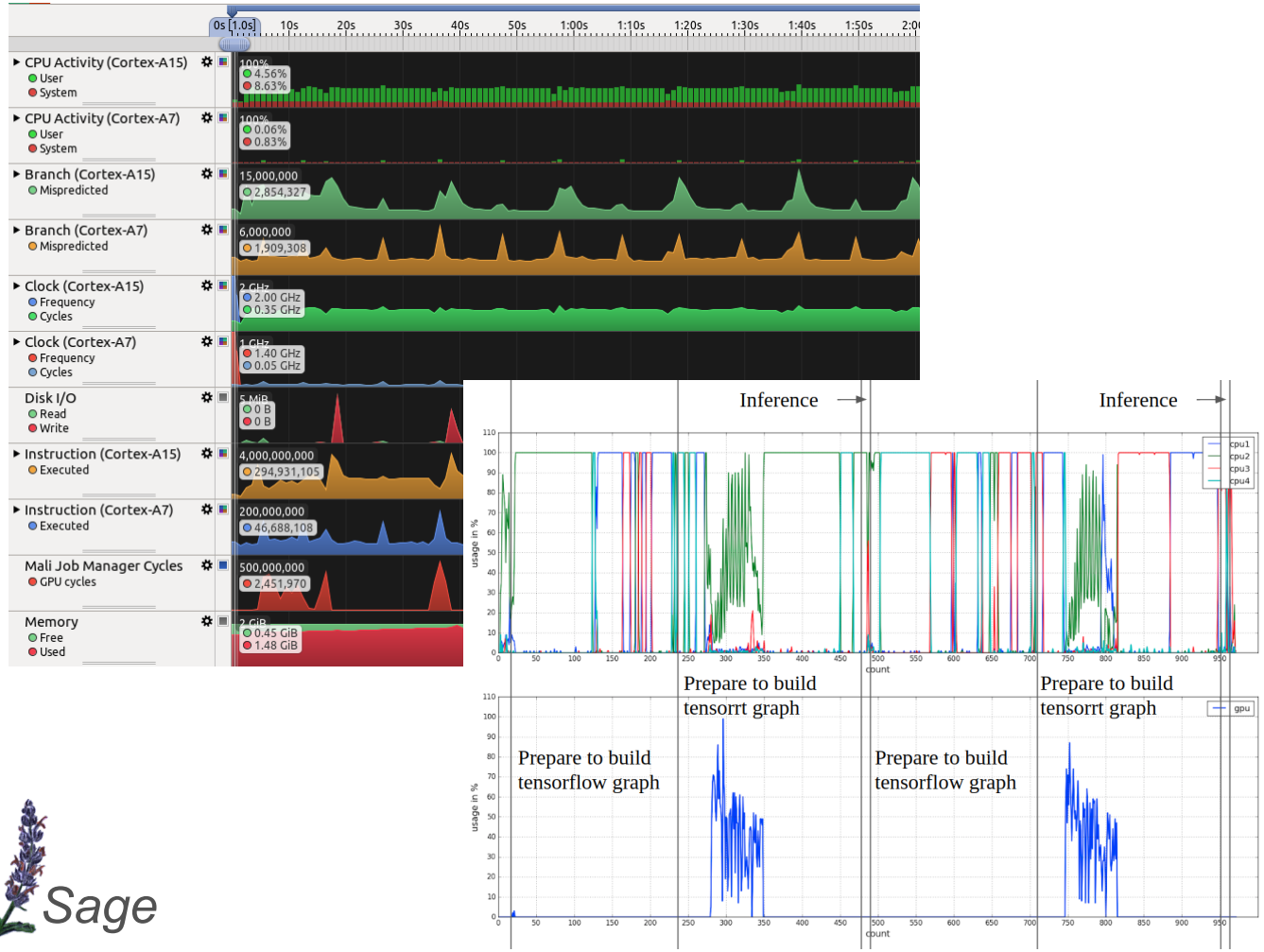
SAGE Technical Architecture



Sage

Edge Code Repository: Think DockerHub for SAGE AI@Edge

- Profiling edge plugins based on a various performance metrics and goals generates a series of configurations. A configuration can chosen by the SAGE Edge Scheduler to support multi-tenancy.



Key R&D Issues

- Performance database: “Will it Fit?”
- Privacy/Security
- Control knobs for dynamic adjustments

Sage

Sage Edge Scheduler

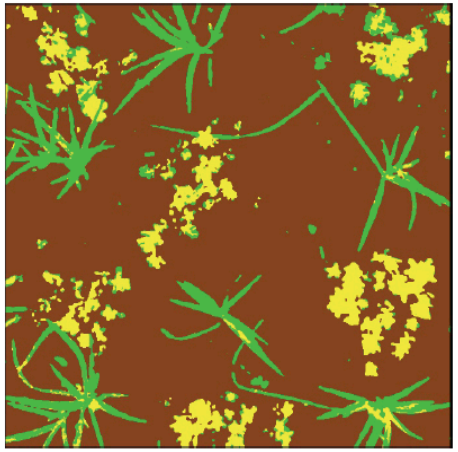
Key R&D Issues:

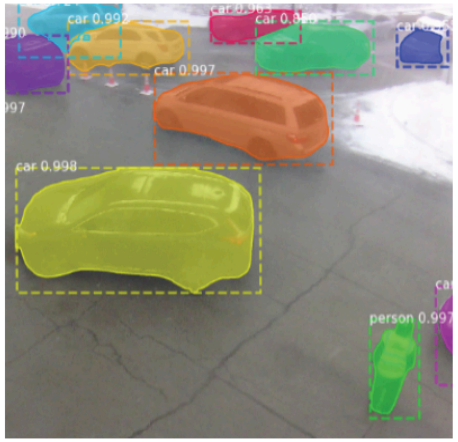
- Multi-level **Goal-based** Autonomy
- Actuator Arbitration and Security

Wildfires: detecting smoke

Urban flooding

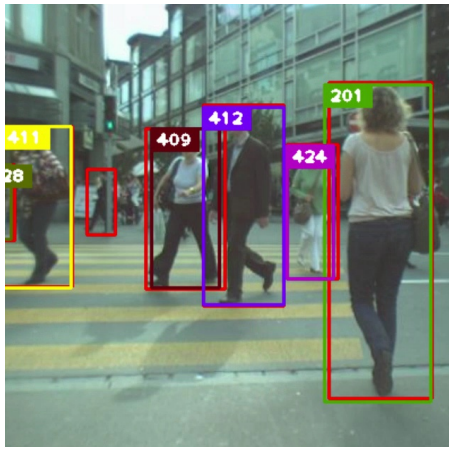
Plant Species





Traffic Flow

Pedestrian Flow

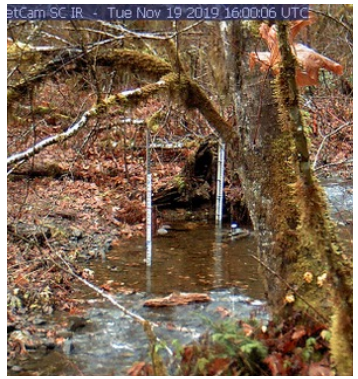


Wildlife

Drone detection

Cloud Coverage

Snow Depth



Water Depth

Sage

Combined Example:

- Sage Edge Scheduler
- Edge Code Repository

1. Wildfire detection code tested, submitted to ECR
2. Cloud analysis tested, submitted to ECR
3. Wolf detection tested, submitted to ECR
4. Wildfire, Cloud, and Wolf codes sent to SES along with ***goal***

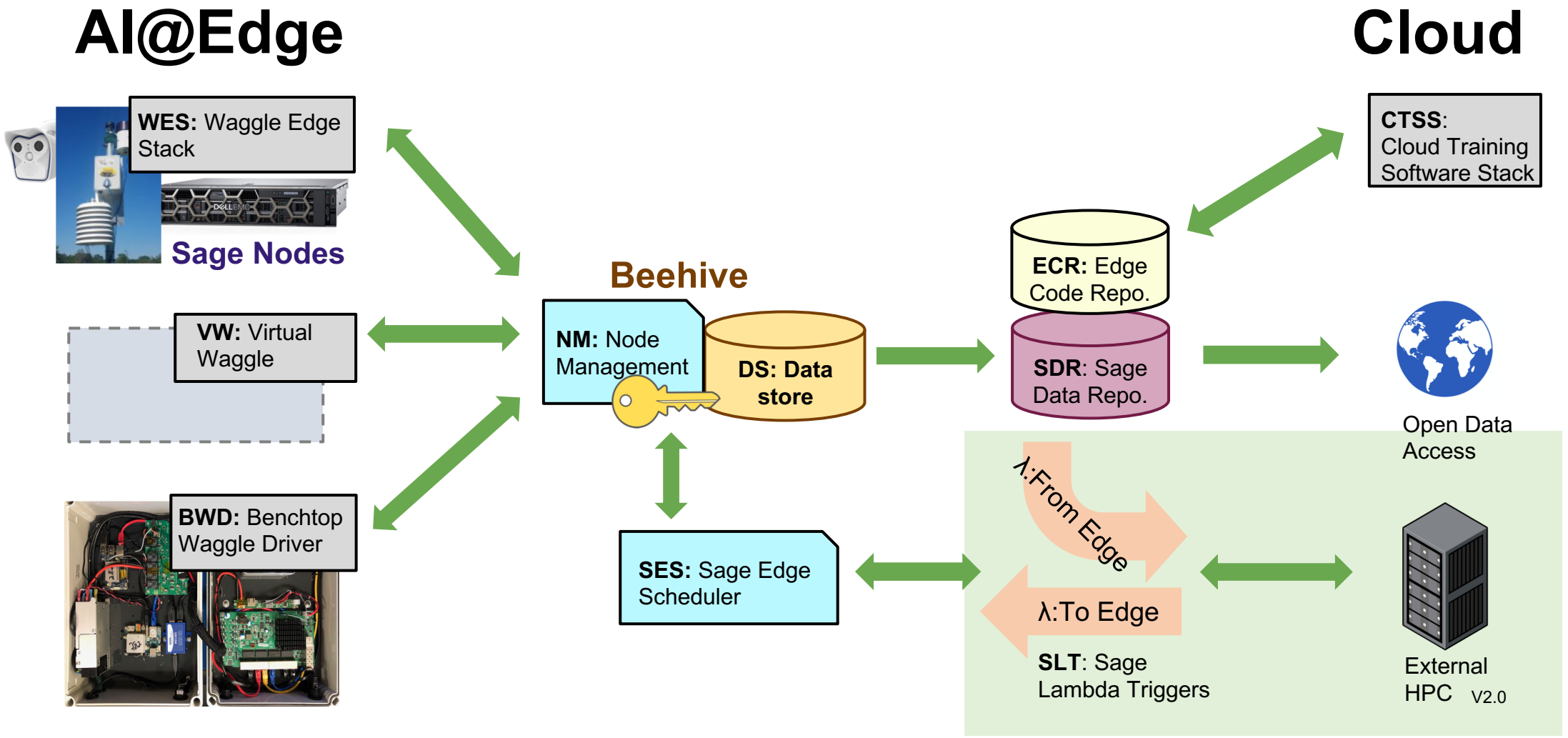
Image from HPWREN tower, where Sage will deploy AI@Edge for real-time fire detection

Sage will move Pan-Tilt-Zoom cameras to suspected outbreaks using AI@Edge to search for fire

Sage

SDSC WIFIRE project runs HPC simulation to predict wildfire

SAGE Technical Architecture



Sage

Being Edgy is Dynamic!
Sage Lambda Triggers (SLT)

AI@Edge

LIDAR

From-Edge To-Edge

Edge-Analyzed Sensor Data

Change LIDAR operational controls

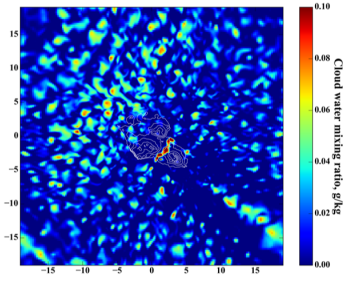
Switch image processing to detect surface flooding

Cloud

Real-time small-droplet rain Trigger

Activate Cloud Forecast

Data Archive



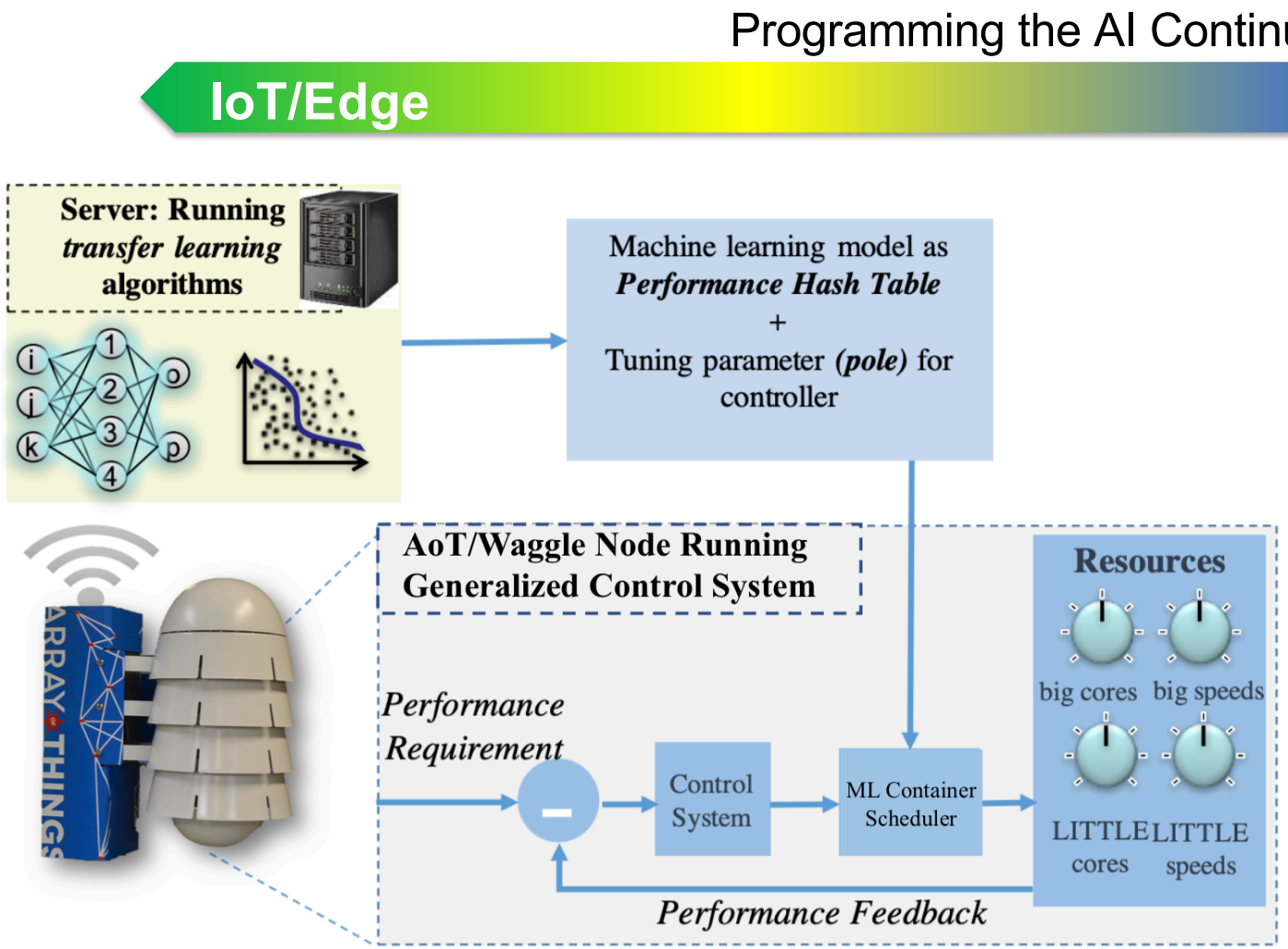
Real-time data path with bidirectional control

Triggered computing & instrument steering

Sage

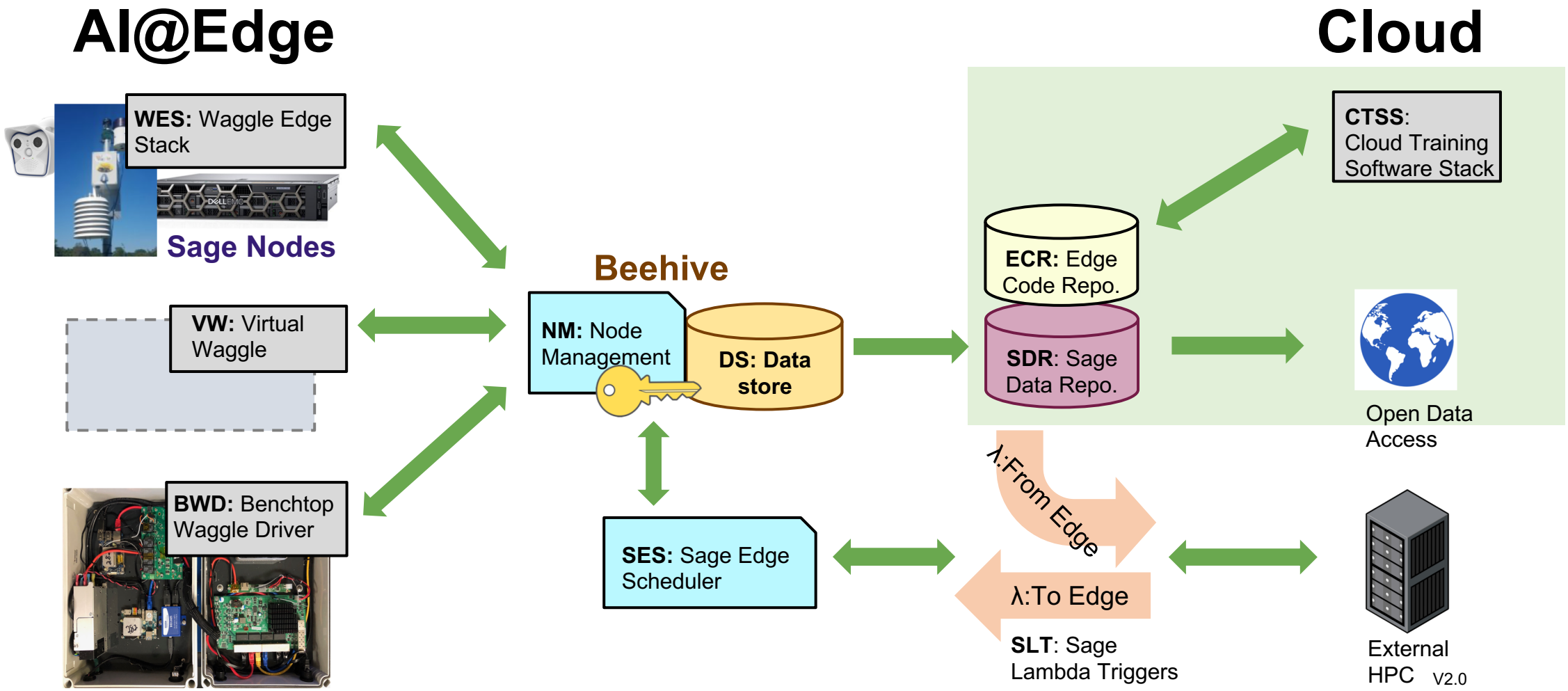
Towards Goal-oriented, Adaptive AI@Edge

Work with Hank Hoffmann @ University of Chicago



- Dynamic, goal-based decisions
- Multi-tenancy, Multi-Goal
- Resource management and adaptive inference priority
  - AI@Edge is limited by power and computation – just like HPC

SAGE Technical Architecture



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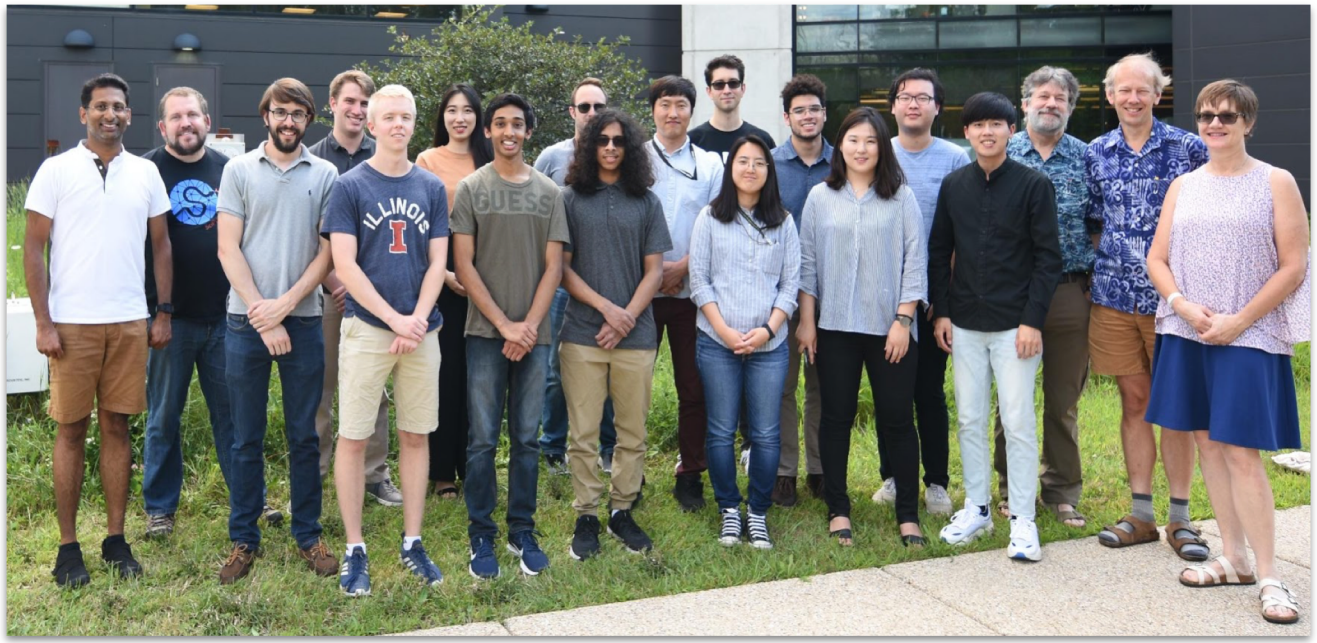
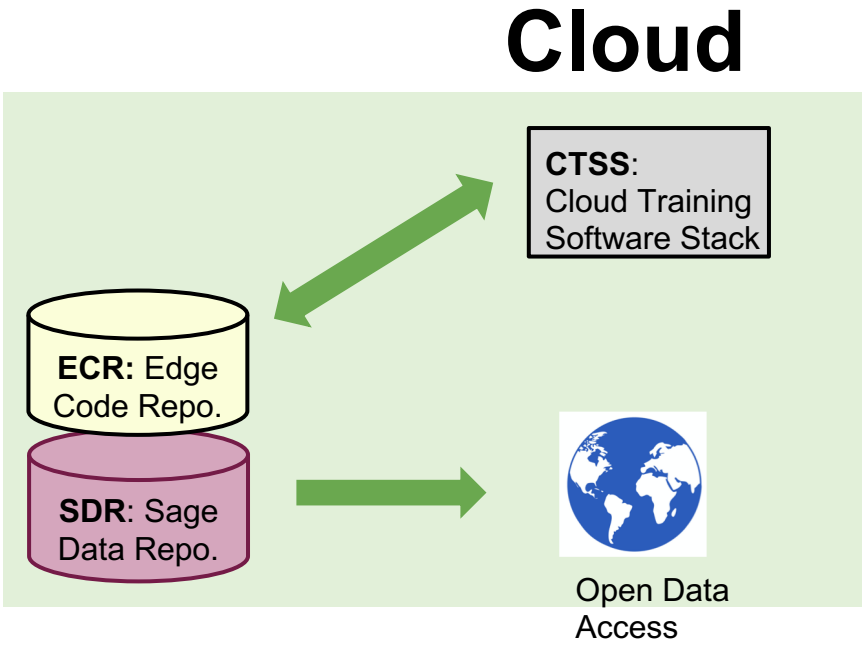
Sage Cloud Training Software Stack (CTSS)





Provide tools for AI@Edge to EVERYONE!

- Access training data and develop new computer vision algorithms at university
- Example codes and tutorials for AI@Edge
- Simple tests with Virtual Waggle
- Run tests on Chameleon
- Request time on SAGE and run in cities, mountains, and snow fields…

Sage

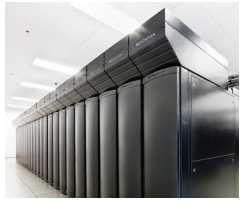
Programming The Computing Continuum

IoT/Edge ⟶ **HPC/Cloud**

Size	Nano	Micro	Milli	Server	Fog	Campus	Facility
Example	Adafruit Trinket	Particle.io Boron	Array of Things	Linux Box	Co-located Blades	1000-node cluster	Datacenter
Memory	0.5K	256K	8GB	32GB	256G	32TB	16PB
Network	BLE	WiFi/LTE	WiFi/LTE	1 GigE	10GigE	40GigE	N*100GigE
Cost	$5	$30	$600	$3K	$50K	$2M	$1000M

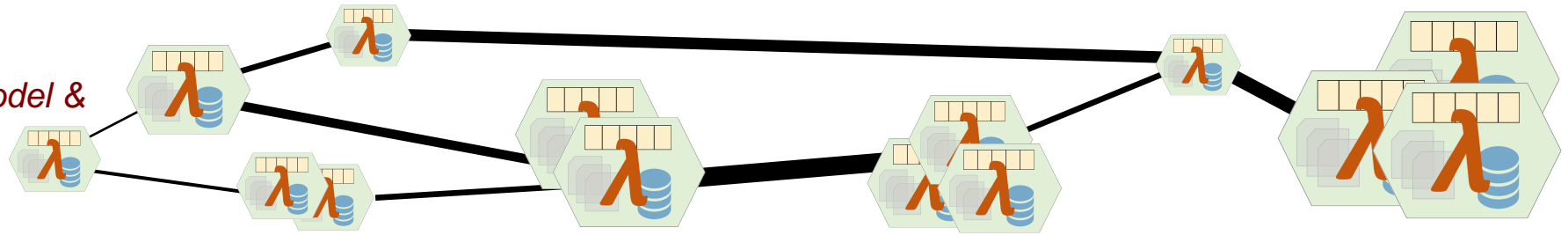
Count = 10^9
Size = 10^1



Count = 10^1
Size = 10^9

Continuum Abstract Model & Runtime

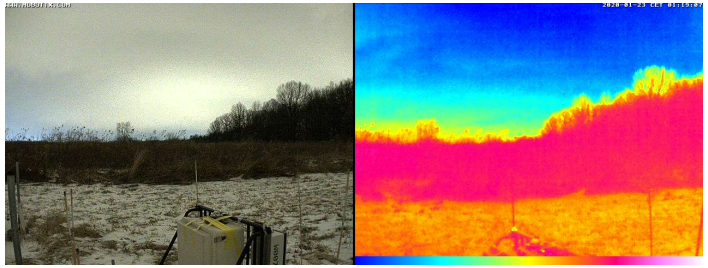


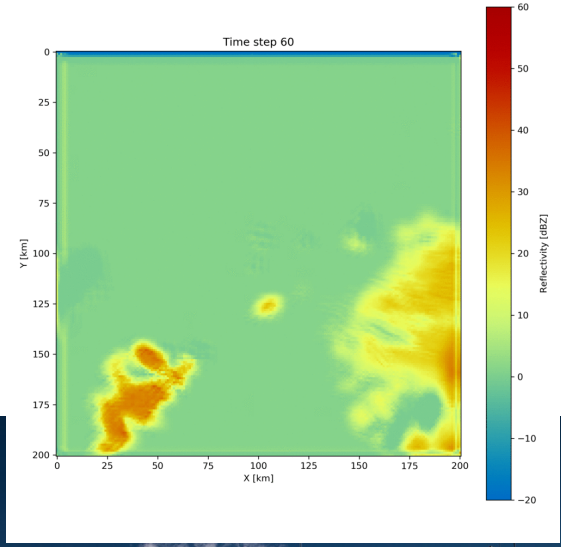
The Computing Continuum will be the future facility;
it needs a run-time system and programming model.

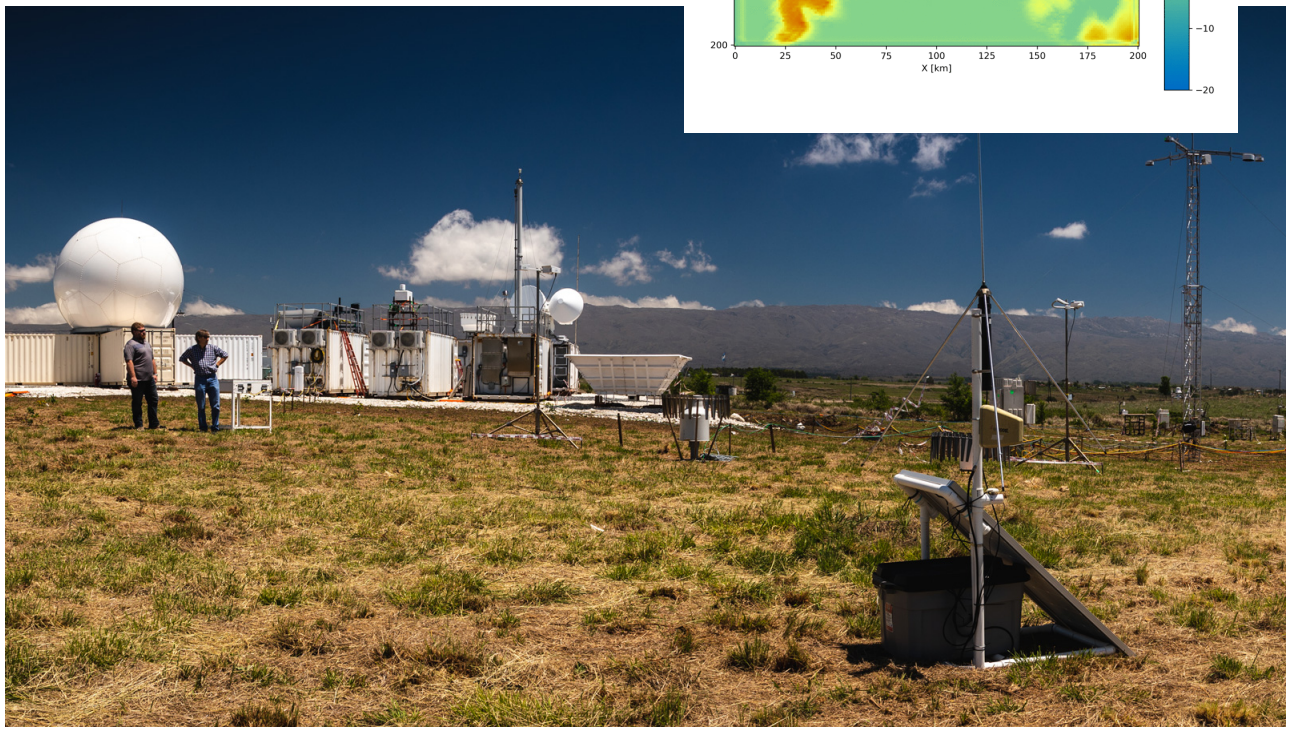
SAGE is prototyping these capabilities for distributed instruments

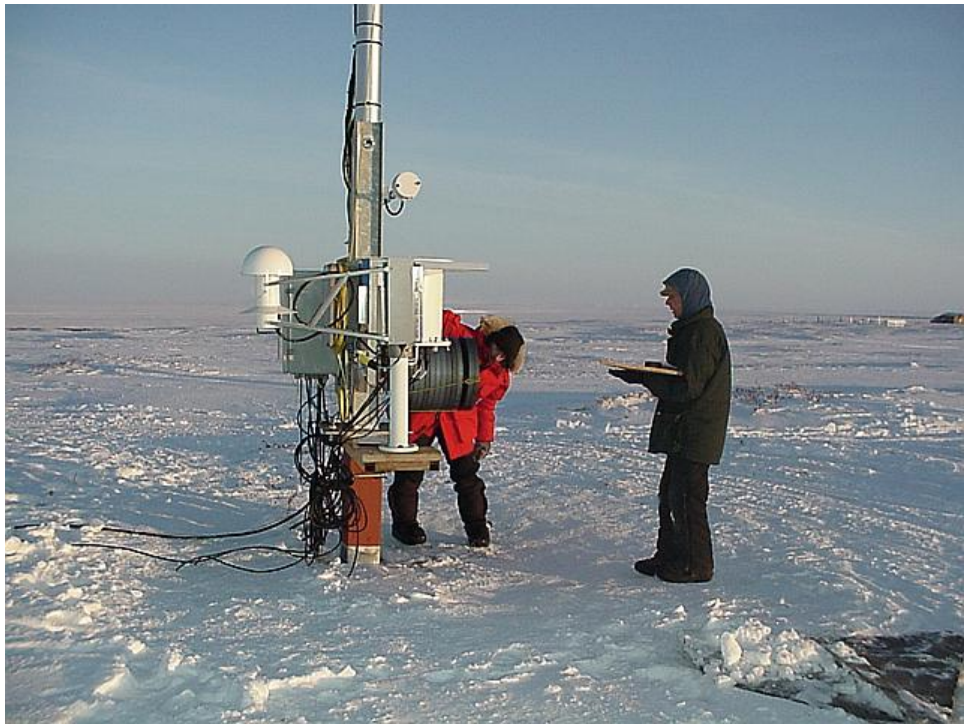
Sage

Future









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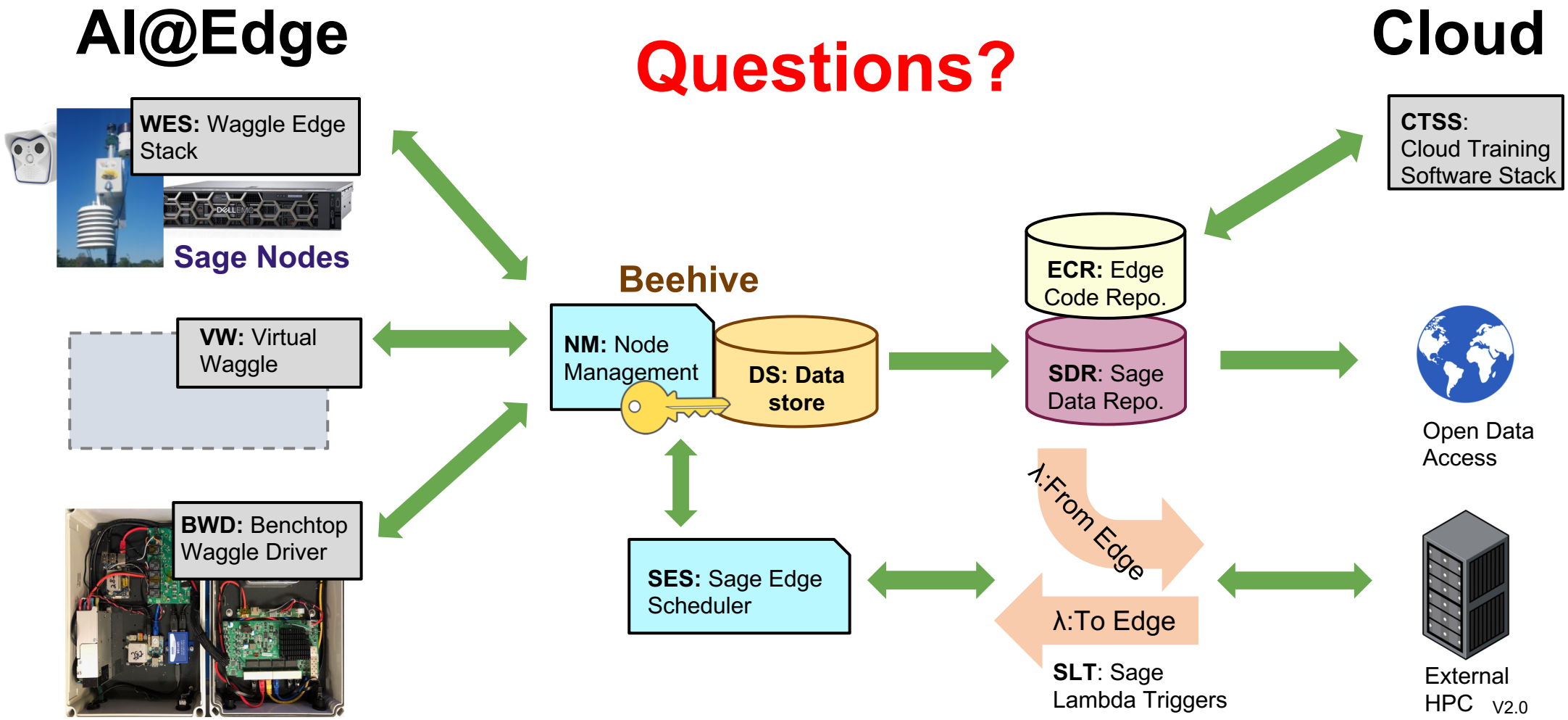
SAGE Technical Architecture



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