



*Cyberinfrastructure for
AI@Edge Computing*

The Sage Grande Testbed

Nicola Ferrier

Northwestern Argonne Institute for Science and Engineering
Deputy Director of Sage Grande Project

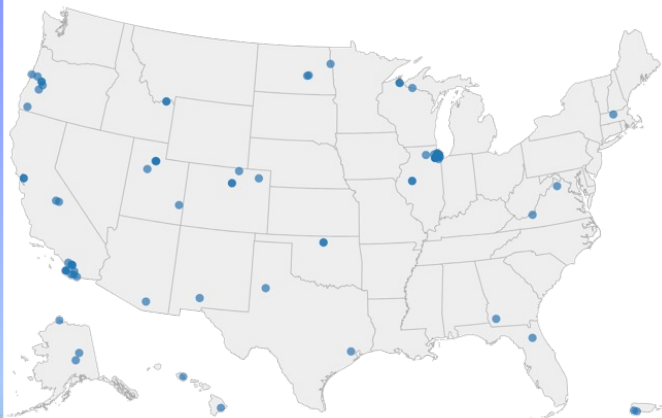


6th GLOBAL RESEARCH PLATFORM WORKSHOP, Sept 15, 2025



Sage Grande: An Open **Artificial Intelligence Testbed**

Supporting Edge Computing and Intelligent Sensing



First generation Sage nodes deployed 2019-2024
(MSRI-1 #1935984 2019-2024)



Partnerships with
American Companies

Goals

Training and Educating
the AI Workforce



Embed AI with the Edge
Enable intelligent sensing

Provide academic community AI resources to:

- Develop new AI algorithms and technologies
- Advance techniques to enhance AI safety & privacy
- Explore *next-generation* AI-enabled infrastructure for real-time monitoring of wildfire, flooding, and drought to support early warning and mitigation for farms
- Deploy 300 new state-of-the-art AI-enabled platforms across the USA, and in every state
- Train students to use AI-enabled cyberinfrastructure with hackathons, workshops, and new curricula



Institutional Lead: Northwestern Univ.

Partners: Univ. of California, San Diego; Univ. of Illinois Chicago, Colorado State, Univ. of Utah, Univ. of Hawaii, Univ. of Oregon, George Mason Univ.,



Sage Grande

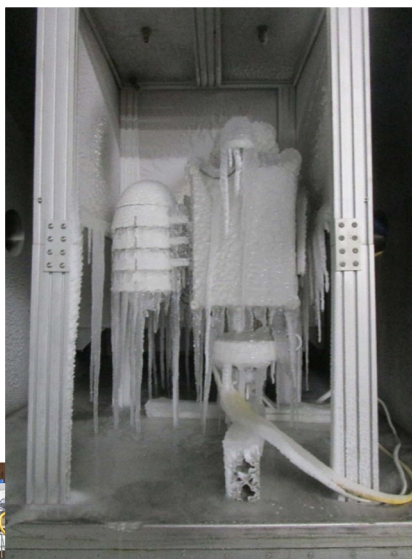
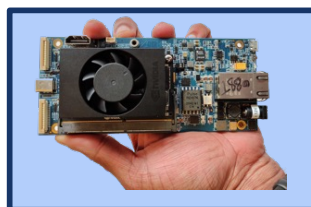
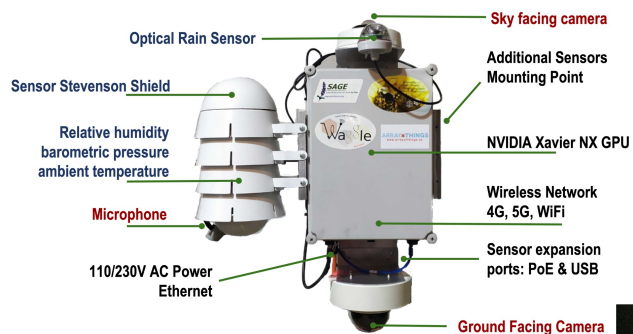
Award: #2436842

Start Date:

2/15/2025

\$25.6M over 5 years

Field Proven



Almost 10
years of experience
NSF MSRI-1 Pilot 2019-2024

Building on
NSF Array of Things
(2016-2018)

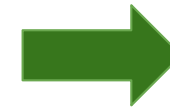
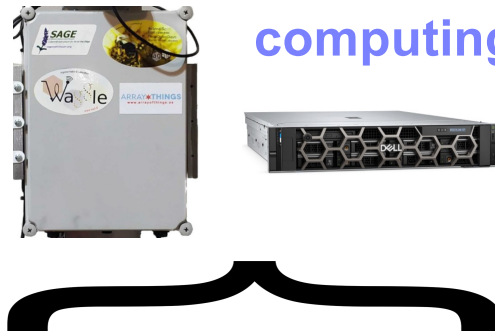


AI@Edge platform brings together sensors, actuators, and computing.



sensors

computing



surface-water-detection Surface Water Detection seonghapark · 8 tags · Updated 127 days ago	avian-diversity-monitoring Records environmental sounds, identifies birds by such sounds and... daridomatties1 · 1 tag · Updated 146 days ago	weather-classification An app for identifying cloud or rain coverage from the ARM Doppler... gjackson · 13 tags · Updated 149 days ago
traffic-state Traffic State Estimator seonghapark · 5 tags · Updated 189 days ago	motion-analysis Motion Analysis seonghapark · 6 tags · Updated 189 days ago	motion-detection A general purpose motion detection system that locates and tracks... seonghapark · 2 tags · Updated 189 days ago
solar-irradiance Solar Irradiance Estimator Using U-Net seonghapark · 3 tags · Updated 189 days ago	cloud-cover U-Net Cloud Coverage Estimator seonghapark · 5 tags · Updated 189 days ago	object-counter Object Counter seonghapark · 5 tags · Updated 189 days ago
cloud-motion Cloud Motion Estimator for the Sky Camera brupendranaut · 2 tags · Updated 190 days ago	wildfire-smoke-detection Wildfire Smoke Detection seonghapark · 2 tags · Updated 246 days ago	sound-event-detection Sound event detection (SED) plugin, using YAMNet audio classificati... daridomatties · 1 tag · Updated 266 days ago

software

Plant Species Pedestrian Flow Birdsong



Traffic Flow Wildlife Cloud Motion Vectors



Wildfires: detecting smoke Flooding / surface water



BYOS – bring your own sensors

- Tree sap monitor
- Hawaii rain
- Insect screen
- Lidar (Nantucket and Chicago)



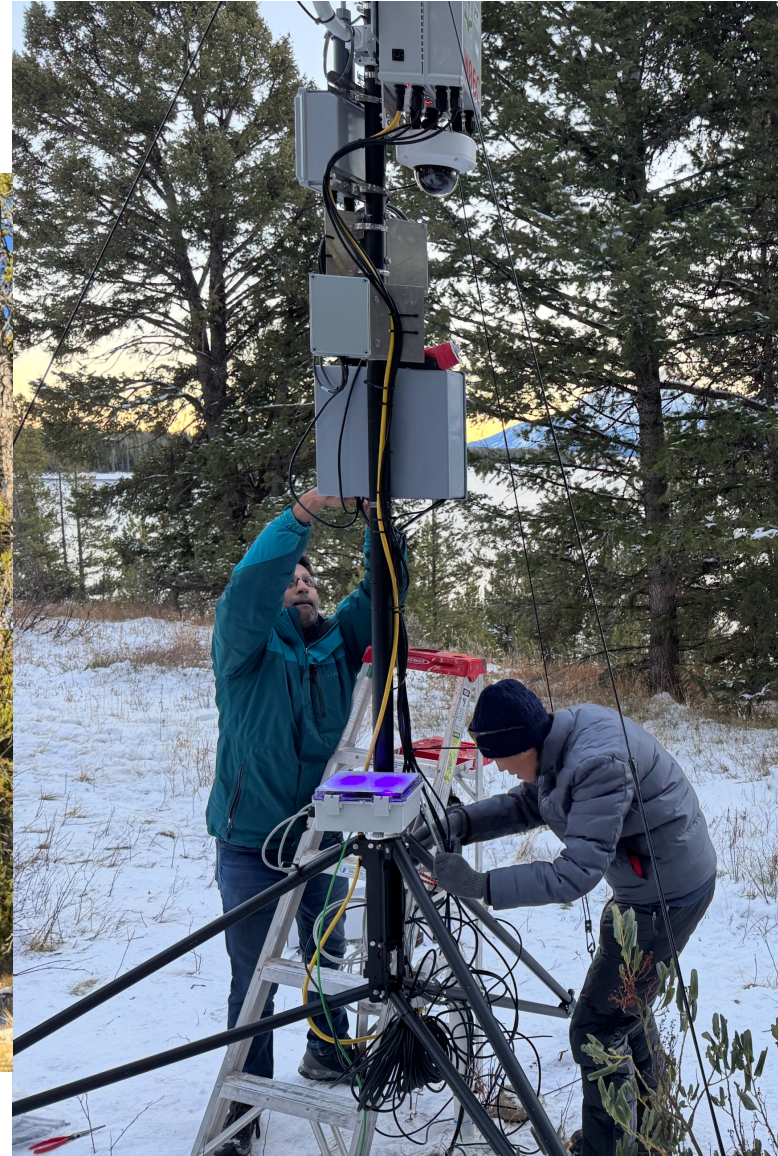
Thomas Giambelluca



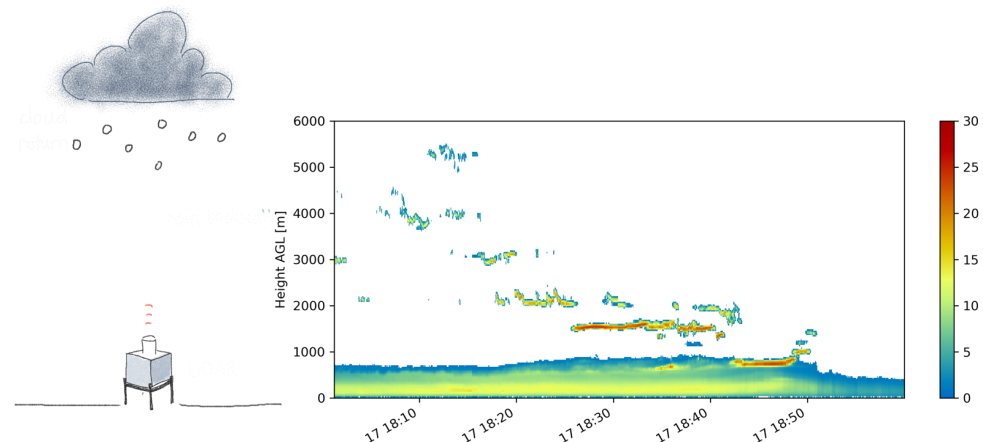
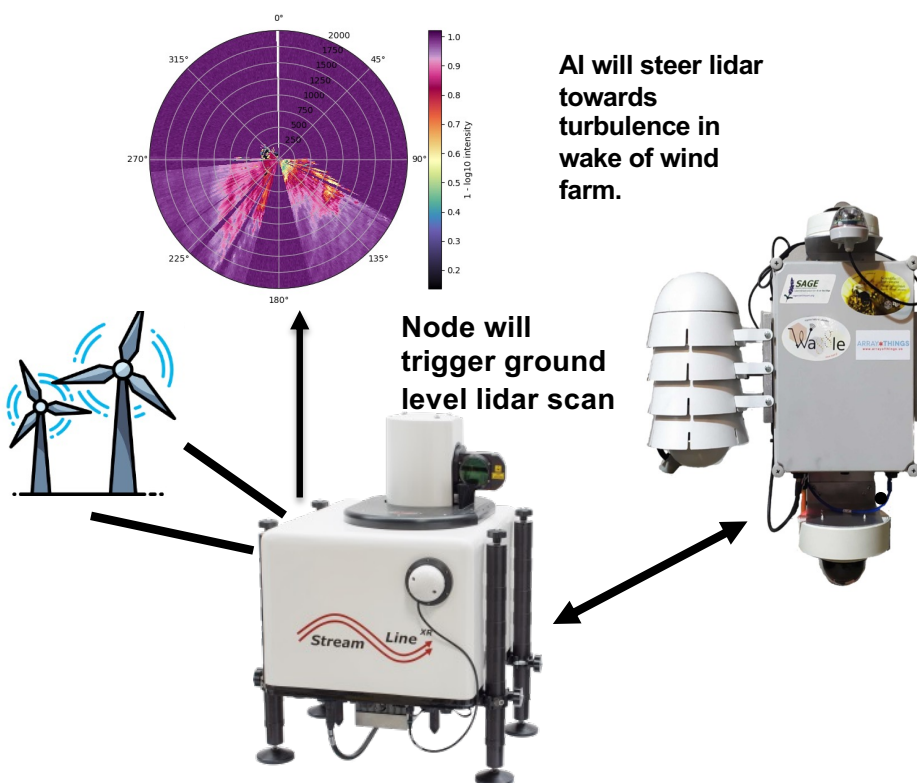
**Volcano National Park
October 2023**



Lorawan connected
tree sap monitor



Sage + Doppler Lidar

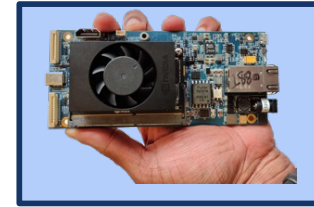


DL is a great target for edge processing:

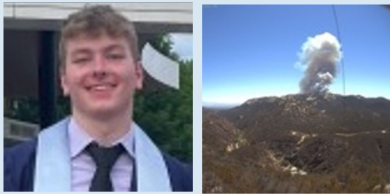
- Doppler spectra are not routinely stored
 - Currently only moments are archived
- Spectra contains rich information that should be processed differently when different phenomena are present

Jackson, R. C., and Coauthors, 2023: ARming the Edge: Designing Edge Computing–Capable Machine Learning Algorithms to Target ARM Doppler Lidar Processing. *Artif. Intell. Earth Syst.*, 2, 220062, <https://doi.org/10.1175/AIES-D-22-0062.1>

A Few Examples of AI@Edge



Wildfire Detection



Jakub Szumny

Biodiversity



Dario Dematties

Urban Safety



Anagha Tiwari

Drought Agriculture



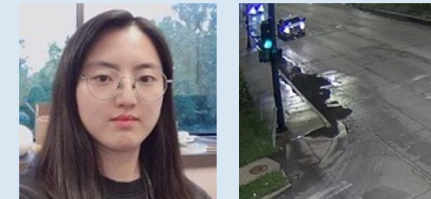
Eugene Kelly

Lidar/Digital Twins



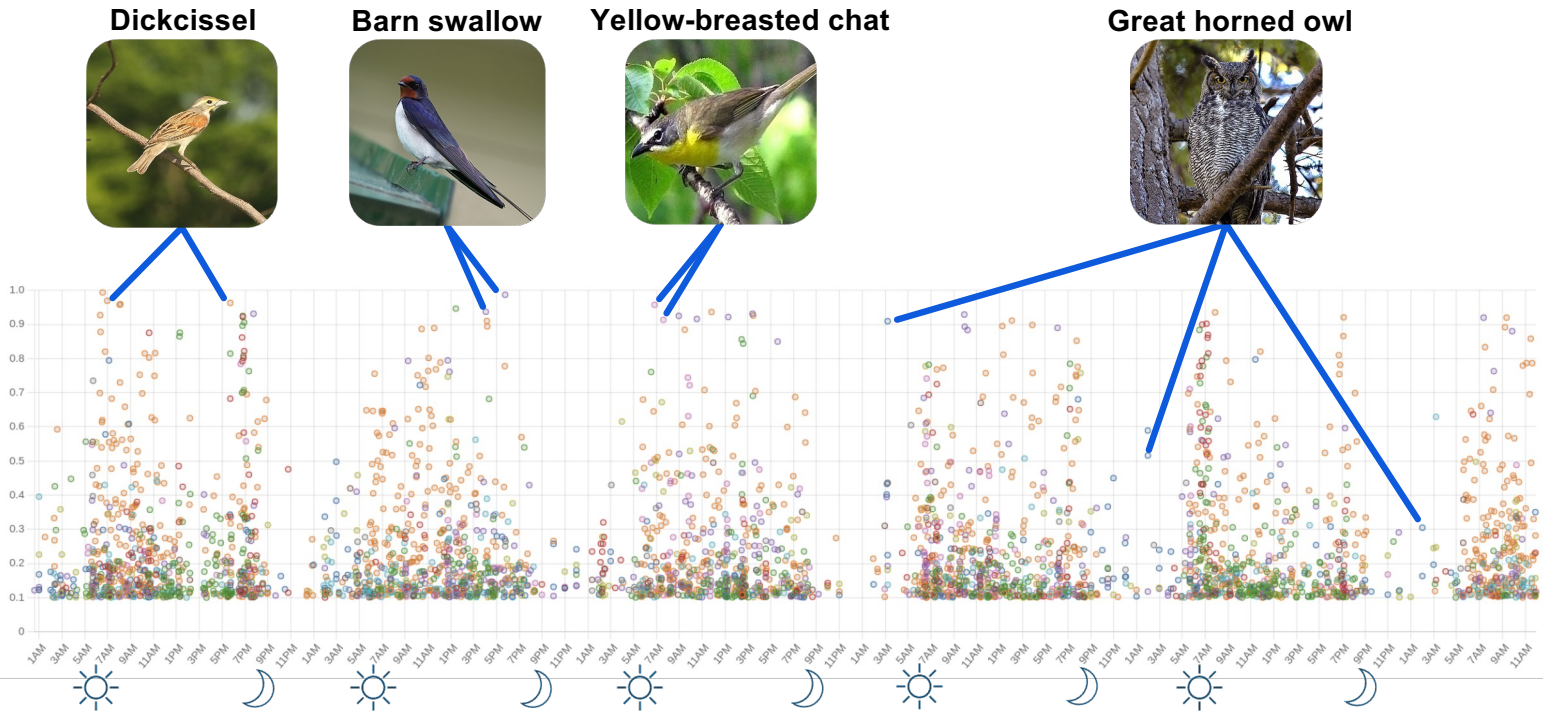
Bobby Jackson

Predict Flooding



Seongha Park

AI to Monitor Biodiversity in Real Time

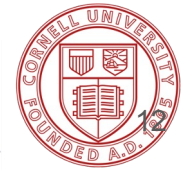
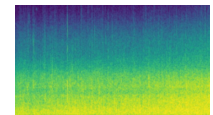
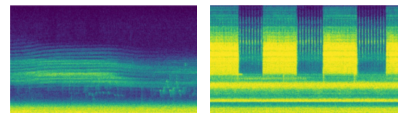
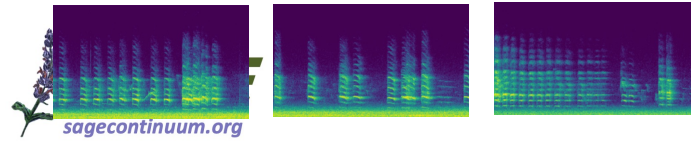


Emiquon National Wildlife Refuge, Illinois. (3/6-11/2024)

Blue Jay: 93.2%

Future AI: Identify Insects

Rain



Building Community for AI@Edge Sage Applications

Sage (beta) App Catalog Job Status Data Docs [Sign In](#)

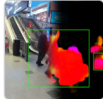
Sage: v2.2.1-pre.3

Explore

My Apps

Search

Featured Apps

 surface-water-detection Surface Water Detection seonghapark · 8 tags · Updated 139 days ago	 avian-diversity-monitoring Records environmental sounds, identifies birds by such sounds and f... dariodematties1 · 1 tag · Updated 158 days ago	 weather-classification An app for identifying cloud or rain coverage from the ARM Doppler ... rjackson · 13 tags · Updated 161 days ago
 traffic-state Traffic State Estimator seonghapark · 5 tags · Updated 202 days ago	 motion-analysis Motion Analysis seonghapark · 6 tags · Updated 202 days ago	 motion-detection A general-purpose motion detection system that locates and tracks m... seonghapark · 2 tags · Updated 202 days ago
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The Edge Code Repository



Wild Sage Node TAFT W06F

reporting

Overview

Sensors (8)

Computes (2)

Peripherals (6)

Overview

Project SAGE

Focus Rural

City & State Lakeview, Montana (MT)

Registration 4/12/2022, 12:05:35 PM

Commissioned -

GPS (static)

44.598866276,
-111.812532858

Sensors

Bottom Camera

XNV-8081Z

Top Camera

XNF-8010RV

Raingauge

RG-15

T-P-H

BME280

Microphone

ML1-WS IP54

T-P-H-G

BME680

Airquality

ES-642

GPS

VK-162

Computes

NX

xavierNX

RPi

RPi4B

Hardware

Stevenson Shield

yes

Last 7 days of data

density

availability

hourly

daily

-∞(daily)

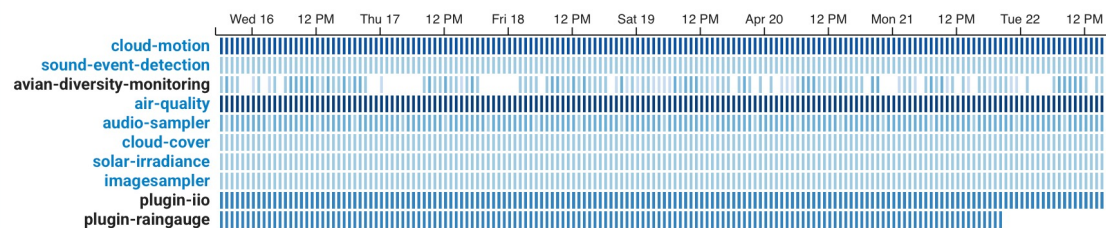
-1y

-90d

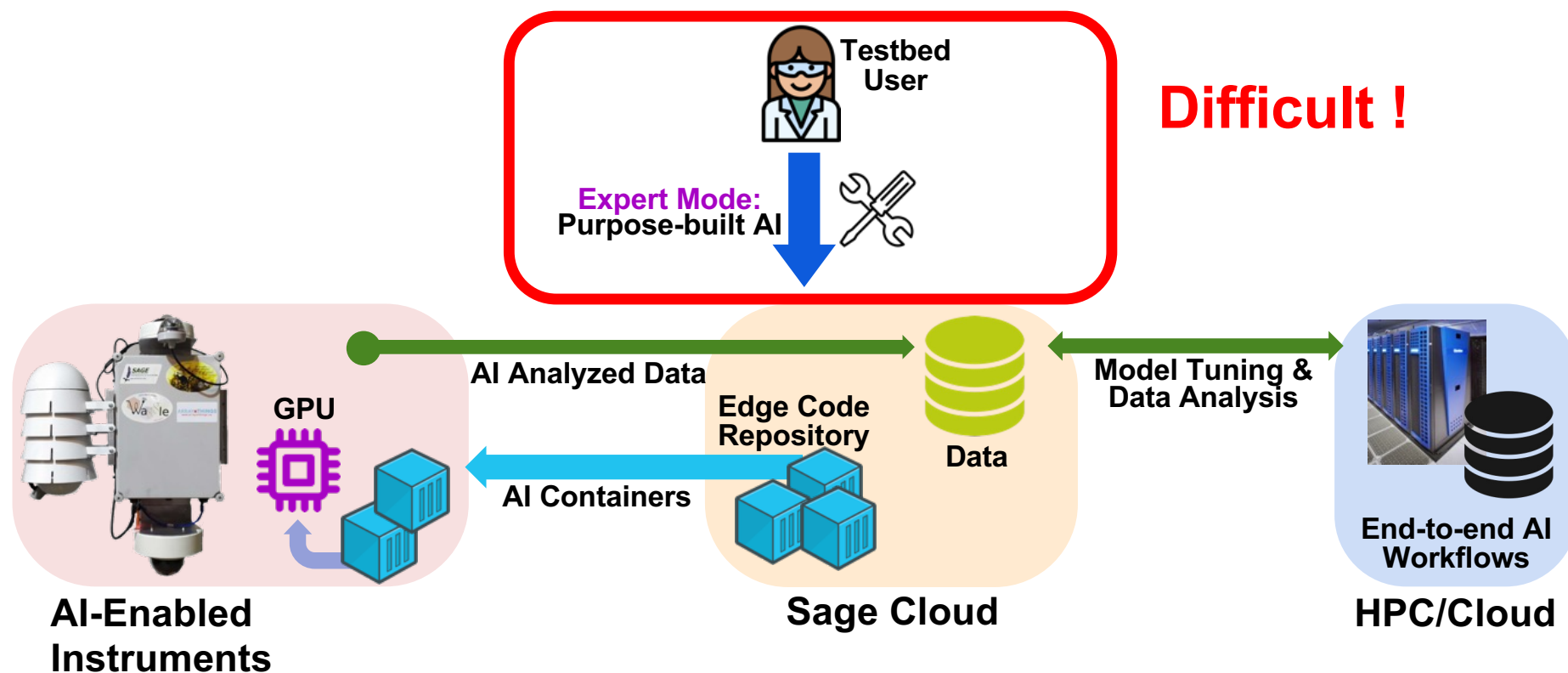
-30d

-7d

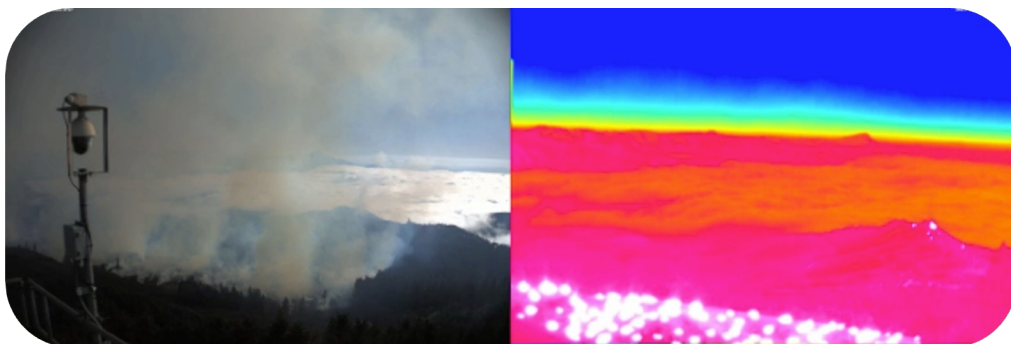
-2d



How Did It All Work?



Testbed Advance AI -- Guide what we can imagine next



National NSF Cyberinfrastructure to Support AI Research

Computer Science:

- AI inference, federated / self-supervised learning
- LLM benchmarking and correctness at edge
- Cybersecurity, privacy, real-time data analysis
- Adaptive power management
- Programming model for continuum computing
- Resource management, streaming data

Domain Science:

- Developing next-gen AI-enabled instruments
- LLMs for in-situ data analysis
- Domain-specific tuned AI models for edge
- Understanding drought, wildfire, and flooding
- Real-time forecasts with edge-HPC models
- Adaptive steering of data collection



Why Edge: Big Data @ Edge, Autonomy, Real-time



Nodes App Catalog Job Status Data

Docs Help beckman

Apps

Names
Images
Audio

App Filters

Apps
chrislee/moondr...Nodes
W097

Names

cURL download

curl https://data.sageco...

Python snippet

```
import sage_data_client

df = sage_data_client.query(
    start="2025-02-16T18:00:00",
    end="2025-02-16T19:00:00",
    filter={
        "plugin": "registry",
        "vsn": "W097"
    }
)
```

install client

docs

Node	Time	Name	Value
W097	1.8 days ago	caption	The image depicts a lush, verdant forest, with a variety of trees and shrubs in shades of green and brown. The forest is densely packed with deciduous and evergreen trees. The perspective is from a high vantage point, providing a bird's eye view of the forest. The sky is a light blue with wispy clouds. In the distance, a dark, possibly volcanic, landscape is visible, with a faint suggestion of a crater or vent. The image is taken from a distance, making it difficult to discern the exact location or scale of the forest and the distant landscape.
W097	1.8 days ago	points	[{"query": "smoke", "points": [{"x": 0.6015625, "y": 0.1728515625}], {"query": "fire", "points": []}, {"query": "hazard", "points": [{"x": 0.607421875, "y": 0.1728515625}]}]
W097	1.8 days ago	query	[{"query": "Is there a fire?", "response": "Yes, there is a fire visible in the image, located near the forest."}]



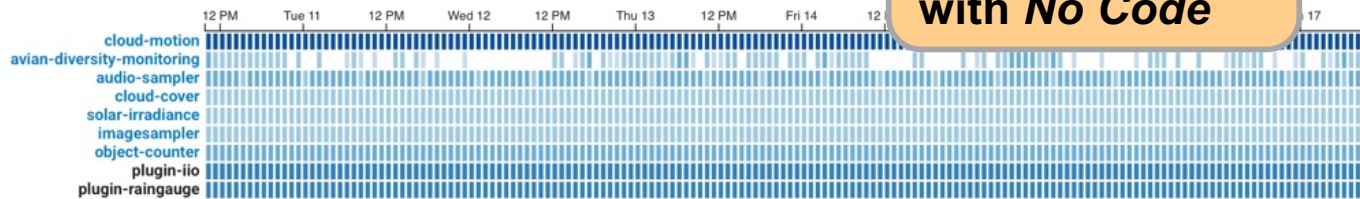
**Query: 'Is there a fire?',
response: 'Yes, there is a
fire visible in the image,
located near the forest.))**



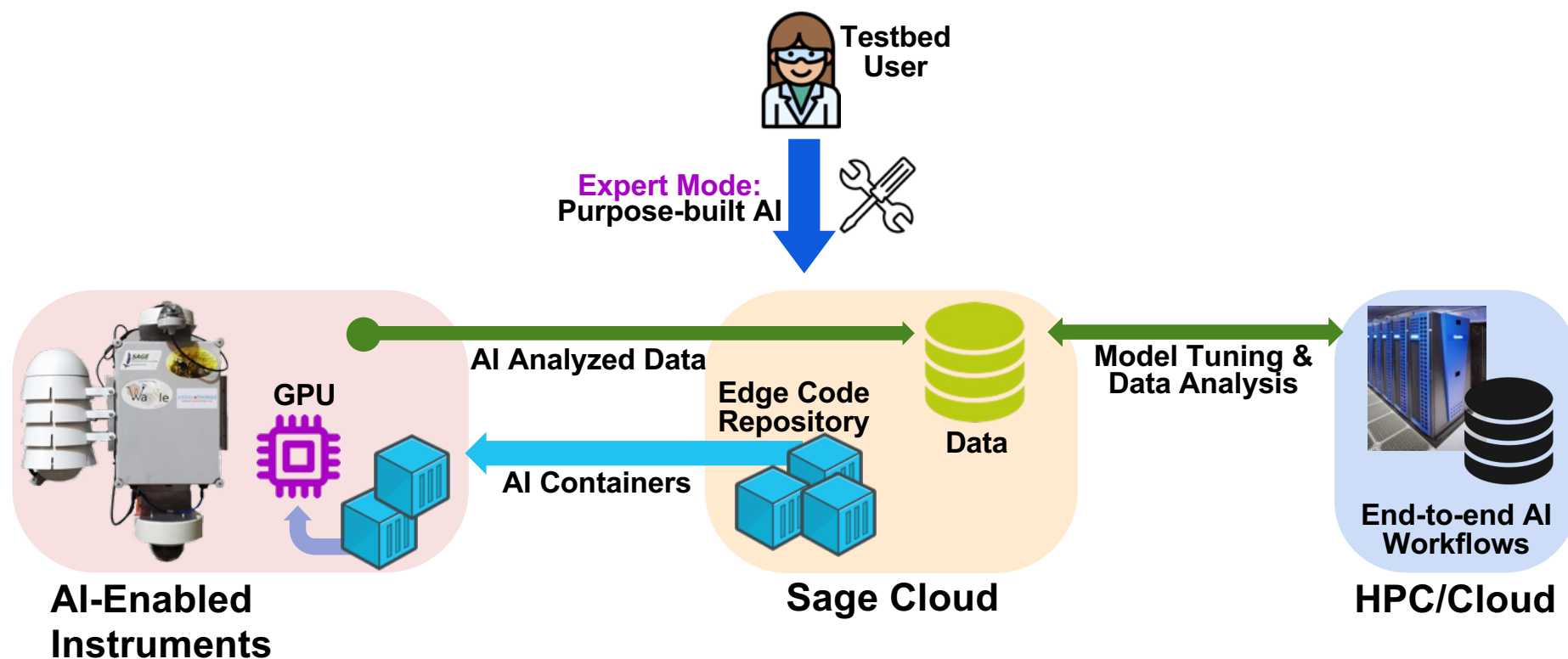
**SageChat:
Using LLMs
with No Code**

Last 7 days of data

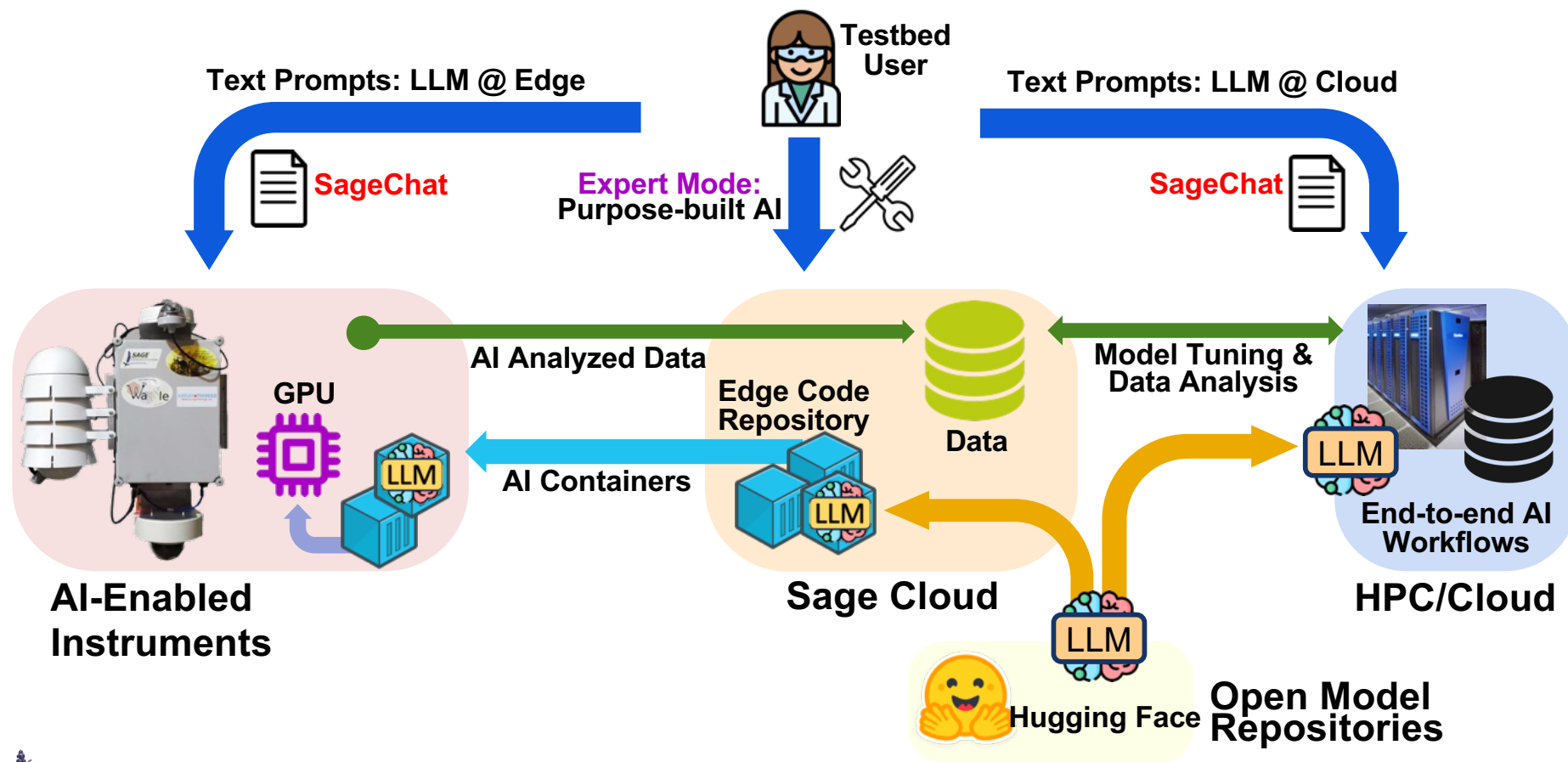
density availability hourly daily -∞(daily) -1y -90d -30d -7d



Sage v1: How *Did* It All Work?

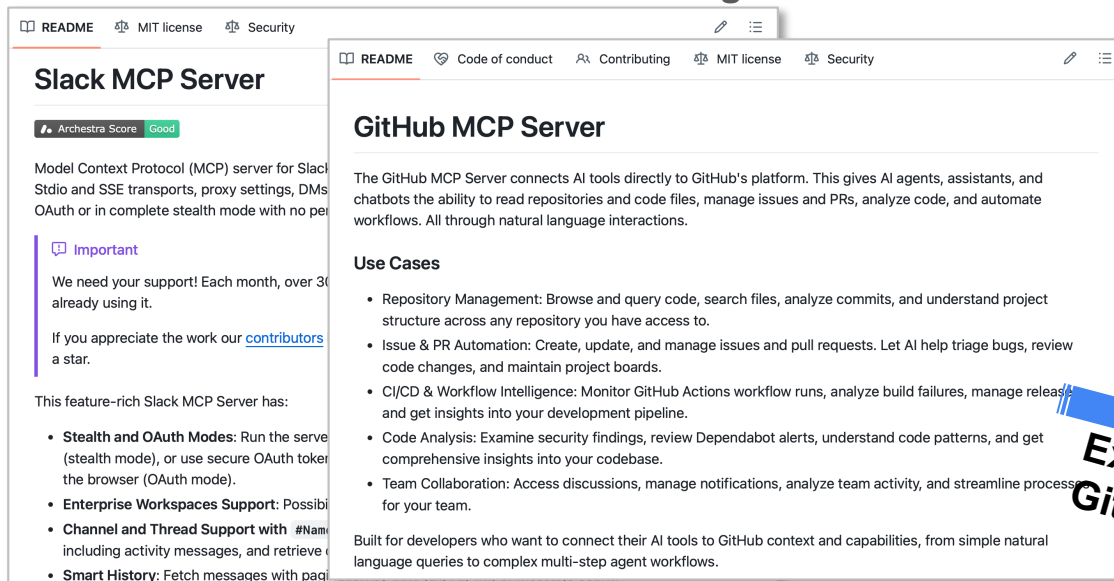


How Does (Will) It All Work?

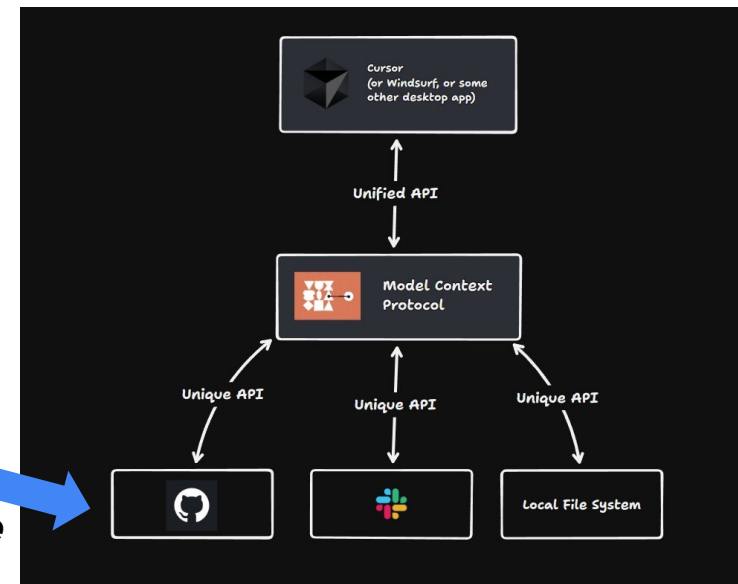


Natural Language to interact with Sage Grande Testbed: SageChat Prototype and Future Directions

- Goal: Harness LLMs --- provide natural language interfaces and expand user community for AI-enabled cyberinfrastructure and edge computing.
- Anthropic's "*Model Context Protocol*" (MCP) is open standard: Nov 2024
 - Provides standard way for computing systems to publish interfaces that AI can use
 - MCP is a link between **AI Agents** and APIs to everything



Example
GitHub



Sage Grande has a Prototype MCP!!!

Sage MCP Server

A Model Context Protocol (MCP) server for interacting with the Sage Grande Testbed, cyberinfrastructure for AI@Edge. This server provides tools, resources, and prompts for querying sensor data, submitting jobs, and managing Sage nodes.

Quick Setup with Cursor IDE

The easiest way to use Sage MCP is through Cursor IDE with our hosted server:

1. Configure Cursor MCP

Add this to your Cursor MCP configuration file (`~/.cursor/mcp.json`):

```
{
  "mcpServers": {
    "sage": {
      "url": "https://mcp.sagecontinuum.org/mcp",
      "headers": {
        "Authorization": "Bearer {username}:{auth_token}"
      }
    }
  }
}
```



Build a sage app from code

Once you provide this information, I can deploy the app for you!

hmm... can you deploy it to all sky facing cameras?

Called MCP tool `deploy_sage_app` ✓

```
"V031"
],
"args": []
}
```

Result:

Error executing tool `deploy_sage_app`: Argument `--input` is required. This app requires a camera to be provided as input as `--input <camera_name>`.

The deployment requires a camera to be specified as an argument using the `--input` flag (e.g., `--input top_camera` or `--input sky-cam`).

For the sky-facing cameras, here are the required arguments:

- W027: `--input top_camera`
- V031: `--input sky-cam`

Would you like to deploy to both nodes with these camera inputs? If you have any additional arguments to pass, please let me know, otherwise I'll proceed with these defaults.

What does the SGT MCP Provide Users?

A new way to write programs and control Sage

Some Examples:

Core Capabilities

1. Sensor Data Exploration

Discover what's available:

```
"Show me all available Sage nodes and their sensors"
"What environmental data is available from the last hour?"
"List nodes in Chicago with temperature sensors"
```

Query specific data:

```
"Get temperature readings from node W06D0"
"Show me rainfall data from all nodes"
"What's the current air quality in na"
```

3. Job Submission & Management

Submit jobs easily:

```
"Deploy a cloud cover detection job to n
"Run audio sampling on all nodes in Hawa
"Start a multi-plugin ML suite on prairi
```

Monitor and manage:

```
"Check the status of job 12345"
"Show me recent data from my flowering p
"Remove job 67890 from the scheduler"
```

2. Plugin Discovery & Development

Find existing plugins:

```
"Find plugins for monitoring bird sounds"
"What computer vision plugins are available for plant detection?"
"Show me plugins that work with PTZ cameras"
```

Get development guidance:

```
"How do I create a custom Sage plugin for detecting flowers?"
"What's the best approach for real-time audio analysis on edge nodes?"
"Help me optimize a YOLO model for edge deployment"
```

Research & Data Analysis

Exploratory Data Analysis:

```
"I'm studying pollinator activity. What Sage data would be m
"Show me temperature trends across different ecosystems in t
"Find correlations between flowering patterns and weather da
```

Hypothesis Testing:

```
"Compare bird activity between urban and rural nodes during
"Analyze the relationship between air quality and plant heal
"Test if rainfall patterns affect flowering timing in prairi
```

Publication-Ready Analysis:

```
"Generate a statistical summary of biodiversity metrics from
"Create a comprehensive environmental report for node W06D0
"Export data in a format suitable for scientific publication
```

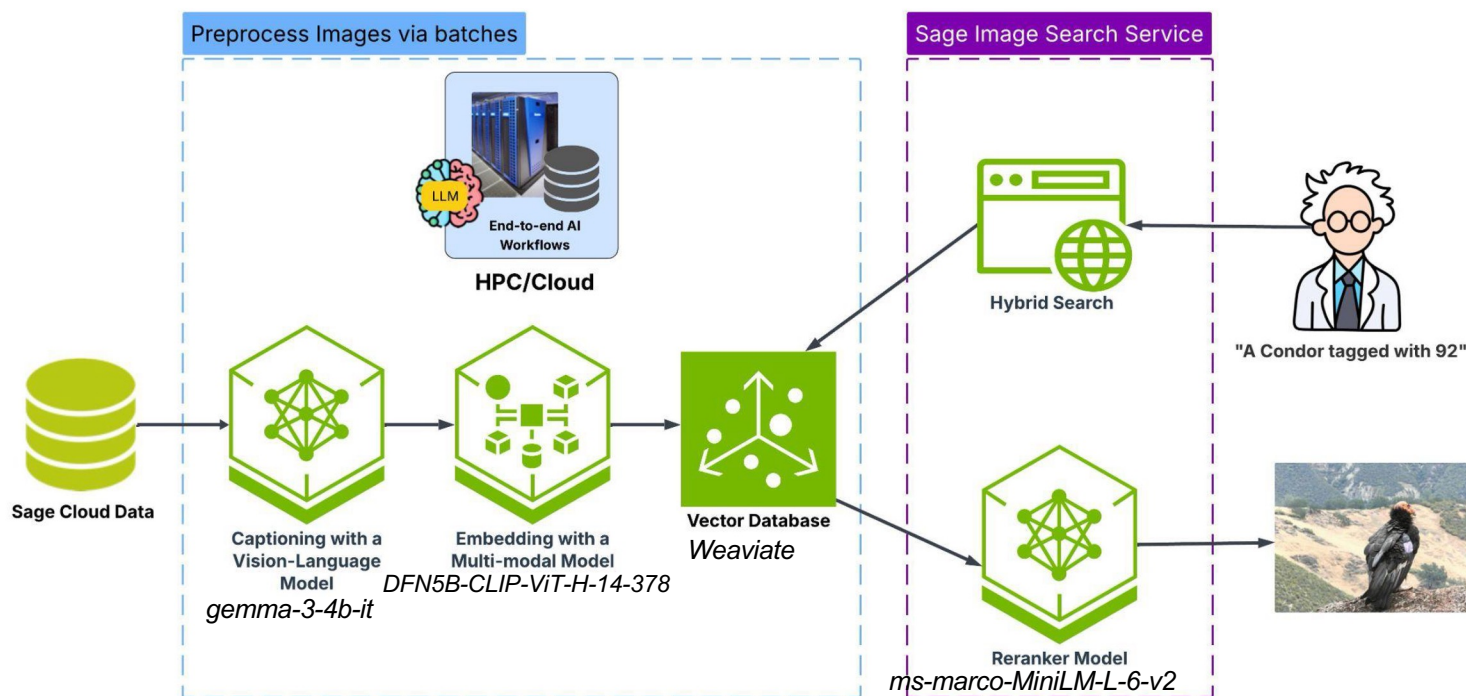
SageChat --- The Future

- Tutorial and educational interactions:
 - “Teach me about AI inference at the edge”
- Code and AI model development:
 - “I’d like to improve the performance of my code, either by quantizing the model or using a more efficient run-time system. Provide some step-by-step paths forward”
- Workflows spanning MCPs:
 - “I’d like to link my AI@Edge code with a HPC forecast that predicts drought. Please find the HPC resources and apply for a starter allocation and then run my workflow”
- MCP for the ***edge: (Agents at the Edge!)***
 - I’d like to examine all incoming data at the edge for anomalies and then autonomously modify the data sampling protocol and redirect cameras and instruments to better collect data”

Resources:

- <https://github.com/waggle-sensor/sage-mcp/blob/main/docs/EXAMPLES.md>
- <https://github.com/waggle-sensor/sage-mcp/tree/main>

Process Archived Data with AI Use Natural Language Search Interface



(as of June, 2025)

Preprocess Computation:

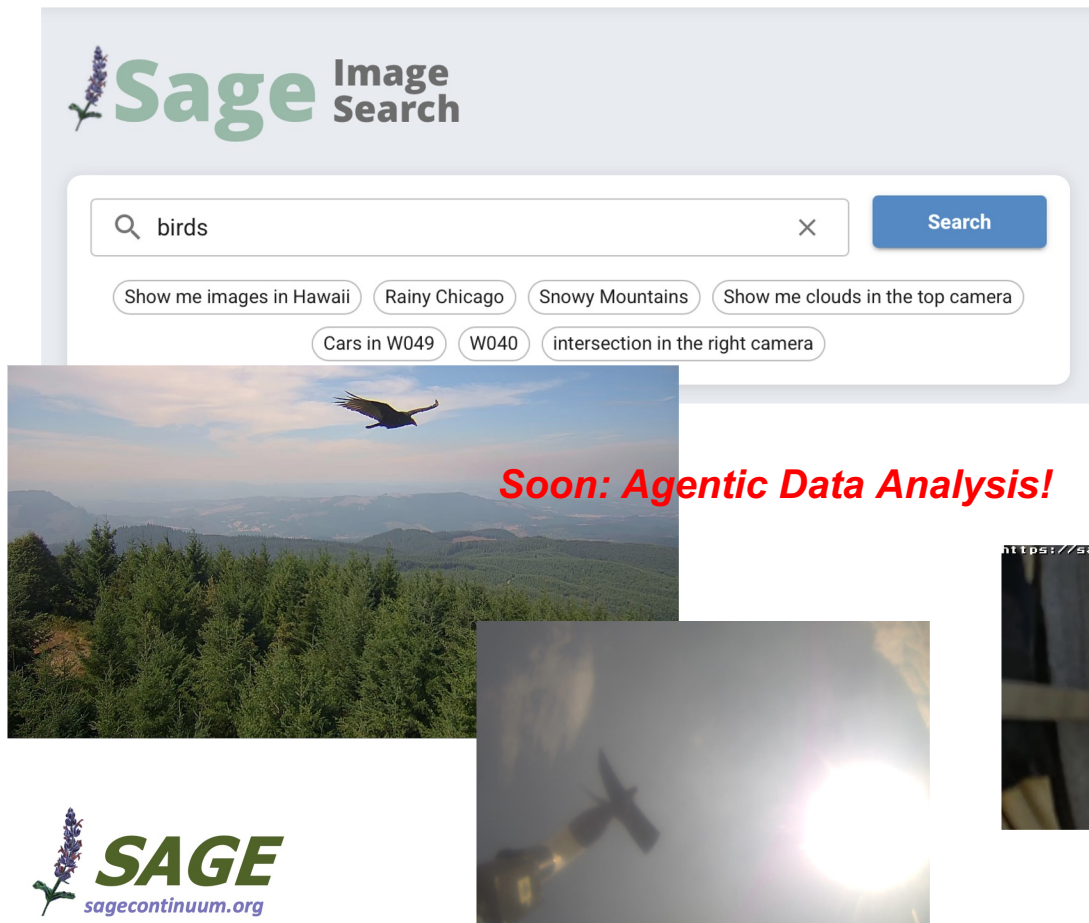
- 10 sec/image.
- Sage archive: ~33M images
- 15K images/day
- ~382 weeks of H100 (unparallelized).
- scales by Images/Nodes

Sage Image Search Service Computation:

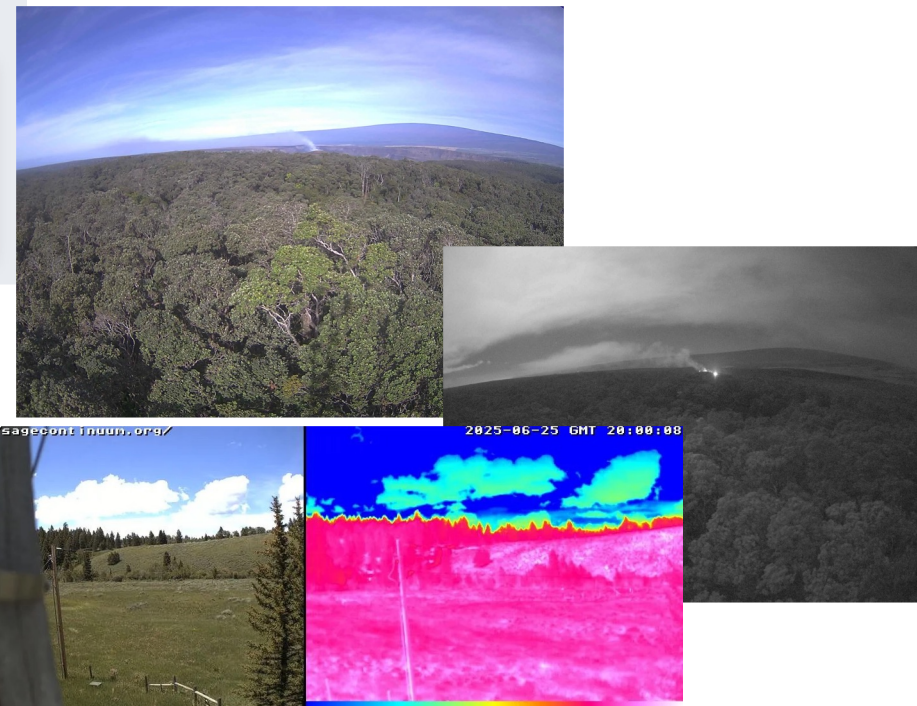
- 20 sec/query for top 25 images.
- Sage has ~303 users
- If all users made one query, it would take ~1.68 hours of H100 to process all. (not yet parallelized).
- Scales by Users.

AI to Make Data Useful and Broadly Accessible to Scientific Communities

Early Prototype that shows the promise of AI for data insights



“Wildfire Smoke”



<https://sage-hybrid-search.nrp-nautilus.io/>

Integrating Sage Grande with other NSF Resources: NRP/NDP, Pelican/OSDF, PATH (HT Condor)

Thank you SDSC
& U Wisconsin!

