

SADE-SIM: A Scalable Simulation Platform for Validating City-Scale Multi-sUAS Missions

Bridging Flight Dynamics, Photorealistic Environments, and Regulatory Constraints for Safe Autonomous Aerial Systems at Scale

Authors

Laxminarayana Vadnala - lvadnala@nd.edu

Lucas Parzianello - lparzianello@nd.edu

Bohan Zhang - bohan.zhang.1@slu.edu

Michael Murphy - mmurph51@nd.edu

Ankit Agrawal - ankit.agrawal.1@slu.edu

Douglas Thain - dthain@nd.edu



Research Grant: 80NSSC23M0058



Birdy - The sky was simple. Every object in the air was another bird. Nature handled the traffic.



How would our cities change if we managed thousands of autonomous drones in the sky with the same rigor, structure, and safety guarantees that today's air traffic control provides for airplanes?

Birdy - They all will crash into each other!!

Who's making sure none of Drones/sUAS crash into each other?



They killed my freedom



Imagining Drones included airspace management

Credits: Image generated using ChatGPT (AI image generation)



The SADE Project: Safety-Aware Drone Ecosystem

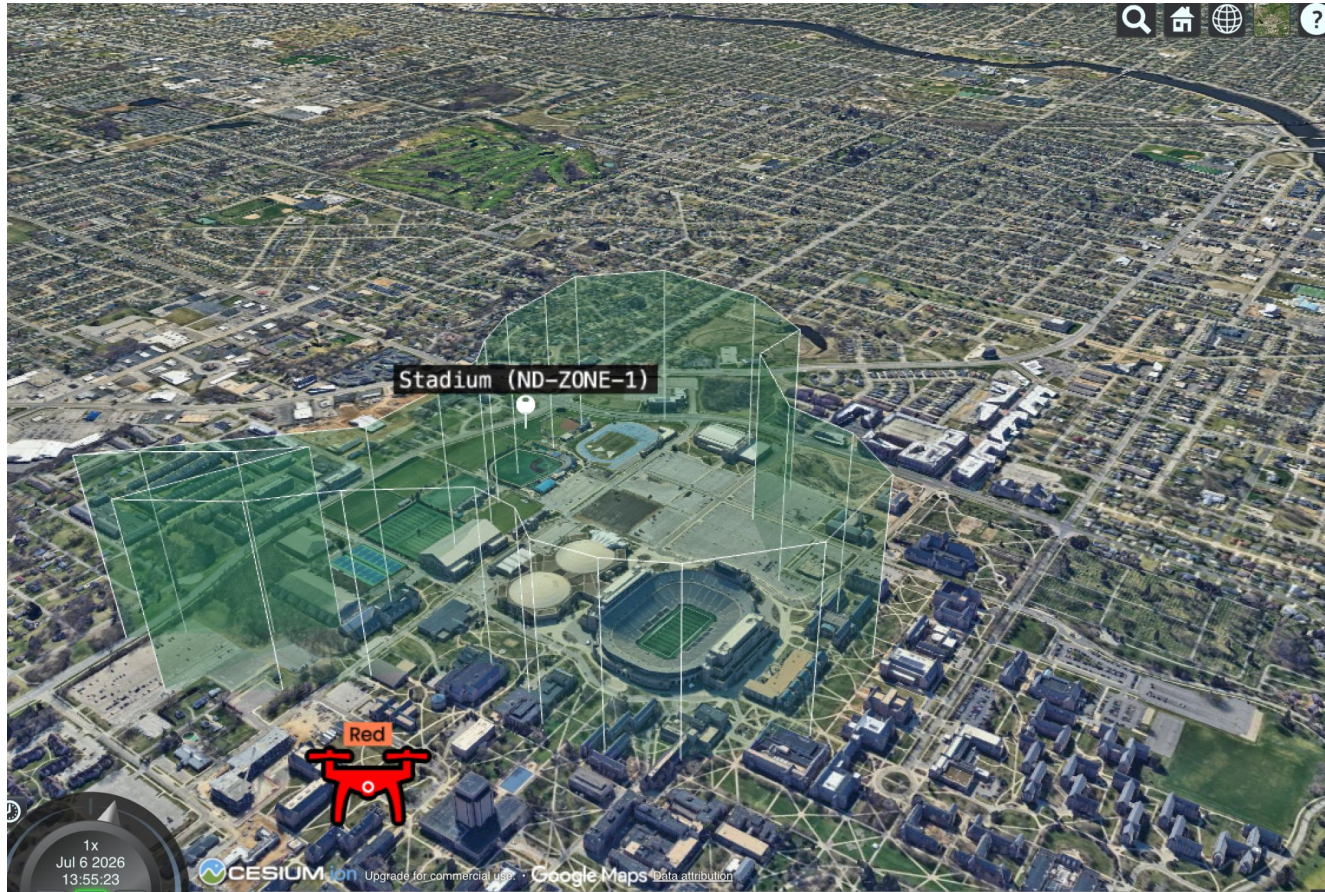
SADE: A New Ecosystem for Drones

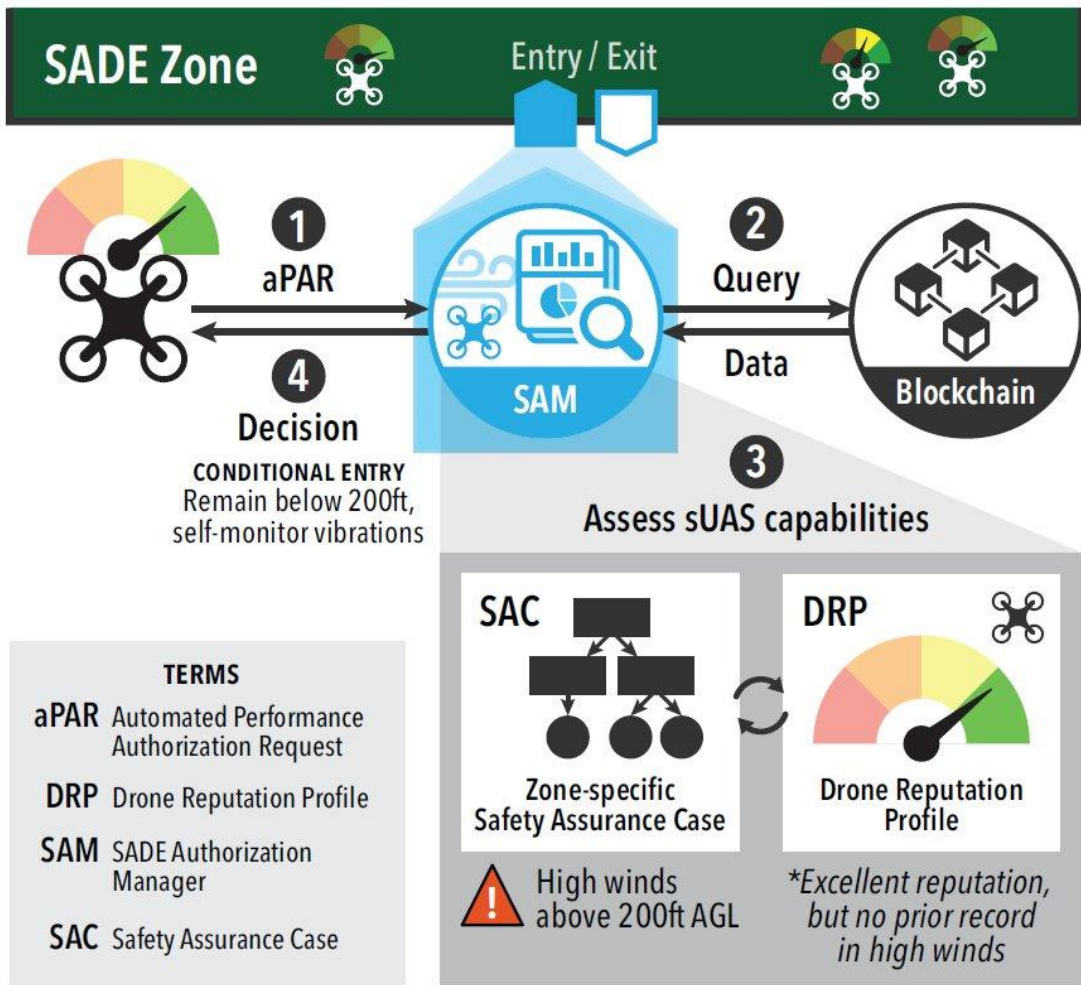


SADE Zones from SADE-SIM Platform

**Birdy - What are
SADE ZONES?**

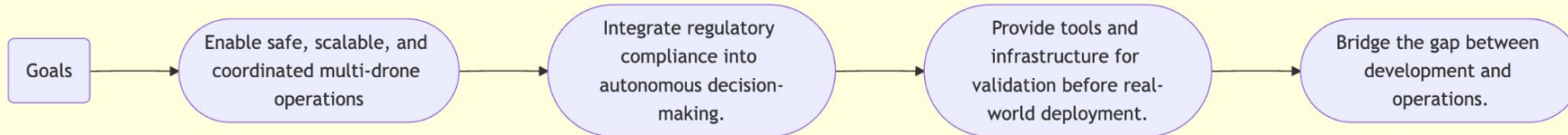




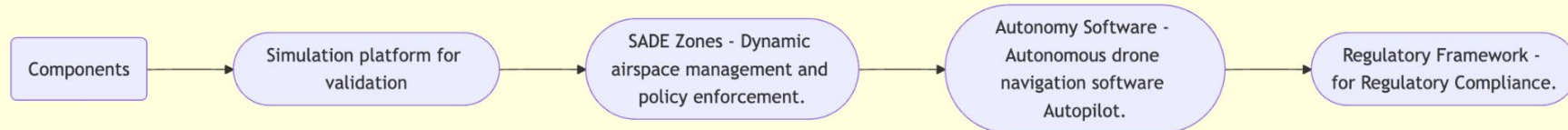


Project Goals & Components

SADE-SIM Goals

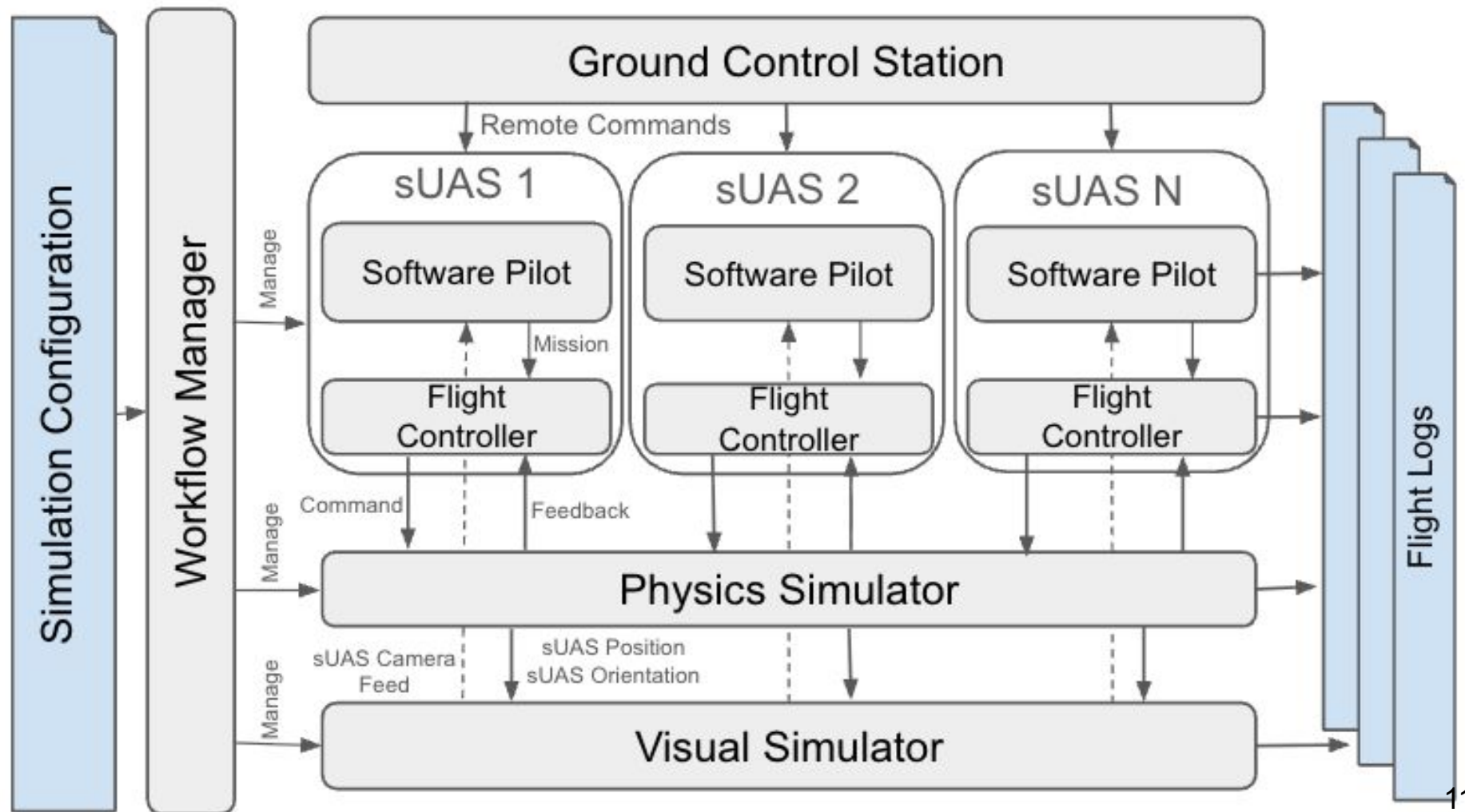


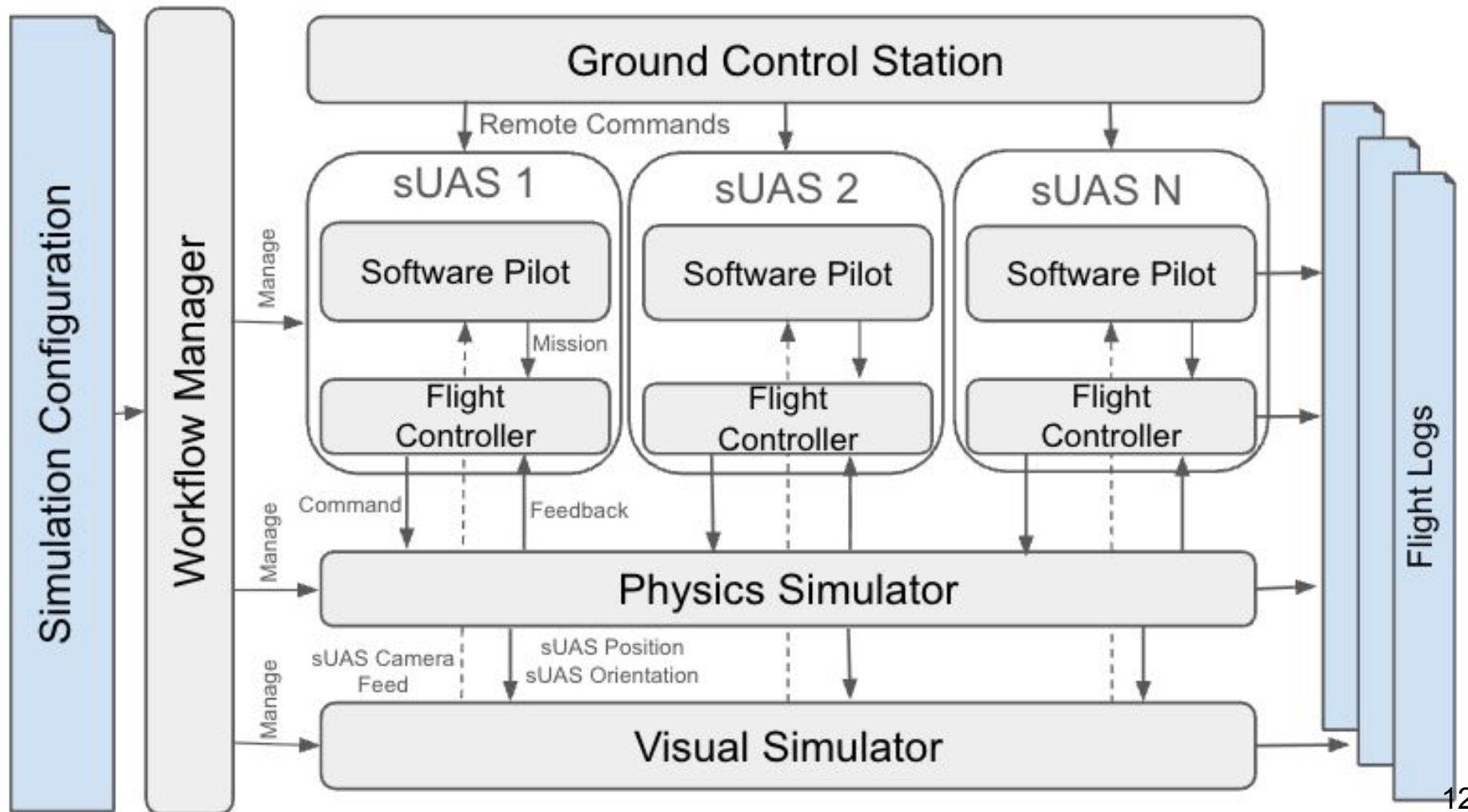
SADE-SIM Components



SADE-SIM: Simulation Platform for Safe Drone Deployments

Fig: SADE-SIM Conceptual Architecture





Development Objectives

**Distribute Physics
and Rendering
Workload**

**Custom Software
Pilots**

**Airspace
Management**

**Automated
Simulation
Infrastructure
Management**

Development Objectives

DO1: Distribute Physics and Rendering Workload

- Physics and environment rendering workloads distributed across multiple nodes
- Maintain consistent shared world state
- Modular design for environmental factors such as Terrain, GPS, Wind and other factors which can be integrated as plugins
- Extensible architecture for fog, weather, and other environmental factors

Development Objectives

DO2: Custom Software Pilots and DO3: Airspace Management

- Support standard communication interfaces between flight controller (PX4-Autopilot) and custom software pilots (MavSDK, Dronekit, etc.,)
- Native integration of operational constraints (no-fly zones, regulator-controlled zones)
- Explicit support for dynamic airspace rules and zone constraints.

Development Objectives

DO4: Automated Simulation Infrastructure Management

- Single specification for complete workflow configuration.
- Automatic resource provisioning and scaling.
- Persistent simulation logs for debugging and analysis.
- Reliable cleanup and reset between runs.
- Challenge addressed: Manual orchestration makes testing time-consuming, brittle, and hard to reproduce

SADE-SIM Simulation Infrastructure

Fig: SADE-SIM Complete Architecture

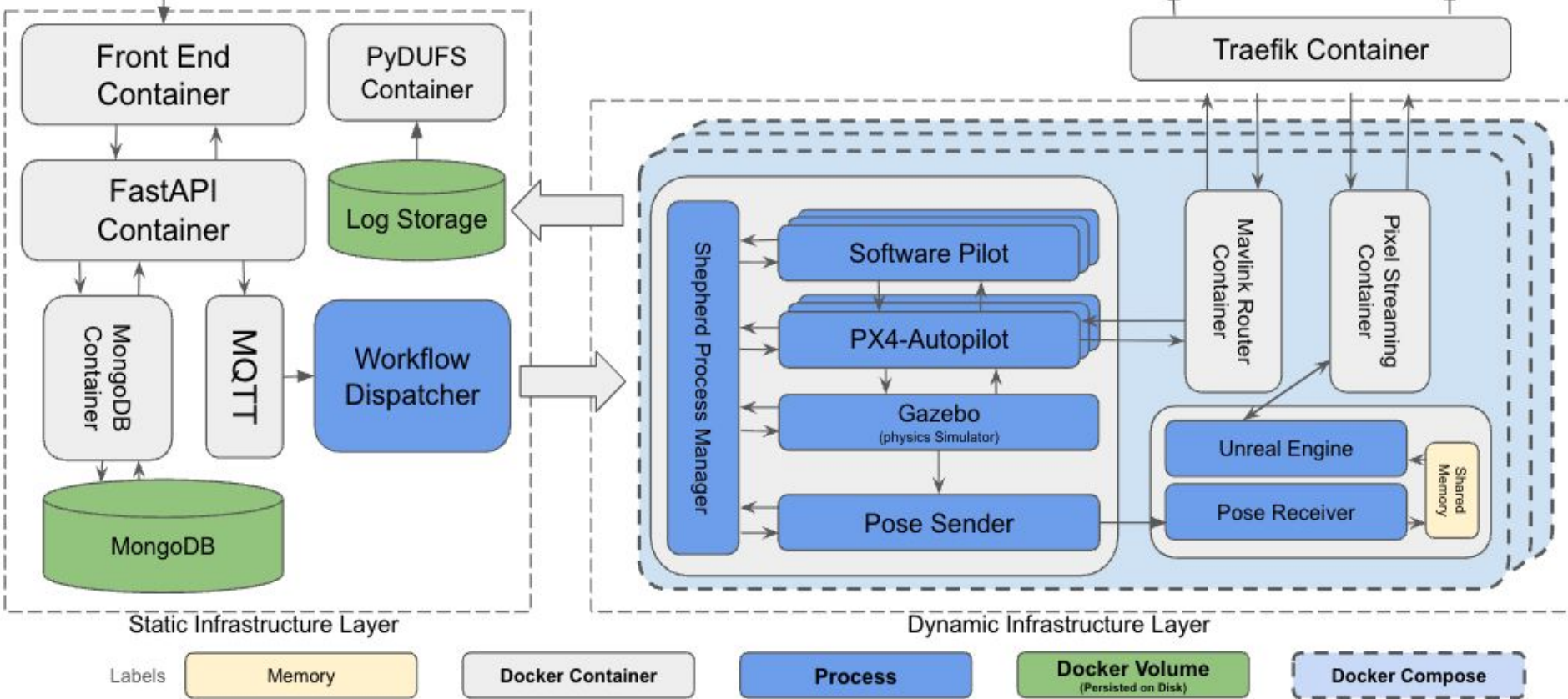
Configuration



Runtime Control



Simulation Video



SADE-SIM Architecture

- Static Infrastructure Layer
- Dynamic Infrastructure Layer
- Synchronization and Data Streams among services

Simulation Workflow Lifecycle

1. Configuration Generation (frontend + cesium JS)
2. Artifacts Generation
 - a. Terrain Scan
 - b. Wind Vectors generation using OpenFOAM
3. Configuration setup (Workflow generates configs)
4. Containers initialization
5. Execution, Monitoring and Teardown

BACK

NEXT

ENVIRONMENT

SUAS

SOFTWARE PILOT

SIMULATION
ORIGIN

WIND

SADE ZONE

Origin Hutchinson Field... 

Origin Latitude 41.871514

Origin Longitude -87.618865

Radius
0.3 miles

0.4828 km

Time of day
07:29:19  Left Click + Drag to pan Middle Click + Drag to rotate Scroll to zoom in and out

BACK

NEXT

ENVIRONMENT

SUAS

SOFTWARE PILOT

SIMULATION
ORIGIN

WIND

SADE ZONE

Number of SADE
Zones

- 1 +

sz-52b8

Name

sz-52b8

Ceiling (m) (sea l...

0500

Rectangle (4 vertices)

Vertex 1

Lat

41.872634490569

Lon

-87.618862513992

Vertex 2

Lat

41.872634490569

Lon

-87.616411434056

Vertex 3

Lat

41.8697306113984

Lon

-87.616411434056

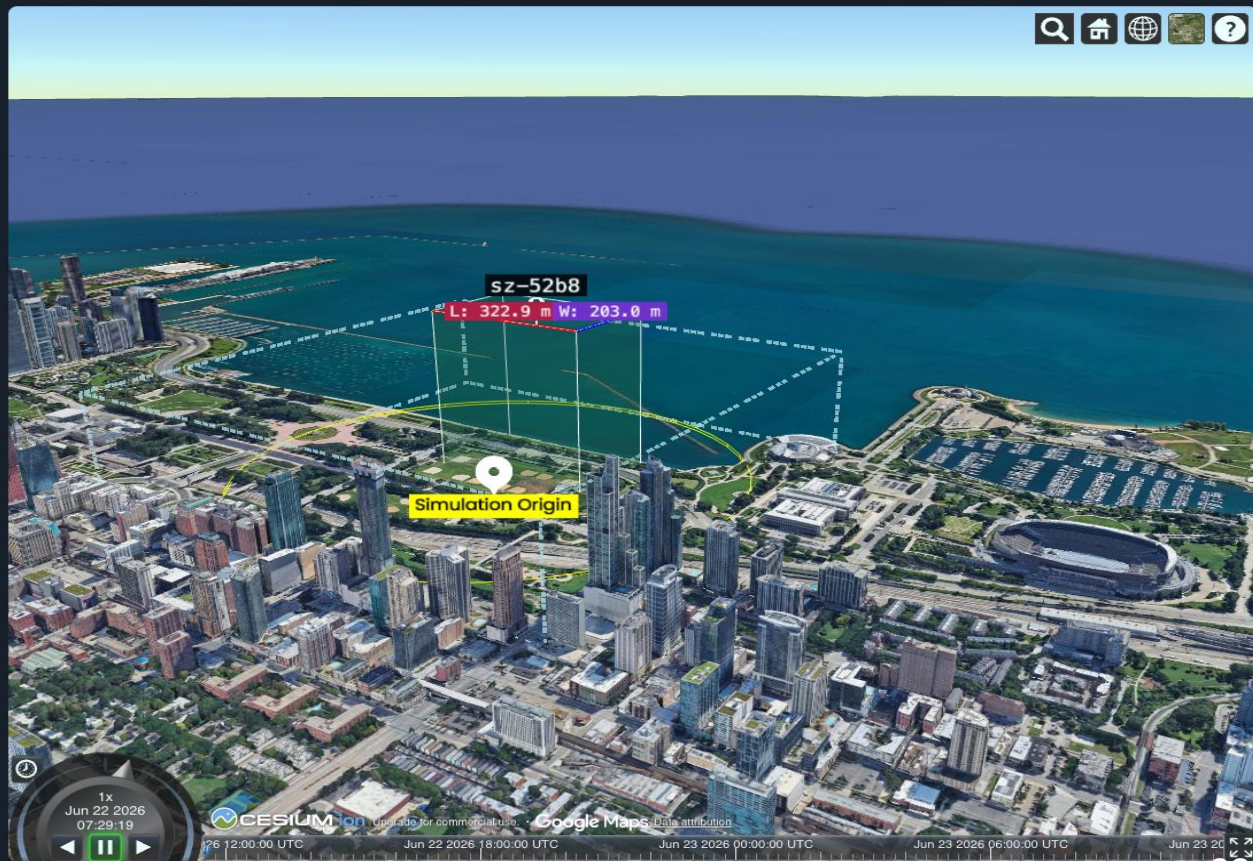
Vertex 4

Lat

41.8697306113984

Lon

-87.618862513992



BACK

NEXT

ENVIRONMENT

SUAS

SOFTWARE PILOT

Download Simple Pilot
JSON Template

↓ INDEX TEMPLATE

↓ NAME TEMPLATE

Upload JSON Template

↑ UPLOAD SIMPLE PILOT
JSON TEMPLATE

Add uncrewed aerial vehicles by dragging their icon
onto the map

Number of sUAS

2

Red

1



Name

Red

Color

#ff0000

Vehicle
Type

Multi Rot...

Vehicle
Model

Parrot A...

Home Location

Latitude

41.871514

Longitude

-87.618865

Elevation (m)

145.735

Simple Pilot Configuration

Simple Pilot Params

()



[BACK](#)

FINISH

ENVIRONMENT

SUAS

BRANCHES & COMMITS

**MERGED
PRS**

Branch

Commit ID

0caf444 • 2 months ago
Merge pull request #1 from La

[View commit on GitHub](#)

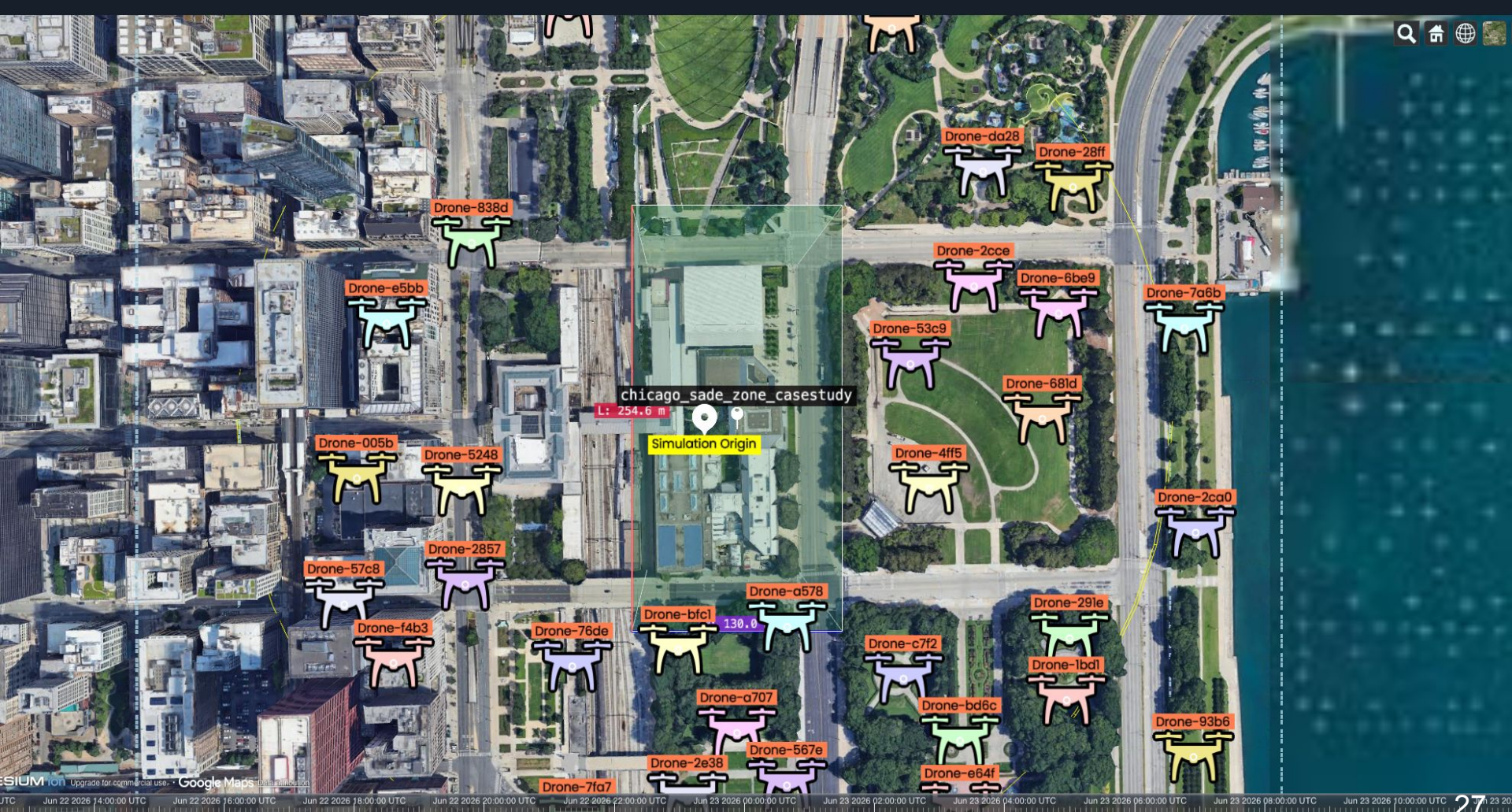


Case Study - Emergency Response Scenario

- **Location:** Museum in downtown Chicago
- **Trigger:** Emergency response event requiring airspace management
- Chicago Department of Public Safety (DPS) establishes dynamic, high-priority SADE Zone.

Case Study - Emergency Response Scenario

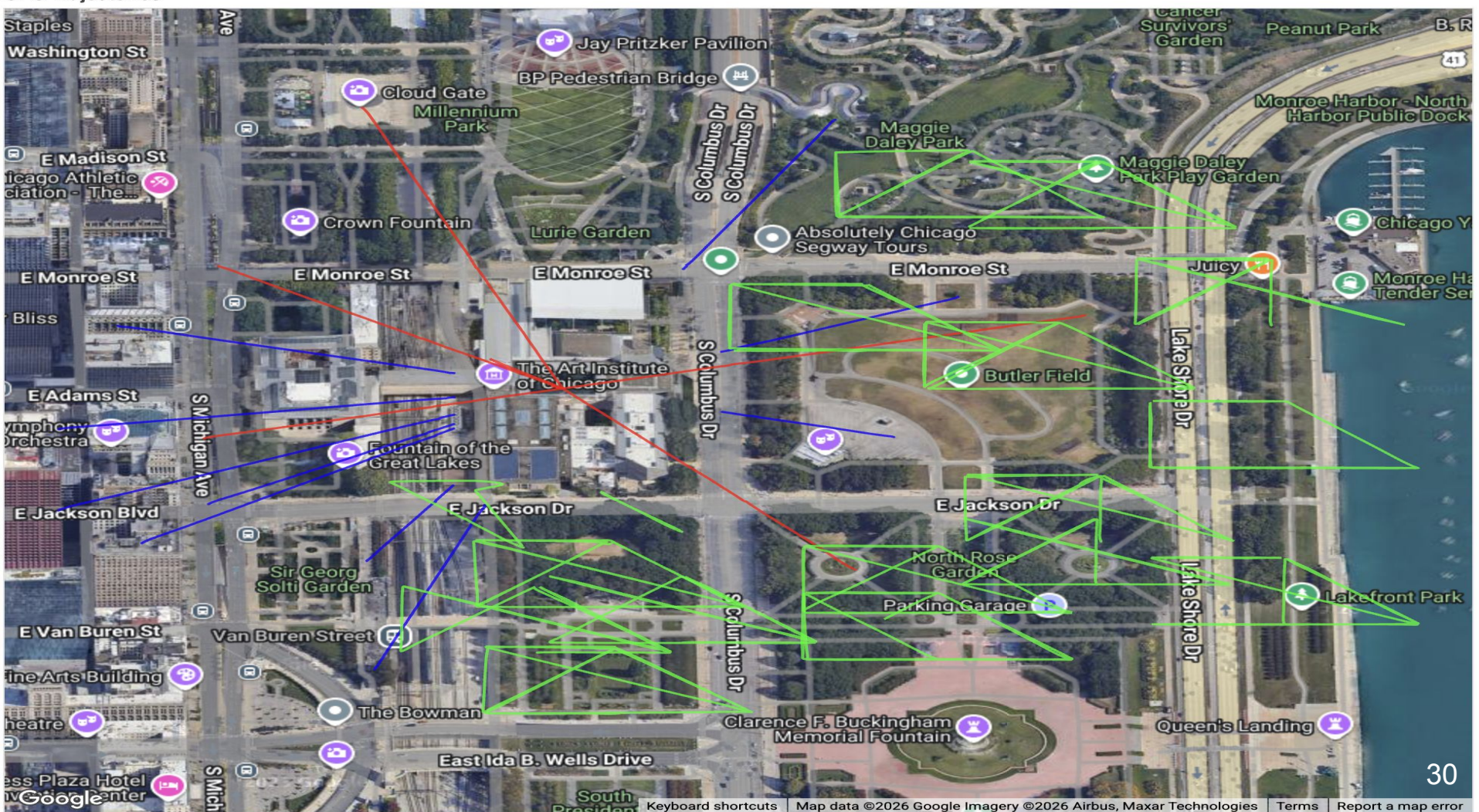
Group	Count	Role	Authorization	Behavior
Public Safety	5	Emergency response & crowd monitoring	Always Granted	Navigate directly to zone, maintain formation
Journalists	10	Live aerial broadcast capture	Denied	Scattered deployment, attempt zone entry
Recreational	17	Unauthorized footage capture	Denied	Random waypoint navigation, frequent zone boundary probing





 Copy Subject
 Share Subject...





SIMULATION MANAGEMENT
Simulation Runs

	Peppermint field trail 1	scrubbed	
	polysade_zone_testing	scrubbed	
	polysade_zone_testing	stopped	

SUBMITTED
5 days agoRECEIVED
5 days agoCREATED
5 days agoBUILT
5 days agoSTARTED
5 days agoSTOPPING
5 days agoSTOPPED
5 days agoQGroundControl Link
not running (STOPPED)

SADE Simulation

Final State: STOPPED
Pixel Streaming URL: not running
Environment ID: 7d00c8a9-f2d0-487a-bcdc-2e3d3f8399b8

	demo_testing_new	scrubbed	
	demo_testing_new_2	scrubbed	

PREV

1 / 1

NEXT

Files & Logs

unreal

shepherd.log

copy_ports_config.log

copy_ports_config_error.log

copy_mavlink_config_error.log

gazebo_server.log

gazebo_server_error.log

px4_1.log

px4_1_error.log

spawn_model_1.log

spawn_model_1_error.log

pose_sender.log

pose_sender_error.log

run_mission_1.log

run_mission_1_error.log

compose.log

state_times.json

px4

instance_1

sitl_typhoon_h480_1

log

2026-06-17

15_47_01.ulg

Future Work

- Scale SADE-SIM to almost 100 drones.
- Vision-Based autonomous navigation relying on onboard cameras.
- Validate navigation algorithms under realistic urban GPS denial (by integrating GPS plugin).
- Validate FAA dynamic airspace management protocols.
- Test AI/ML models in simulation before field deployment.

Team



DThain



Lucas



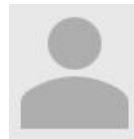
Lax



Michael



SAINT LOUIS
UNIVERSITY.



Bohan



SAINT LOUIS
UNIVERSITY.



Ankit



DEPAUL
UNIVERSITY



Wil Meyer

SADE-SIM: A Scalable Simulation Platform for Validating City-Scale Multi-sUAS Missions



Authors

Laxminarayana Vадnala - lvadnala@nd.edu

Lucas Parzianello - lparzianello@nd.edu

Bohan Zhang - bohan.zhang.1@slu.edu

Michael Murphy - mmurph51@nd.edu

Ankit Agrawal - ankit.agrawal.1@slu.edu

Douglas Thain - dthain@nd.edu



sade.crc.nd.edu/about

