LLM-Enabled Voice-Command of Multi-Robot Systems

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NAMUR Project: **N**atural-language **A**ssisted **Mu**lti-**R**obot Interaction and Planning
Funded by: Independent Research Fund Denmark under grant 10.46540/4264-00105B

Motivation

Disaster response - chaotic and high-pressure, requiring rapid, accurate coordination

Traditional multi-robot control platforms:

- Require **specialized training**
- **High cognitive load**

Natural language control:

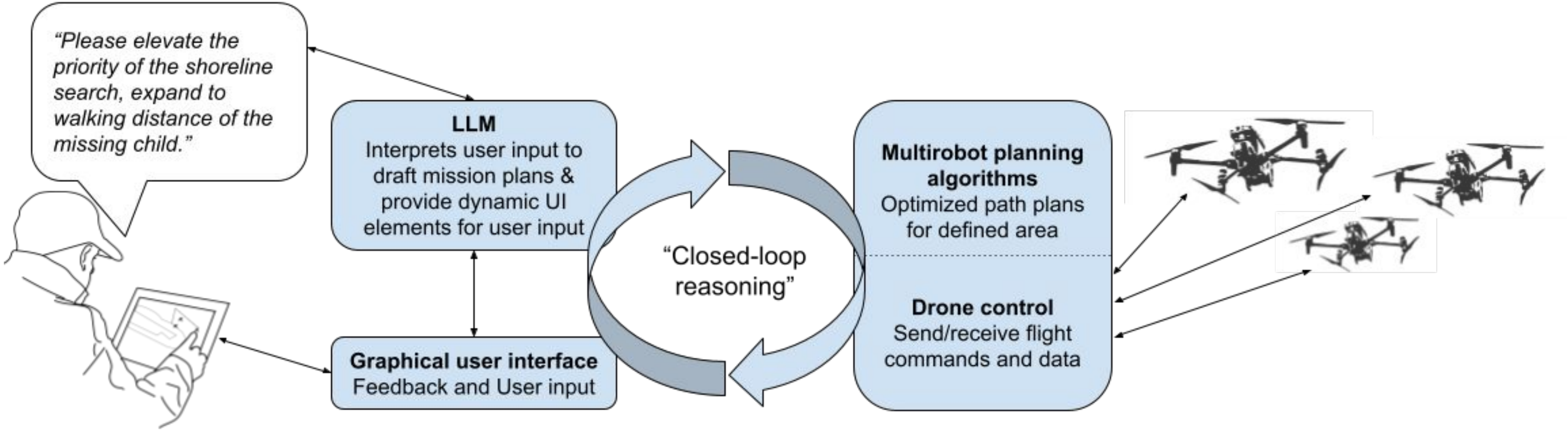
- **intuitive**, hands-free control for **non-expert operators**
- efficient, safe logistics in live SAR missions

NAMUR: **N**atural-language **A**ssisted **Mu**lti-**R**obot Control

Challenge Multi-robot teams are hard to manage, especially for non-experts.

Opportunity LLMs enable simple, natural team control.

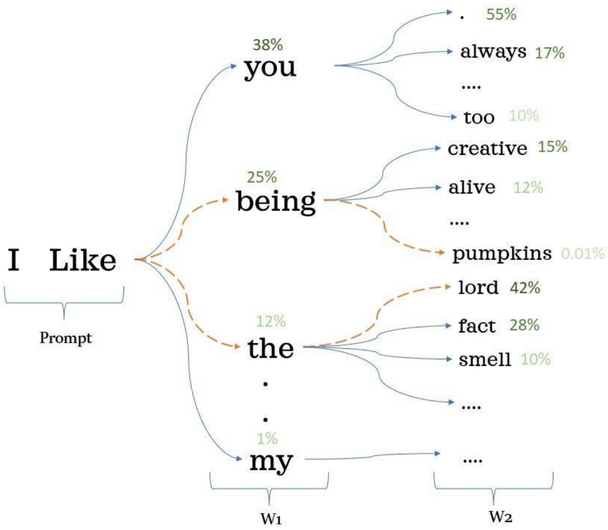
Vision Operators speak, drones act.

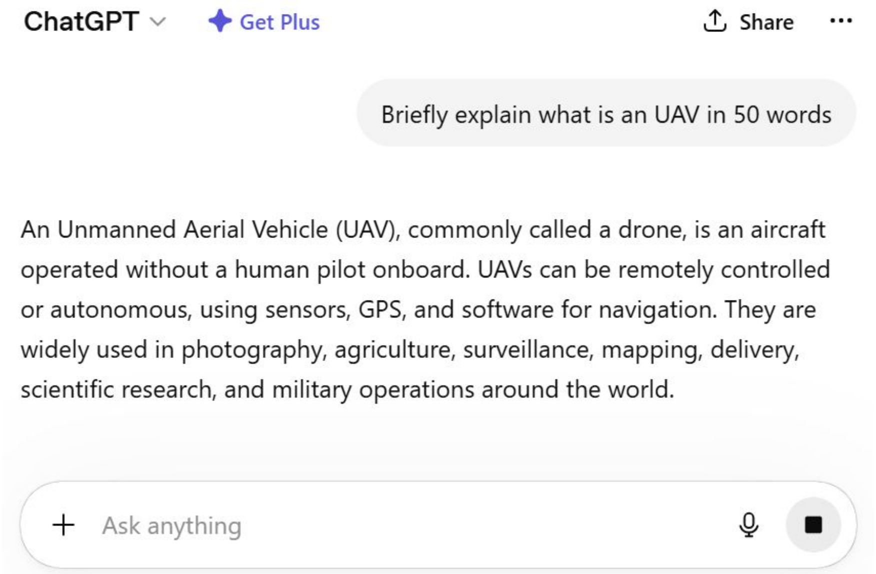


But how do we achieve this?
Intro to LLMs as Agents

Large Language Models (LLMs)

Definition: AI system trained on vast text data that generates language by predicting the next word in a sequence based on context.





Limitations of LLMs

Problem #1: Outdated Knowledge

- Trained only on available data at the time of training
- Cannot access real-time updates (e.g., weather, stock values, sport results)

Problem #2: Weak in Math

- Strong at writing and summarizing text
- Prone to errors with simple math operations

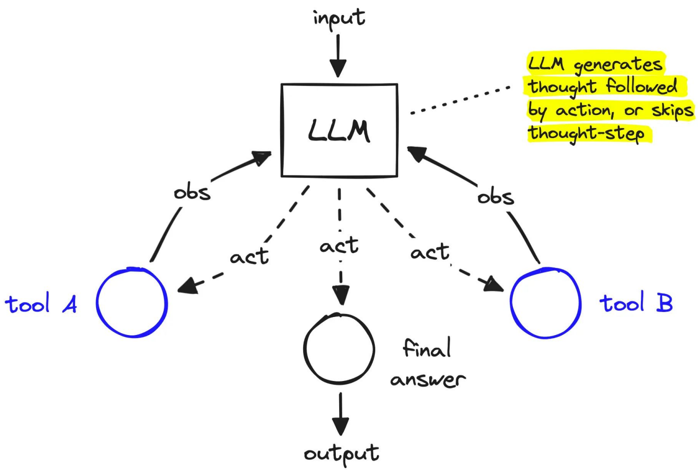
Problem #3: Cannot Interact with the Real World

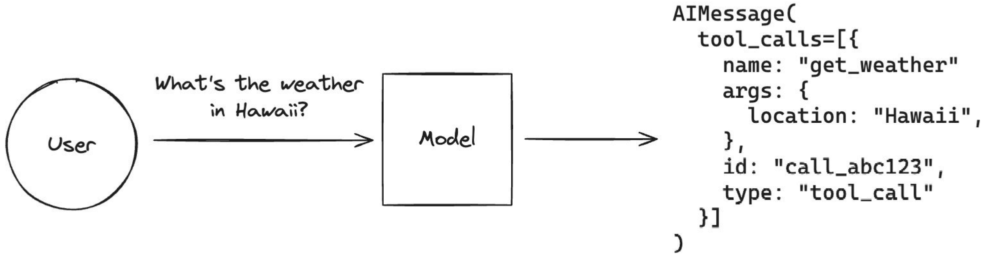
- Only able to give text responses depending on user query
- Cannot add entries to your calendar, turn on the light in your living room, or:

`Move drones in the real-world on demand`

Solution: LLM Agents - Tools as Superpowers

We can enable the agent to call *"**tools**"* whenever necessary to solve the task instead of hallucinating a response.





1. Predict text but in an structured and well-defined way that triggers a tool call
2. Execute the tool
3. Analyze output
4. Generate text response using tool output

Solution: LLM Agents - Tools as Superpowers

Problem #1: Outdated Knowledge

- Tool for internet searches

Problem #2: Weak in Math

- Access to a calculator tool

Problem #3: Cannot Interact with Real World

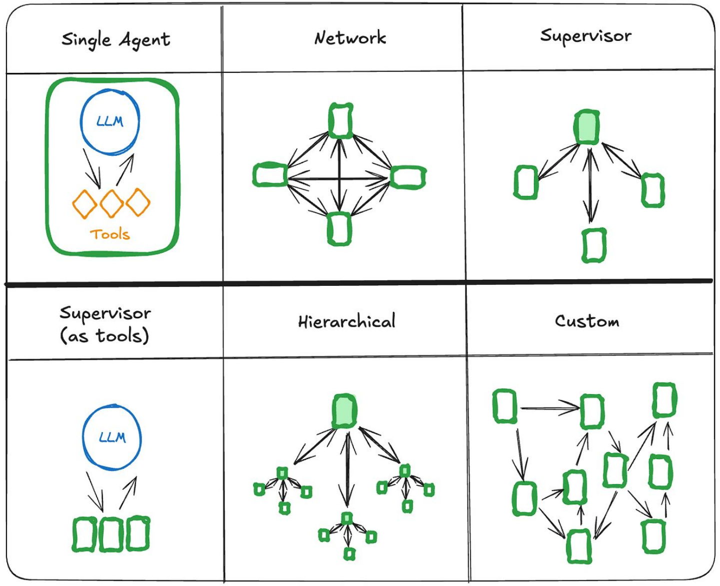
- Tool for creating calendar entries
- Tool to make a drone take off or go to a coordinate / follow a trajectory

LLM Multi-Agent Systems (LLM - MAS)

Agents collaborating to solve a task

Aspect	Multi-agent	Single-agent
System design	Many specialized agents	One general agent
Best for	Large, complex tasks	Small, simple tasks
How work happens	Parallel and split	Step-by-step
Running cost	Higher coordination cost	Lower overall cost
Model usage	Large planner, small executors	Same model does all
Main benefit	Scales and specializes	Simpler and easier to manage
Main drawback	Harder to coordinate	Harder to scale

Different possible architectures / ways of connecting them.



May / June 2025 - JEMERG 2025 - First Real-World Application to Deliver Critical Materials with an UGV via Voice-Commands

Real-World Deployment of an LLM-Enabled Voice-Commanded UGV for Logistics in SAR Missions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Venue:
XIX Workshop on Security, Emergencies, and Catastrophes - JEMERG 2025

Presented at:
2025 IEEE International Symposium on Safety, Security, and Rescue Robotics

[1]**UAS Drone Center**, University of Southern Denmark (SDU), Odense, Denmark
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NAMUR (Independent Research Fund Denmark- grant 10.46540/4264-00105B)

University of Málaga (Ministerio de Ciencia, Innovación y Universidades, Gobierno de España - grant PID2021-122944OB-I00)

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Contribution

Voice-commanded UGV in real-world SAR:

150+ first responders involved

3 critical material delivery missions

UGV (RoverJ8) +

Smart helmets for live position tracking

Commands Interpretation - LLM-MAS

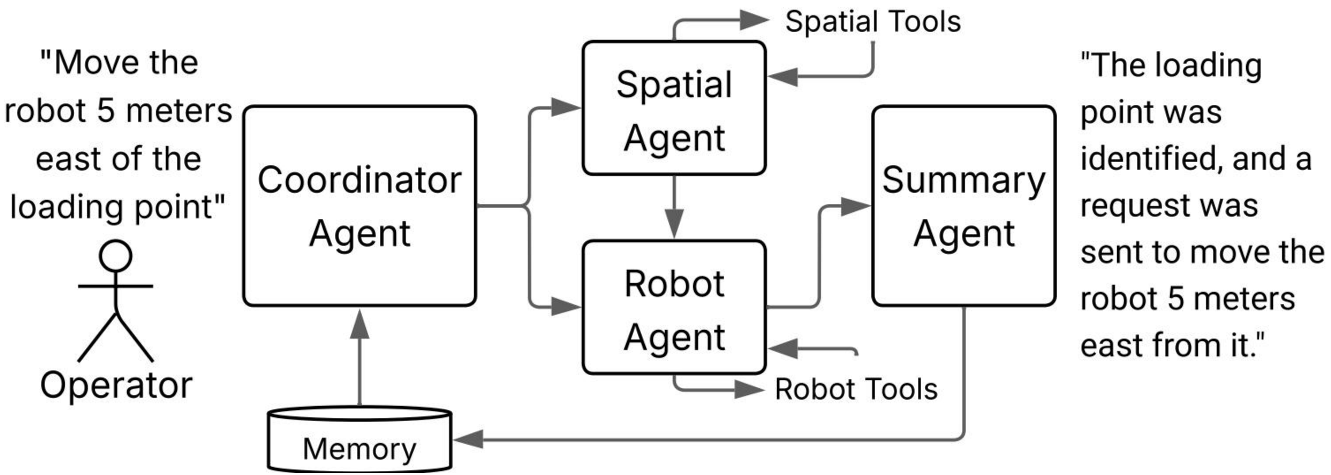
Coordinator → decomposes tasks

Spatial Agent → spatial awareness and coordinates

Robot Agent → robot planning and movement requests

Summary Agent → conversational memory

Operator preview before confirmation = safety and correctness



Missions & Results

TABLE I: Summary of operator commands, execution times, and outcomes for each mission.

Mission	Operator Command (Spanish / English)	Command Time	Arrival Time	Total Time	Notes
#1a	*Envía J8 al casco 6* / Send J8 to helmet 6	10:37:00	10:39:46	2m 46s	Successful
#1b	*Envía J8 a R6* / Send J8 to R6	10:39:50	10:42:08	2m 18s	Successful
#2a	*Envía J8 a 5 metros al Oeste del casco 3* / Send J8 five meters west of helmet 3	11:18:45	11:21:10	2m 25s	Successful
#2b	*Envía J8 a R6* / Send J8 to R6	11:21:34	11:24:05	2m 31s	Successful
#3	*Envía J8 a 5 metros al Noroeste del casco 8* / Send J8 five meters northwest of helmet 8	13:41:27	13:46:50	5m 23s	Successful. Manual supervision necessary due to hazardous slope.

(a) Requesting batteries.

(b) UGV following its route autonomously.

(c) Battery pickup.

Fig. 6: Sequence from Mission #1 showing the delivery workflow: (a) the drone pilot requests additional batteries, (b) the UGV autonomously navigates to the delivery point, and (c) the pilot retrieves the batteries directly from the robot.

IEEE International Symposium on Safety, Security, and Rescue Robotics

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Plan de Recuperación, Transformación y Resiliencia

Funded by the European Union

January 2026 -
Introducing Swarm-Steward -
Real-World Drone Swarm Voice Control

Swarm-Steward: Scalable and Reliable Natural-Language Coordination of Autonomous Aerial and Ground Robots


Alejandro Jarabo-Peñas[1]


Juan Bravo-Arrabal[1]


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Anders L. Christensen[1]

Accepted on *2026 Int´l Conference on Unmanned Aircraft Systems, Corfu, Greece*

[1]**UAS Drone Center**, University of Southern Denmark (SDU), Odense, Denmark

Funded by:

NAMUR Project (DFF funded: 10.46540/4264-00105b) | namurproject.com
PERSIST Project (IFD funded: DIREC U07) | direc.dk/persist-autonomous-drones-to-protect-denmarks-infrastructure
WildDrone Project (EU funded: 101071224) | wilddrone.eu

Contributions and GUI Example

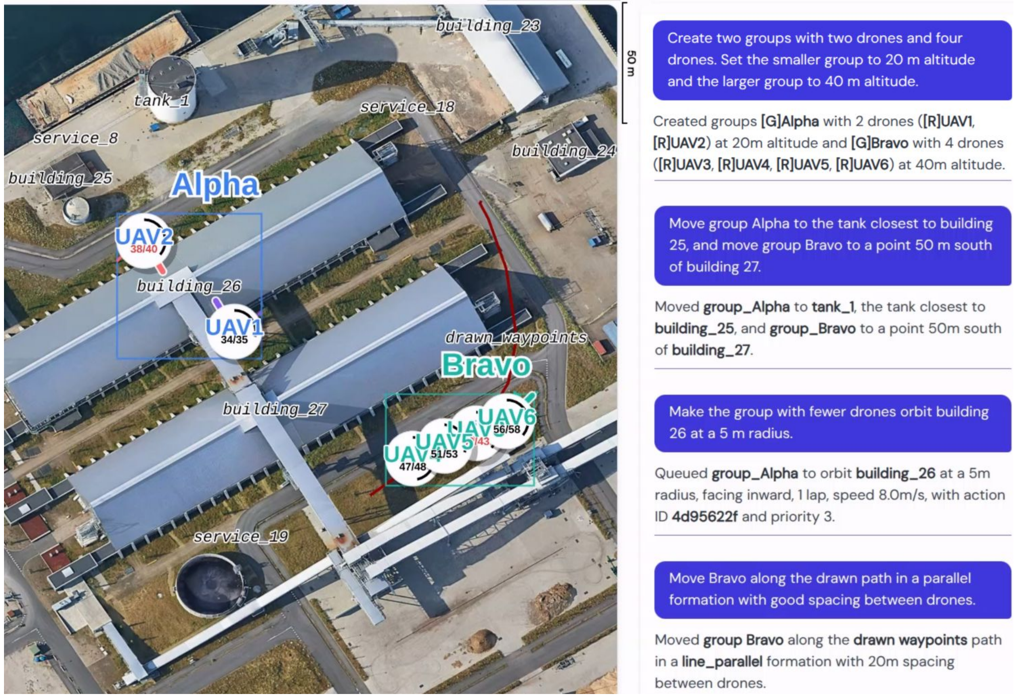
Talk to drone teams using normal language.

Understands commands using map areas and live drone data, for example:

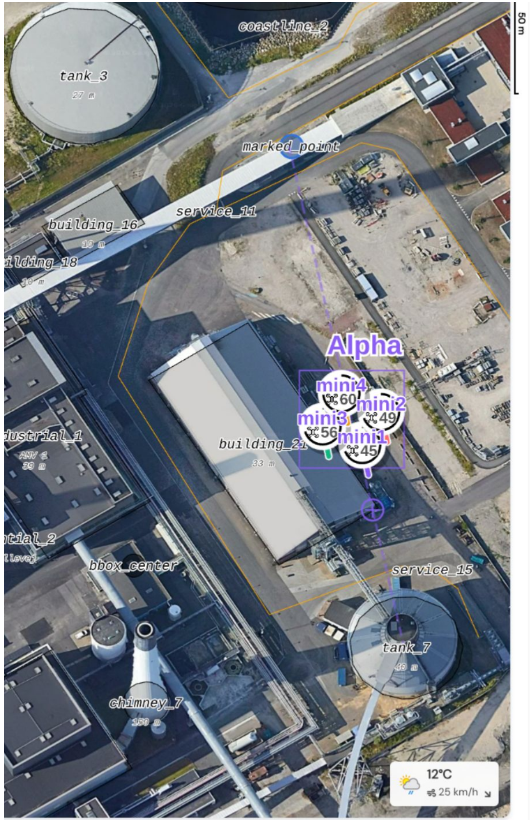
- “orbit around Building 27”
- “search the drawn area”
- “send the drone with the lowest battery back home.”

Safety checks happen before any real action is carried out and during execution.

Tested both in simulation and with real drones.



Example 1 – Map understanding & Movement



Move alpha to the closest tank to building 21

Coordinator Agent : 2.1s, 1 iter

▸ INPUT

▸ THOUGHT PROCESS

Goal: Move group Alpha to the tank nearest to building_21.

- 1 – **spatial_agent:** Find the tank closest to building_21. Return the feature name.
- 2 – **swarm_agent:** Move group Alpha to the tank identified as closest to building_21 (get the name from information from other agents).

1 – Spatial Agent : 2.3s, 3 iter

▸ INPUT

▸ TOOL CALLS (1)

`find_nearby_to`

Found 50 nearby features and 5 nearby entities for '[F]building_21'

reference **[F]building_21** nearby features **50 items** nearby entities **5 items** JSON

The tank closest to [F]building_21 is [F]tank_7, located at a distance of 28.9m.

2 – Swarm Agent : 3.5s, 3 iter

▸ INPUT

▸ TOOL CALLS (1)

`move_to`

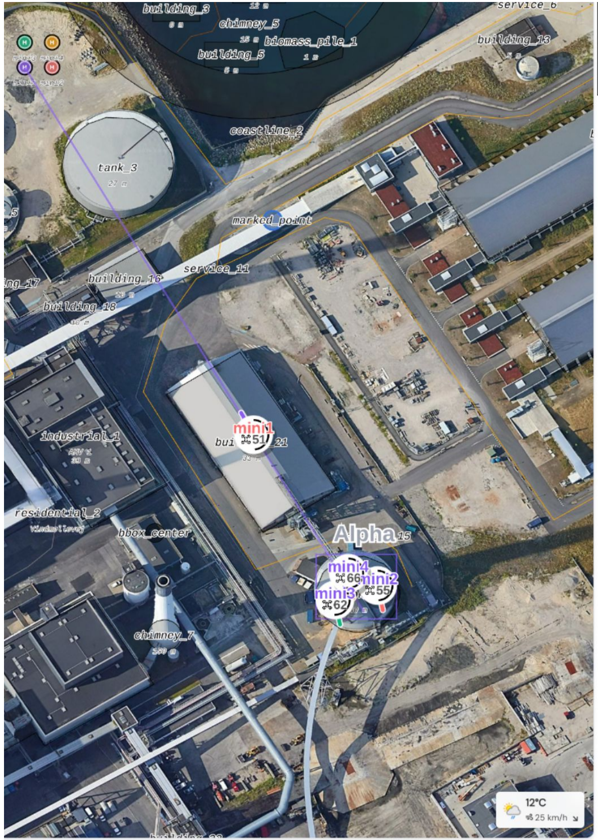
Executing move_to '[F]tank_7' for group '[G]Alpha': circle formation, radius 10m, speed 12.0m/s, ETA 15s.

action id **eab41352** action **move_to '[F]tank_7'** group **[G]Alpha** action status **execu** JSON

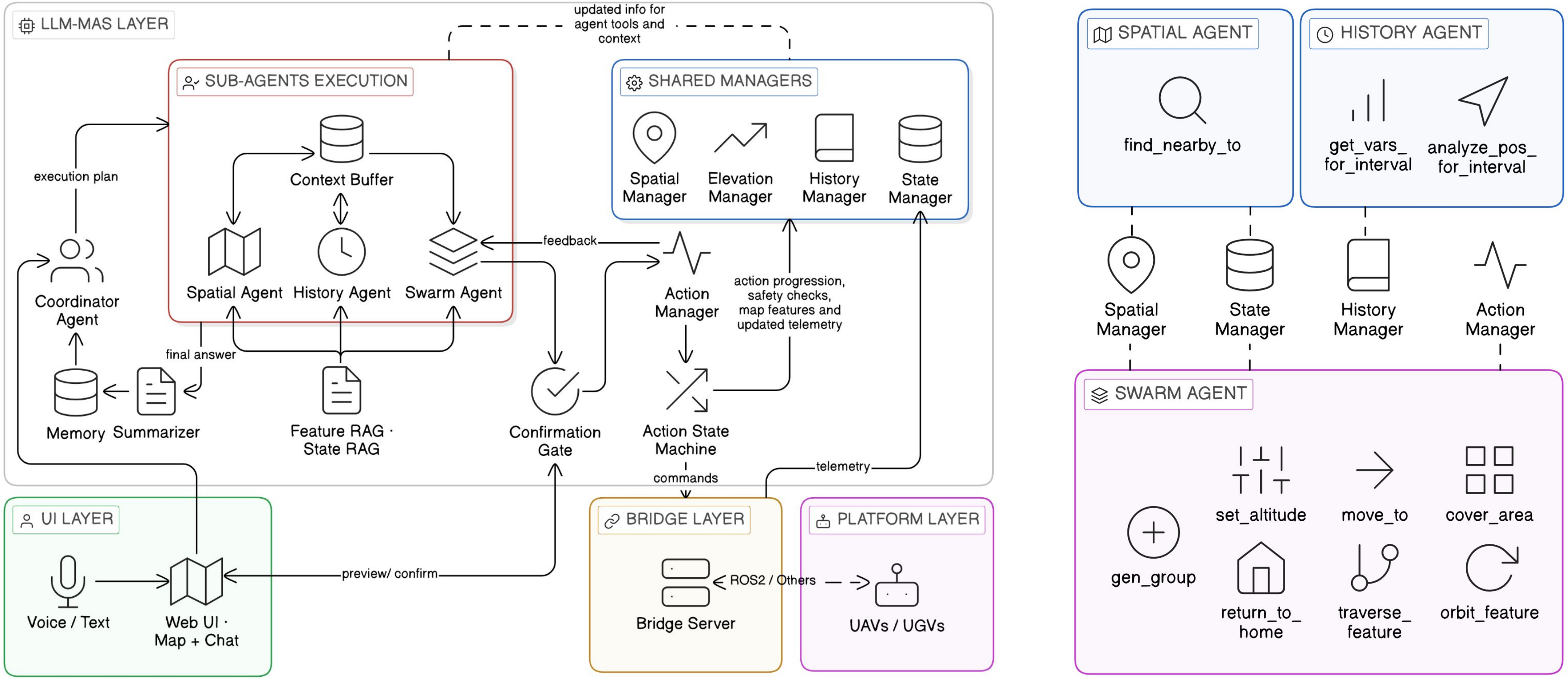
Group **[G]Alpha** has been dispatched to **[F]tank_7**, the tank identified as closest to **[F]building_21**, and is currently moving in a circle formation with an estimated arrival time of 15 seconds.

Type or hold CTRL+Space to record...

Example 2 - Understanding telemetry



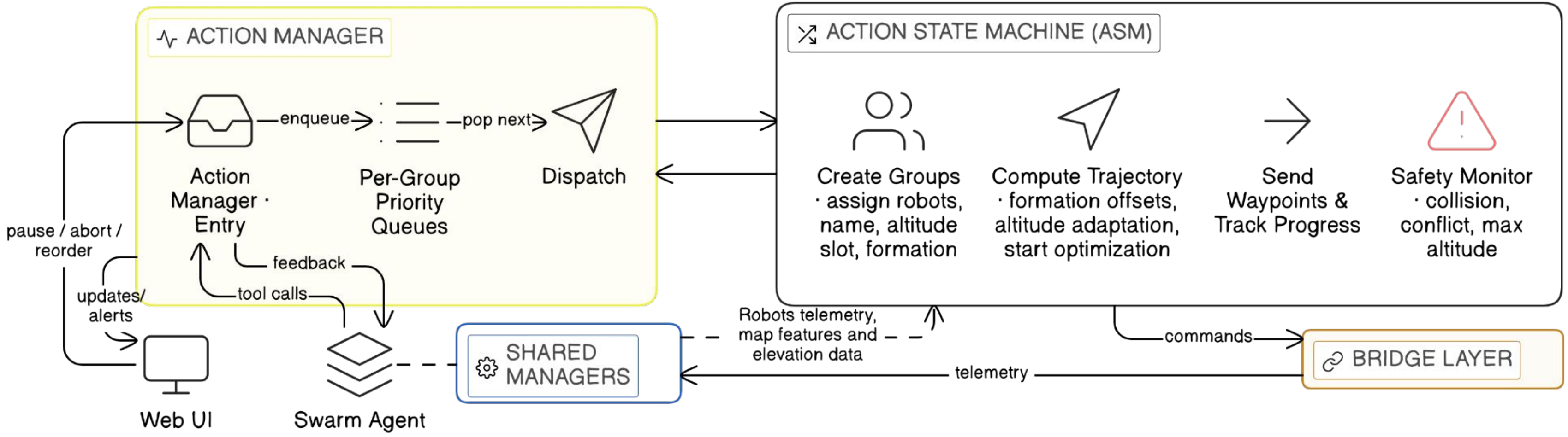
Architecture



Action State Machine

Underlying system that handles individual drone movements and safety constraints to perform the swarm tool calls safely and correctly.

- The LLM doesn't move the drones, just calls the tools that handle its movement!



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S² | Swarm-Steward

Swarm-Steward: Scalable and Reliable Natural-Language Coordination of Autonomous Aerial and Ground Robots

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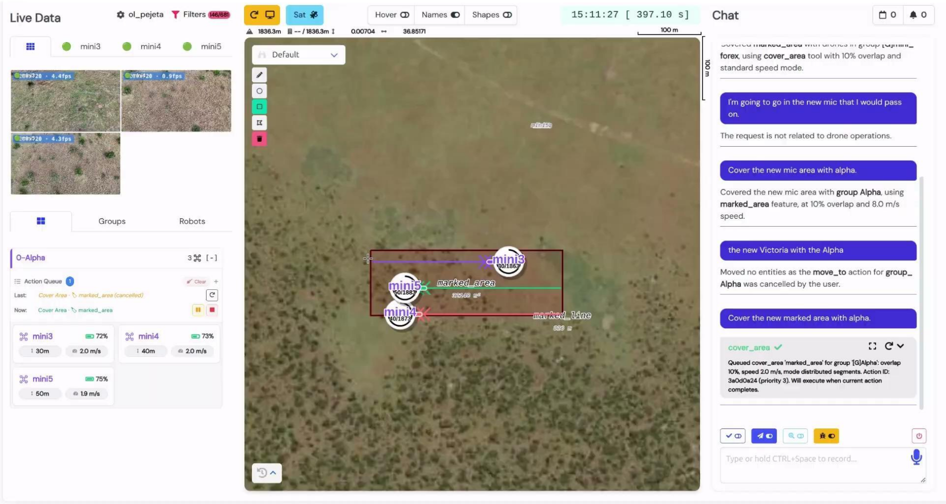
PERSIST Project (IFD funded: DIREC U07) | direc.dk/persist-autonomous-drones-to-protect-denmarks-infrastructure

February / March 2026 - Rhino Search in Ol Pejeta Conservancy, Kenya

Adding computer vision to the system

Rhino Search - Ol Pejeta Conservancy, Kenya



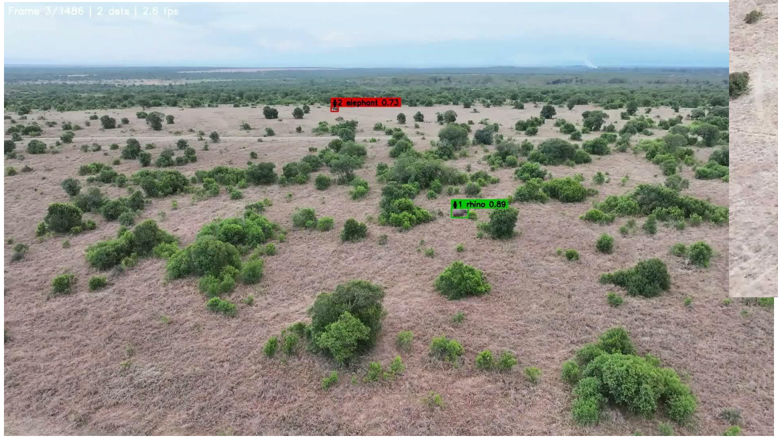
Finding rhinos in the savanna

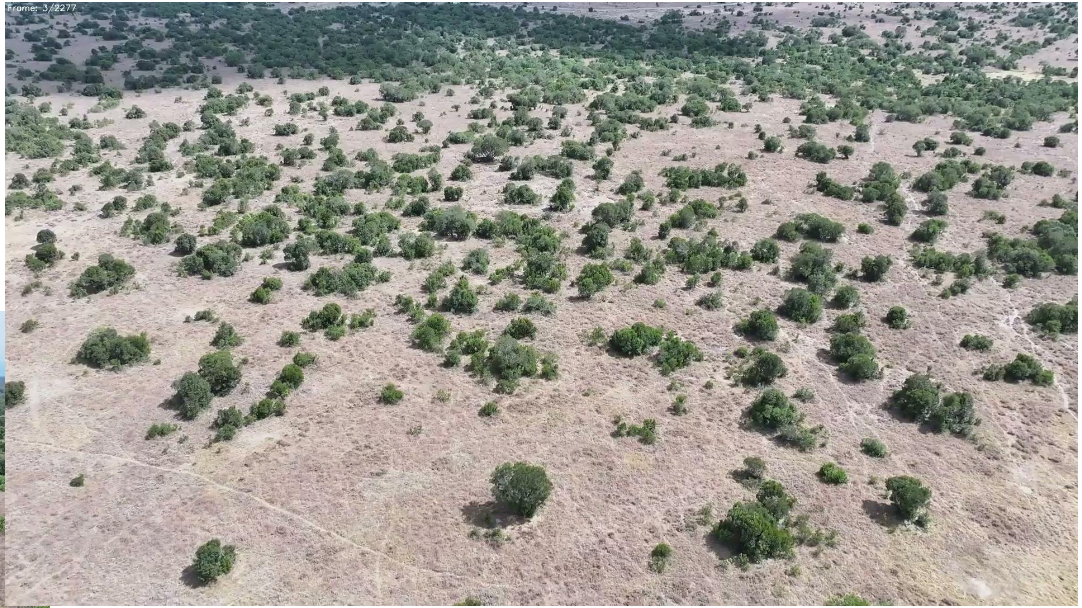
YOLO to detect rhinos trained on 5000 drone pictures from different PoVs

Search with 3x DJI Mini 4 Pro autonomously controlled via voice commands.

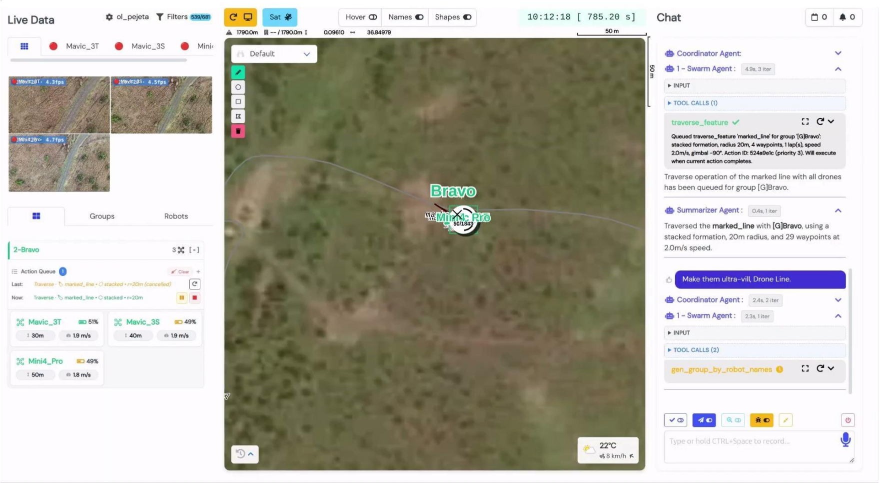
Posterior analysis and video capturing with manual drone control by a biologist once rhinos are found

It worked quite well offline…





Extra - Coordinating Drones with Different Camera Types to Take Footage of Elephants



Camera Types

DJI Mini 4 Pro - RGB - 50m altitude

DJI Mavic 3S - Spectral - 40m altitude

DJI Mavic 3T - Thermal - 30m altitude

Sync. movement of all drones to follow elephants coordinated with Swarm-Steward

April / May 2026 - Victim Search and Rescue in JEMERG 2026, Malaga, Spain

JEMERG 2026 - UMA - MALAGA, SPAIN

Finding and geolocating victims in a realistic search-and-rescue scenario.

Search with 6x DJI Mini 4 Pro autonomously controlled via voice commands.

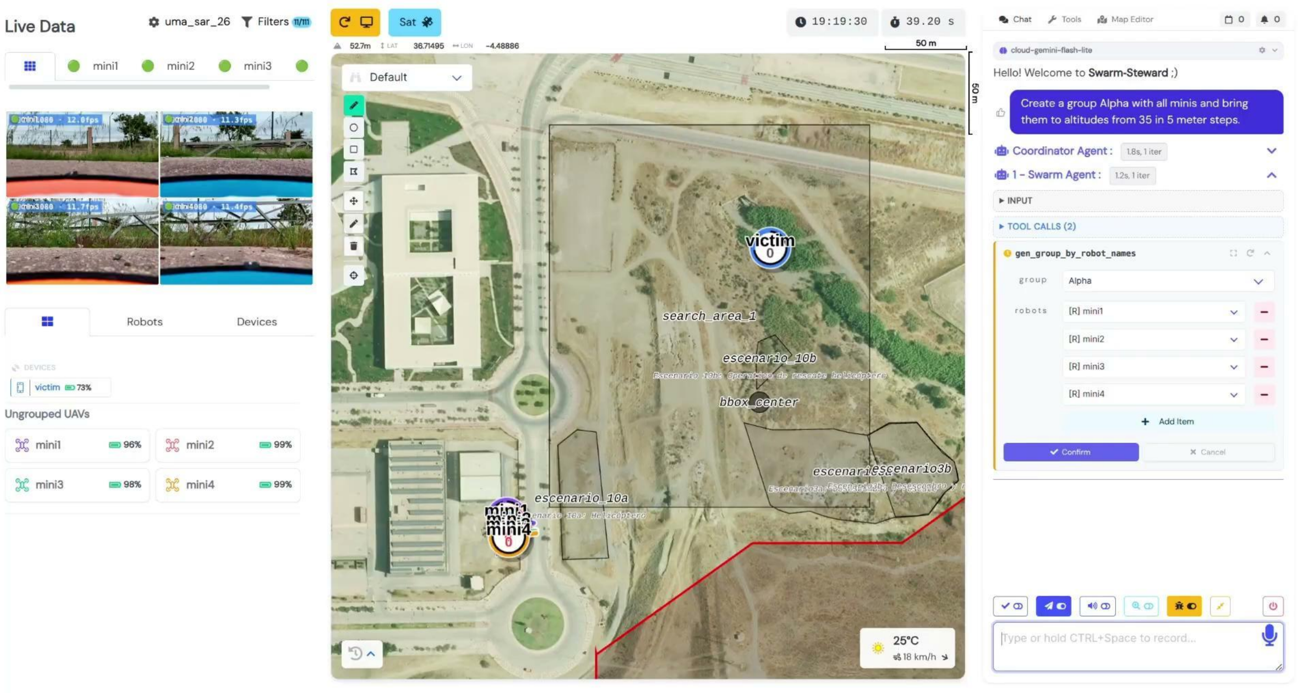
Position of victim shared with UGV robot for evacuation.

Orbiting around found victim until evacuation takes place.

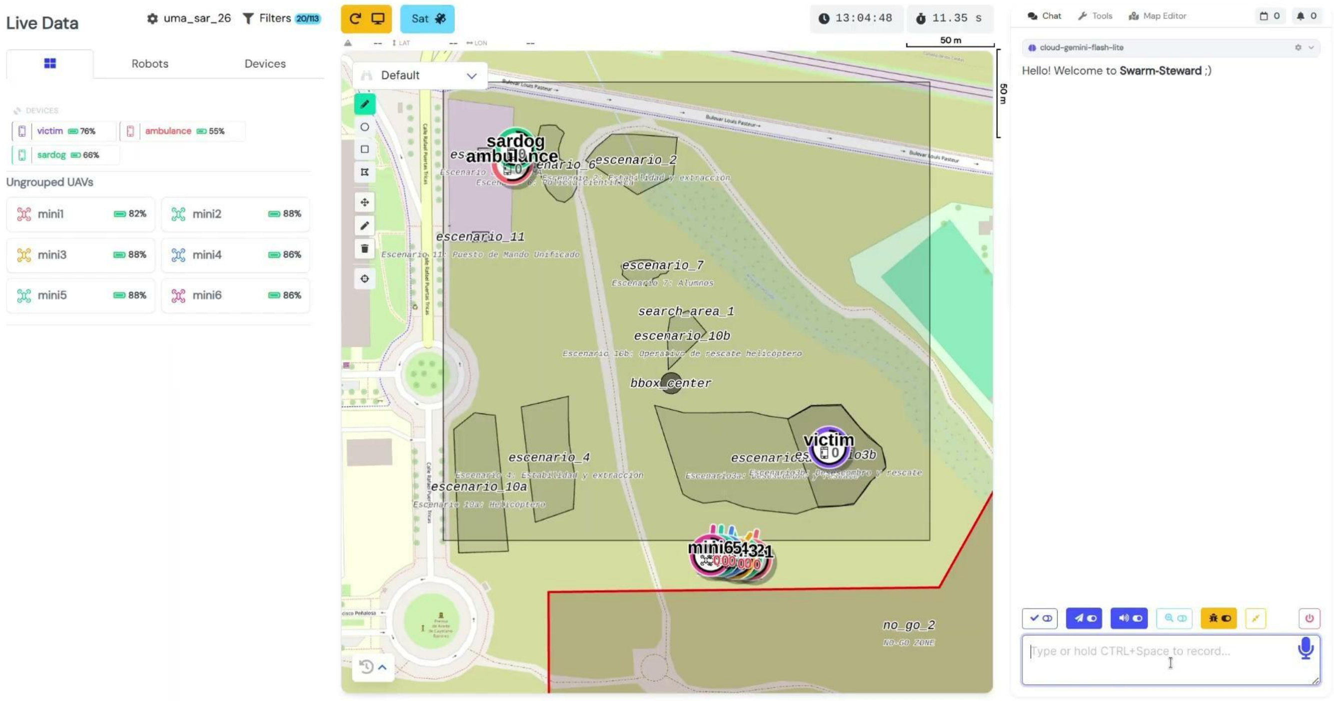
Drone tracking and following of entities of interest:

- Search and rescue dog
- Evacuation UGV
- Ambulance

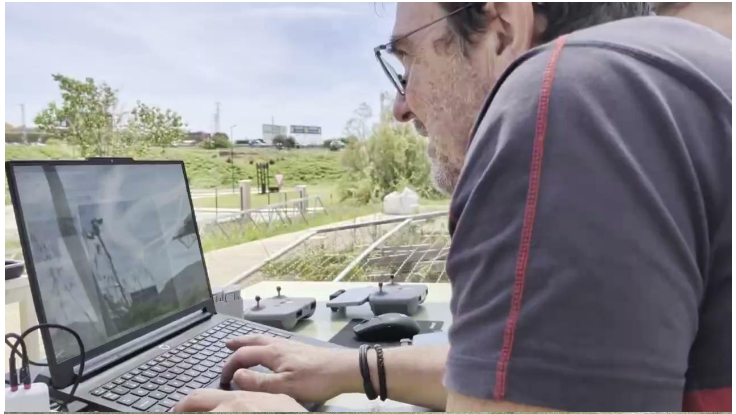
Swarm Search & Landing

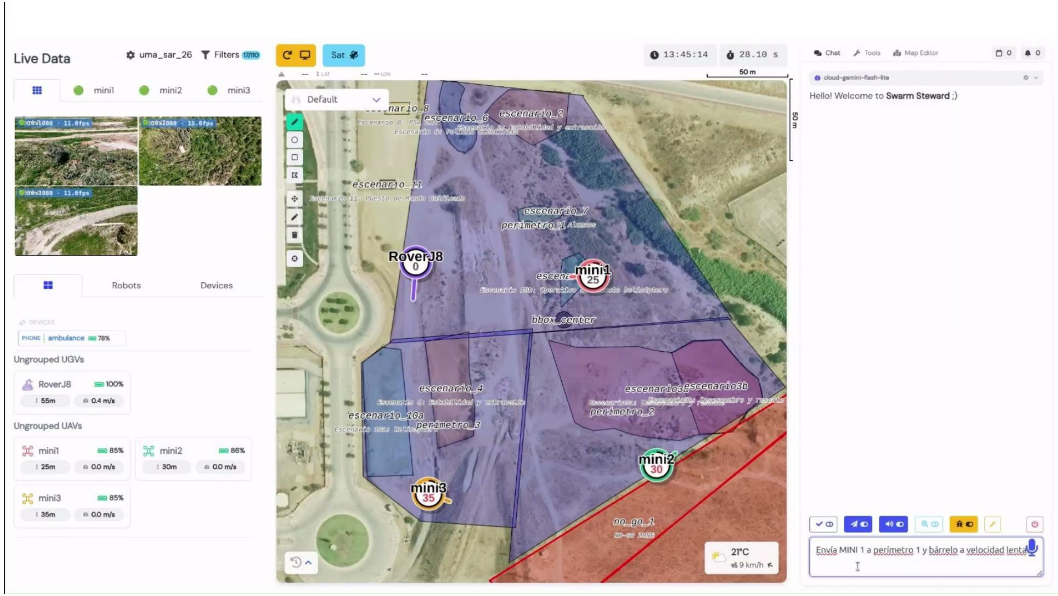


Orbit around found victim position & Ambulance following



Firefighter test & Evacuation UGV





Live Demo?

Thank You :)
Questions?

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