

Project Background

From single-drone to multi-drone management



Using a team of multiple units is more effective than a single drone, but coordinating a collective strong is complex. To balance between micro-management (i.e., directly piloting every unit in real-time) and assigning global objectives to a fleet of drones, **what's the ideal user interface for monitoring and operating a drone swarm?**

Single-drone management¹

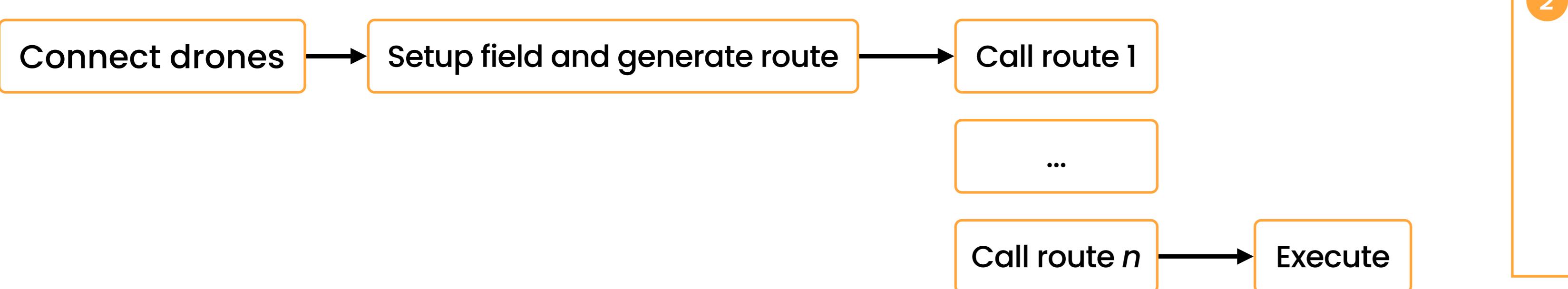
Using DJI AGRAS as an example, it's custom drone control software designed for agricultural purposes. Its basic operation involves creating adjustable task routes based on the work area and manually assigning them to one or more drones. This method is efficient with fewer than 3 drones, but as the fleet grows, it leads to diminishing time and cognitive resources allocated to tasks **because each unit requires direct control.**



Multi-drone management

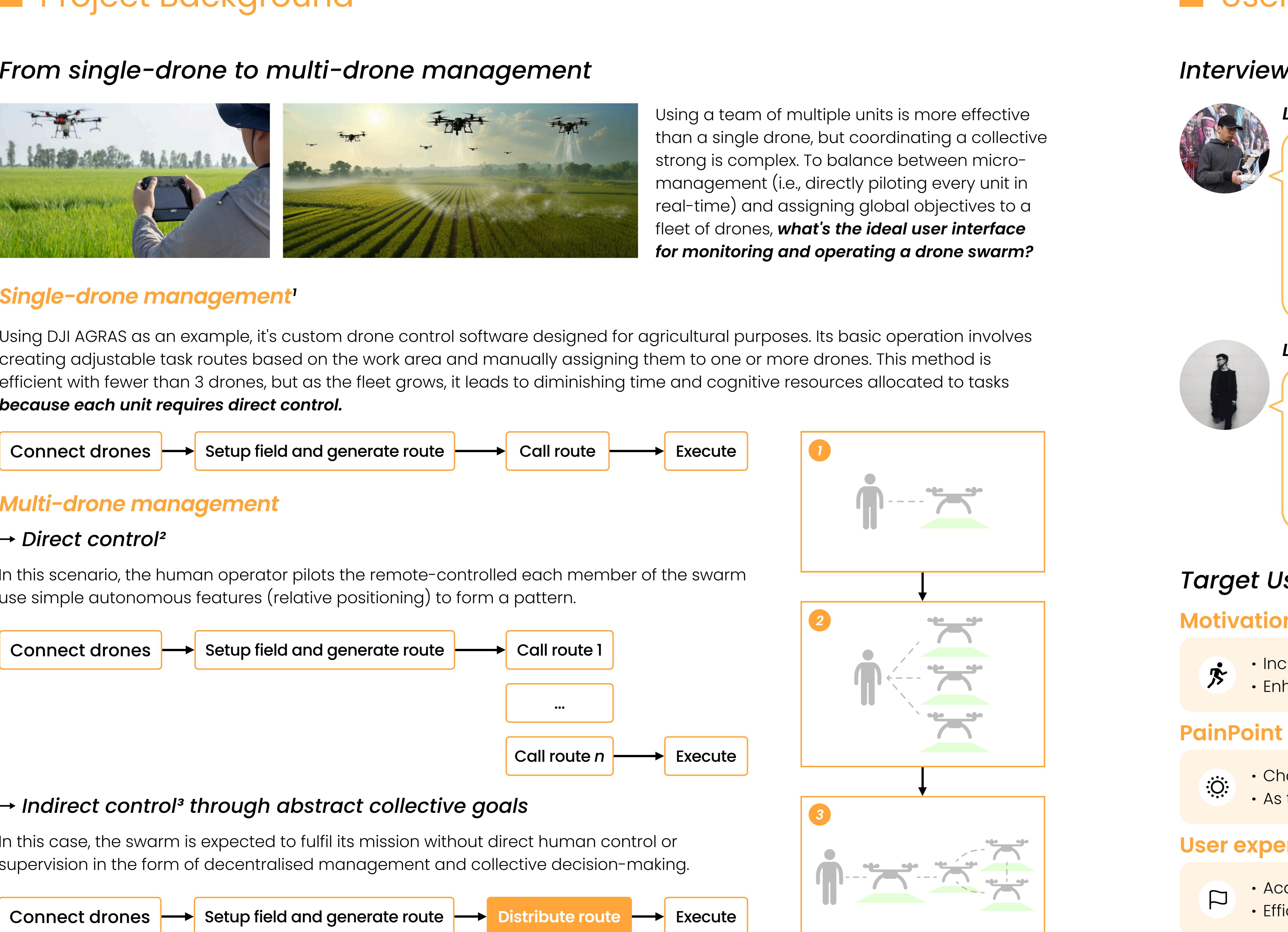
→ Direct control²

In this scenario, the human operator pilots the remote-controlled each member of the swarm use simple autonomous features (relative positioning) to form a pattern.



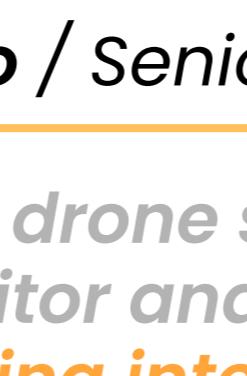
→ Indirect control³ through abstract collective goals

In this case, the swarm is expected to fulfil its mission without direct human control or supervision in the form of decentralised management and collective decision-making.



User Research

Interview



Lin Bao / Senior Agricultural Drone Pilot

"In a drone swarm, we need to simultaneously monitor and coordinate multiple UAVs, but the existing interfaces often struggle to effectively manage this complexity."
"...We require a more intuitive and user-friendly interface to better control the entire swarm, rather than having to manage each UAV individually as we do currently."



Lingfeng Liu / DJI Innovation & Interaction Designer

"DJI SmartFarm is also engaged in similar initiatives. We aim to transition the interaction system to computers or other mobile devices as part of our digital agriculture solution. This aligns with the future trend of drone swarms and the growing demand for reducing labor requirements in agriculture."

Target User - Plantation custodian

Motivation

- Increasing the acceptance of crop protection drones
- Enhancing the management efficiency of the swarms

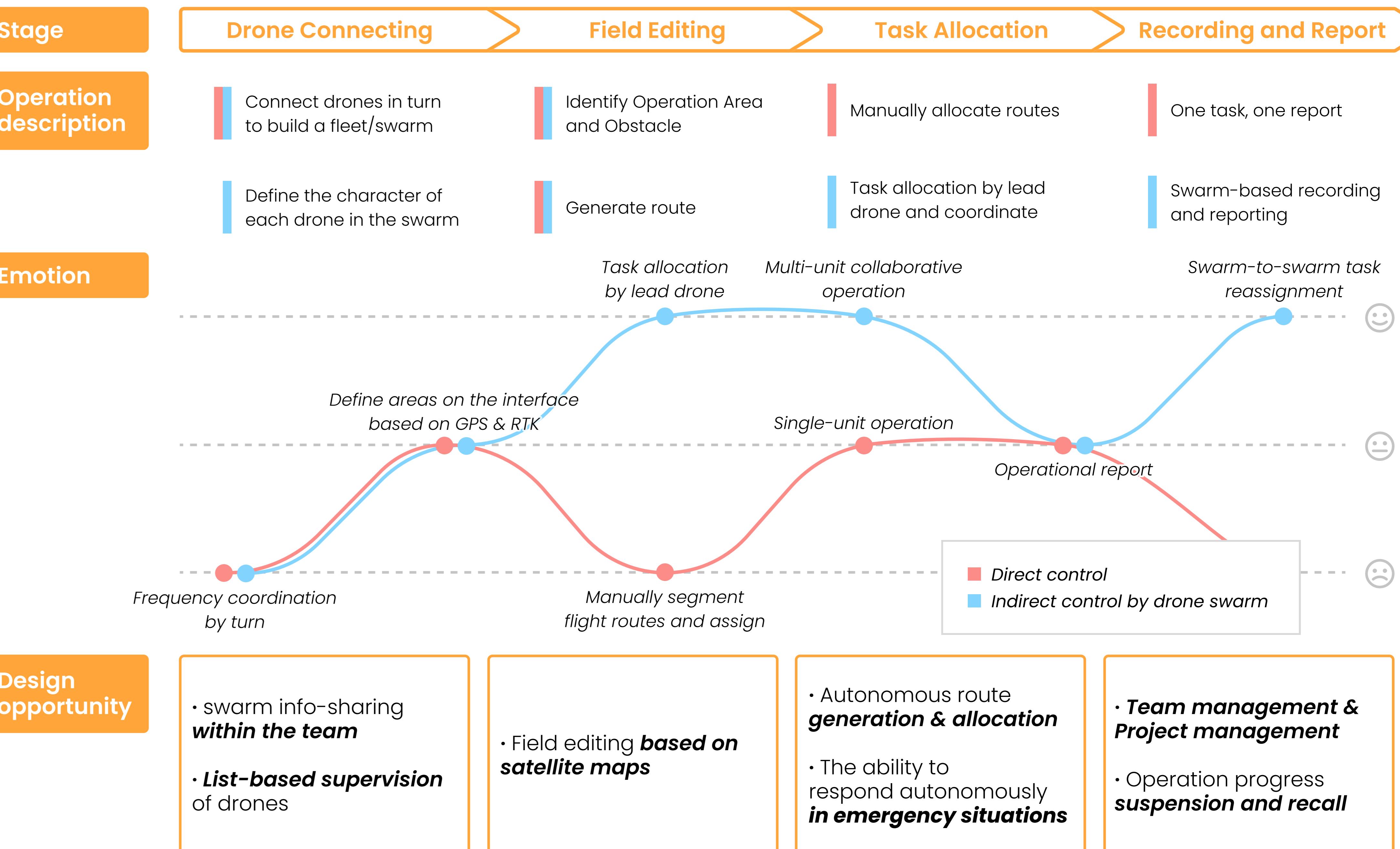
PainPoint

- Challenges in promoting drones among farmers
- As the scale of operations increases, labor costs rise

User experience objectives

- Acquiring orders & establishing collaborations with farmers
- Efficiently managing fleets while reducing labor costs

User Journey Map



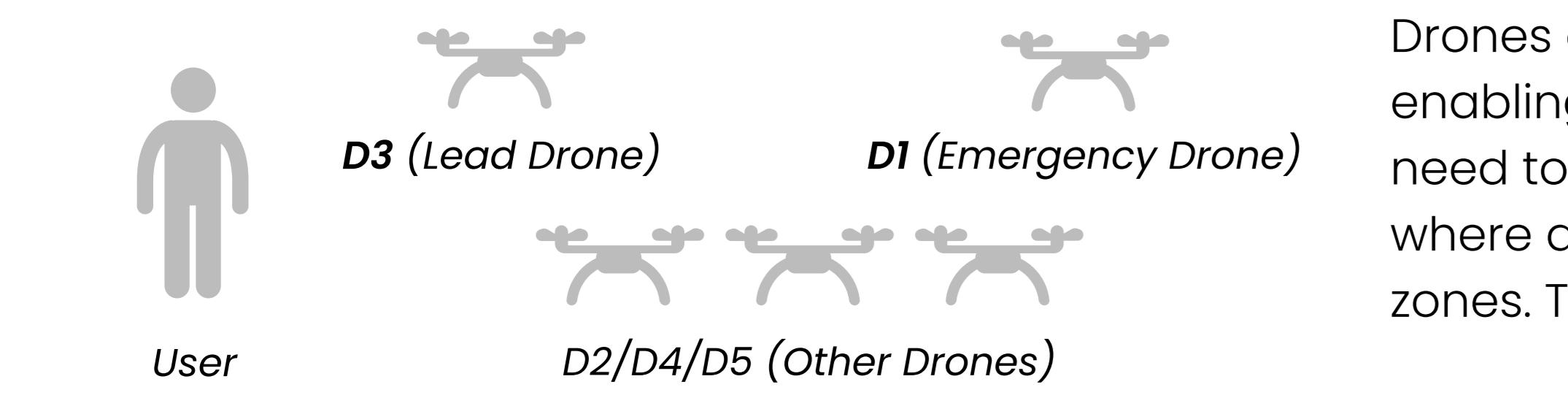
Design principle

Using the theoretical framework, called **Ecological Interface Design (EID)**, for designing interfaces for this complex human-machine systems. The goal of EID is to **make constraints and complex relationships in the work environment perceptually evident**. This allows more of users' cognitive resources to be devoted to higher cognitive processes such as problem solving and decision making.

K. J. Vicente and J. Rasmussen,
"Ecological interface design: theoretical foundations," in IEEE Transactions on Systems, Man, and Cybernetics, vol. 22, no. 4, pp. 589-606, July-Aug. 1992, doi: 10.1109/21.156574.

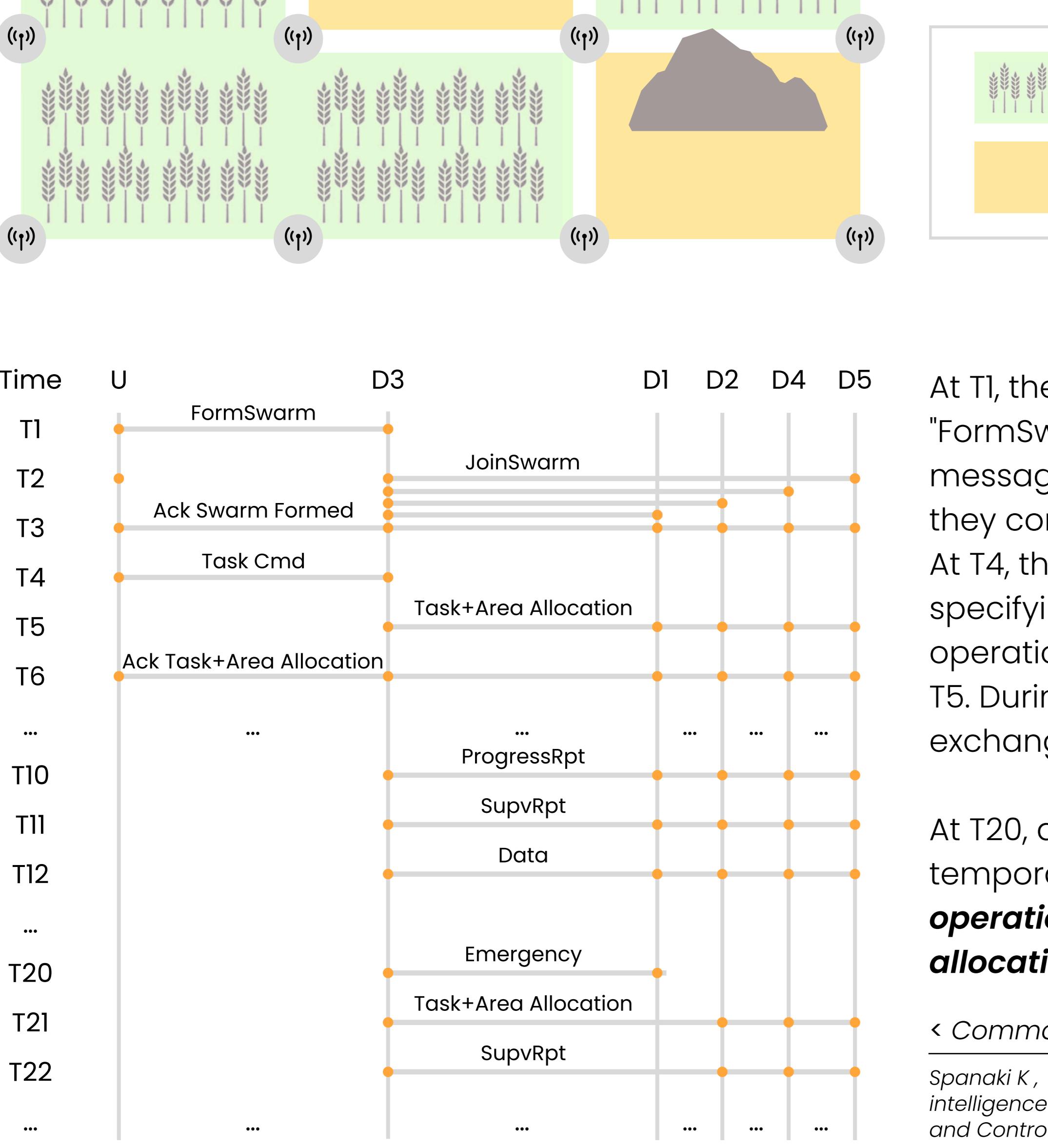
Design Concept

Hypothetical scenario

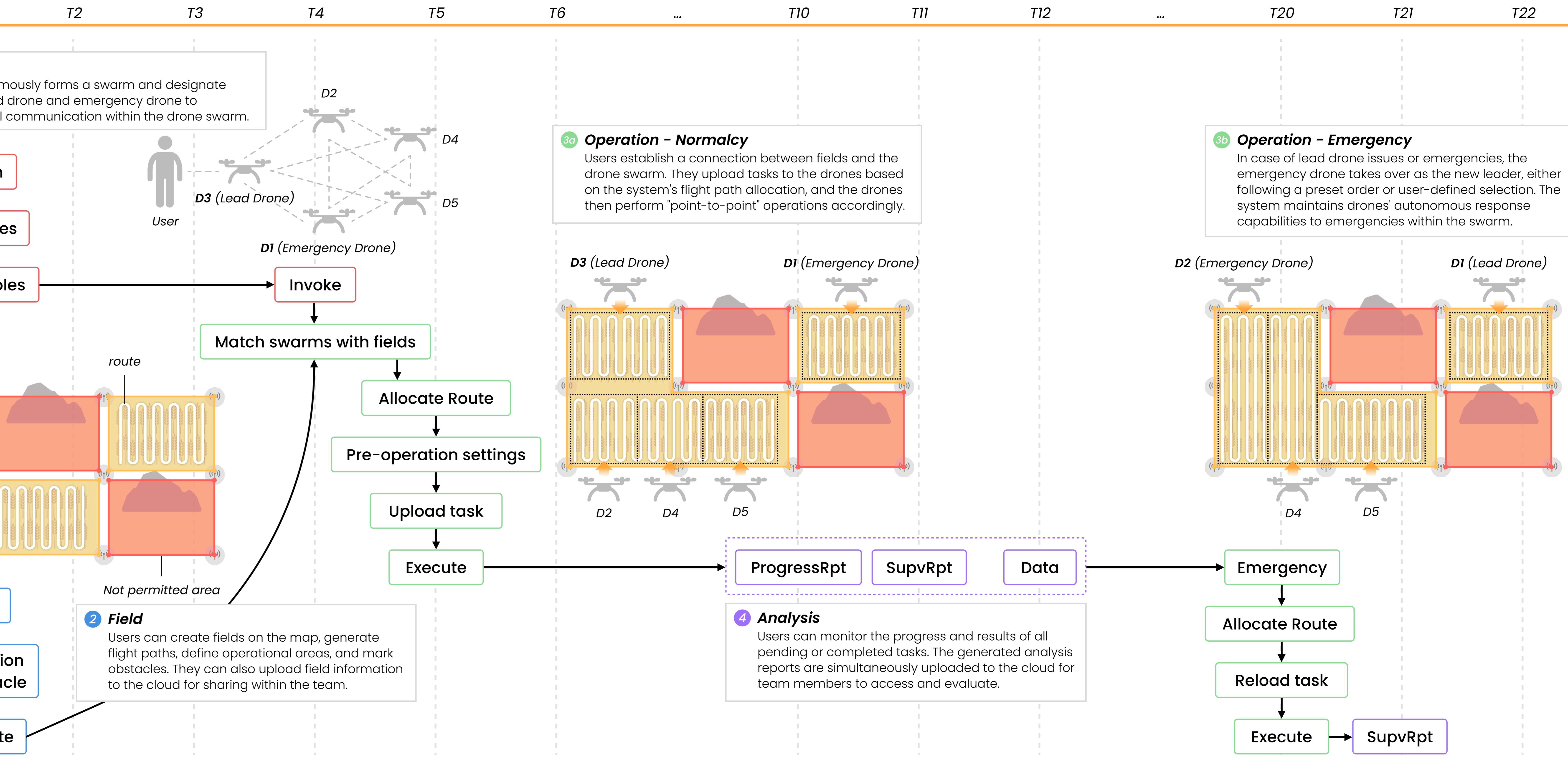


Drones can communicate directly with users while also enabling communication among themselves. Operators need to provide relevant information about the areas where drones need to take off or land, as well as restricted zones. They also preset a series of tasks for execution.

Furthermore, drones will collect information about the operational area by connecting with Internet of Things (IoT) devices on the ground. This collected data will be referenced during subsequent operations.



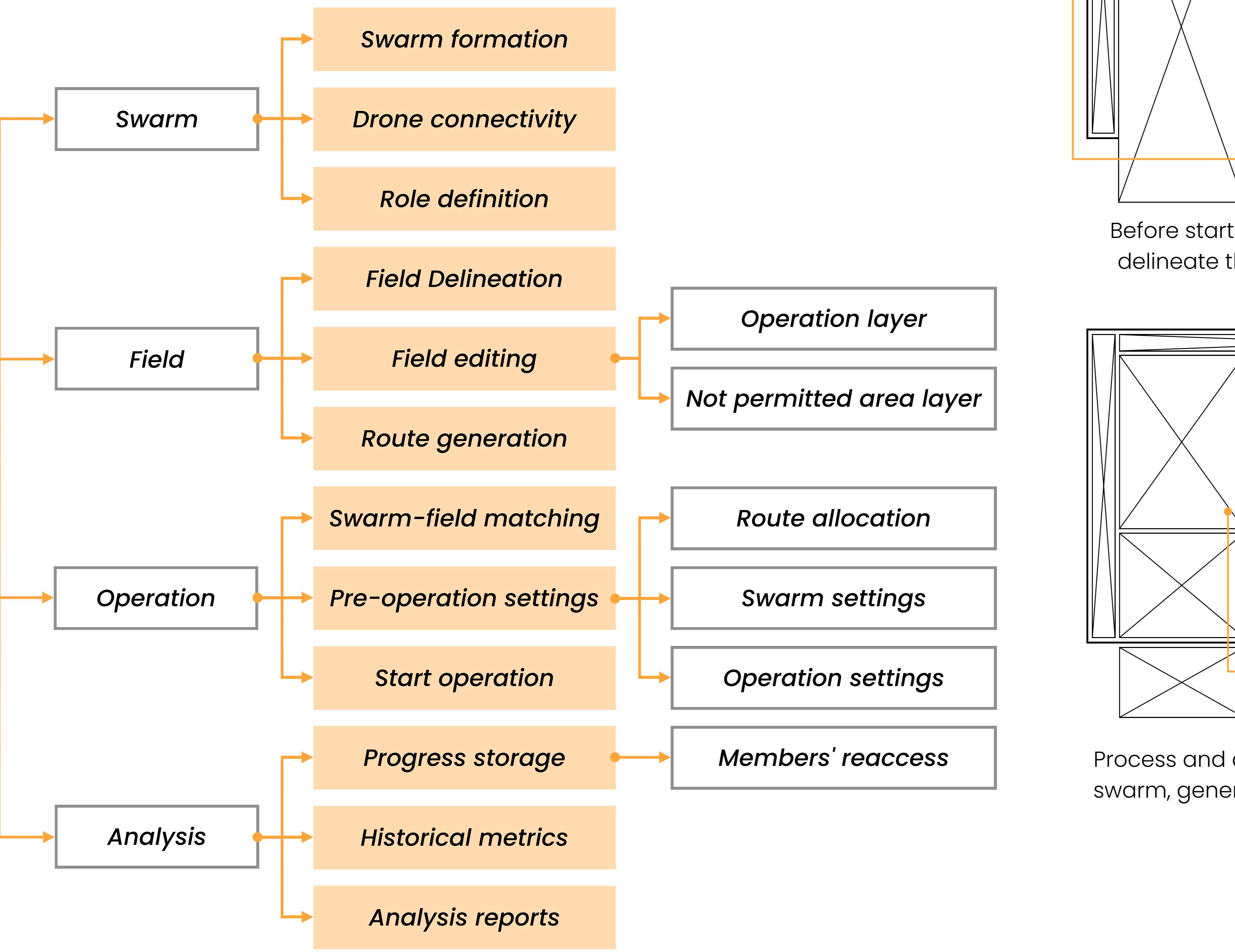
Workflow



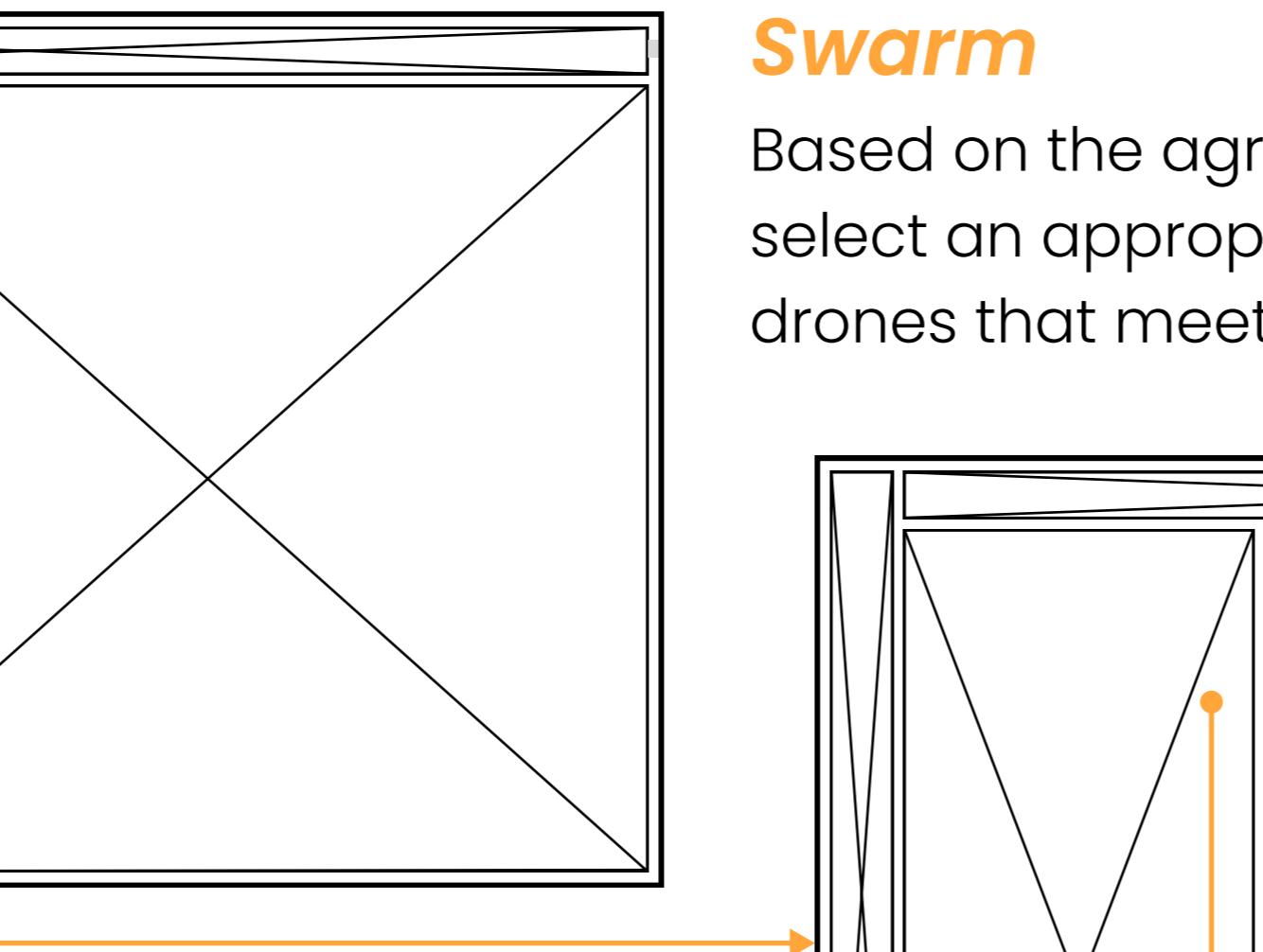
Function Refinement

Sitemap

In the '**Swarm**' section, users can form swarms and manage modular organization. In the '**Field**' section, users can establish fields on the map, create routes, delineate supervised areas, and mark obstacles. In the '**Operation**' section, users establish connections between fields and swarms, and subsequently conduct 'point-to-point' operations. In the '**Analysis**' section, users can review progress and results of all stored or completed operations.

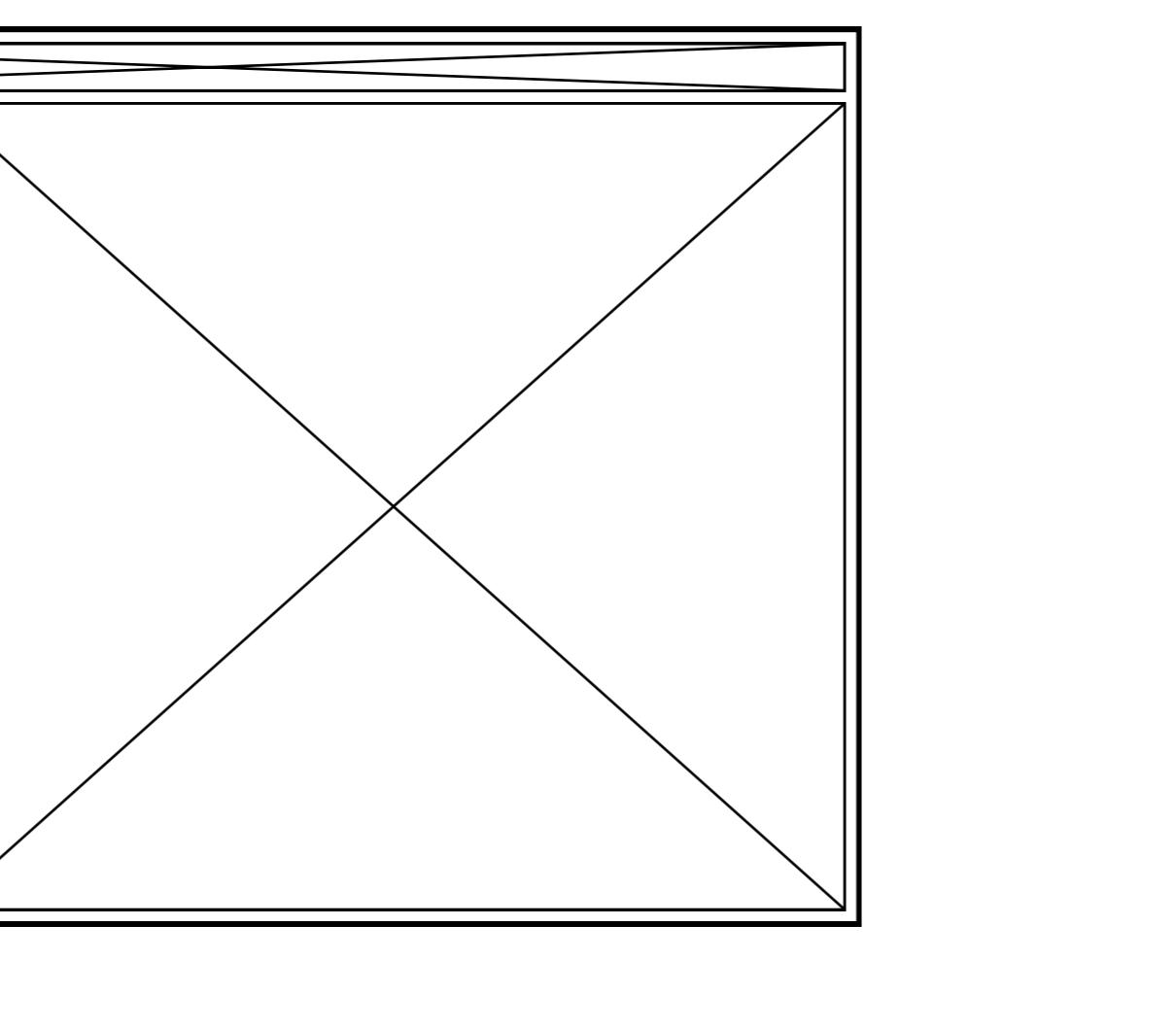


Wire-frame



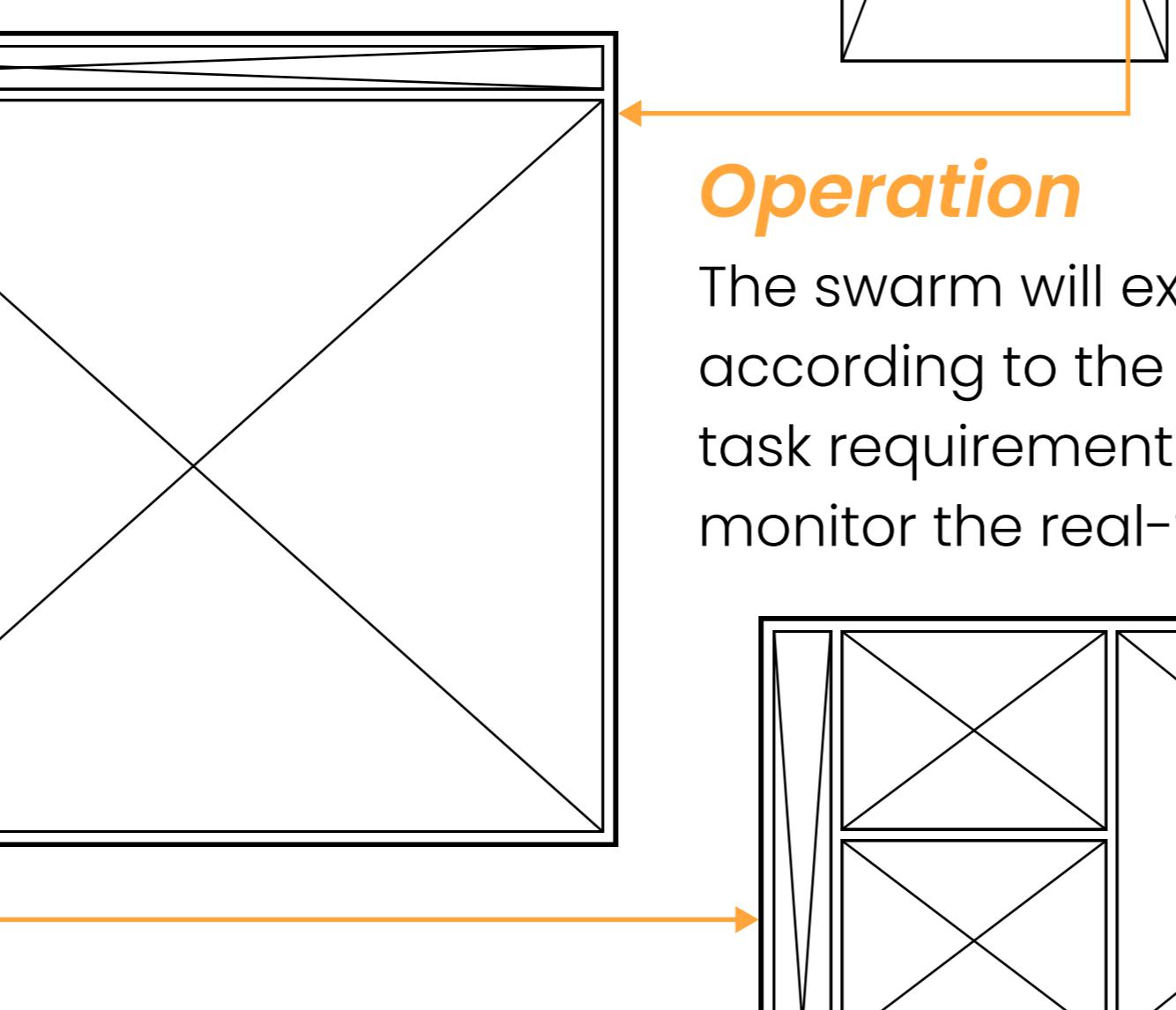
Swarm

Based on the agricultural operation scenario, select an appropriate number and type of drones that meet the specific requirements.



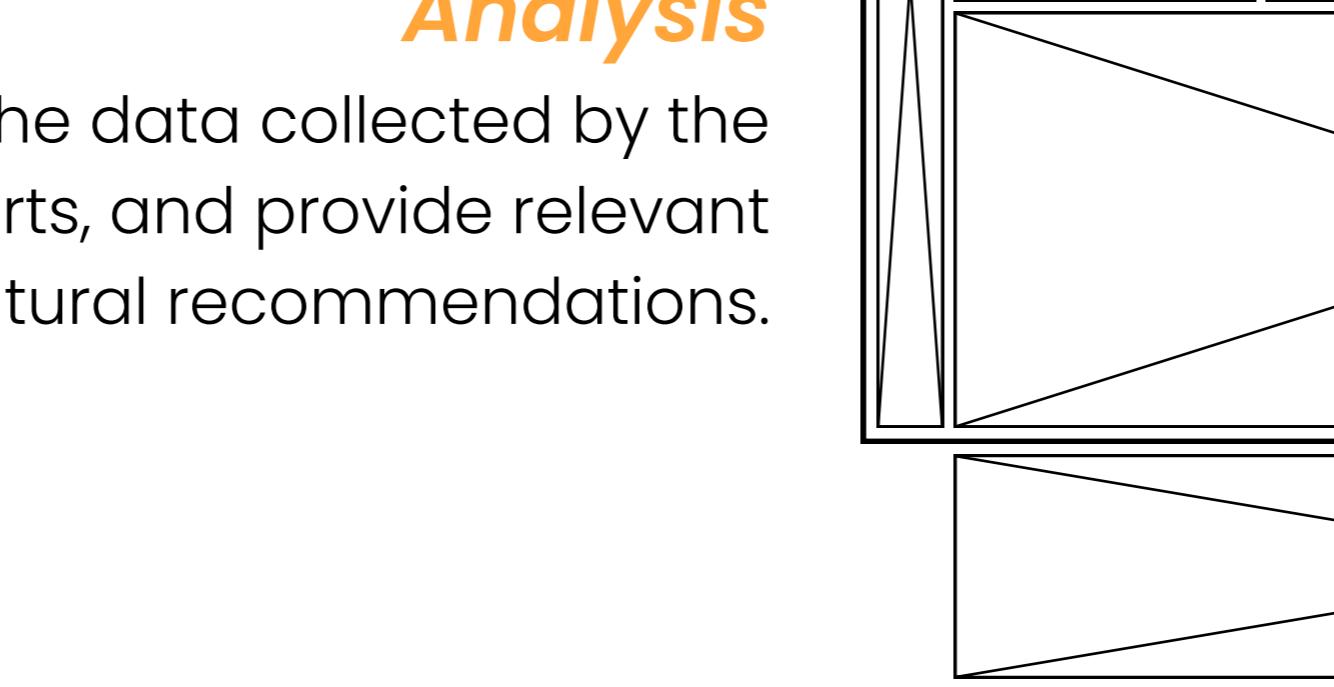
Field

Before starting the operation, it is essential to delineate the operational area and conduct route planning and control.



Operation

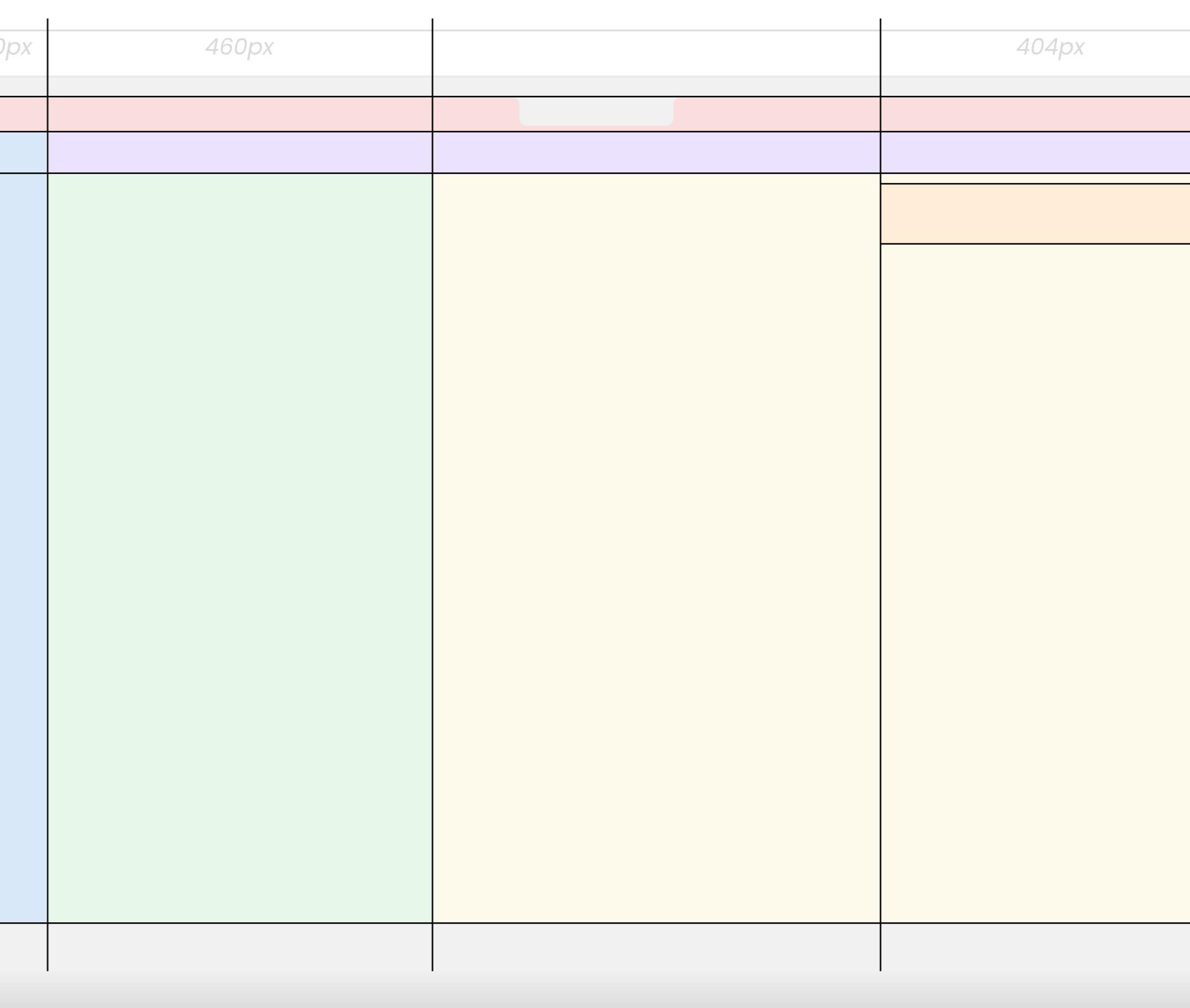
The swarm will execute the operation according to the predefined flight path and task requirements, while the operator can monitor the real-time flight status of the drones.



Analysis

Process and analyze the data collected by the swarm, generate reports, and provide relevant agricultural recommendations.

Design Criteria



Components

Sliders

Switches

Color picker

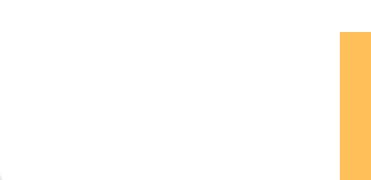
Cards

Popover

Accordion

Progress indicators

Checkboxes



FFC05A



494949



B3B3B3



D9D9D9

Avenir Medium

Avenir Medium

Primary Heading

20pt

Secondary Heading/Body Text

16pt

Descriptive Text

14pt

Subheading

12pt

Minimum Text Size

10pt

Navbar icons

Function icons



27px

20px

Mockup: Macbook Pro 14" (1512x982)

Status bar

Dock

Action bar

Work area

Satellite map

Message area

Components

FormSwarm message

You have appointed D1 as the emergency drone.

Cmd message

Please the allocation or make further adjustments.

Ack message

Please select a point on the map.

Guidance message

Please select a point on the map.

FormSwarm message

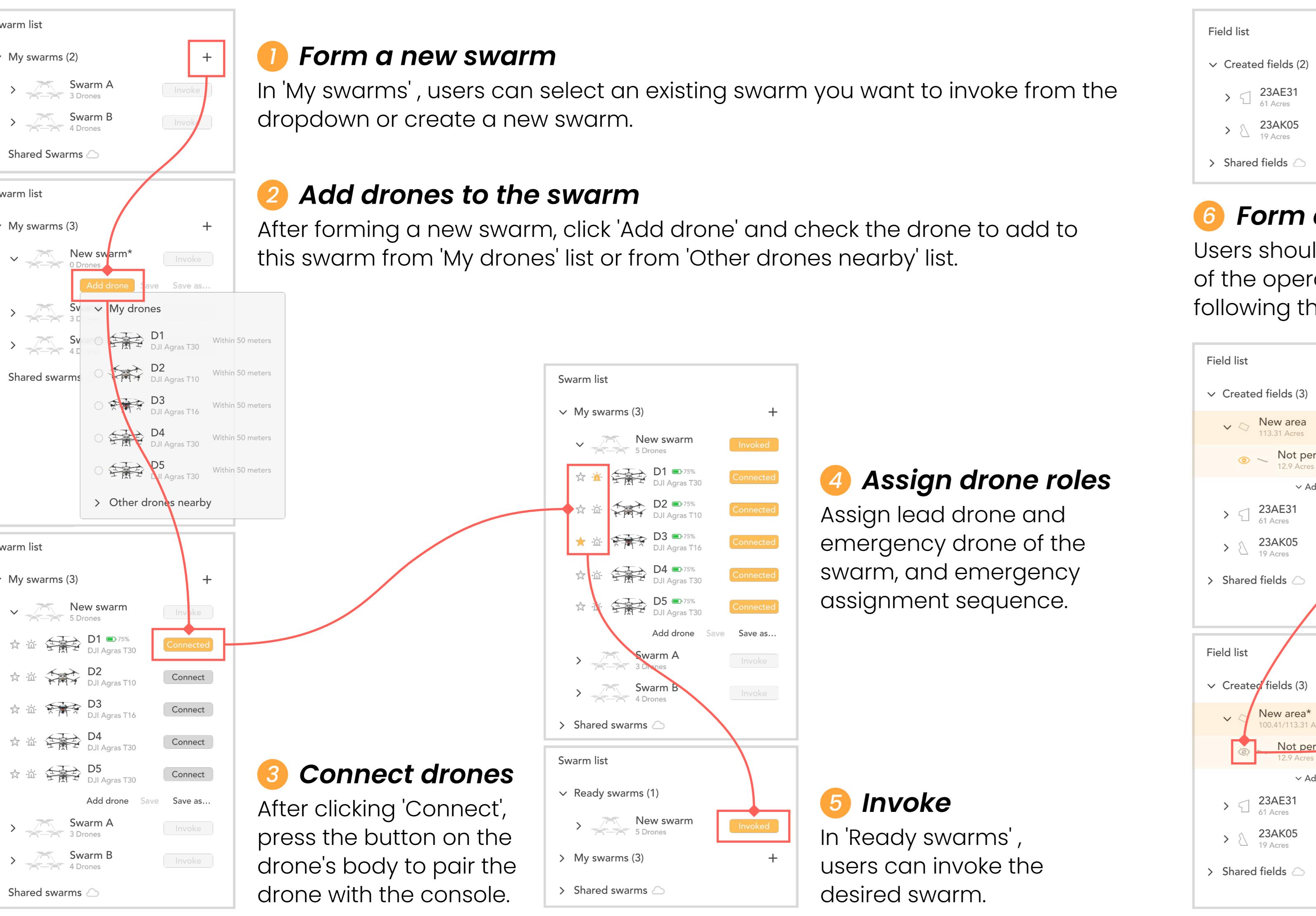
The new swarm has been saved successfully.

Hint message

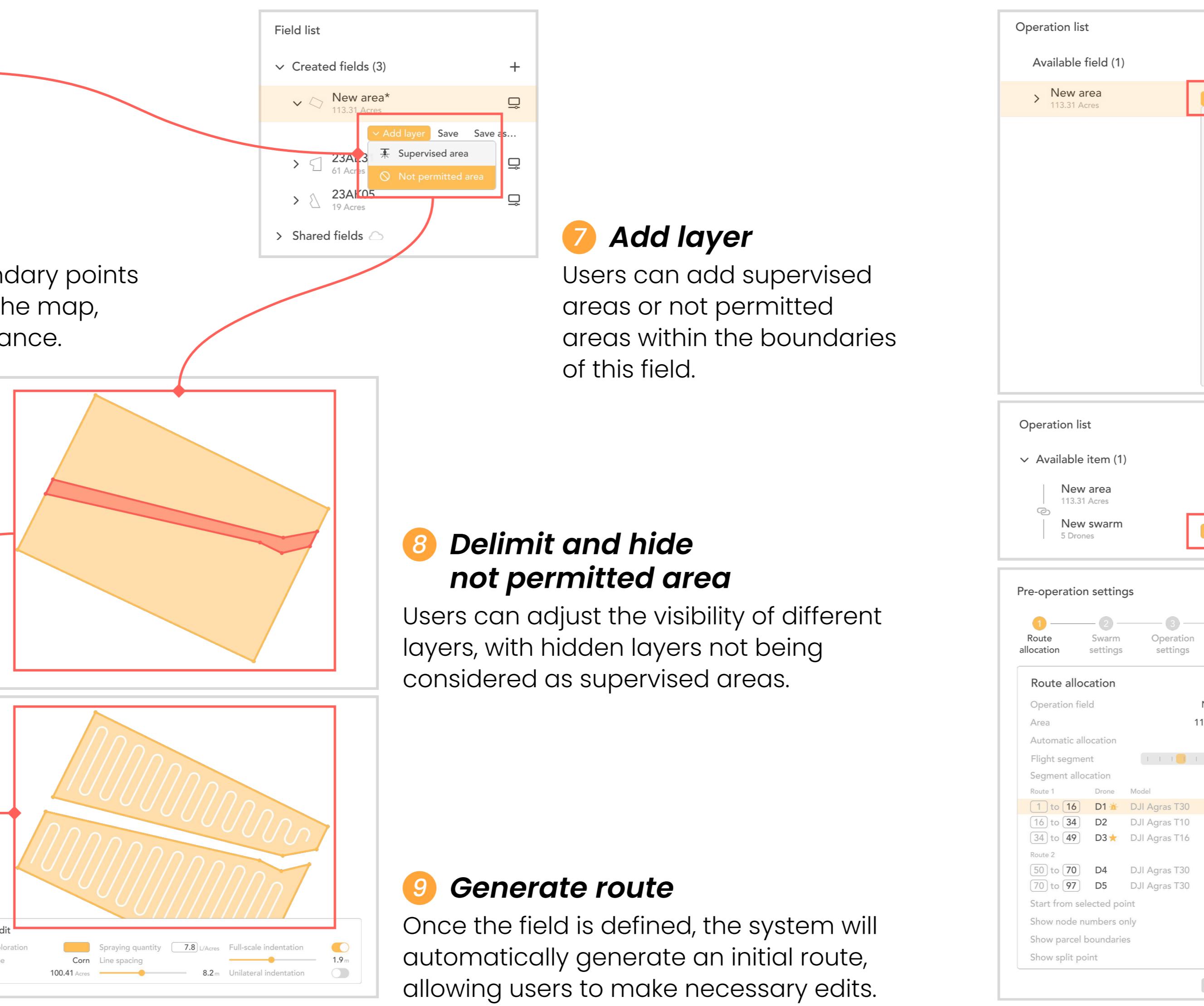
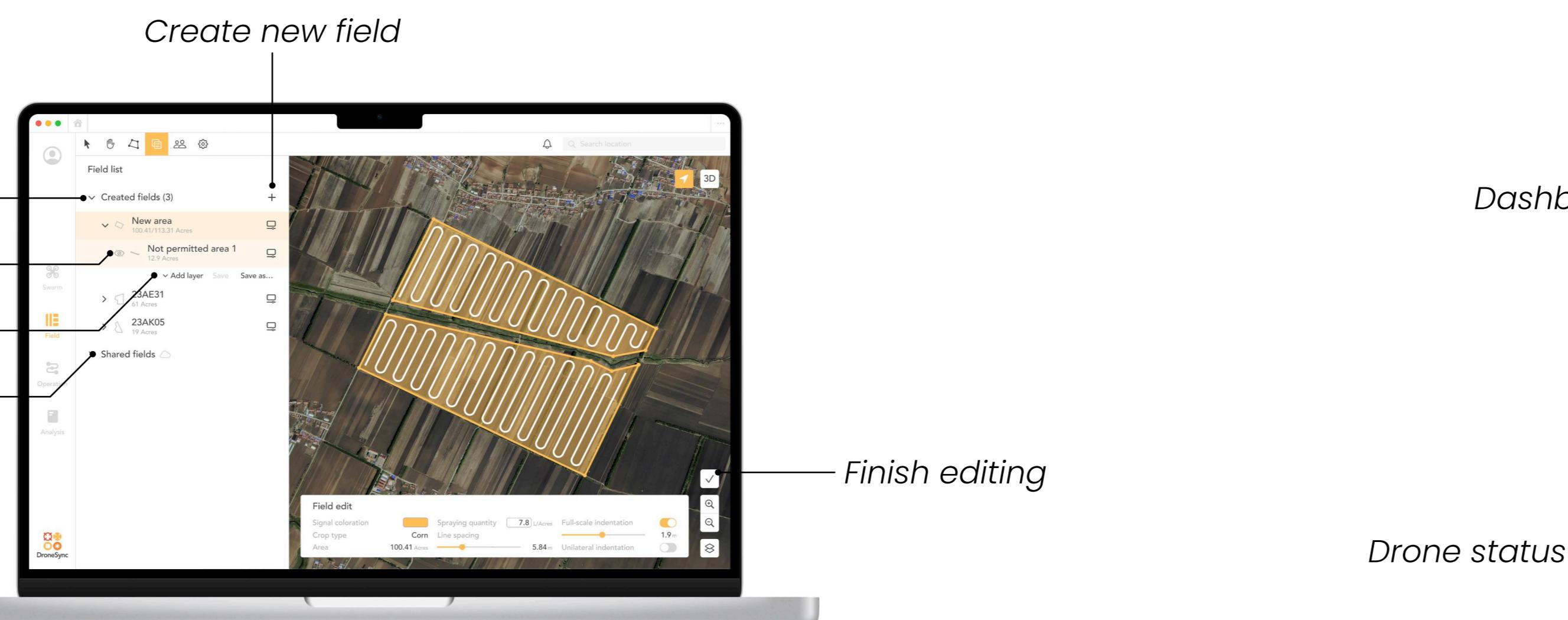
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User Interface Design & Interaction Flow

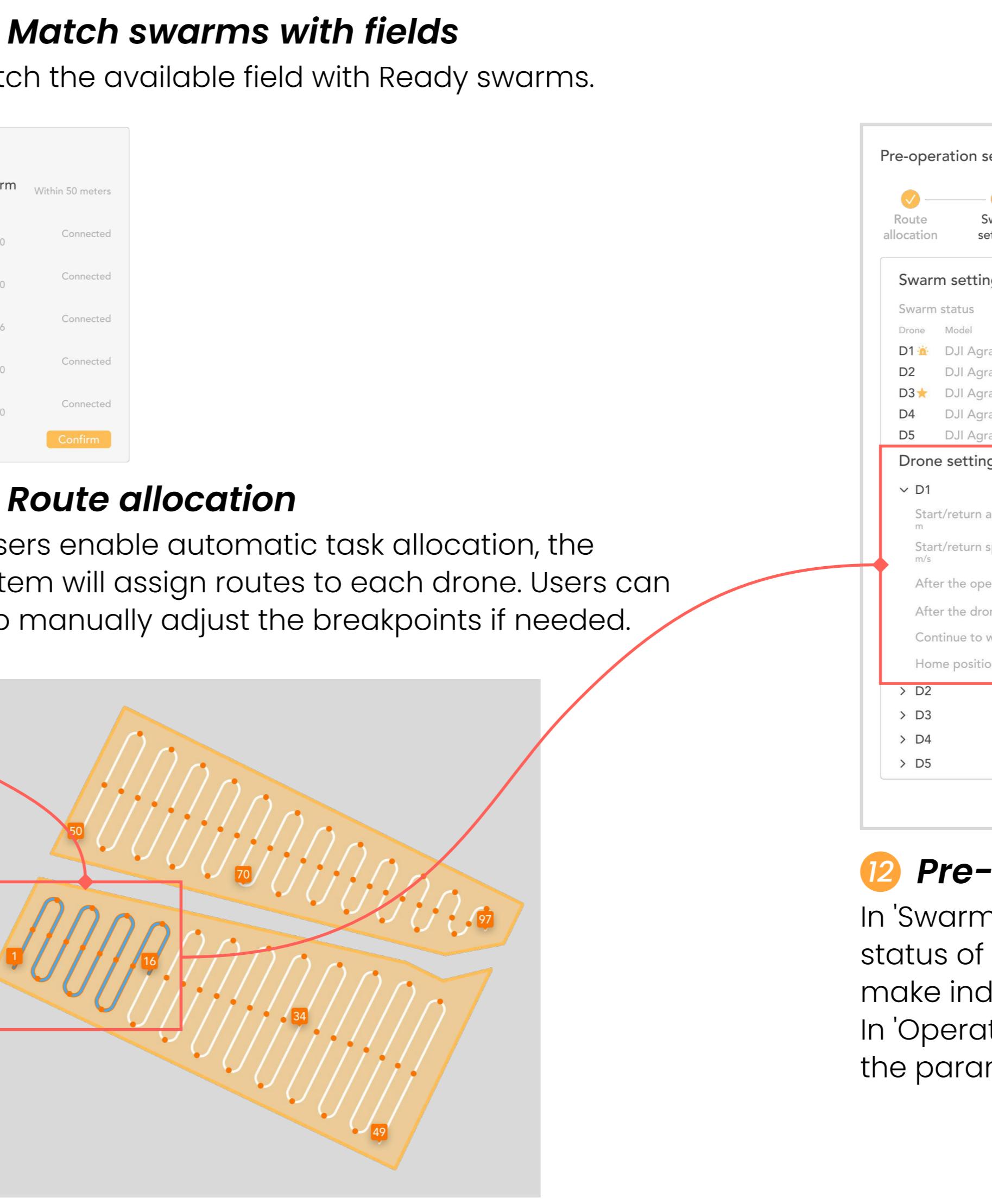
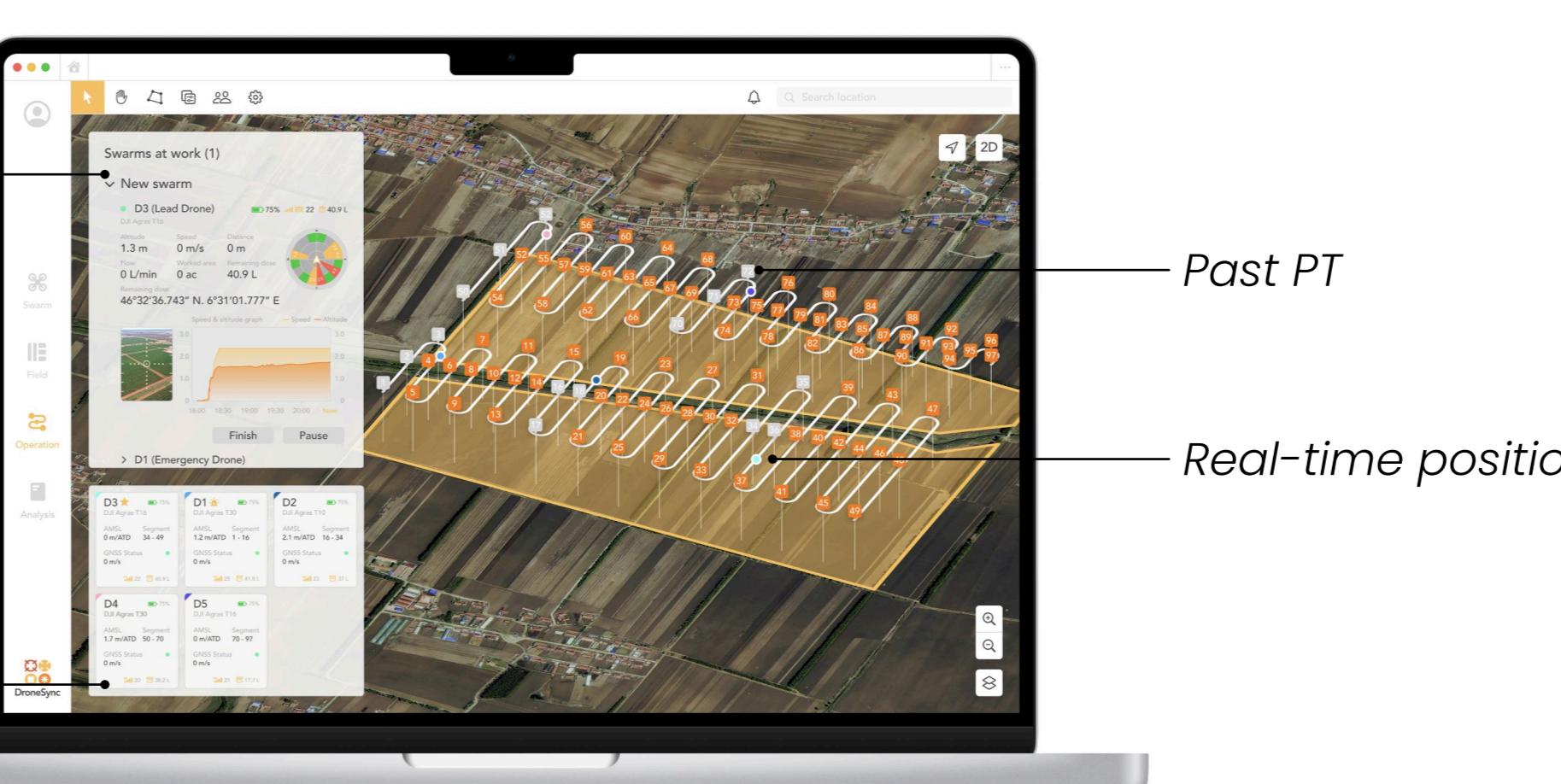
Swarm



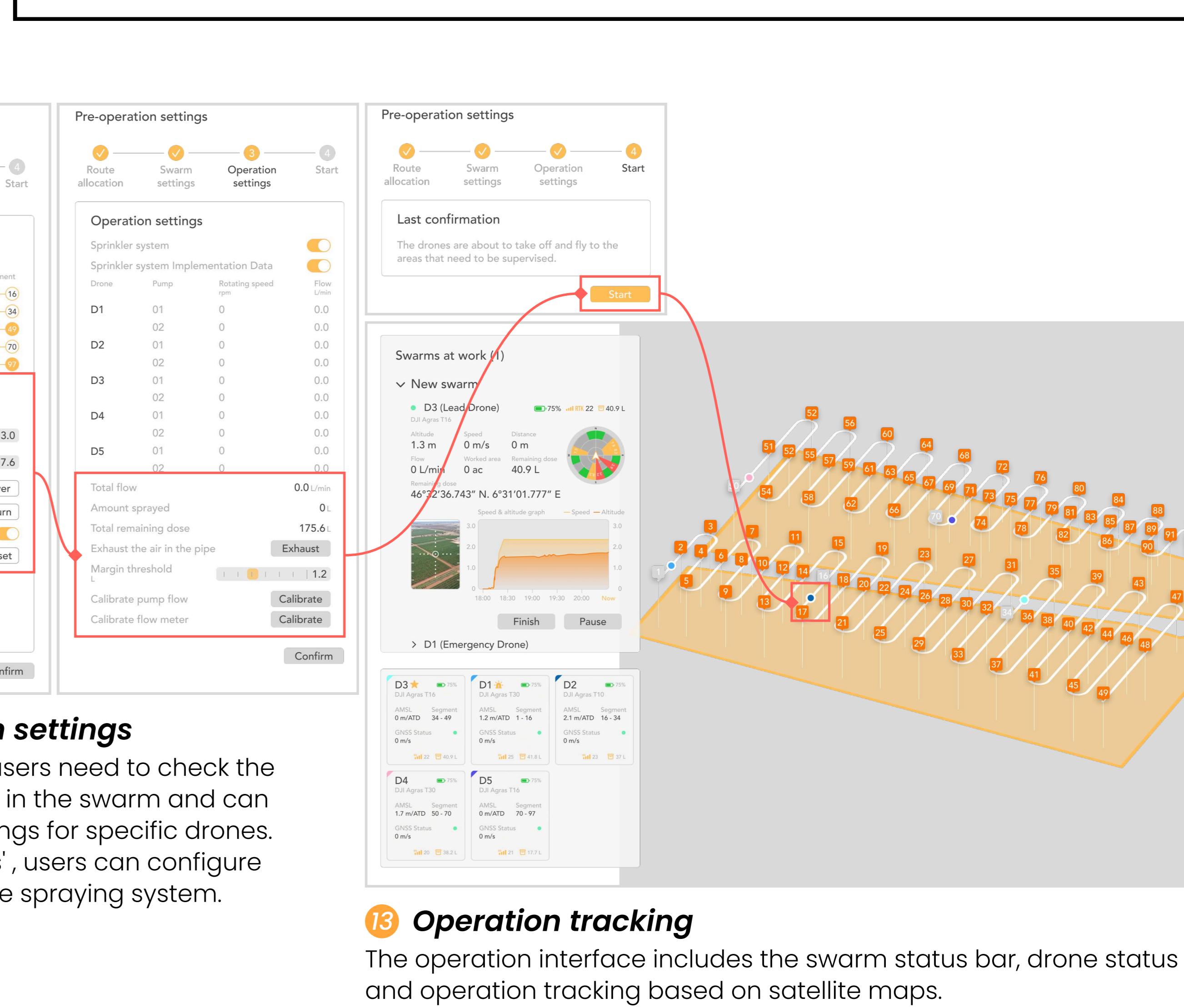
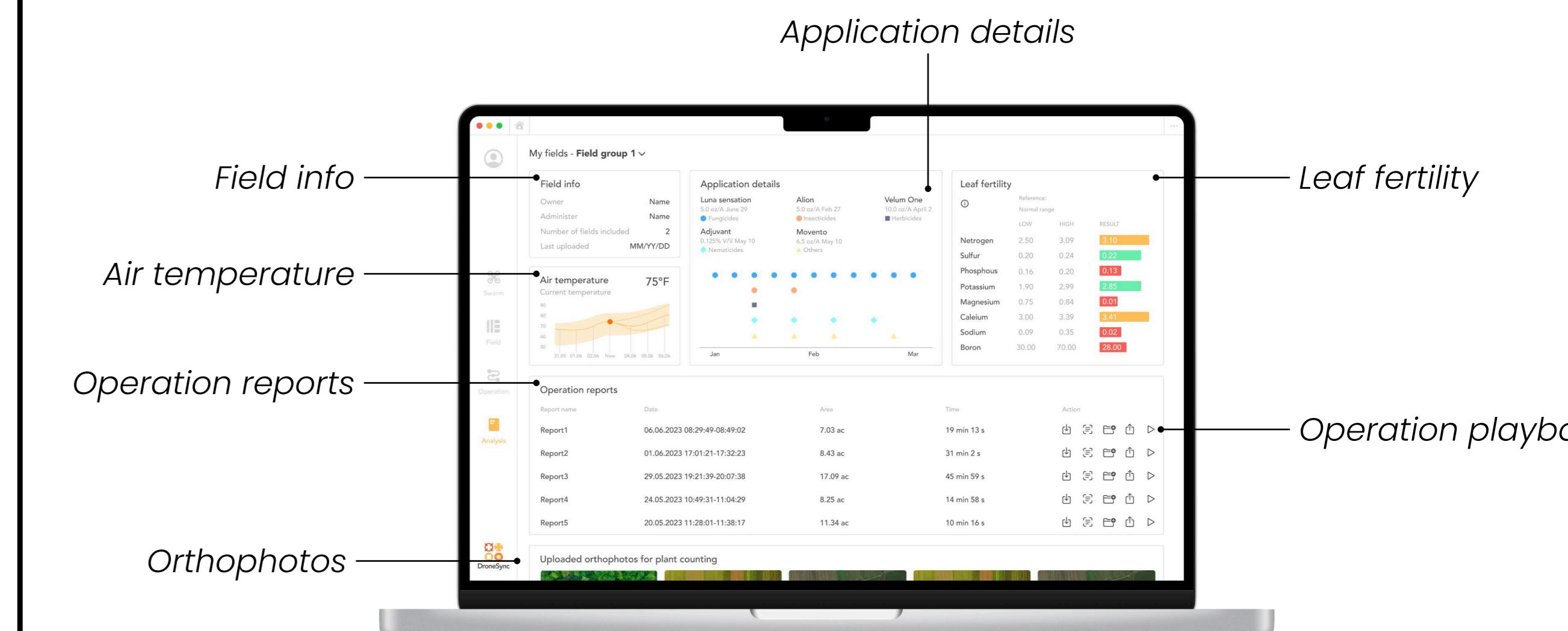
Field



Operation



Analysis



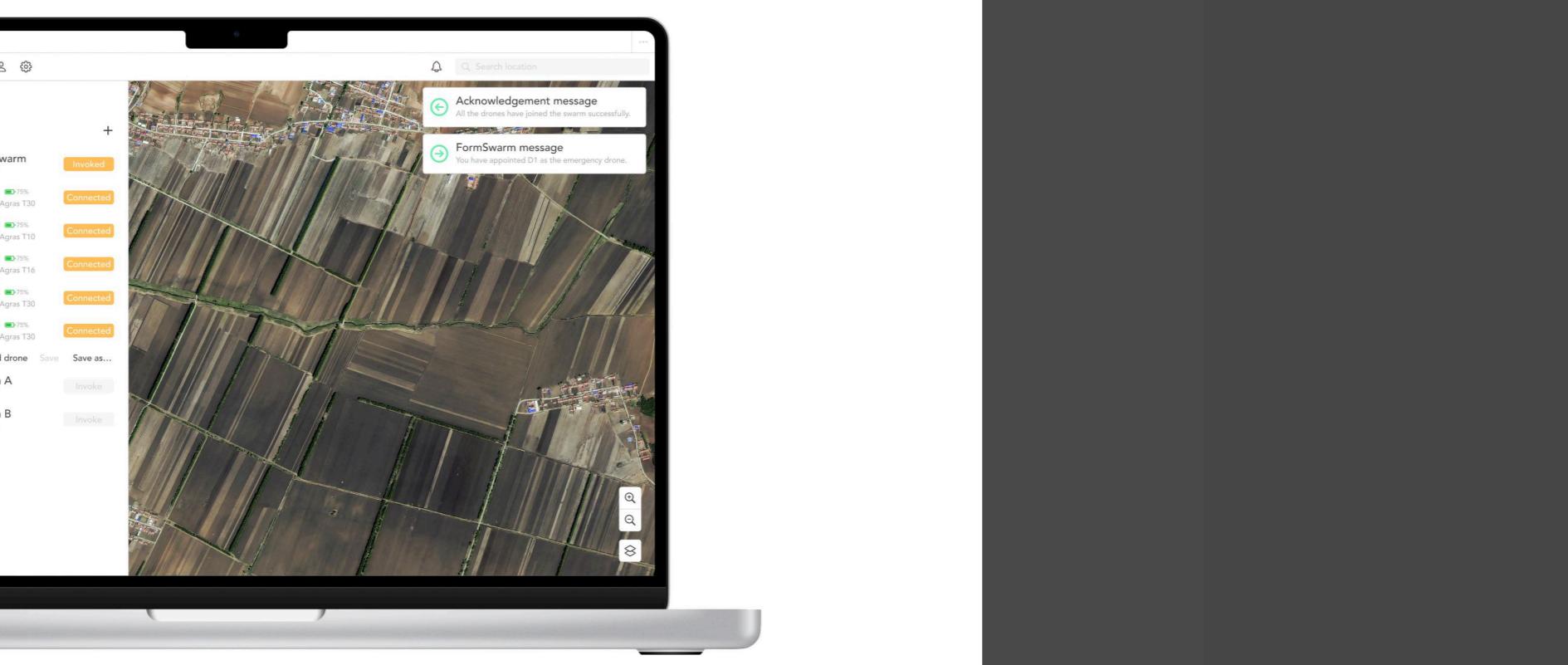
Assessment

SRK framework

In EID, the **Skills, Rules, Knowledge (SRK) framework** or SRK taxonomy defines three types of behavior or psychological processes present in operator information processing. By supporting skill- and rule-based behaviors in familiar tasks, more cognitive resources may be devoted to knowledge-based behaviors, which are **important for managing unanticipated events**.

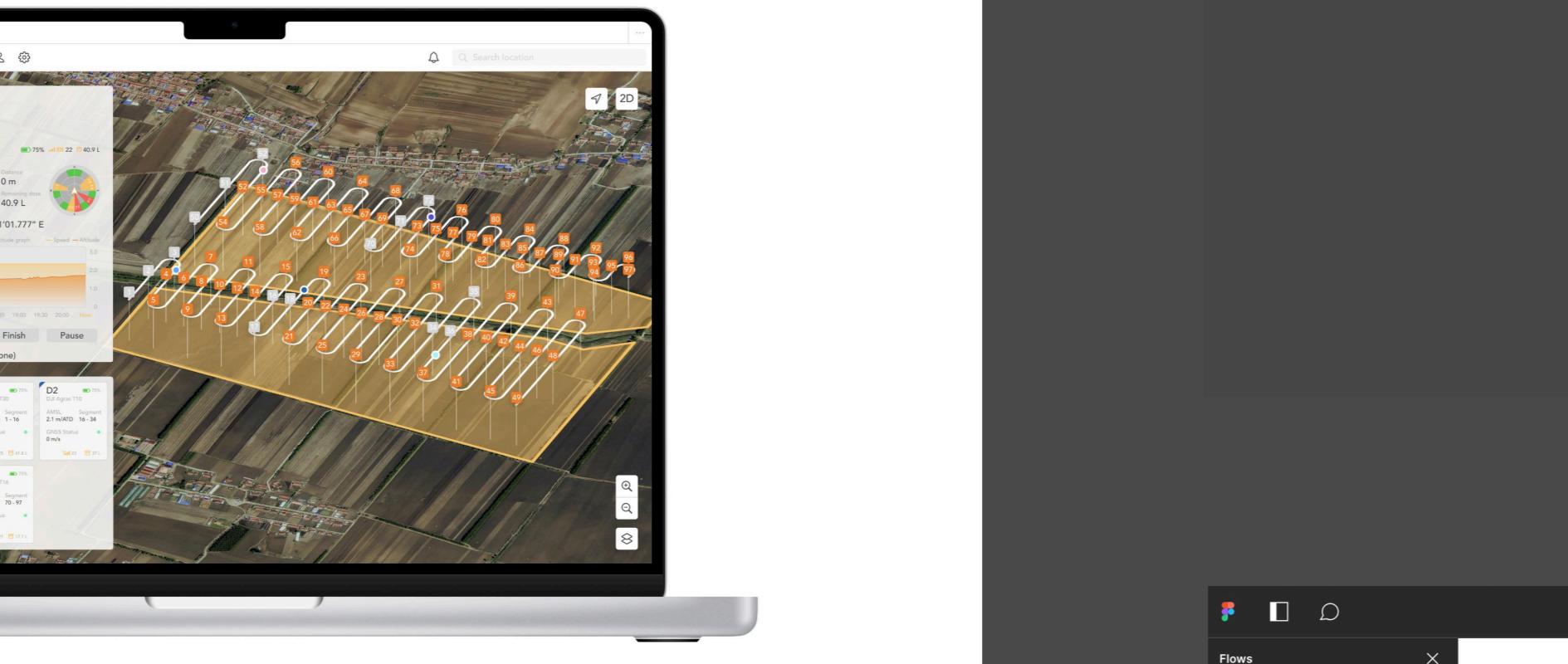
Skill-based level

A skill-based behavior represents a type of behavior that requires very little or no conscious control to perform or execute an action once an intention is formed. For example, when the user creates a swarm, they **only need to select the required drones and complete the pairing operation in which very little attention is required**.



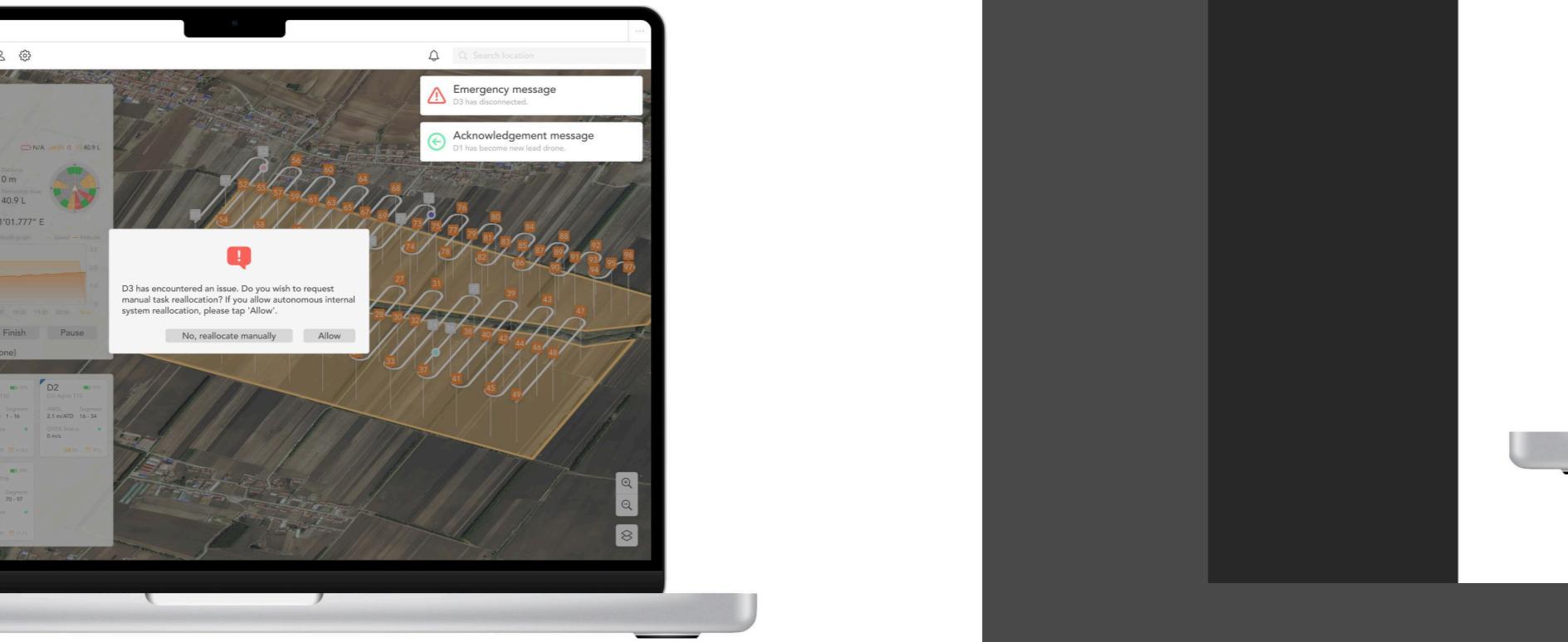
Rule-based level

A rule-based behavior is characterized by the use of rules and procedures to select a course of action in a familiar work situation (Rasmussen, 1990). During the 'Operation' phase, **operators are not required to know the underlying principles of a system, to perform a rule-based control**.

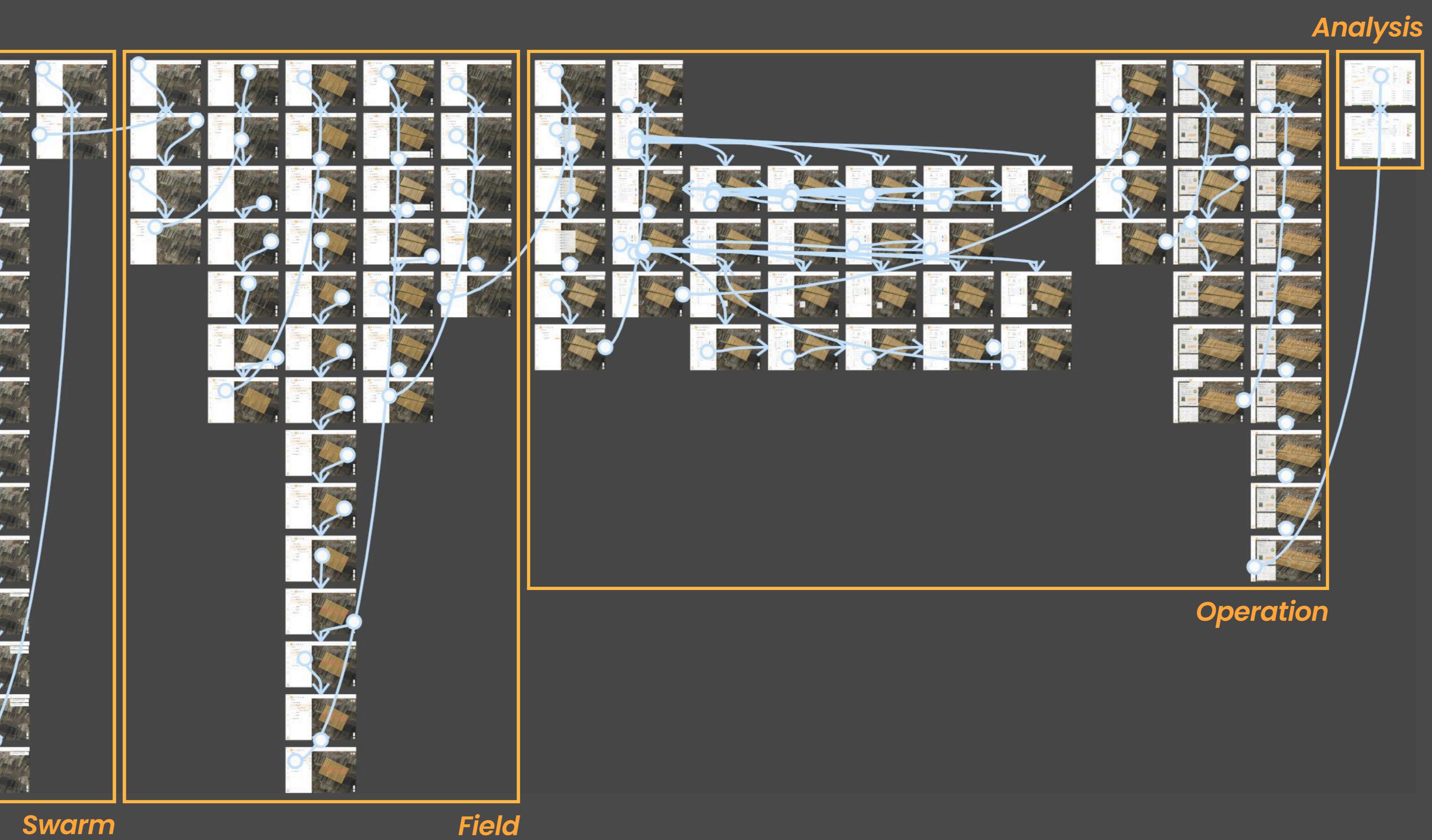


Knowledge-based level

A knowledge-based behavior represents a more advanced level of reasoning (Wirstad, 1988). In case of an emergency, users can allow the system to respond autonomously. However, even if the user doesn't manually resolve the issue, **it's essential to form a clear judgment based on their current analysis of the system**.

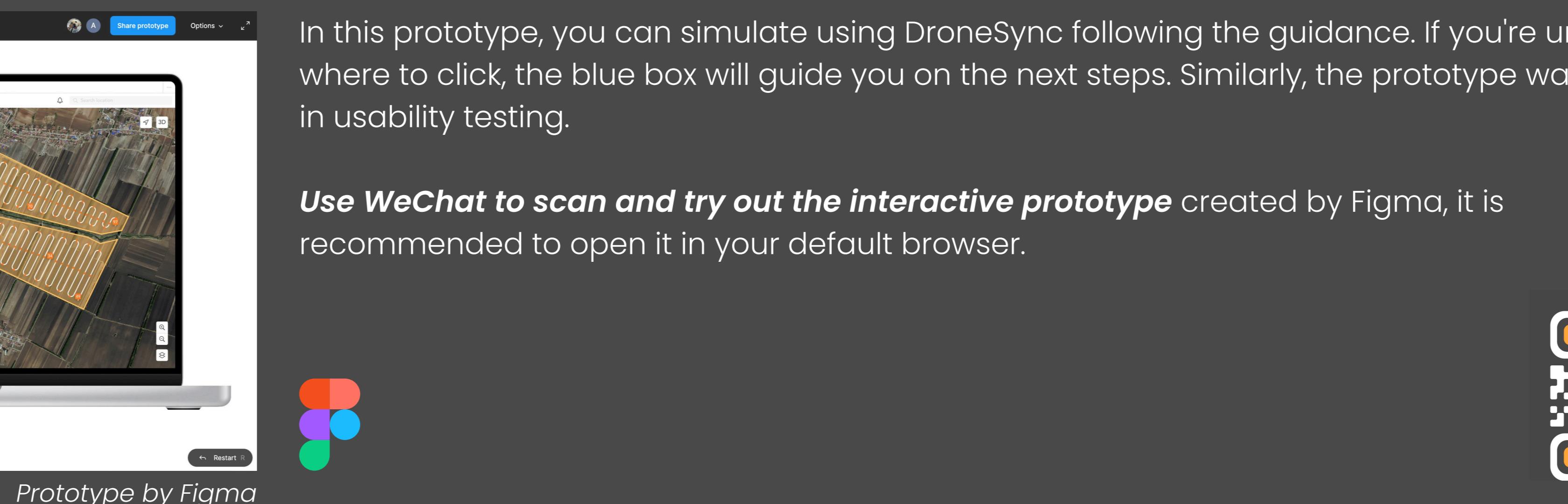


Prototype



In this prototype, you can simulate using DroneSync following the guidance. If you're unsure where to click, the blue box will guide you on the next steps. Similarly, the prototype was applied in usability testing.

Use WeChat to scan and try out the interactive prototype created by Figma, it is recommended to open it in your default browser.



Usability test

This project conducted usability testing using the SUS (System Usability Scale) questionnaire. By inviting users to complete 4 tasks and rate the system, the final score on the scale is calculated.

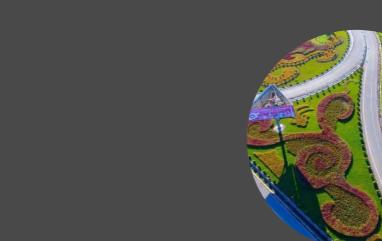
Sample size



Mr. Zhang

41 yrs old

A certain crop protection team leader who was previously a member of the collaborative design and development project team for a smart agriculture project, participating in the early stages of the project.



Mr. He

38 yrs old

A senior crop protection team member primarily responsible for the daily maintenance and upkeep of crop protection drones and accessory materials, possessing fundamental operational skills.



Mr. Yang

27 yrs old

A crop protection team member who is relatively new to the field but has a wealth of operational experience.

- n=3
- They **all have experience** with agricultural management platforms.
- They are **looking forward to improving the efficiency** of drone spraying.

Conclusion

Task	Avg Time	UX
Create a new swarm	1m04s	"When connecting a new drone that has never been connected before, there may be a lack of some guidance information."
Setup a new field based on the guidance	3m08s	"Consider how to quickly correlate the delineated field on the map with the actual field in the real world."
Match the swarm with the fields	2m34s	"Intuitive"
Pre-setting before the operation	2m09s	"Displaying the steps is beginner-friendly, but it's better to categorize and summarize the tuning section."

After the usability test is completed, quantify it using the SUS usability scale. Users quickly complete each question without overthinking. After calculation, the SUS score of 79.6 (>68) corresponds to a grade of A-. On a percentage scale, this would fall within the range of 85-89.

