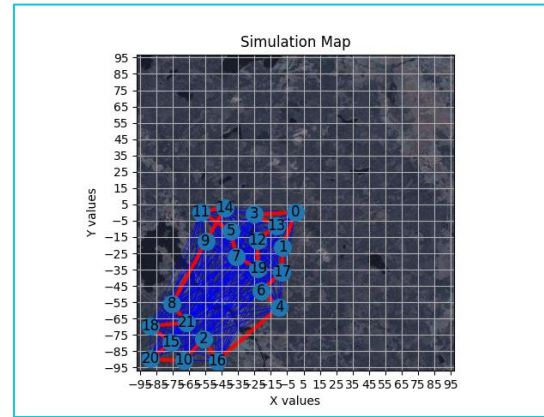
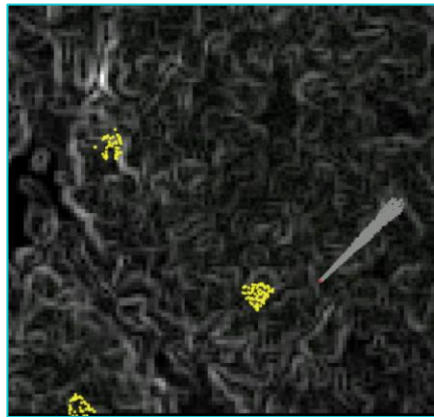
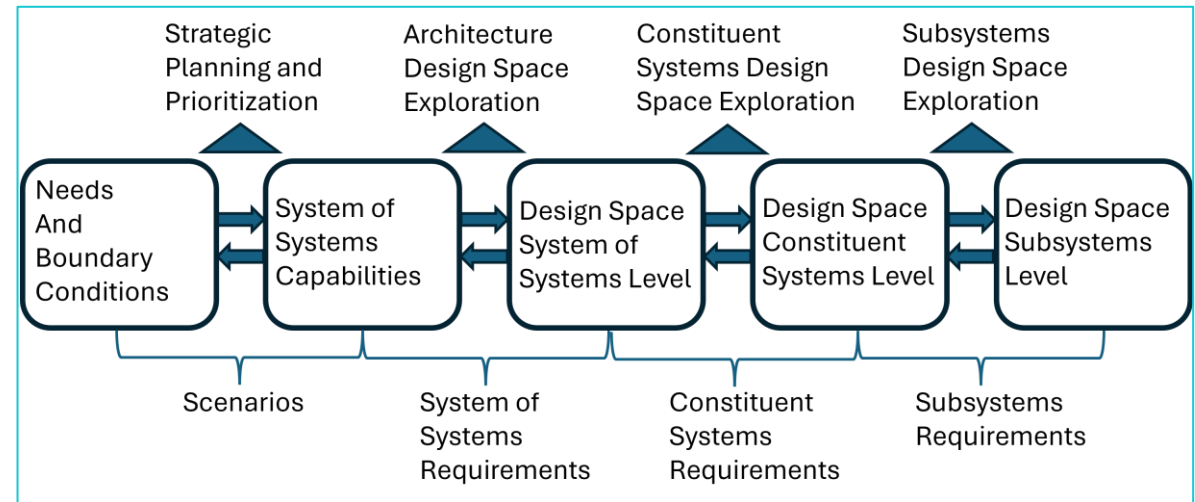


Generative AI in Modelling and Simulation

Jorge L. Lovaco PhD Candidate

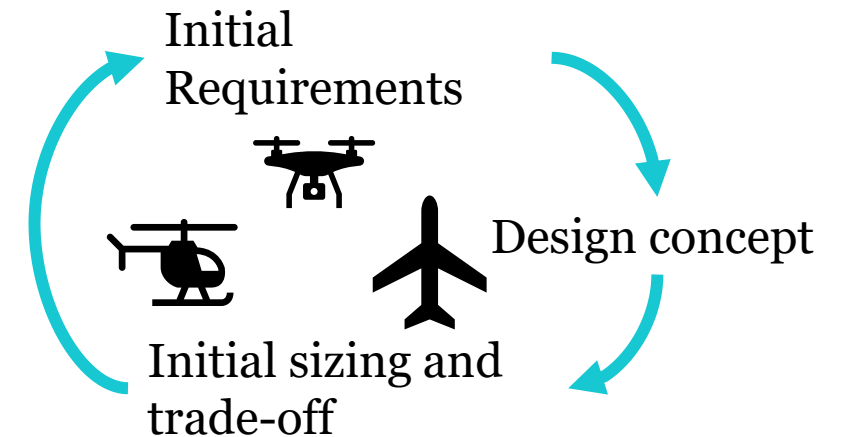
1. Background – The Research Itself

- **System of Systems (SoS)** : Independent systems integrated in such a way that the group value is increased beyond prediction.



1. Background

- *What is System of Systems (SoS)?*
 - Communication & Collaboration.
 - Emergent behaviours.
 - Needs and capabilities define **Requirements**.
- *How do we analyse a System of Systems?*
 - Agent-Based Modelling and Simulation.
- *Aircraft Conceptual Design (ACD):*
 - **Capabilities** that fulfill a need.



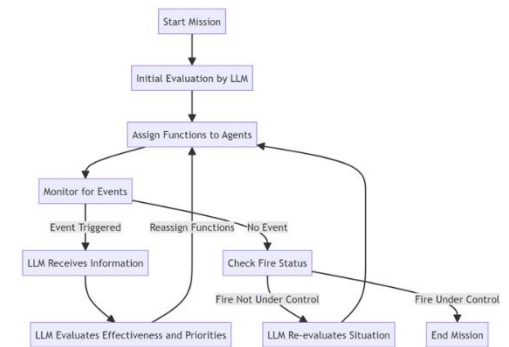
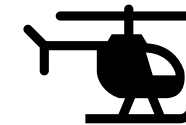
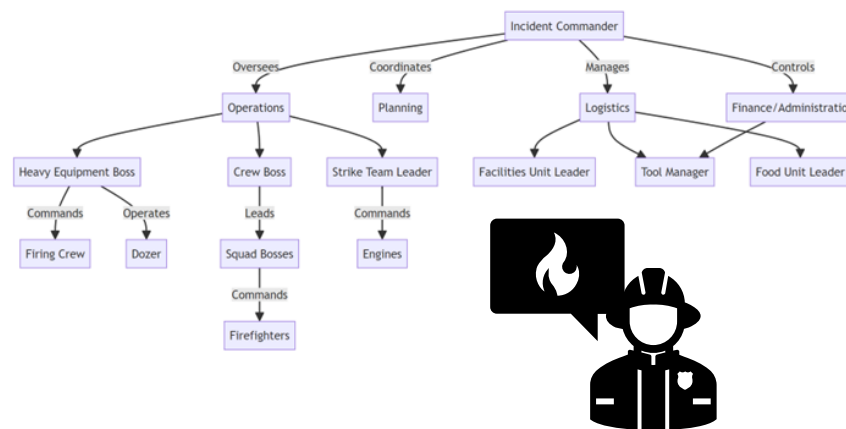
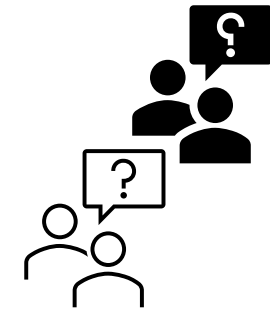
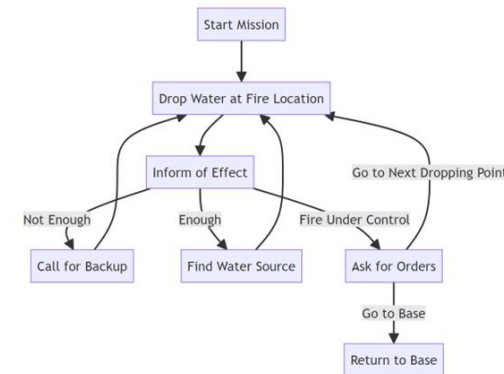
2. Large Language Models & Applications

- *What is Large Language Model (LLM)?*
 - In short: a combination of statistics and neural networks.
- *How/why do they work?*
 - In short: a sufficiently complex neural network can approximate any continuous function (according to the *Universal Approximation Theorem* and *Borel measurable functions*).
- *In this study, the LLM replaces traditional decision trees in an Agent-Based Model by taking the role of an Incident Commander in a wildfire scenario.*

Honourable mention: Claude Shannon, the father of Information Theory.

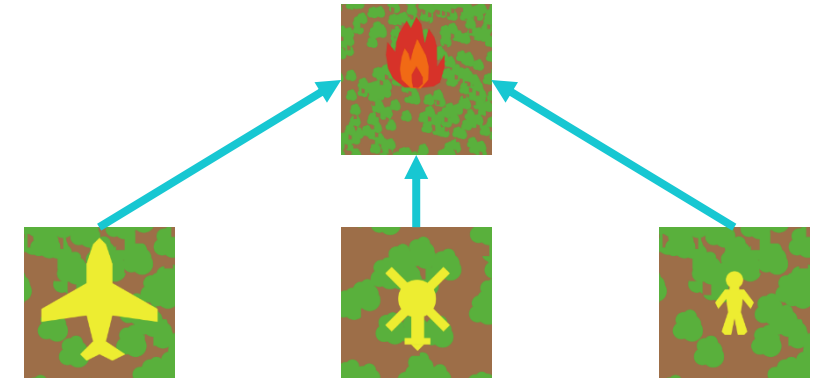
2. Large Language Models & Applications

- *Concept of Operations for firefighting guidelines are given to the LLM as a “constraint”.*
- *Simple actions to follow orders.*

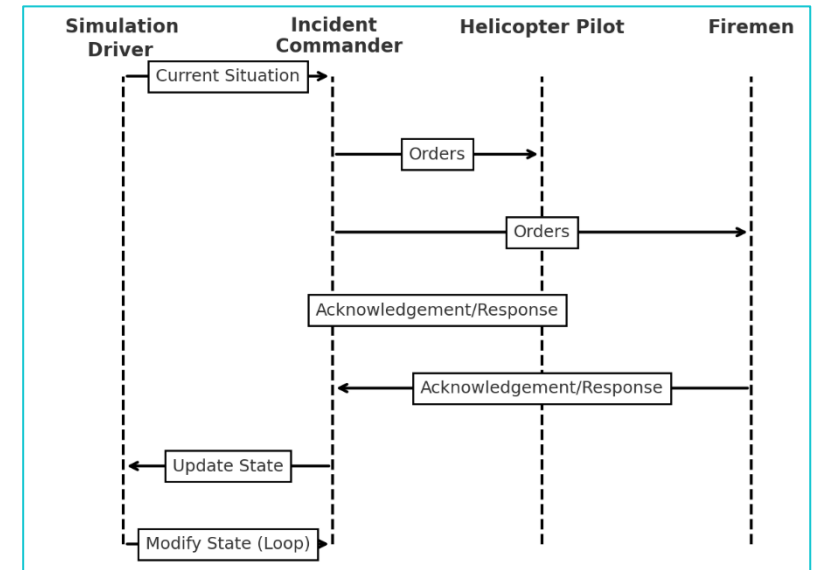
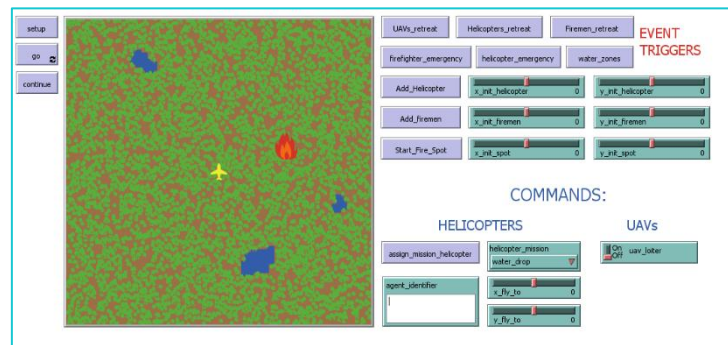


3. Simulation Setup

- Agents in the simulation include helicopters, unmanned aircraft, and firemen. Each playing specific roles in wildfire management.



- User Interface:



3. Simulation Setup

PROMPT: [Summarised CONOPS]

Got it. I will act as the Incident Commander during a wildfire situation and ensure we follow the provided CONOPS. Let's start with an initial briefing and intent to establish our objectives and prepare the team.

Initial Briefing and Intent

Task: Our primary task is to contain and control the wildfire while ensuring the safety of all personnel involved.

Purpose: The purpose of this mission is to prevent the wildfire from spreading to populated areas, protect natural resources, and minimize damage to property and infrastructure.

End State: The end state of this operation is to have the wildfire fully contained with no injuries to personnel, minimal damage to property, and a thorough plan for monitoring and managing hotspots.

Key Actions and Responsibilities

1. Provide Complete Briefings:

- Communicate the mission objectives clearly to all team members.
- Ensure everyone understands their specific roles and responsibilities.

PROMPT: The map of remote area is divided in coordinates from -50 to 50 in the X axis and -50 to 50 in the Y axis. An UAV is patrolling over the area and a wildfire is reported. It is unknown for how long it has been burning and its actual size. One helicopter and two firefighter teams are available in the local agency. Please state your decision and keep consistency with the Incident Commander CONOPS.

Incident Commander Decision and Plan of Action

Given the coordinates and available resources, here is the plan of action to address the reported wildfire while adhering to the Incident Commander CONOPS:

1. Initial Assessment and Briefing

- **UAV Patrol:**
 - Task the UAV with conducting an initial assessment to locate and report the exact coordinates, size, and intensity of the wildfire.
 - The UAV should cover the area methodically, starting from the center coordinates (0,0) and spiraling outward until the fire is located.
 - Establish a dedicated communication channel with the UAV operator for real-time updates.
- **Briefing to Teams:**
 - **Helicopter Crew:**
 - Prepare for rapid deployment to either conduct aerial water drops or assist with reconnaissance.
 - **Firefighter Teams:**
 - Assemble and prepare equipment for ground engagement.
 - Ensure all team members understand the briefing, their roles, and the importance of safety zones and escape routes (LCES).

4. Results

Incident Commander Decision and Communication Plan

1. Initial Assessment

- Wildfire Location: Coordinates (-17.88, 36.07)
- Water Sources:
 - Lake A: (7, -11)
 - Lake B: (-31, 47)
- Helicopter Entrance Point: (-31, -50)

2. Resource Allocation and Plan of Action

- UAV:
 - Continue to monitor and provide real-time updates on the fire's behavior, spread, and intensity.
- Helicopter:
 - The helicopter will enter the map at (-31, -50) and proceed to Lake B (-31, 47) to fill its water tanks due to its proximity to the wildfire.
 - Conduct water drops on the fire located at (-17.88, 36.07) and provide aerial reconnaissance.
- Firefighter Teams:
 - **Team A:** Deploy to approach the wildfire from the north. Suggested entry point: (-17.88, 50).
 - **Team B:** Deploy to approach the wildfire from the south. Suggested entry point: (-17.88, -50).

PROMPT: The wildfire coordinates are reported to be: (-17.88, 36.07). When checking the map of the area, the following coordinates are lakes with water available for water drops: 1) Lake A: (7, -11); 2) Lake B: (-31, 47). Entrance point to the map from the helicopter is (-31,-50). Please, state your decisions and how you would communicate them.

Communication Plan:

To Helicopter Crew: "Helicopter Team, this is Incident Command. Enter the map at (-31, -50) and proceed directly to Lake B at (-31, 47) to fill water tanks. After filling, head to the wildfire at coordinates (-17.88, 36.07) for water drops and aerial reconnaissance. Maintain communication on primary frequency Alpha and report any significant changes. Over."

To Firefighter Team A: "Team A, this is Incident Command. Proceed to coordinates (-17.88, 50) and establish a line approaching the wildfire from the north. Ensure LCES is established and be ready for tactical pause at 1400 hours. Maintain communication on primary frequency Bravo and update status every 30 minutes. Over."

To Firefighter Team B: "Team B, this is Incident Command. Proceed to coordinates (-17.88, -50) and establish a line approaching the wildfire from the south. Ensure LCES is established and ready for tactical pause at 1400 hours. Maintain communication on primary frequency Bravo and update status every 30 minutes. Over."

To UAV Operator: "UAV Operator, continue monitoring the wildfire and provide real-time updates on fire behaviour, spread, and intensity. Report any critical changes immediately on primary frequency, Charlie. Over."

4. Results

PROMPT:

The helicopter pilot reports this upon reaching wildfire: "Alpha frequency, Helicopter six eight x-ray (68X) arrived at coordinates (-17.88, 36.07) for water drops and aerial reconnaissance. Beginning operations now. Over." At the same time, another fire spot has been reported by the UAV: (-19, 36)

Revised Deployment of Resources:

- *Helicopter 68X:*

Prioritize water drops on the initial fire spot at (-17.88, 36.07). Conduct reconnaissance and provide aerial assessments of both fire spots.

- *Firefighter Teams A and B:*

Coordinate efforts to tackle and contain both fire spots. Team A to focus on the northern front of the fires, ensuring both spots are addressed. Team B to focus on the southern front, ensuring containment lines are established and maintained.

PROMPT:

Team B reports the following: "Command, Team B, reporting a medical emergency. Firefighter experiencing heat stroke symptoms. We need immediate medical assistance at our current location. Over."

[...] To UAV Operator: "Charlie frequency, this is Incident Command. Medical emergency at Team B's location. Direct UAV to monitor and provide aerial support for medevac operations. Relay any critical updates or obstacles to the helicopter crew. Over."

PROMPT:

"Command, Team A, reporting signs of severe exhaustion among crew members. Requesting immediate relief and rotation of resources. Over."

"Command, Team C, entering the area from point (-1,50). Over."

"Command, Team D, we are entering from point (-1,50). Over."

"Command, Team E, now entering from point (-1,50). Over."

"Incident Command, this is Helicopter five four zulu (54Z). Entering from point (50, 8). Ready for further instructions. Over."

"Incident Command, this is Helicopter two one tango (21T). Entering from point (50, 8). Ready for further instructions. Over."

Summary of Updated Plan of Action

Team A: Immediate relief by Teams C, D, and E. Ensure safe rotation and rest.

Teams C, D, and E: Take over firefighting operations with clear focus areas and support.

Helicopter 54Z: Refill at Lake A, conduct water drops, and provide reconnaissance.

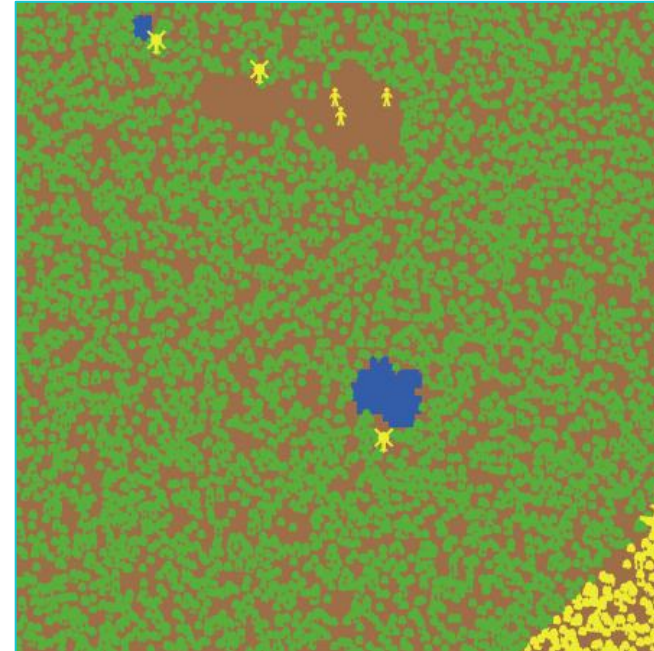
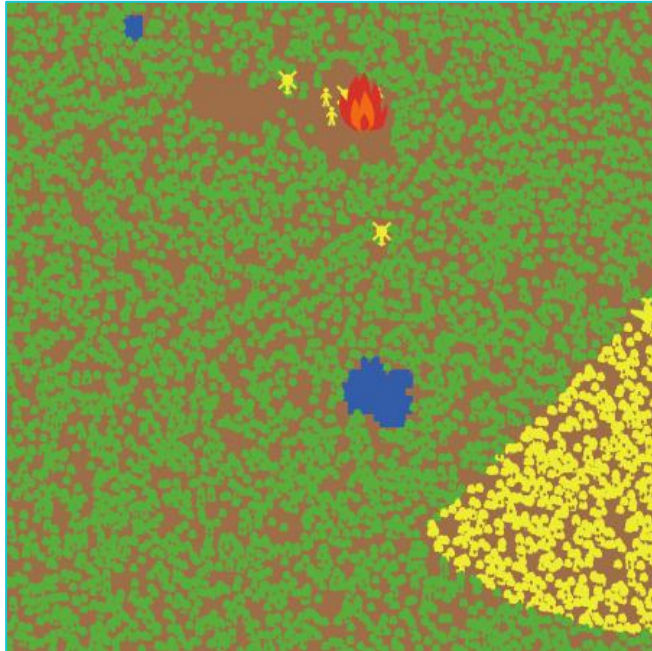
Helicopter 21T: Refill at Lake B, conduct water drops, and provide reconnaissance.

UAV Support: Monitor relief operations and fire behaviour, providing real-time updates.

Continuous Communication: Maintain clear and regular communication with all units, updating on status and any changes.

4. Results

- Successful mission!

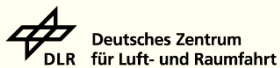


5. Conclusion

- ***LLM-Driven Simulations:***
 - These simulations introduce additional degrees of freedom to agent-based models, offering more realistic scenarios.
- ***Holistic Approach:***
 - This approach leads to more informed decisions, especially when considering trade-offs in generating aircraft concepts.
 - Find if there is any functional capability that the incident commander needs and our systems do not include.

6. Future Work

- ***Direct connection with API:***
 - The emergent "prompt engineering" can be used for a fully controlled simulation.
- ***External connection API:***
 - Tools such as *OpenModelica* could make use of external functions for including Generative AI results into the simulation. For example, several sensors can be used as inputs and obtain a human-like output to control a system.



COLLABORATIVE SYSTEM OF SYSTEMS
EXPLORATION OF AVIATION PRODUCTS,
SERVICES & BUSINESS MODELS

Thank You !



Scan me! 😊



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