



Autonomous Aerial Robots

Tested in:

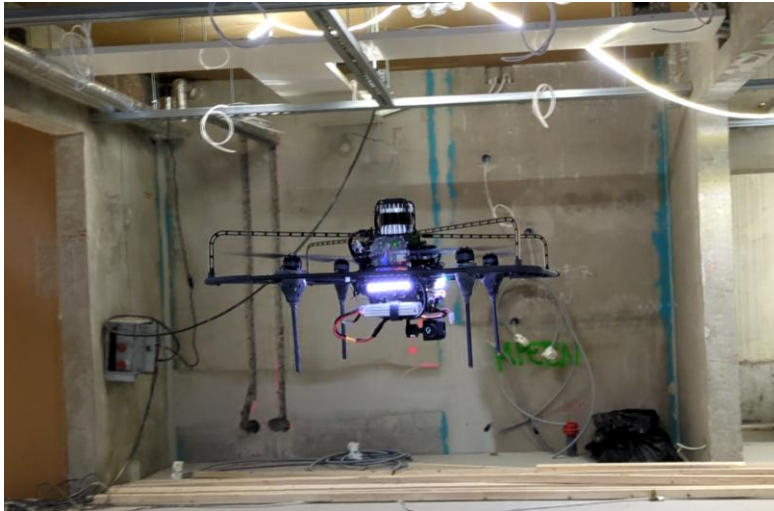
- Road construction & maintenance - highway near Gran Sasso Nord, Italy
- Building construction - Helsinki Metropolitan Area, Finland

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Autonomous Aerial Robots

Introduction

- This work will focus on the design and development of aerial robotic technologies, which involve a system for **outdoor inspection**, and a system for **indoor exploration** which does not make use of satellite-based localization solutions.



CADRIN Drone performing autonomous flight inside building under construction



C750 Drone prepared to perform autonomous road maintenance tasks

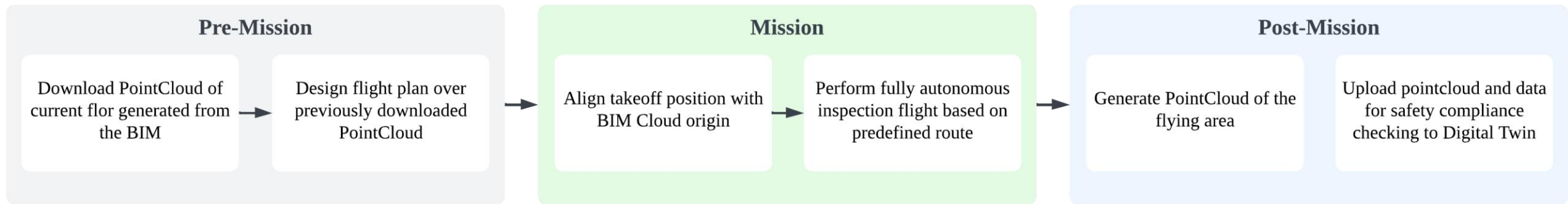


DJI M300 Drone prepared to perform road construction photogrammetry

Autonomous Aerial Robots

Building Construction

- Main goals of the aerial robots in the case study:
 - Perform fully autonomous and safe navigation in reduced-size environments.
 - Generate 3D map after wall building for progress analysis. This 3D map can be generated both in real time and post-processed.
 - Gather raw pointclouds and images data for safety compliance checking.

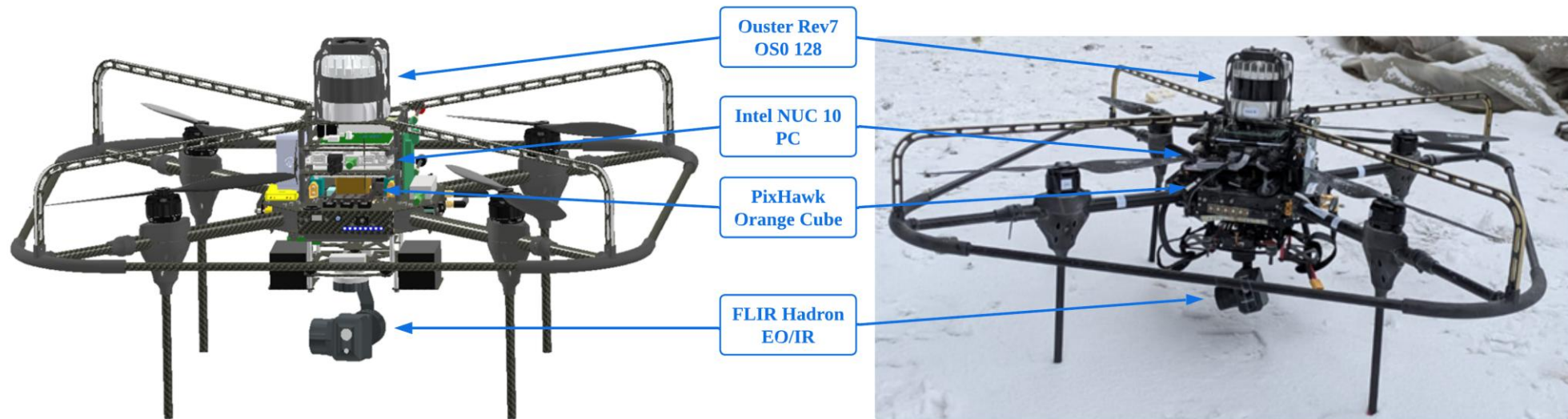


Building Construction Case Study Workflow

Autonomous Aerial Robots

Building Construction

- Fully autonomous flights are carried out in enclosed spaces where GNSS signal aren't available. The aim is to create 3D map of the environment and capture information about it to verify compliance with safety standards.
- Custom aerial vehicle has been designed and manufactured to fit the needs of the environment.

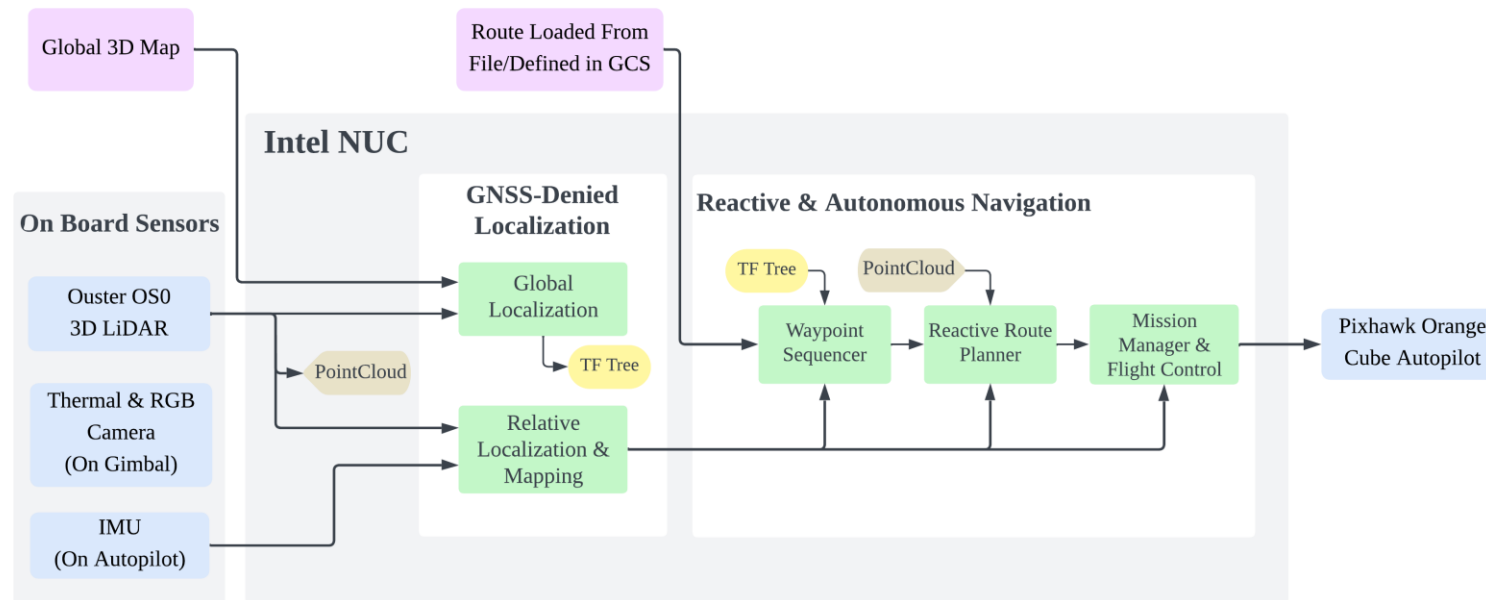


CADRIN Drone CAD and real with onboard sensors

Autonomous Aerial Robots

Building Construction

- The whole computing is performed on the onboard computer of the robot.
- Modular and interchangeable software architecture with two main components: GNSS-Denied Localization system and reactive navigation system with static and dynamic obstacle avoidance.



CADRIN Drone software architecture in building construction case study

Autonomous Aerial Robots

Building Construction

- Tested developments in a real-world environment in a FIRA's building under construction in Helsinki (Finland) with very satisfactory results.



Autonomous mission execution – Sensors Point-Of-View

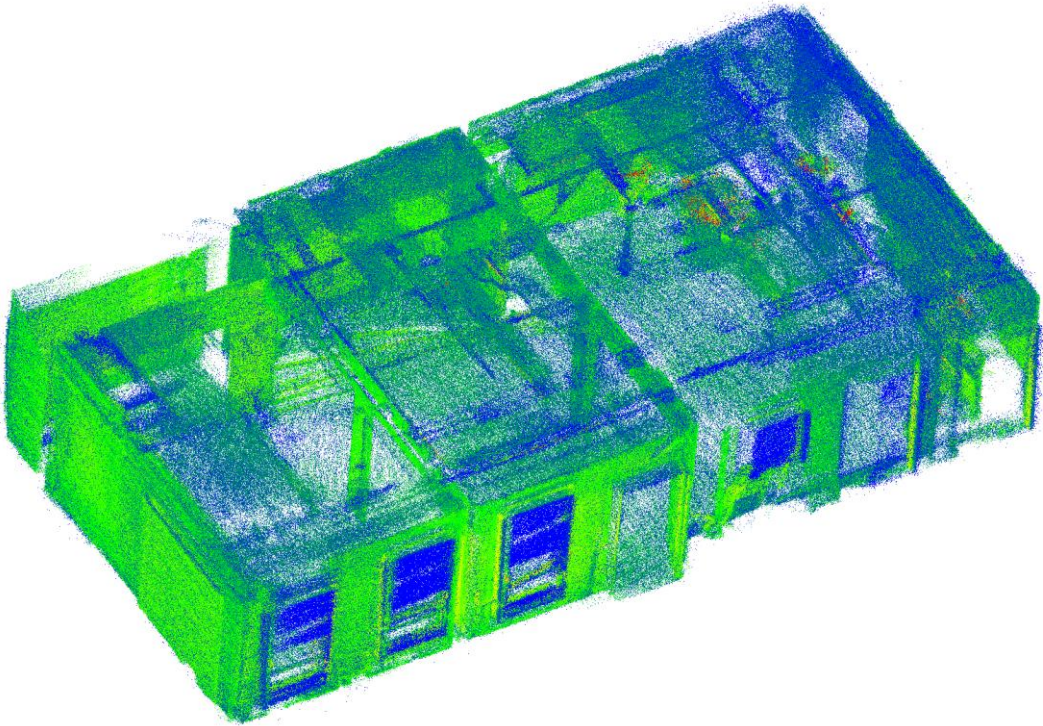


Autonomous mission execution – Outdoor Point-Of-View

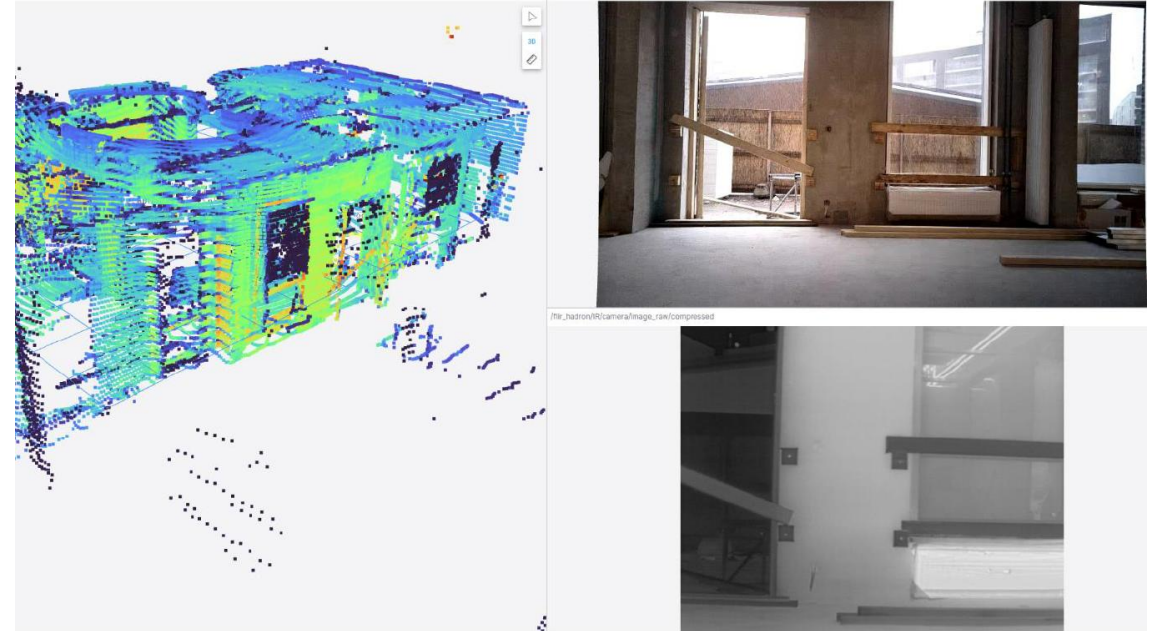
Autonomous Aerial Robots

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Offline Generated Map PointCloud

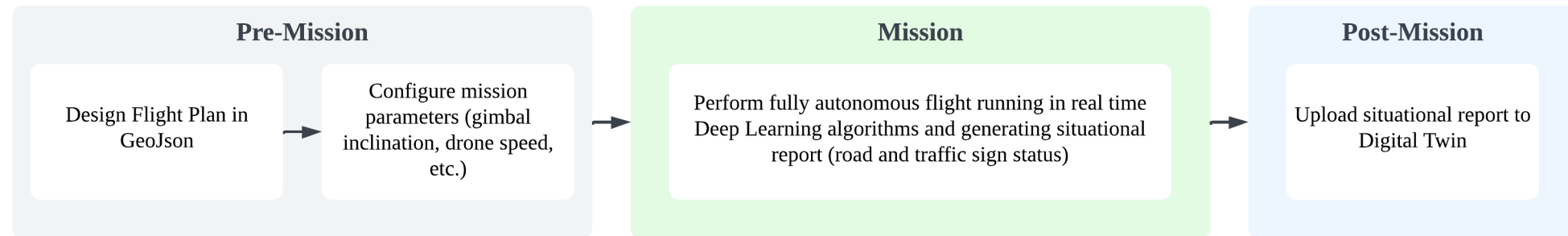


Example data gather for safety compliance checking

Autonomous Aerial Robots

Road Maintenance

- Main goals of the aerial robots in the case study:
 - Assess whether there are any unknown obstacles on the road or vegetation invading it.
 - Qualitatively estimate the condition of vertical traffic signs based on measurements from a 3D Lidar.



Road Maintenance Case Study Workflow

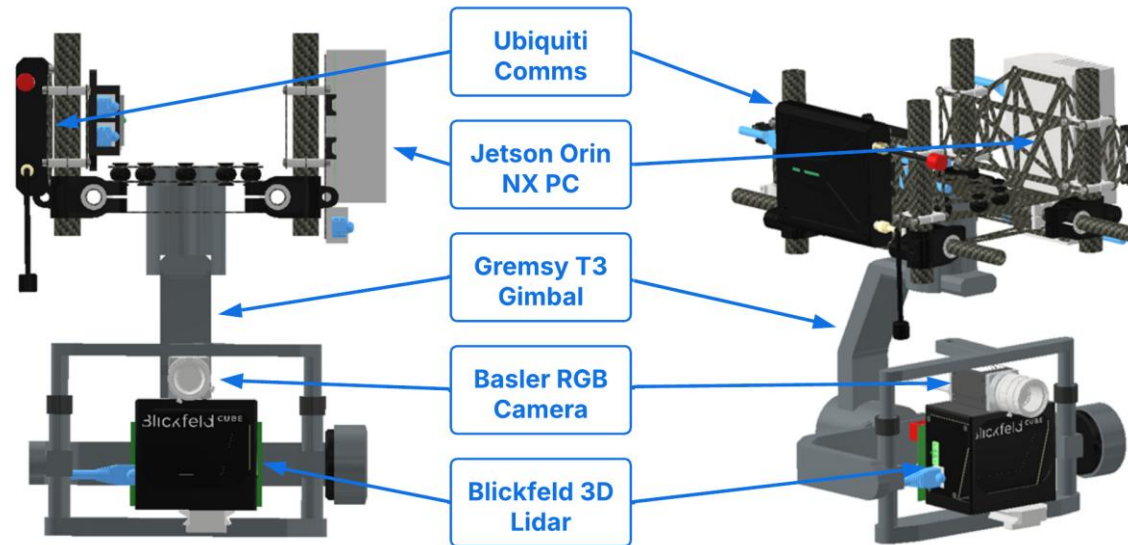
Autonomous Aerial Robots

Road Maintenance

- An analysis of the condition of the road and traffic signs will be carried out in real time and on board the aerial robot, which will perform autonomous flights in an obstacle-free environment.
- Aerial platform designed by CATEC with payload adapted to the case study.



CATEC C750 Drone with Road Maintenance Payload

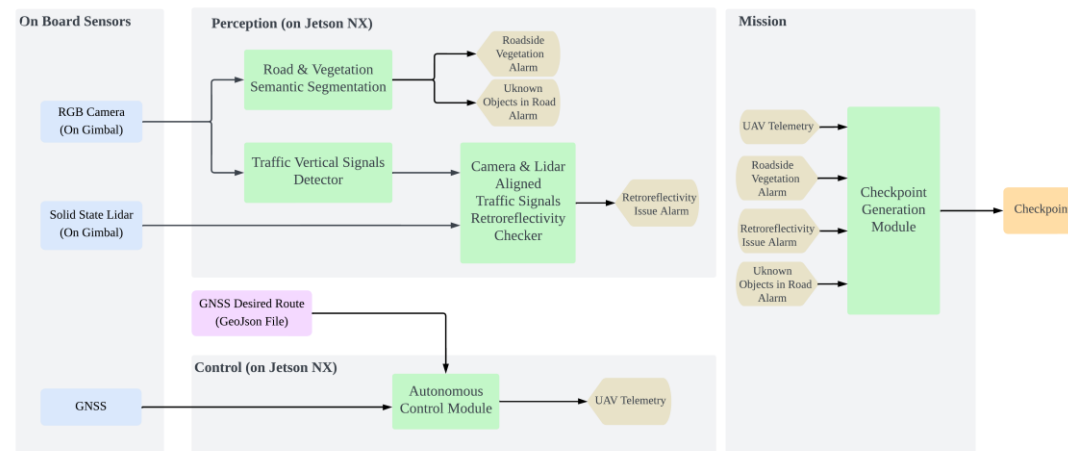


Road Maintenance Payload Components

Autonomous Aerial Robots

Road Maintenance

- Deep Learning-based onboard solutions for image analysis and automatic generation of alerts for subsequent inspections.
 - Road Semantic Segmentation for invading vegetation detection and obstacles.
 - Vertical traffic signs detection for retroreflectivity check alongside 3D Lidar measurements.



C750 Drone software architecture in road maintenance case study

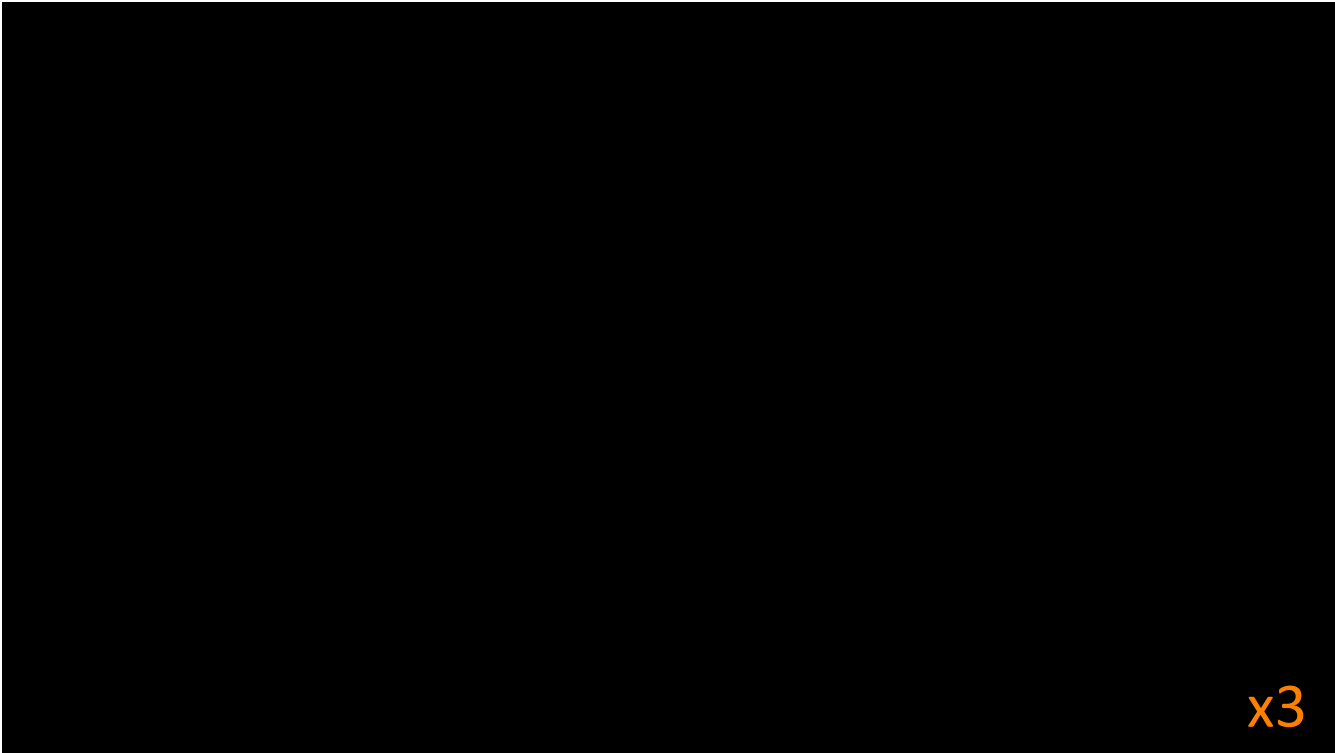
Autonomous Aerial Robots

Road Maintenance

- Tested developments in a real-world environment in a L'Aquila (Italy).



Planned Route on Mission Planner (Drone GCS)



Outdoor recording of C750 performing L'Aquila experiment

Autonomous Aerial Robots

Road Maintenance

- Tested developments in a real-world environment in a L'Aquila (Italy).



Vertical Traffic Sign Real-Time Detection

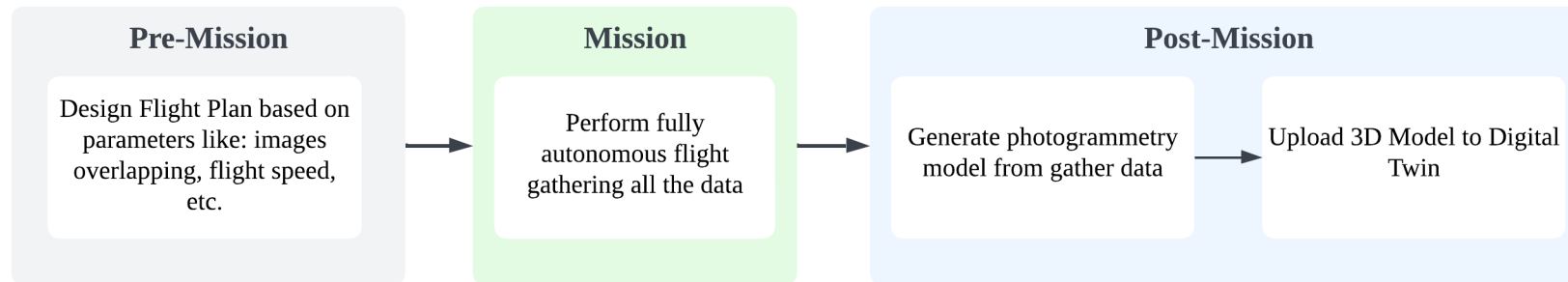


Road, vegetation & Obstacles Real-Time Segmentation

Autonomous Aerial Robots

Road Construction

- Main goals of the aerial robot in the case study:
 - Generate a 3D photogrammetry model at different stages of road construction.
 - These models can be used both as input for the AWL to plan routes and to calculate earthworks.



Road Construction Case Study Workflow

Autonomous Aerial Robots

Road Construction

- 3D models of the construction area will be generated using advanced photogrammetry techniques.
- Use of commercial aircraft with its specific payload: DJI M300 RTK + Zenmuse L1.

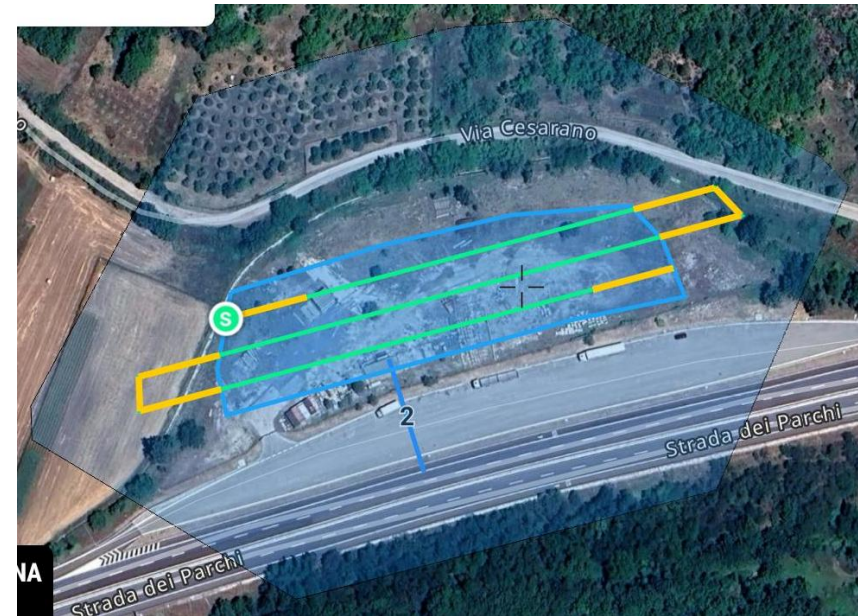
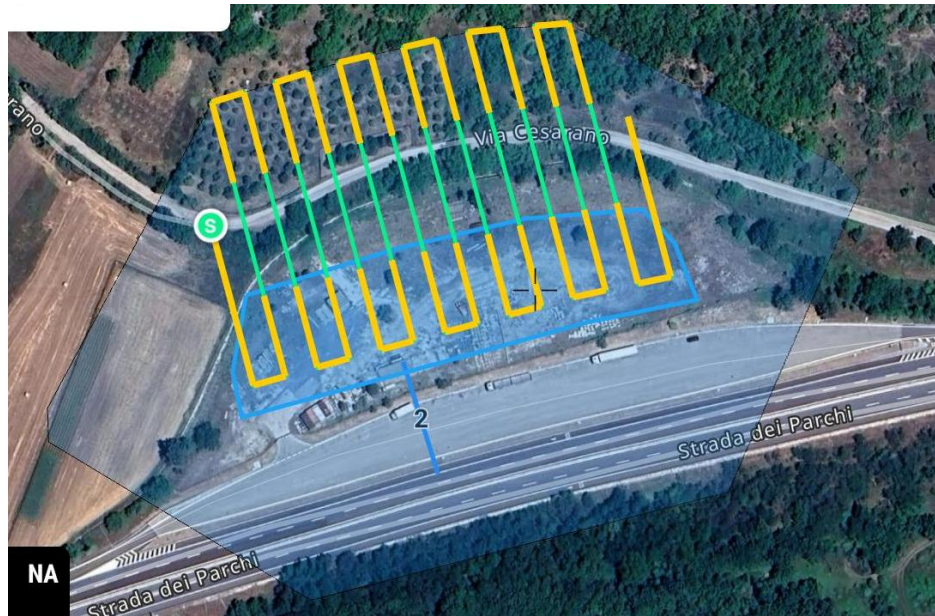


DJI M300 Aerial Robot with Zenmuse L1 Payload

Autonomous Aerial Robots

Road Construction

- Tested developments in a real-world environment in a L'Aquila (Italy).
- Models were created on three different days, moving a pile of sand to calculate the earthworks. In all three models, the volume of earth has been measured at approximately 29 m³.



Different trajectories made over the same area to obtain the greatest amount of detail.

Autonomous Aerial Robots

Road Construction

- Tested developments in a real-world environment in a L'Aquila (Italy).



Photogrammetry model example

Autonomous Aerial Robots

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- Models were created on three different days, moving a pile of sand to calculate the earthworks.



Projection of the generated model over Google Maps



Location of the soil mount on first day

Autonomous Aerial Robots

Road Construction

- Tested developments in a real-world environment in a L'Aquila (Italy).
- Models were created on three different days, moving a pile of sand to calculate the earthworks.



Projection of the generated model over Google Maps



Location of the soil mound on second day

Autonomous Aerial Robots

Road Construction

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- Models were created on three different days, moving a pile of sand to calculate the earthworks.



Projection of the generated model over Google Maps



Location of the soil mount on third day

Autonomous Aerial Robots

Road Construction

- Tested developments in a real-world environment in a L'Aquila (Italy).
- Models were created on three different days, moving a pile of sand to calculate the earthworks.



Detailed screenshots of the location of the mount of soil on first day.



Detailed screenshots of the location of the mount of soil on second day.

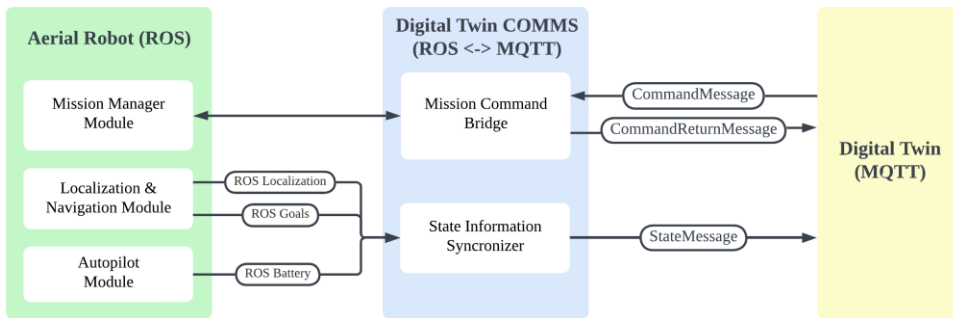


Top: First and second day mount of soil location;
Bottom: Detailed screenshots of the mount of soil on third day.

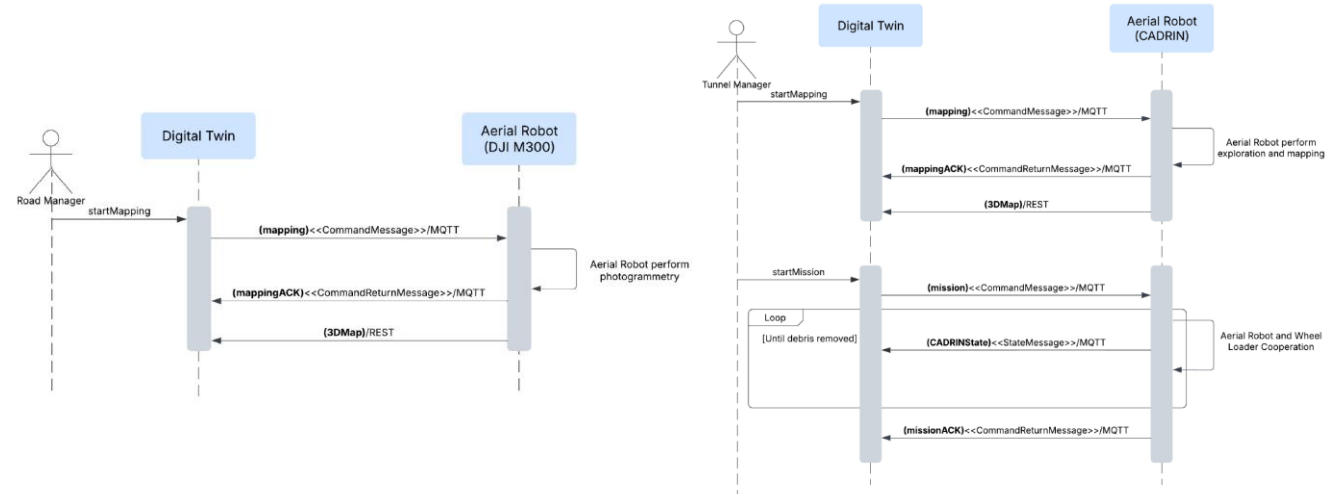
Autonomous Aerial Robots

Digital Twin Integration

- Mission Control & Monitoring → MQTT Communications.
- Download planned mission or upload generated data → REST-API



Communication Diagram Between Aerial Robots and Digital Twin



Examples of refined UML Communication Diagram (Left: Road Construction; Right: Tunnel Construction)