

Lessons Learned from Mount Etna: Autonomous Gas Monitoring for Volcanic Environments with a Legged Robot

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Why do we need autonomous exploration on a volcano?

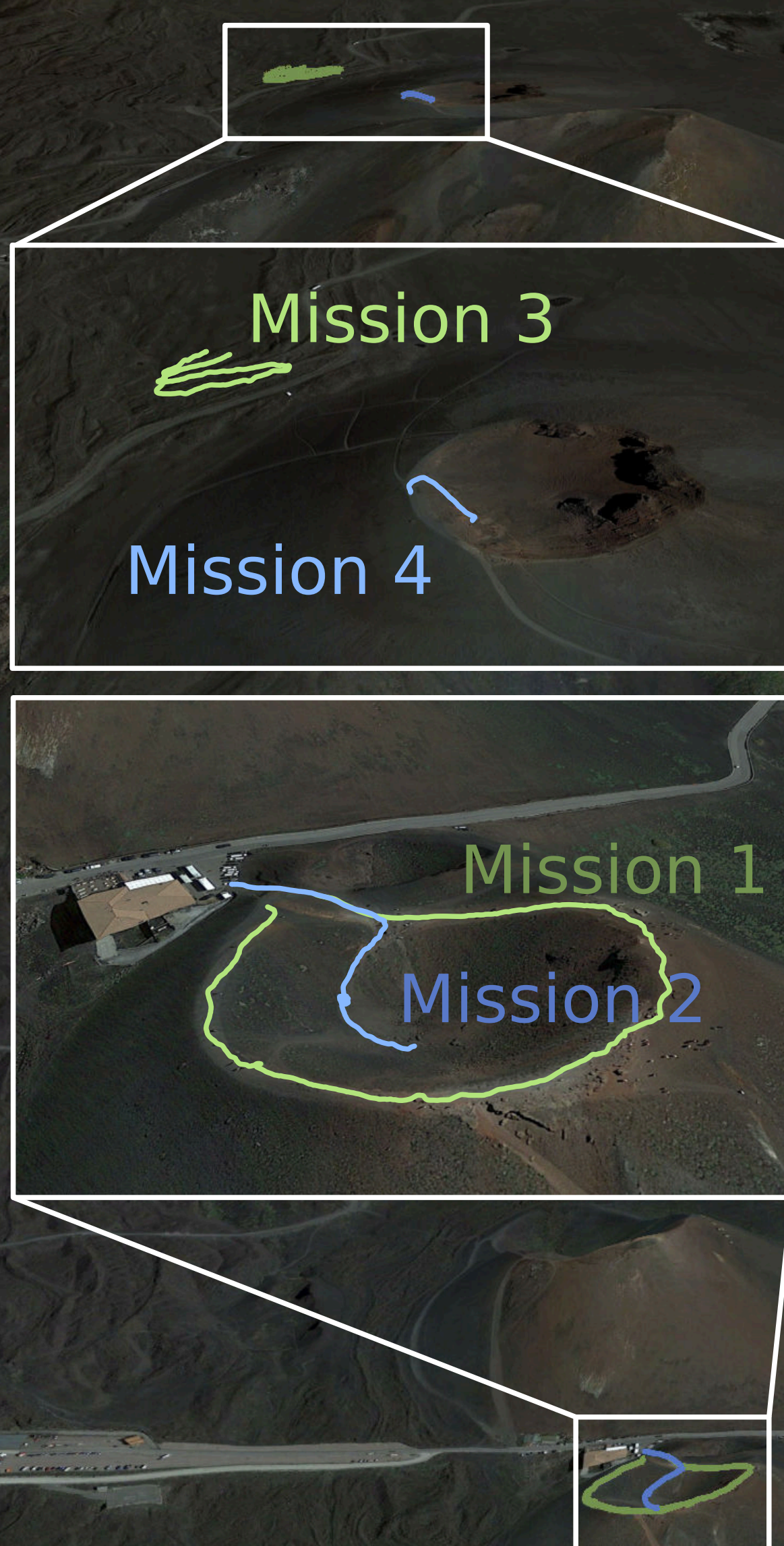
- Volcanic gas monitoring predicts eruptions
- Source-proximal measurements are dangerous for humans
- UAVs cannot reach ground-proximal fumaroles; UGVs lack the locomotion capability for rugged volcanic terrain
- Unreliable radio links demand autonomous operation; full autonomy remains undemonstrated in this domain

Deployments

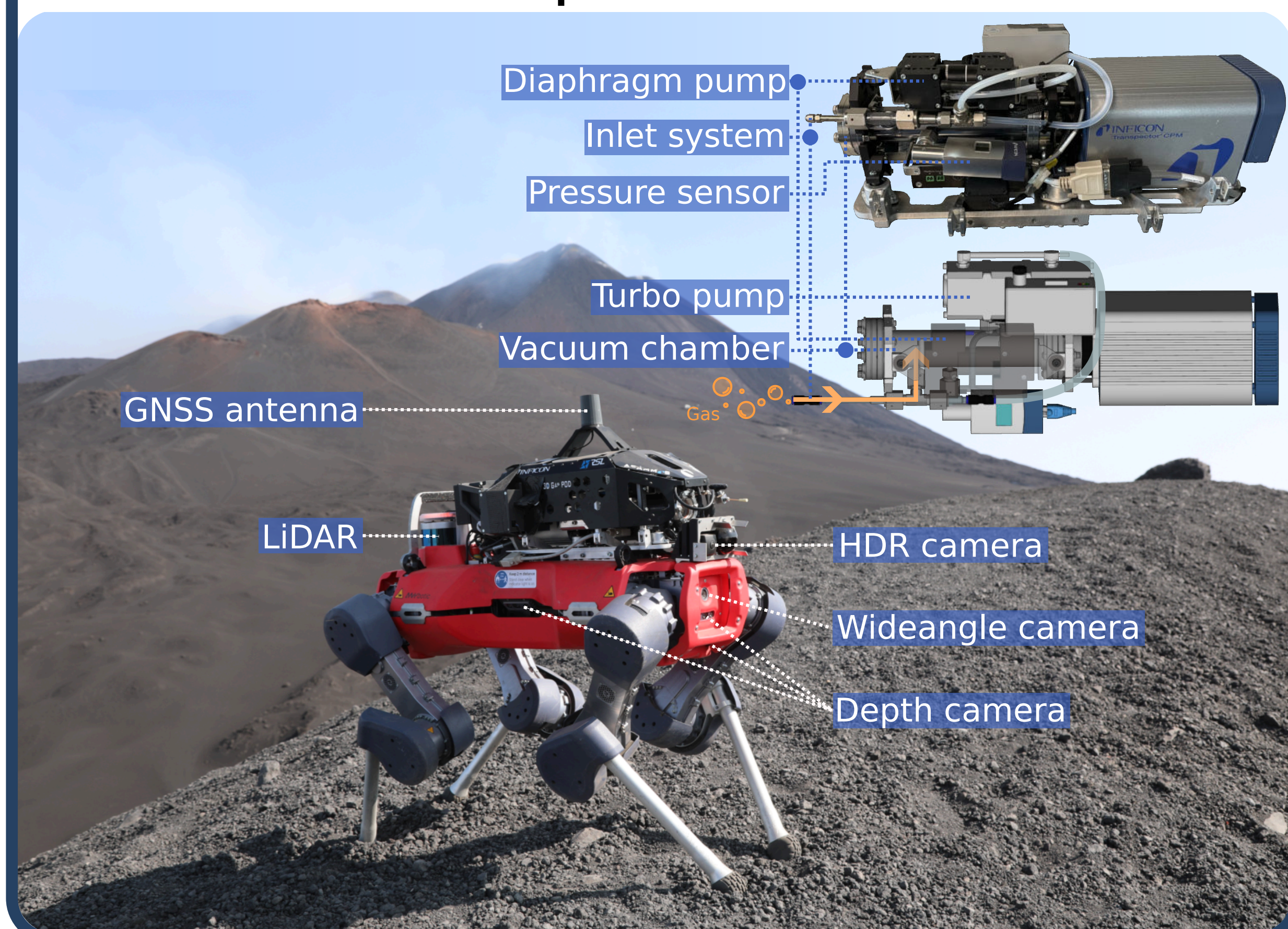
3 Autonomous Missions

- Autonomy Rate 93-100%, Robot Attention Demand <0.1
- Detected 5/8 deployed gas sources

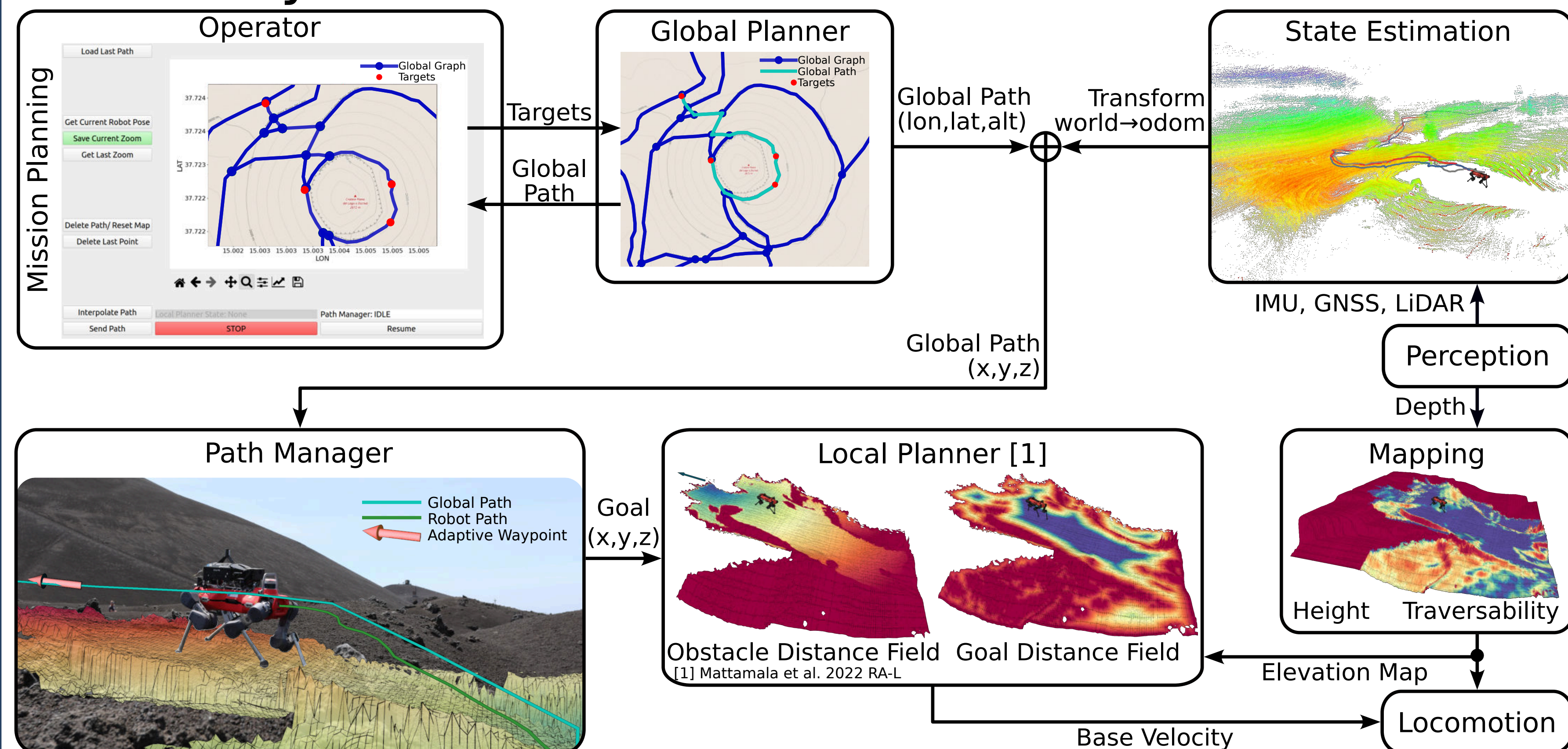
1 Teleoperated Mission
- First ground robot to measure natural fumaroles



Hardware Setup



Autonomy Stack



Lessons Learned

- Failure of gas source localization in **high-wind conditions** → **visual plume tracking** as a viable alternative
 - **Insufficient fidelity of satellite imagery** for local waypoint following → **tighter local-global planner coupling**
 - Visual appearance as **unreliable traversability** indicator → **foot contact sensing**
 - **Fine sand on steep slopes** as key barrier to fumarole access → **adaptive foot design** and **loose-soil locomotion**
 - Missing **shielding from volcanic dust** and sand → improved **sensor enclosures**
- Operational challenges: **limited power budget** for robot and operator pc & **restricted terrain accessibility**
→ reduced on-site testing time and iterative deployment cycles