電機資訊學院 2026 作 BRAIN PLUS HAND 實作專題競賽

Hybrid Environment-Resilient Multi-sensor Exploration System

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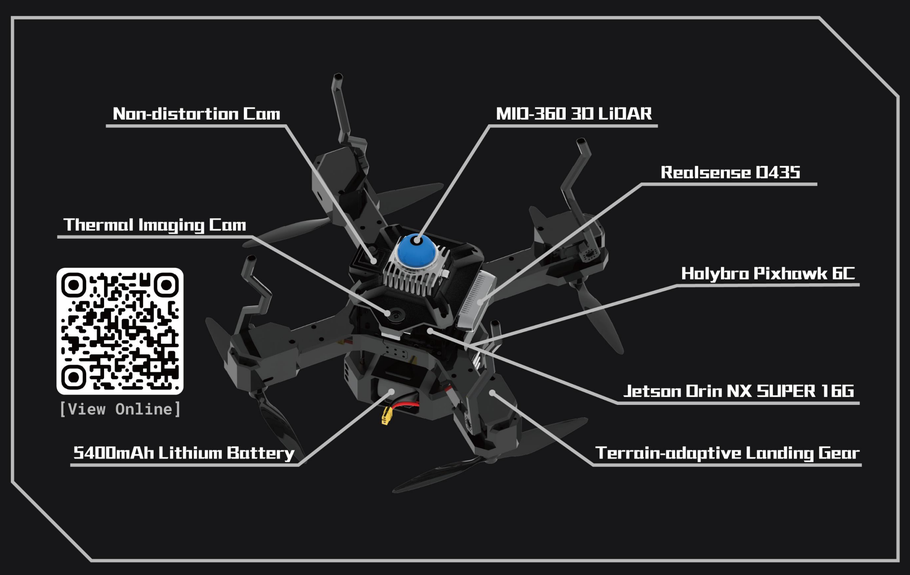
- Abstract -

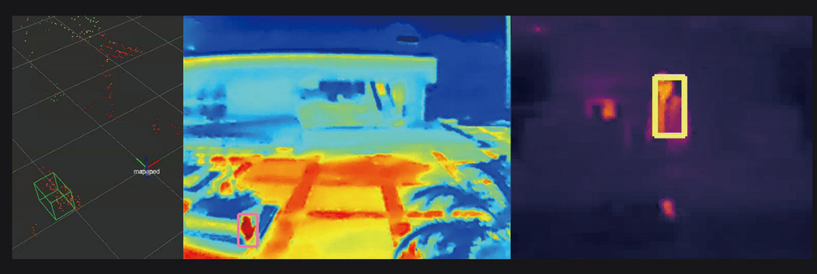
The **HERMES** platform is developed as a low-cost, highly replicable, and open-source end-to-end testbed for resilient multi-sensor exploration, providing an accessible foundation for both research and educational use. Integrating 3D LiDAR, RGB-D (RealSense), and thermal imaging, the system supports the development and evaluation of perception and navigation pipelines under challenging conditions such as wildfires, dense fog, and rainfall. High-resolution and easily obtainable aerial imagery, combined with SfM-based reconstruction, is used to generate coarse environmental models that facilitate autonomous path planning without the need for prior field mapping.

- Payload -



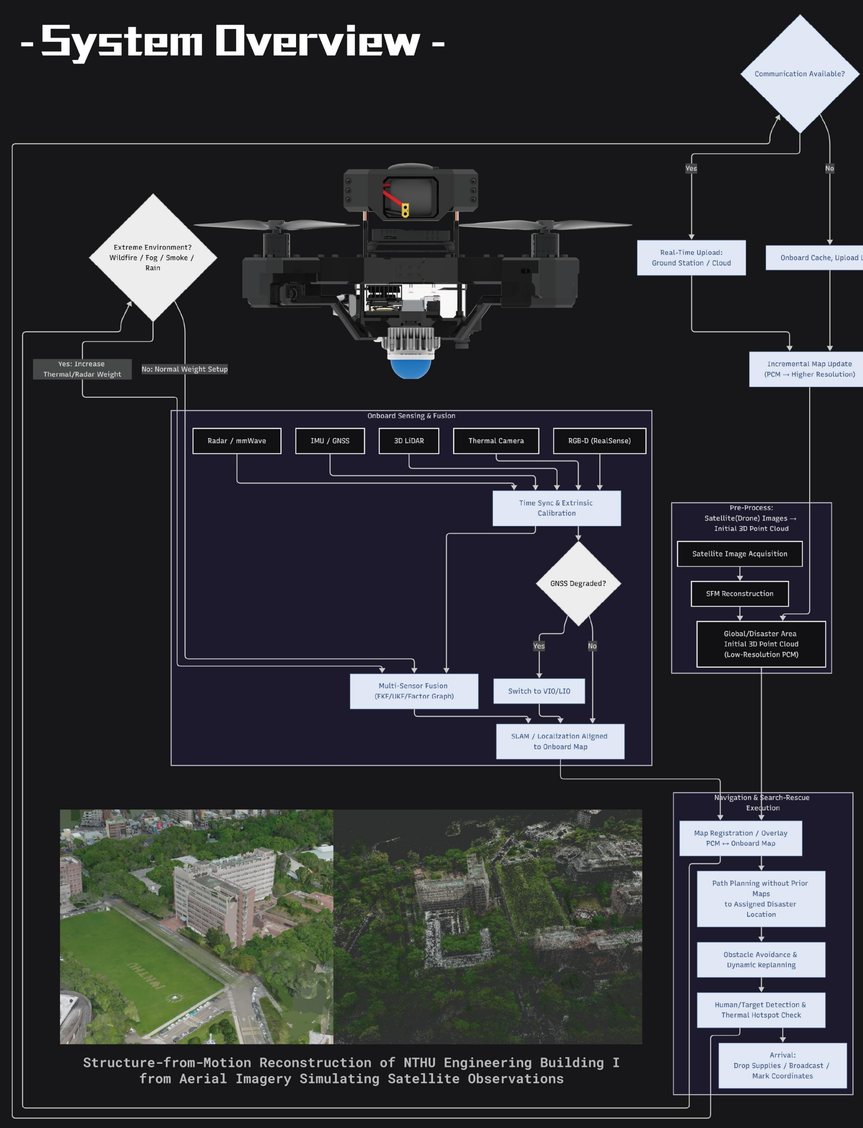
- Experimental Results -

The HERMES platform integrates multi-sensor perception and navigation on a single UAV, combining **FAST-LIO2 LiDAR-IMU SLAM**, **ICP-based global localization**, and PX4 EKF fusion for robust state estimation. On the perception side, **thermal Lucas-Kanade optical -flow** with **DBSCAN clustering**, **LiDAR-based DBSCAN obstacle detection**, and **RGB-based YOLO** enable human detection under low-visibility and normal-light conditions. The overall system is developed on **ROS2 + PX4** and validated both in **Isaac Sim** and real-world flights.

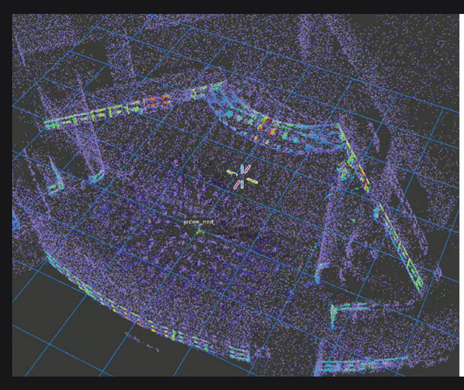


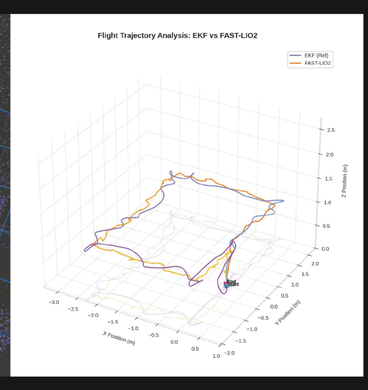
The perception module integrates complementary sensing pipelines to ensure reliable detection across diverse environments. **LIDAR-BASED DBSCAN** clustering with **VOXEL FILTERING** groups consistent 3D structur -es and suppresses sparse noise, enabling robust obstacle awareness. For human detection, **THERMAL LUCAS-KANADE OPTICAL-FLOW** isolates moving heat signatures under low visibility, while RGB-BASED YOLO provides high-confidence recognition in normal-light scenes. Together, these sensing channels form a unified perception stack that enhances the UAV's ability to detect objects and humans across challenging conditions.

- System Overview -



Structure-from-Motion Reconstruction of NTHU Engineering Building I from Aerial Imagery Simulating Satellite Observations





The system demonstrates **LIDAR-CENTRIC MAPPING** and localization in real environments.

The left figure shows **FAST-LIO2 MAPPING** and **ICP ALIGNMENT** inside *NTHU Engineering Building I*, where local scans are continuously fused into the global **IKD-TREE** map with high geometric consistency.

The right figure compares PX4 EKF with FAST-LIO2 ODOMETRY, showing that LiDAR-IMU fusion yields smoother trajectories and significantly lower drift, especially during cornering and repeated loop paths.

- DEMO -

- Conclusion & Future Work -

By November, the HERMES hardware, onboard software interfaces, and core sensing modules have been completed, alongside a simulation environment built with the Pegasus Simulator Framework on **Isaac Sim**. Open-source contributions were released to make the platform accessible to beginners. Future work will focus on deeper system integration and expanding the platform's capabilities.

HERMES