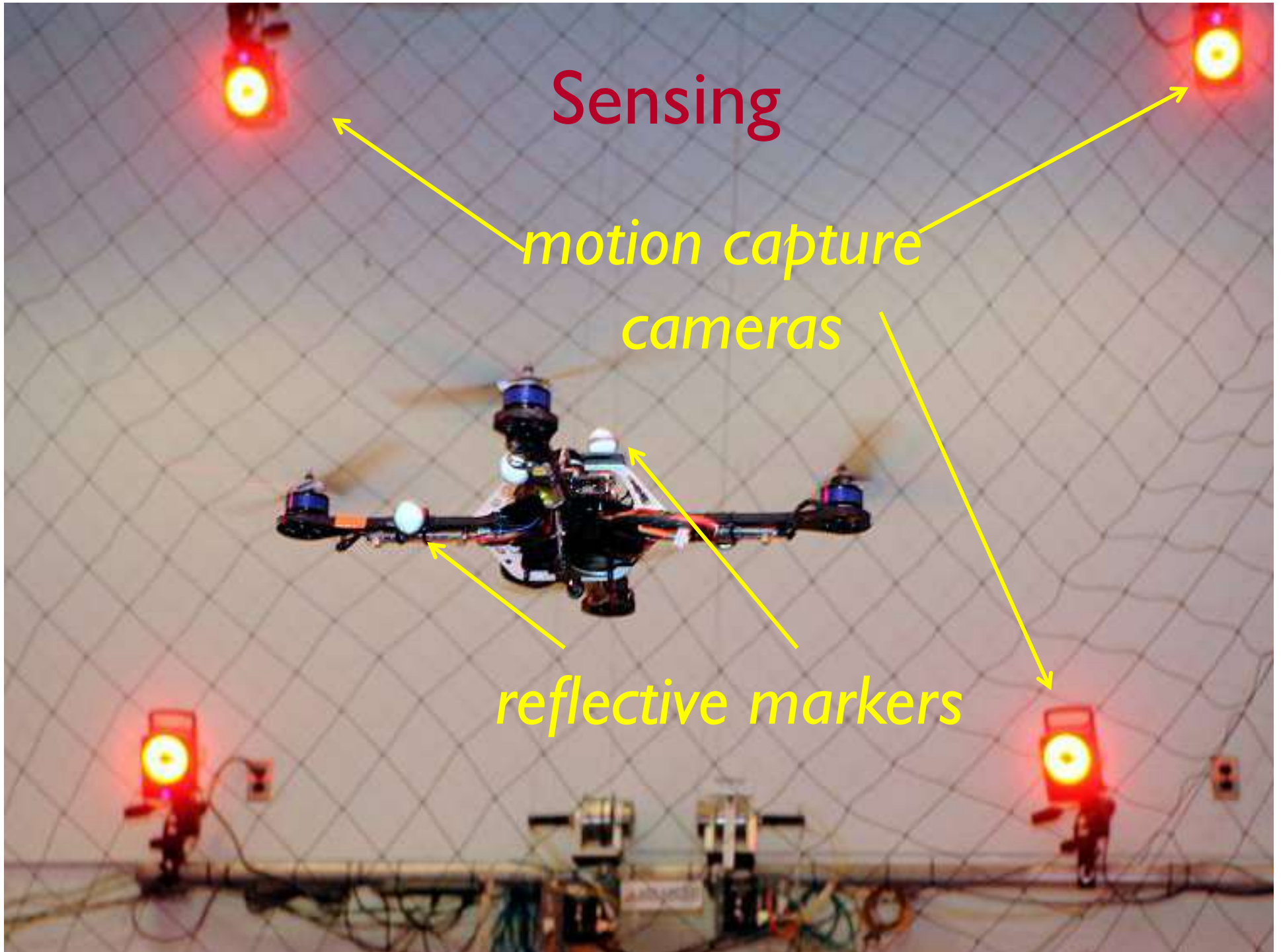


Sensing and Estimation

Sensing

*motion capture
cameras*

reflective markers



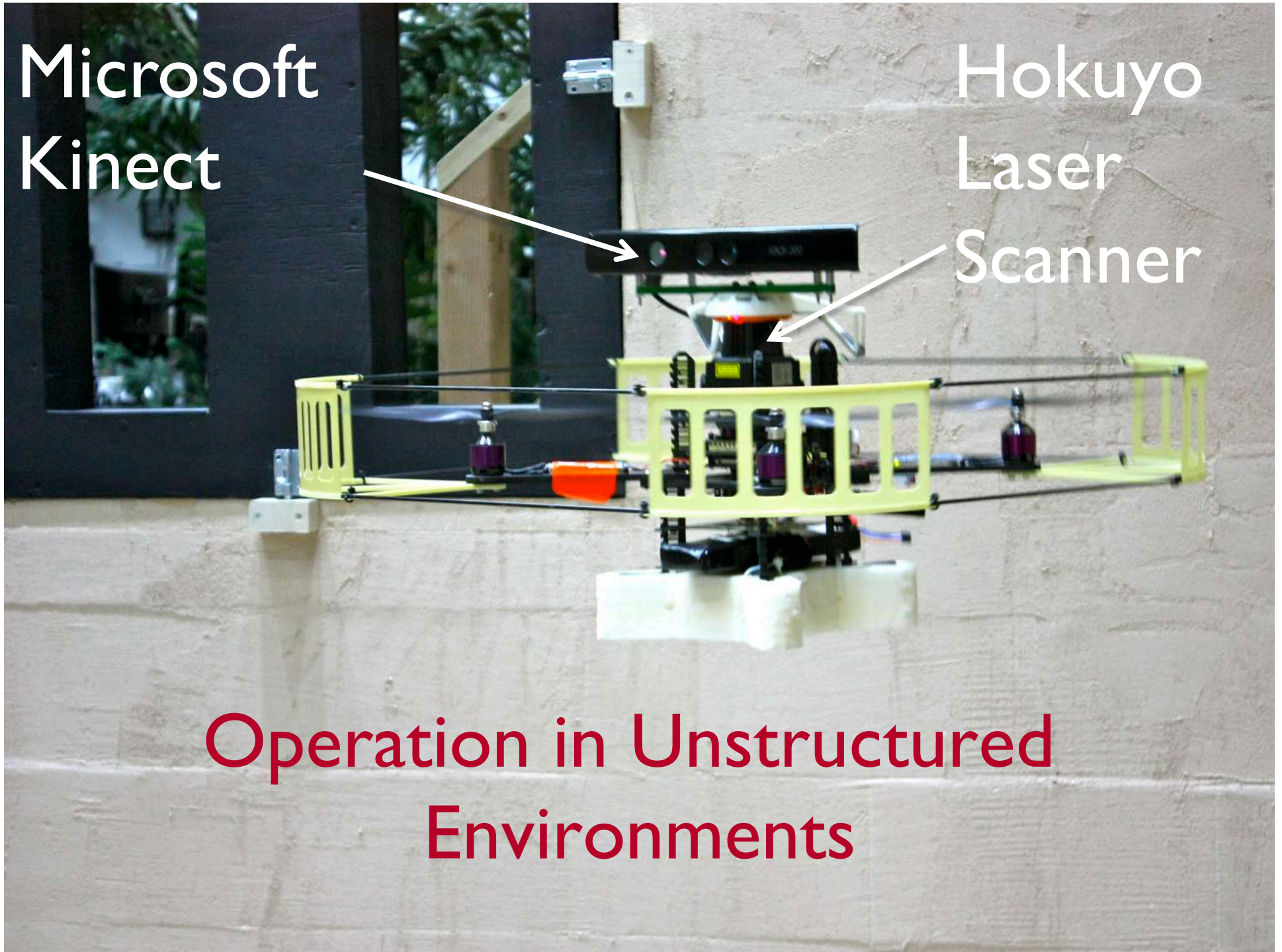
A photograph of a modern interior space, likely a lobby or atrium. The walls are made of large, dark grey stone tiles. A glass-enclosed staircase is visible on the left side. In the center, there is a large window or glass partition. Below the window, there is a wall with vertical wooden slats. The floor is made of dark grey tiles. The text "Onboard State Estimation" is overlaid in yellow.

Onboard State Estimation

Microsoft
Kinect

Hokuyo
Laser
Scanner

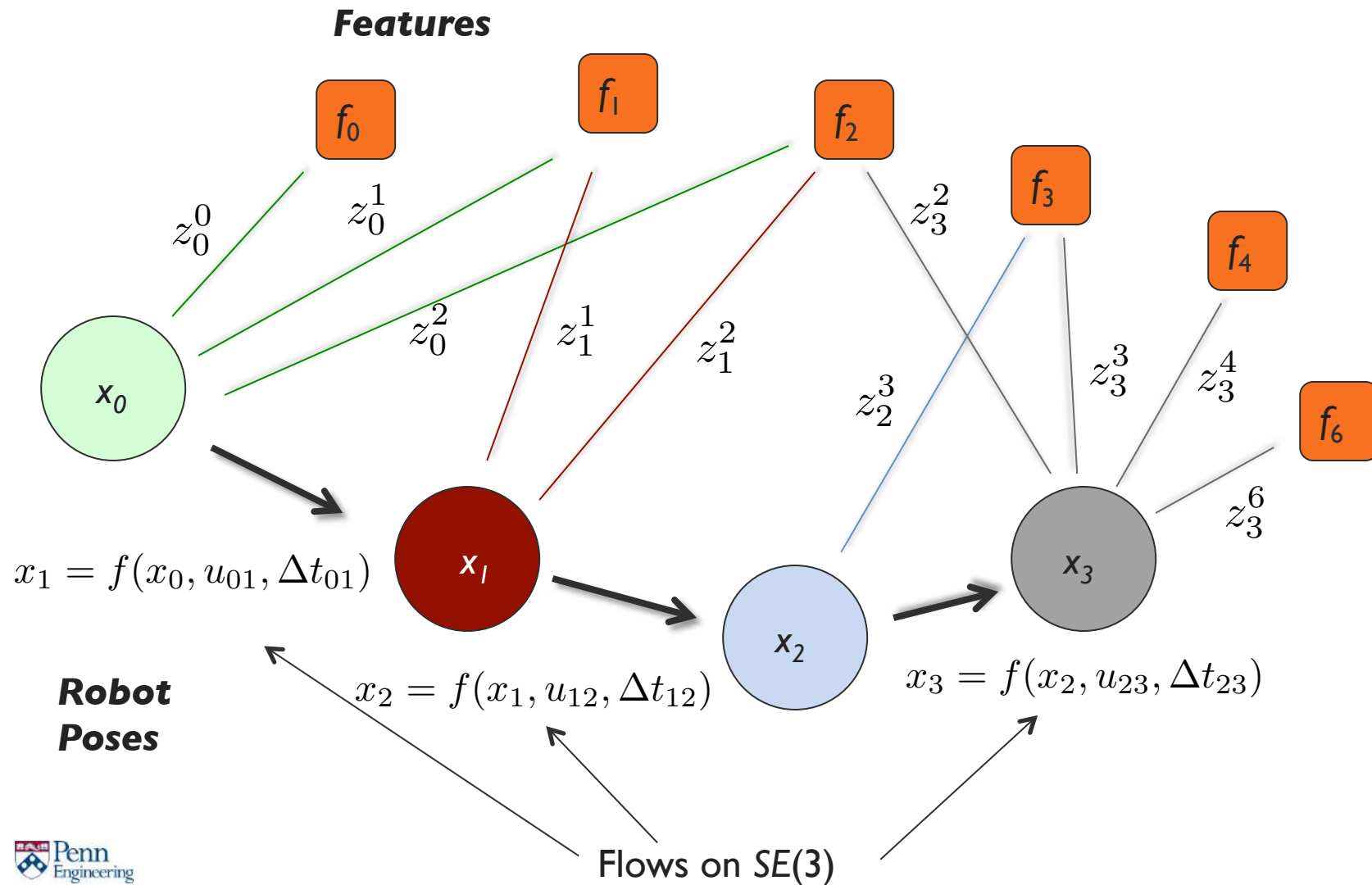
Operation in Unstructured
Environments



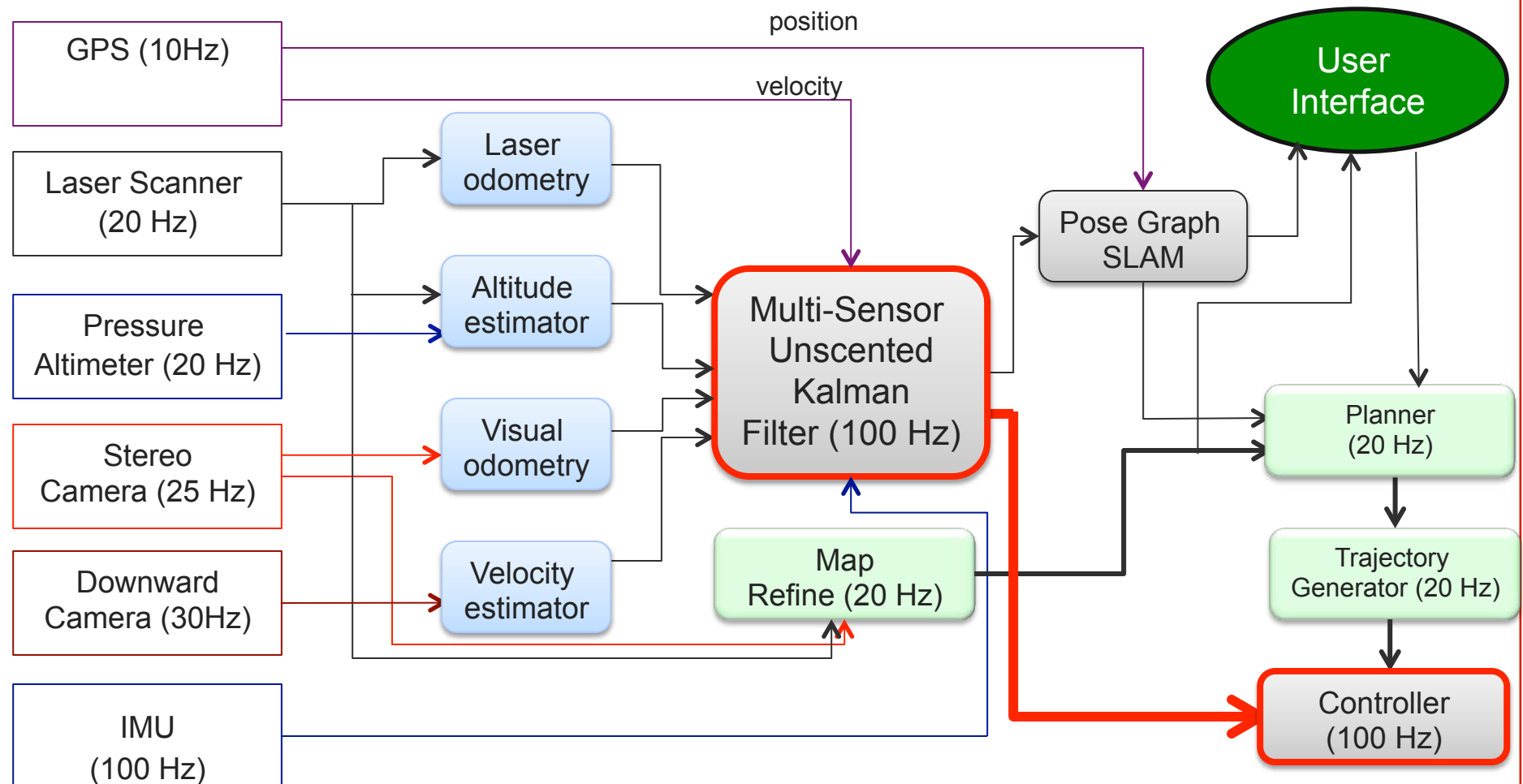


Shaojie Shen, Yash Mulgaonkar, Nathan Michael and Vijay Kumar, "Multi-Sensor Fusion for Robust Autonomous Flight in Indoor and Outdoor Environments with a Rotorcraft MAV," *Proceedings of IEEE International Conference on Robotics and Automation (ICRA)*, 2014.

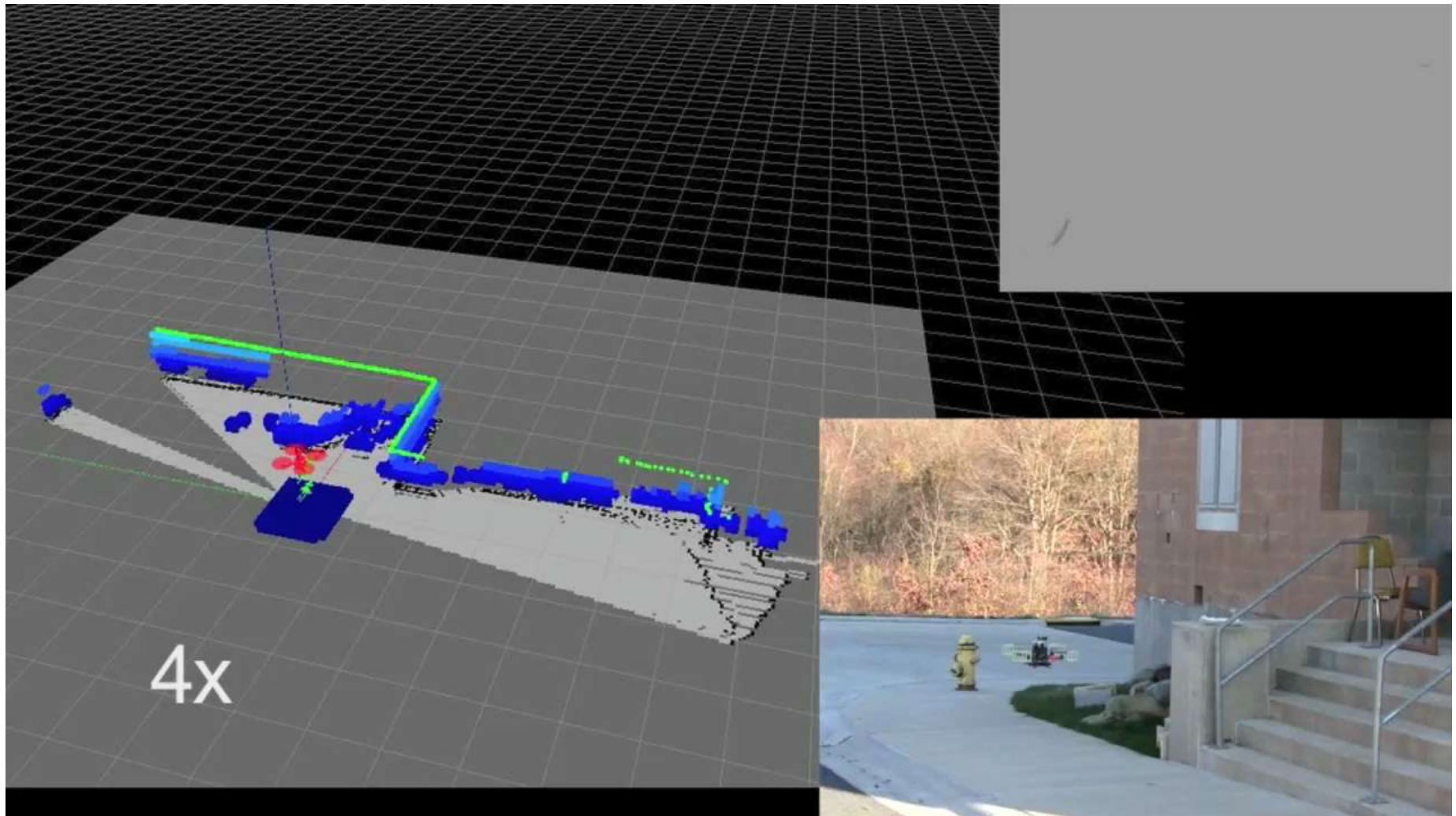
Simultaneous Localization and Mapping also Structure from Motion



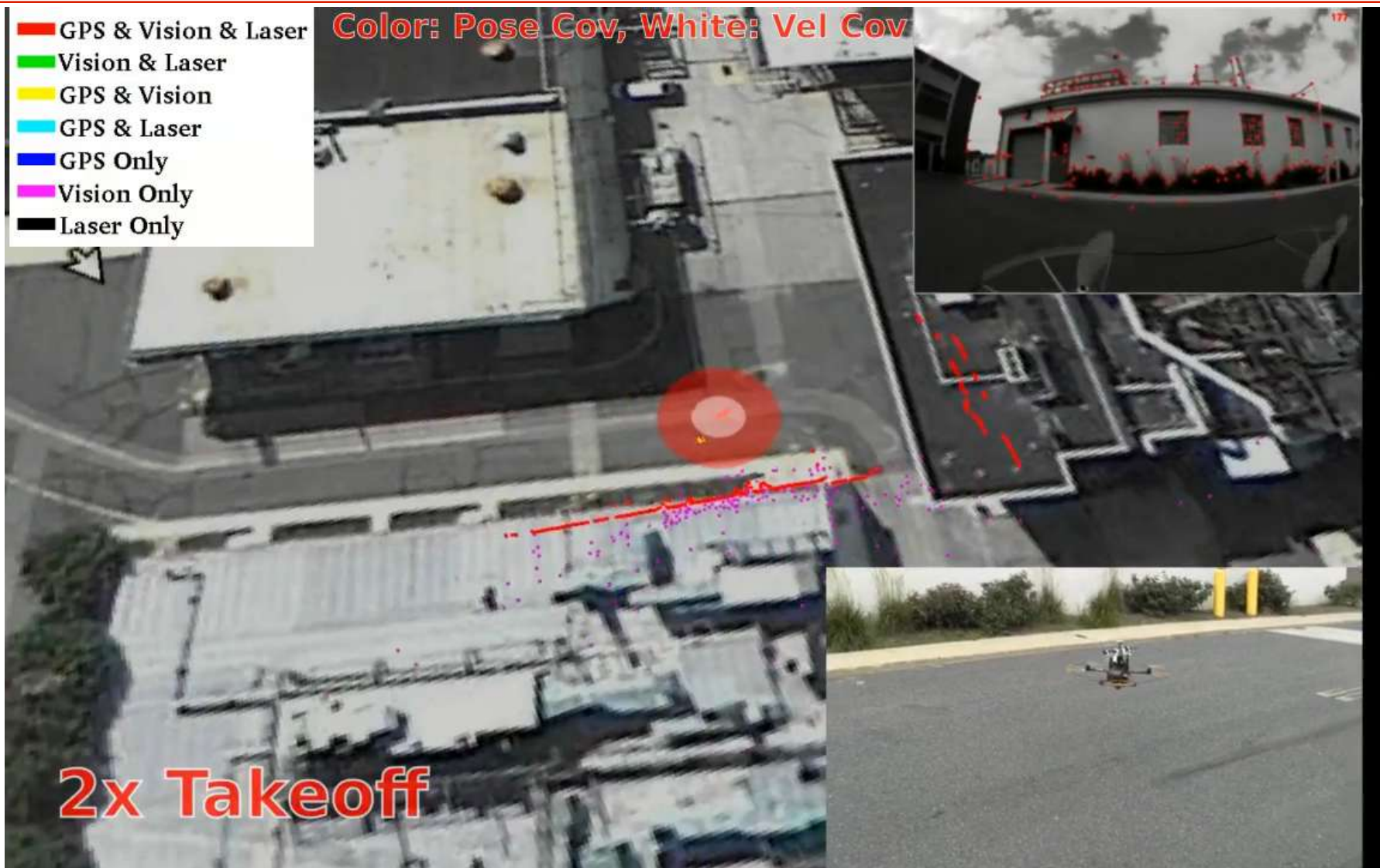
Estimation and Control Architecture



Onboard State Estimation



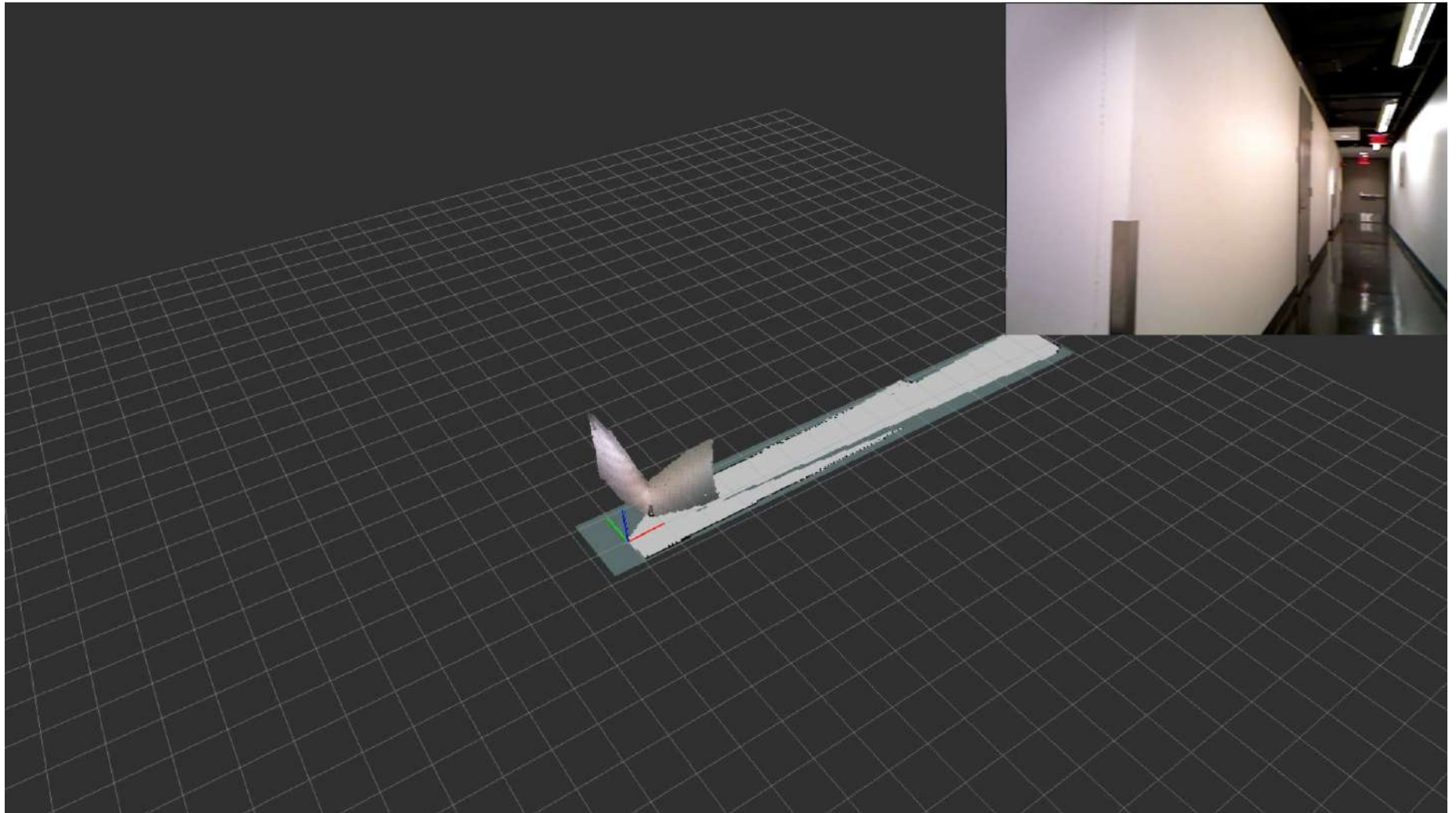
S. Shen, N. Michael and V. Kumar, "Autonomous navigation in confined indoor environments with a micro-aerial vehicle," *IEEE Robotics and Automation Magazine*, 2013

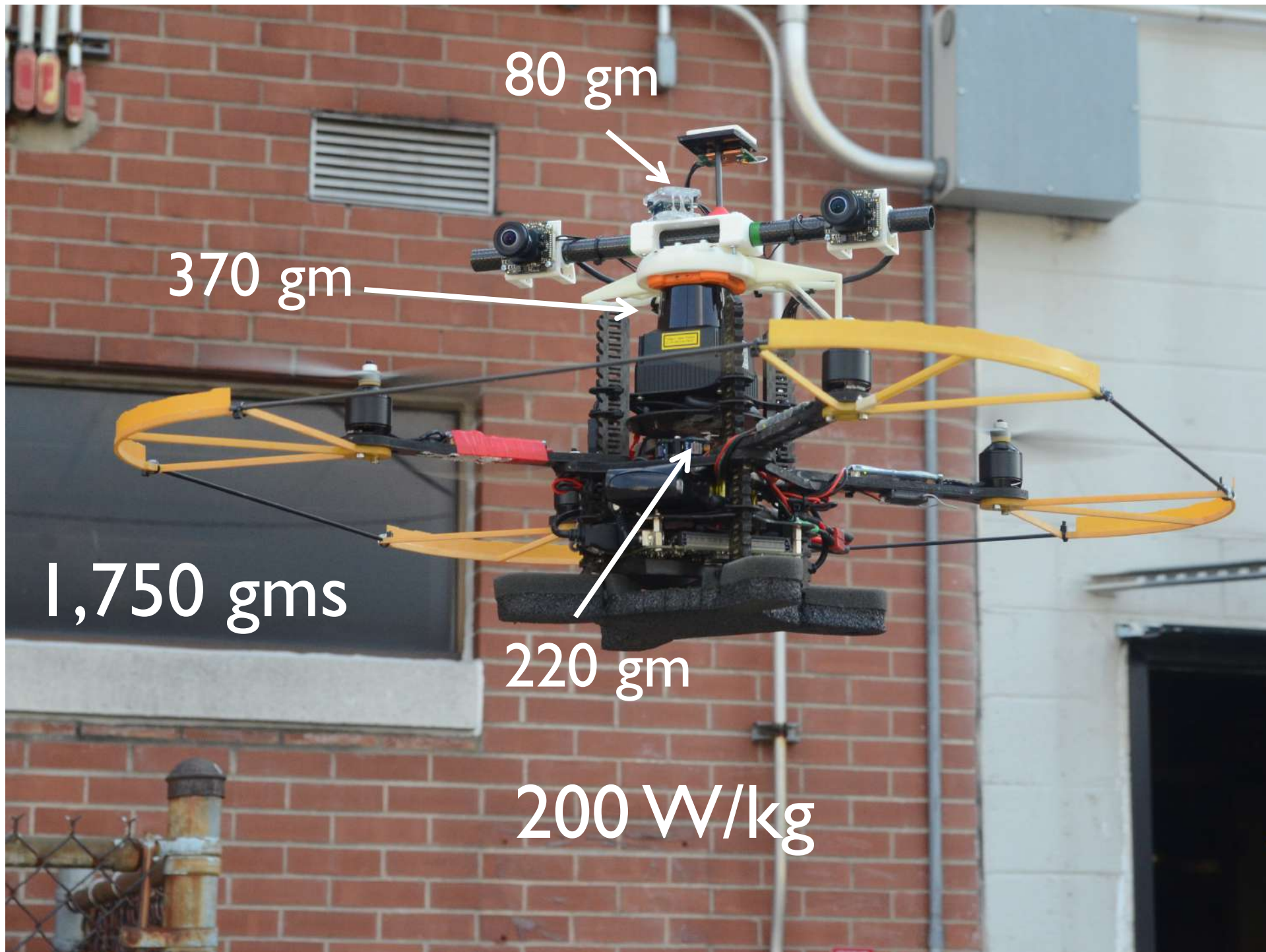


$\frac{1}{2}$ km, 1.5 m/s, indoor/outdoor

Shaojie Shen, Yash Mulgaonkar, Nathan Michael and Vijay Kumar, “Multi-Sensor Fusion for Robust Autonomous Flight in Indoor and Outdoor Environments with a Rotorcraft MAV,”

Indoor Navigation and Mapping





Systems Design Considerations

- Larger vehicles are more capable (better sensors, processors)
- Larger vehicles can exhibit longer missions (bigger batteries)
- Smaller vehicles can navigate in more constrained environments
- Smaller vehicles are more agile and maneuverable