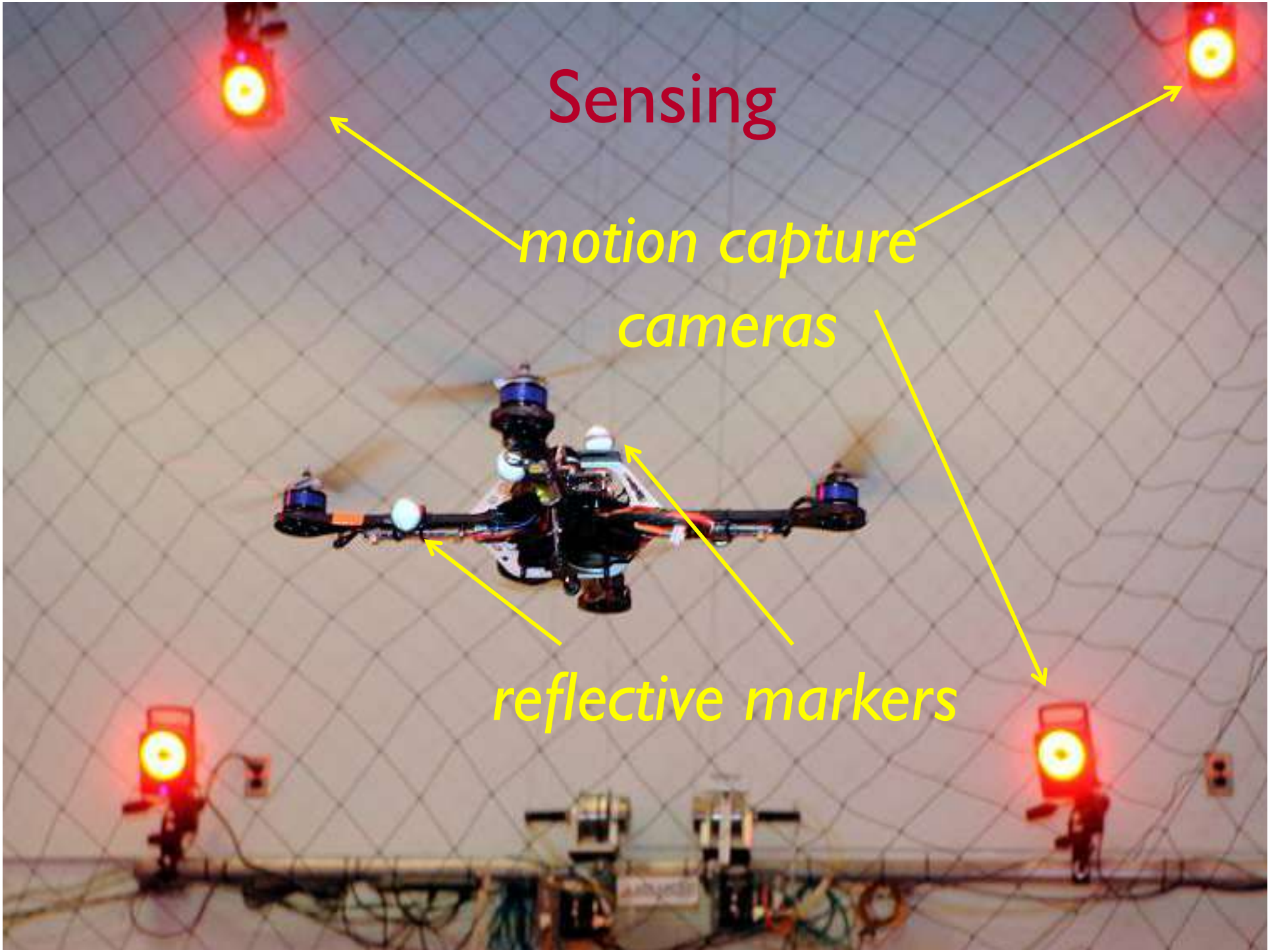
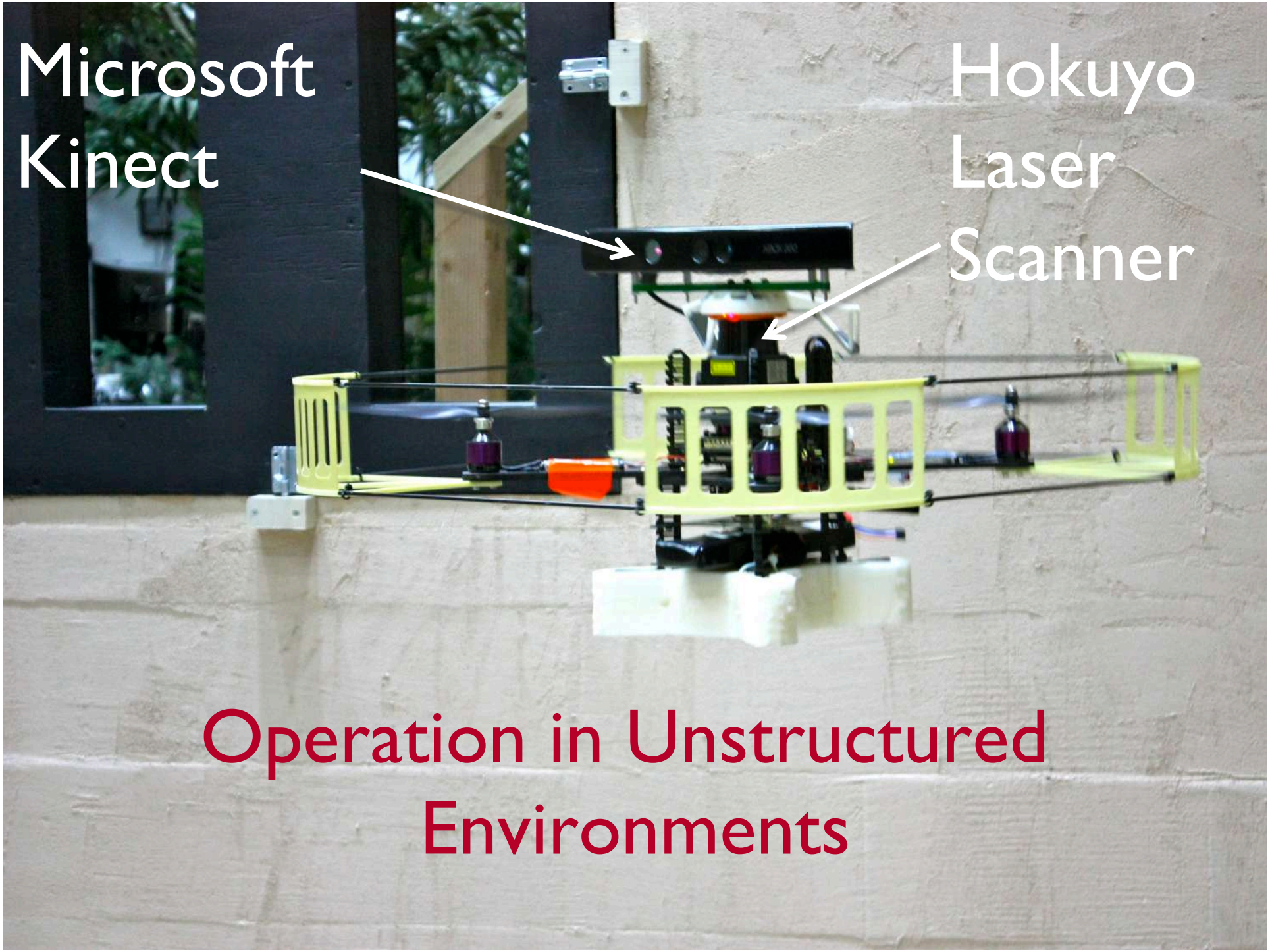
Sensing and Estimation


Sensing
motion capture cameras
reflective markers

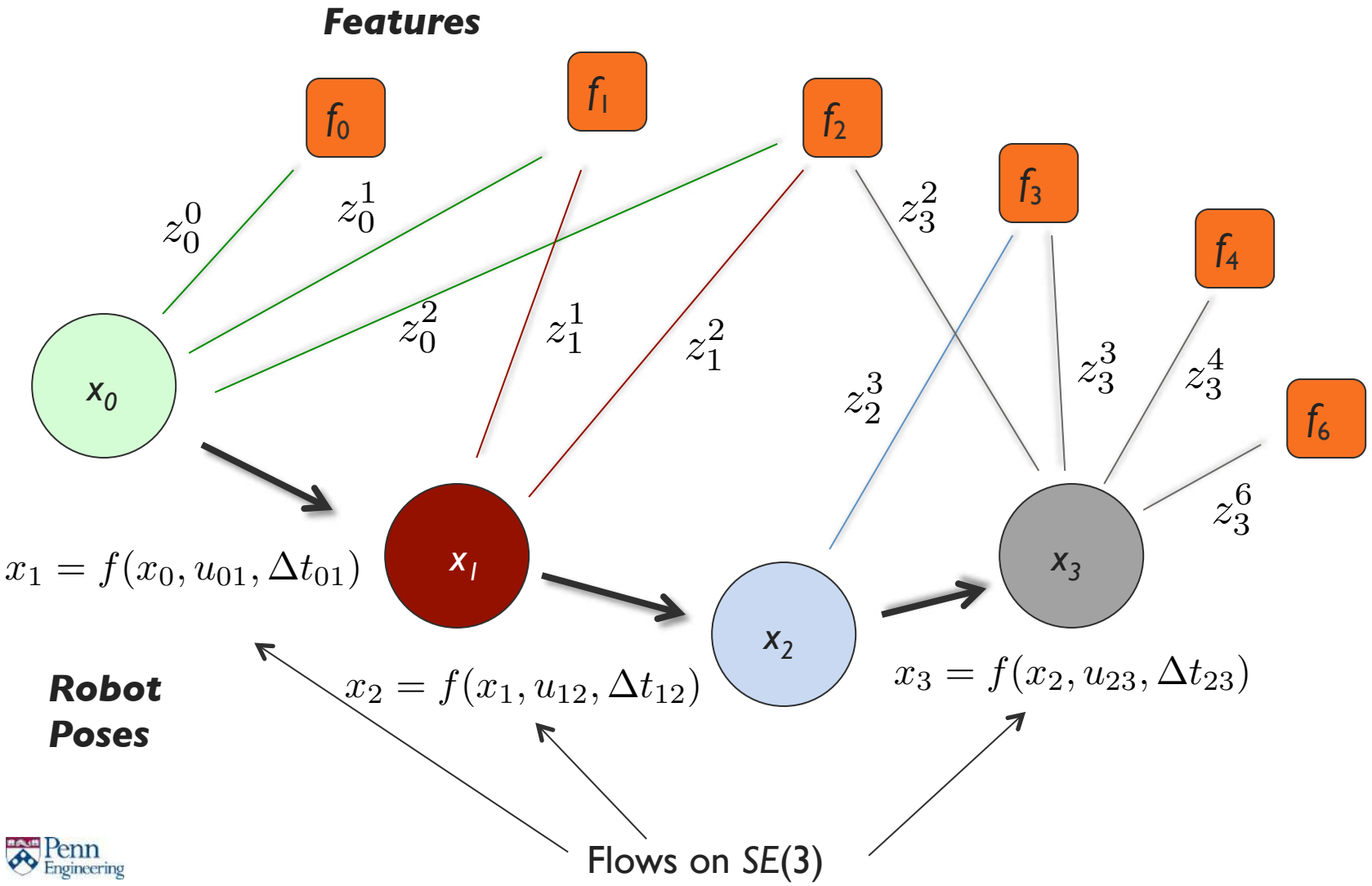

Onboard State Estimation



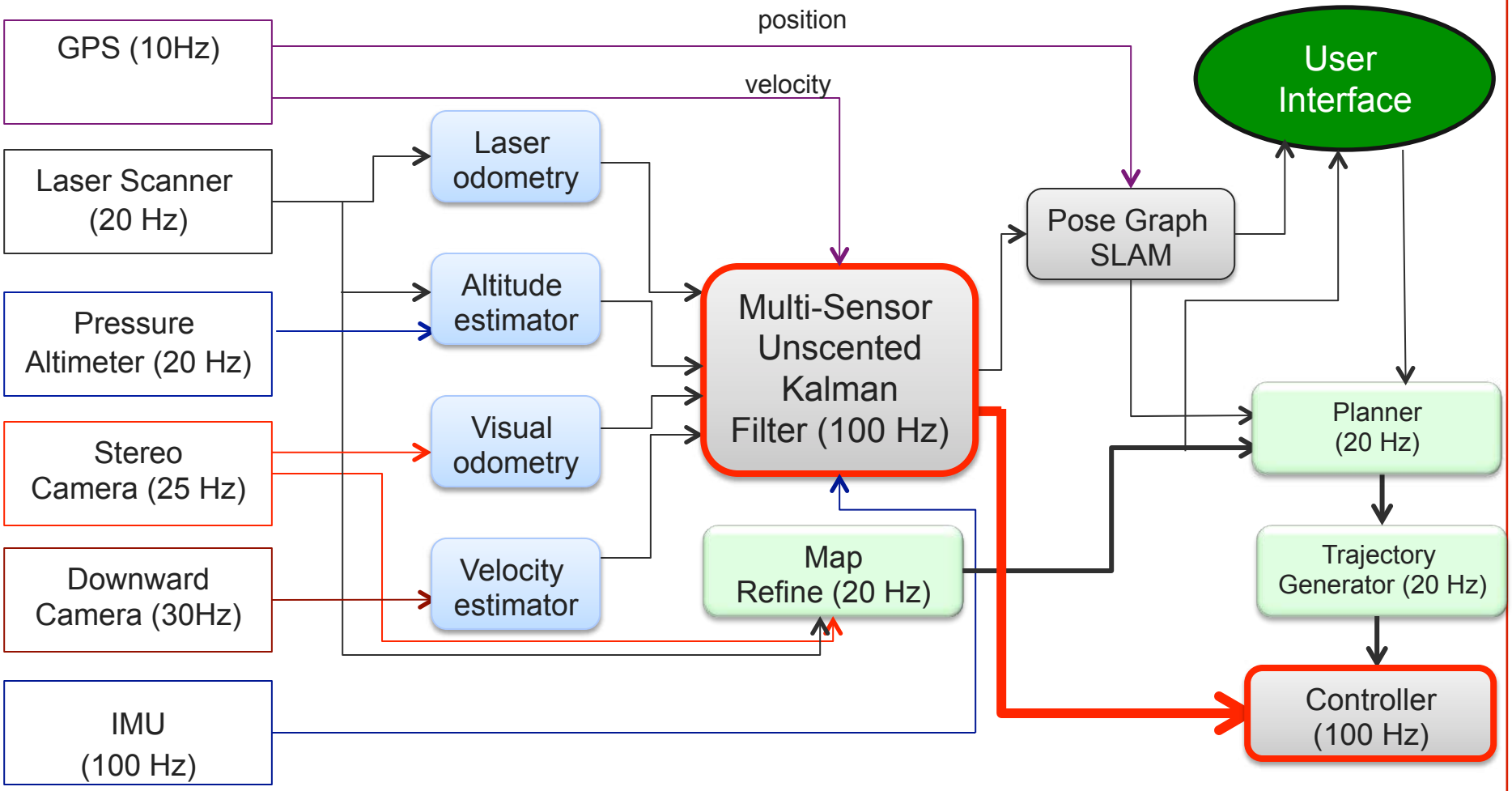
Operation in Unstructured Environments

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.

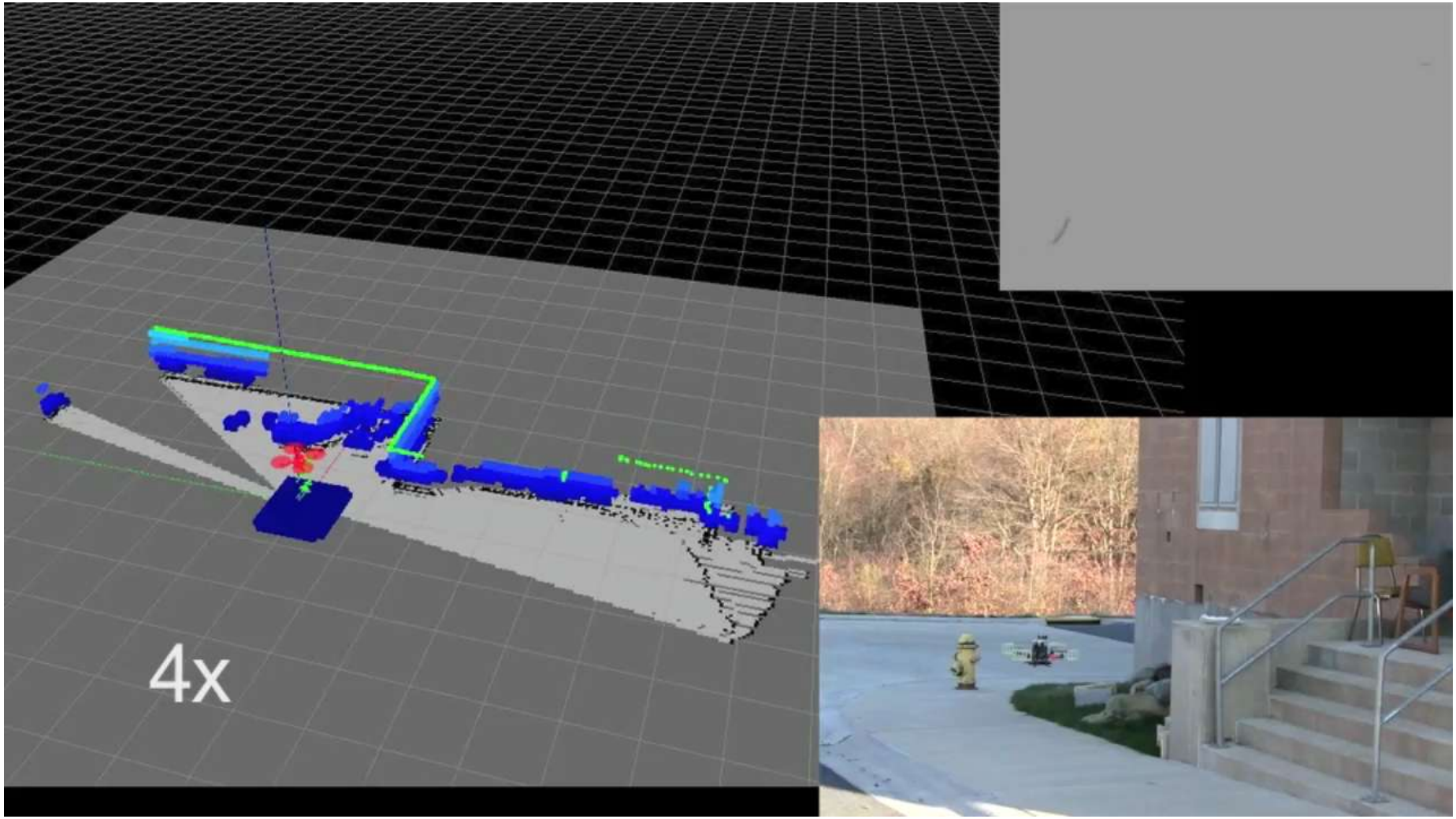
Simultaneous Localization and Mapping also Structure from Motion



Estimation and Control Architecture

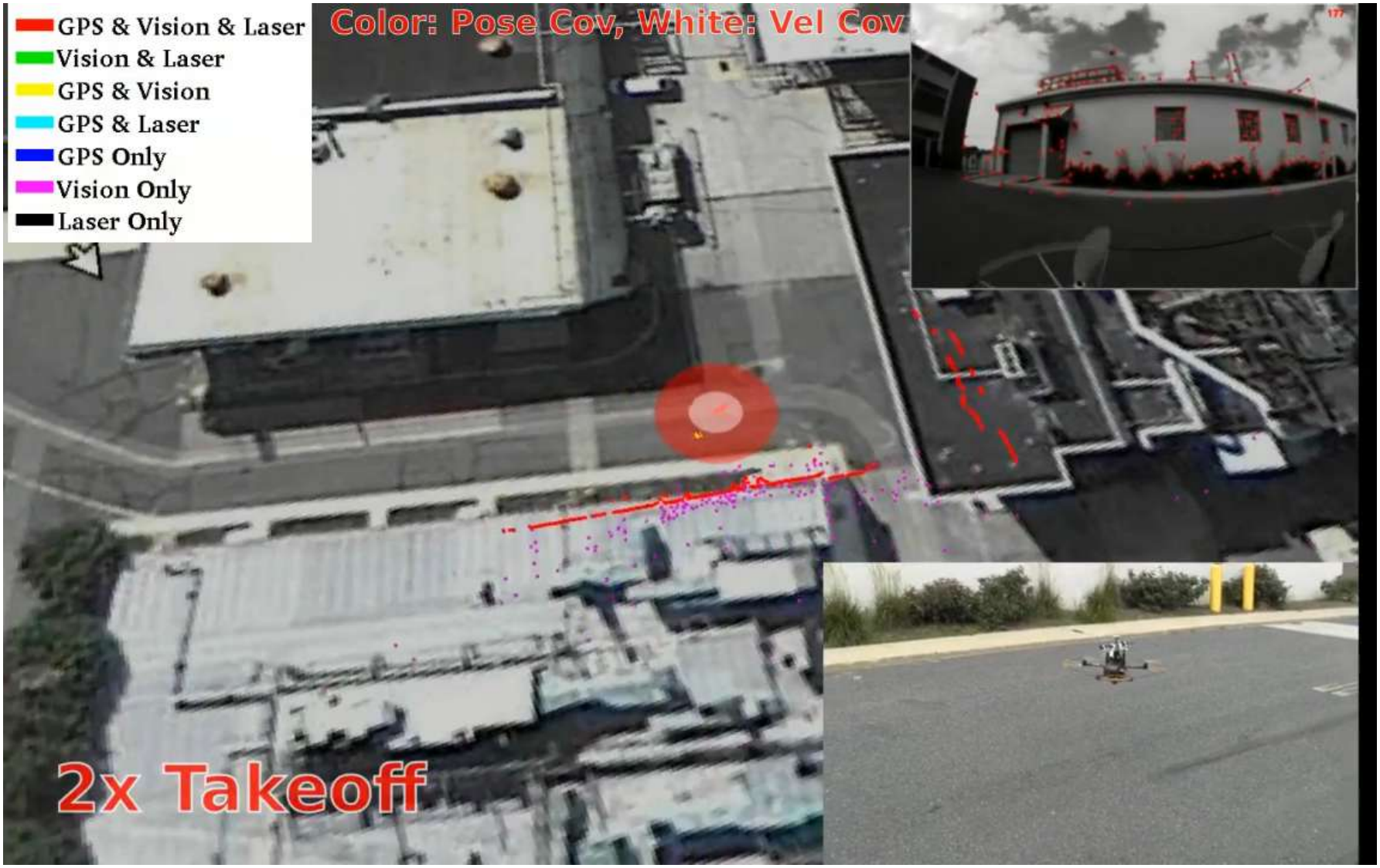


Onboard State Estimation



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

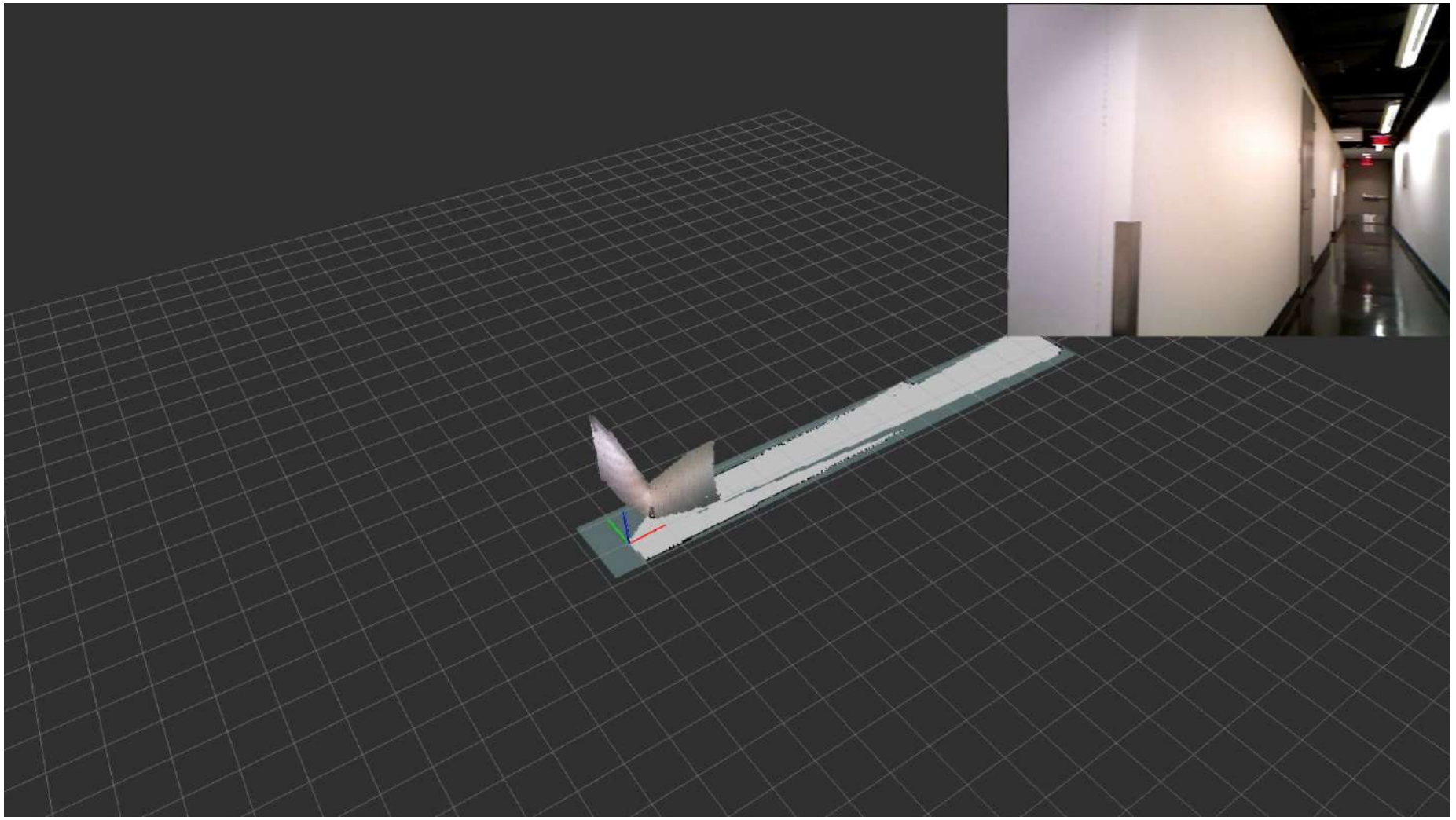
Penn Engineering

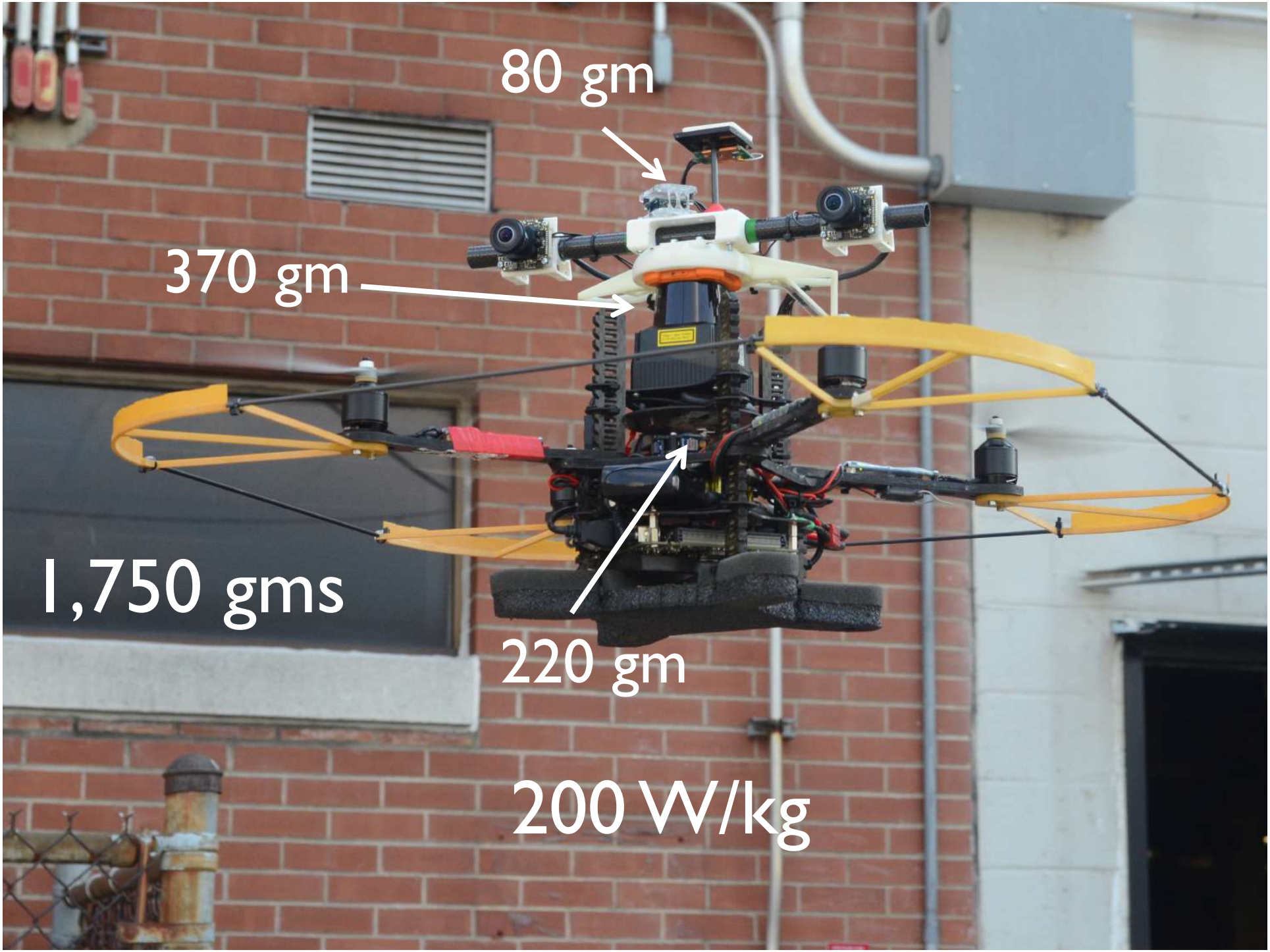


½ km, 1.5 m/s, indoor/outdoor

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," *Proceedings of IEEE International Conference on Robotics and Automation* (ICRA), 2014.

Indoor Navigation and Mapping




80 gm
370 gm
1,750 gms
220 gm
200 W/kg

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