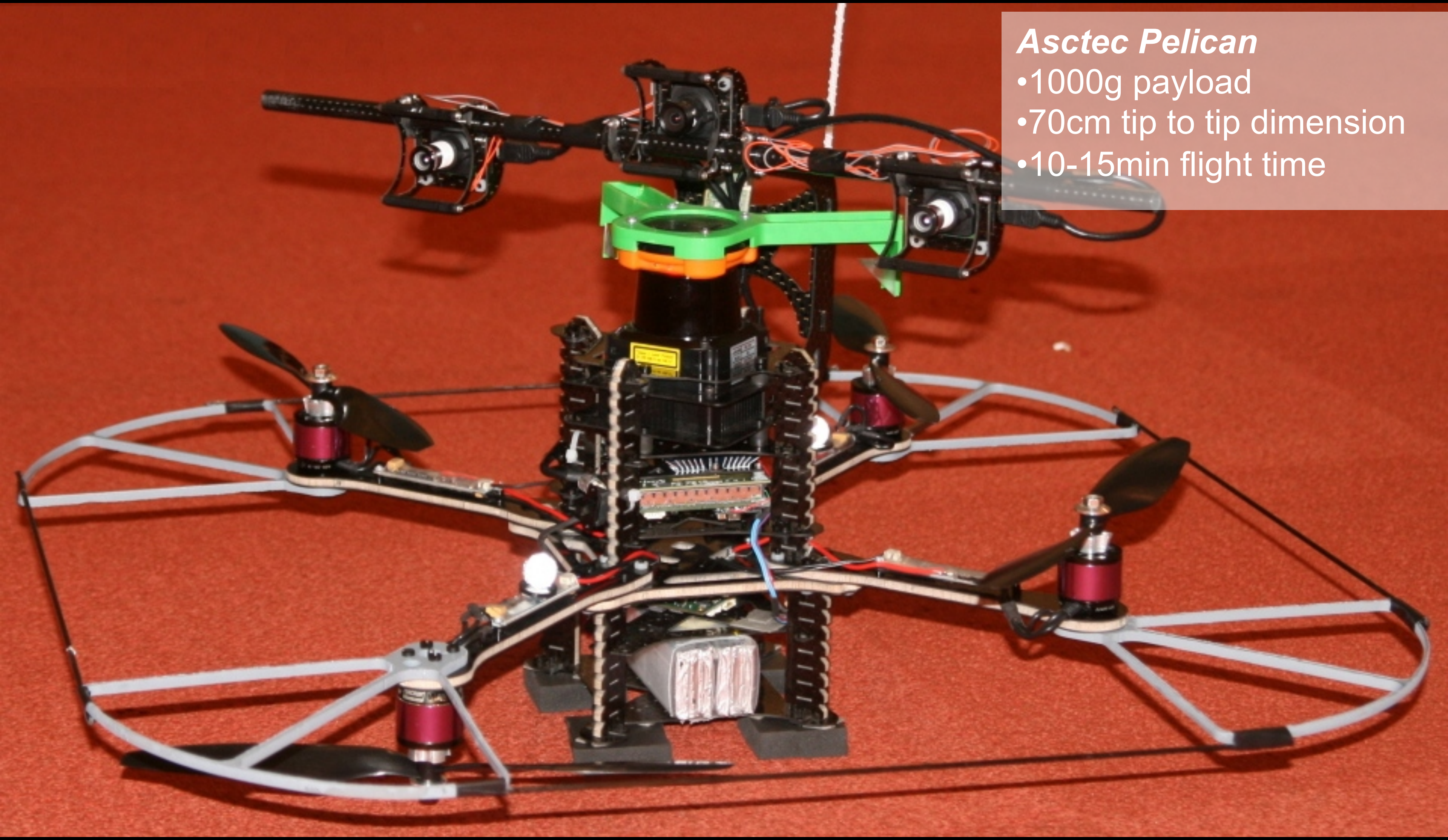
Micro Air Vehicle Flight

Courtesy of Nicholas Roy

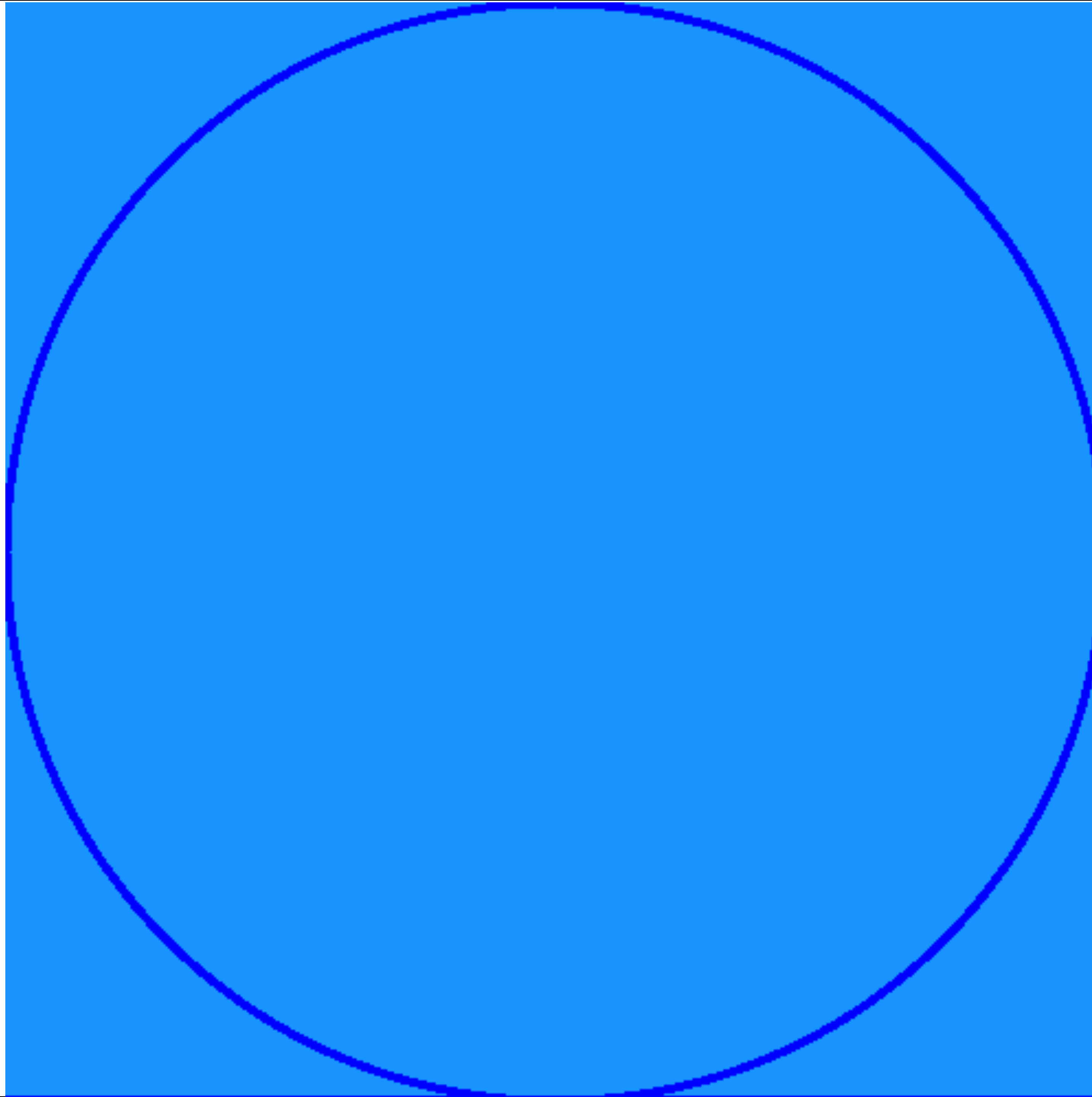
AERO ASTRO

Asctec Pelican

- 1000g payload
- 70cm tip to tip dimension
- 10-15min flight time

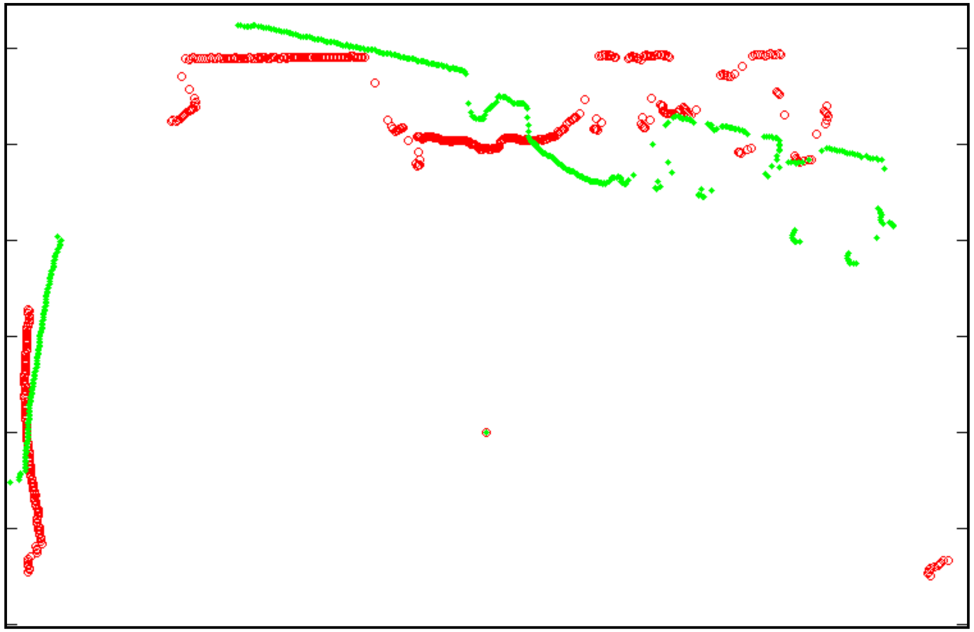



HOKUYO
URG



Laser Odometry

- Scan-matching algorithm
  - Finding optimal rigid body transform between scans



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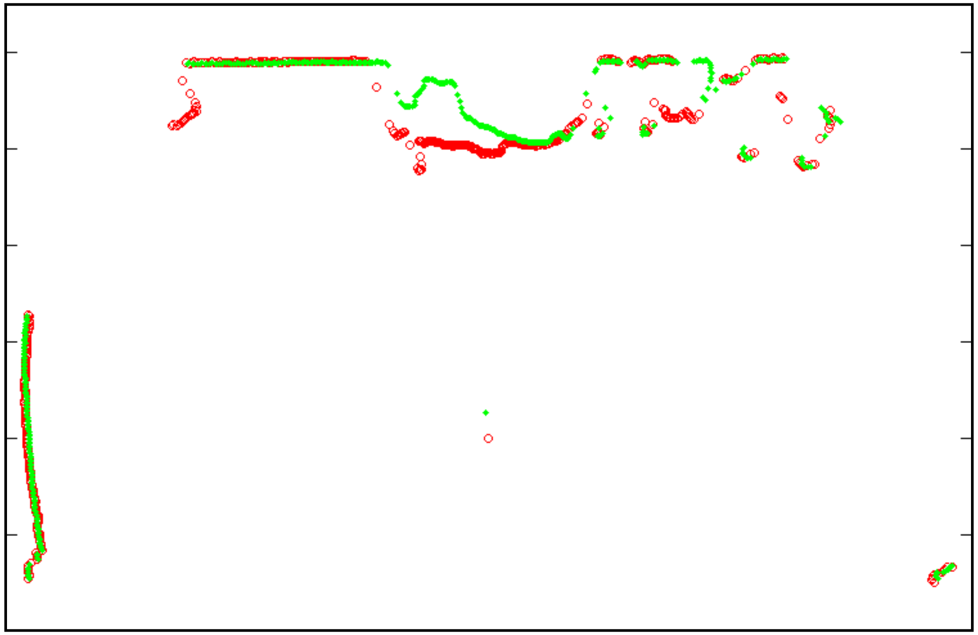
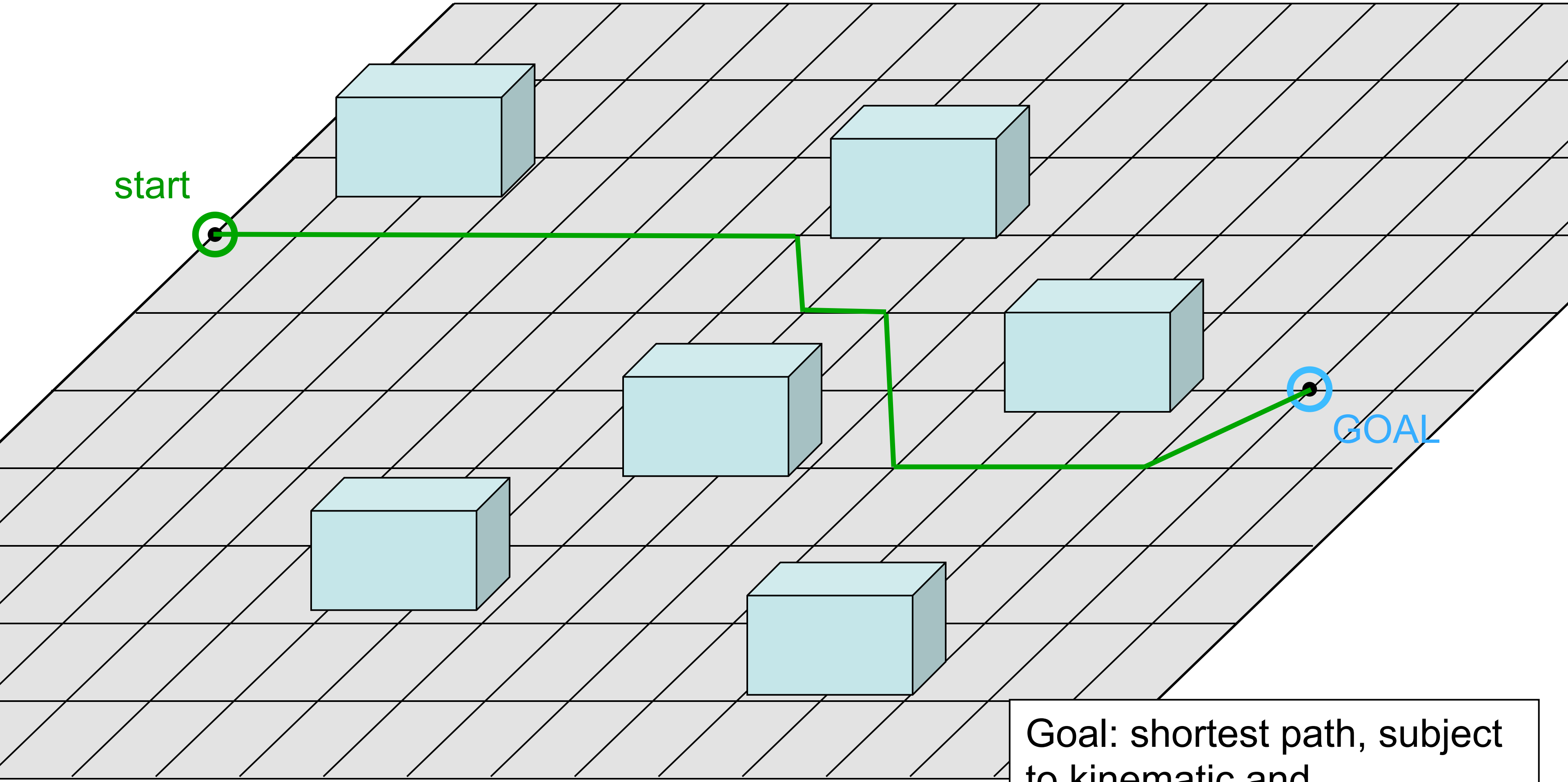


Overview

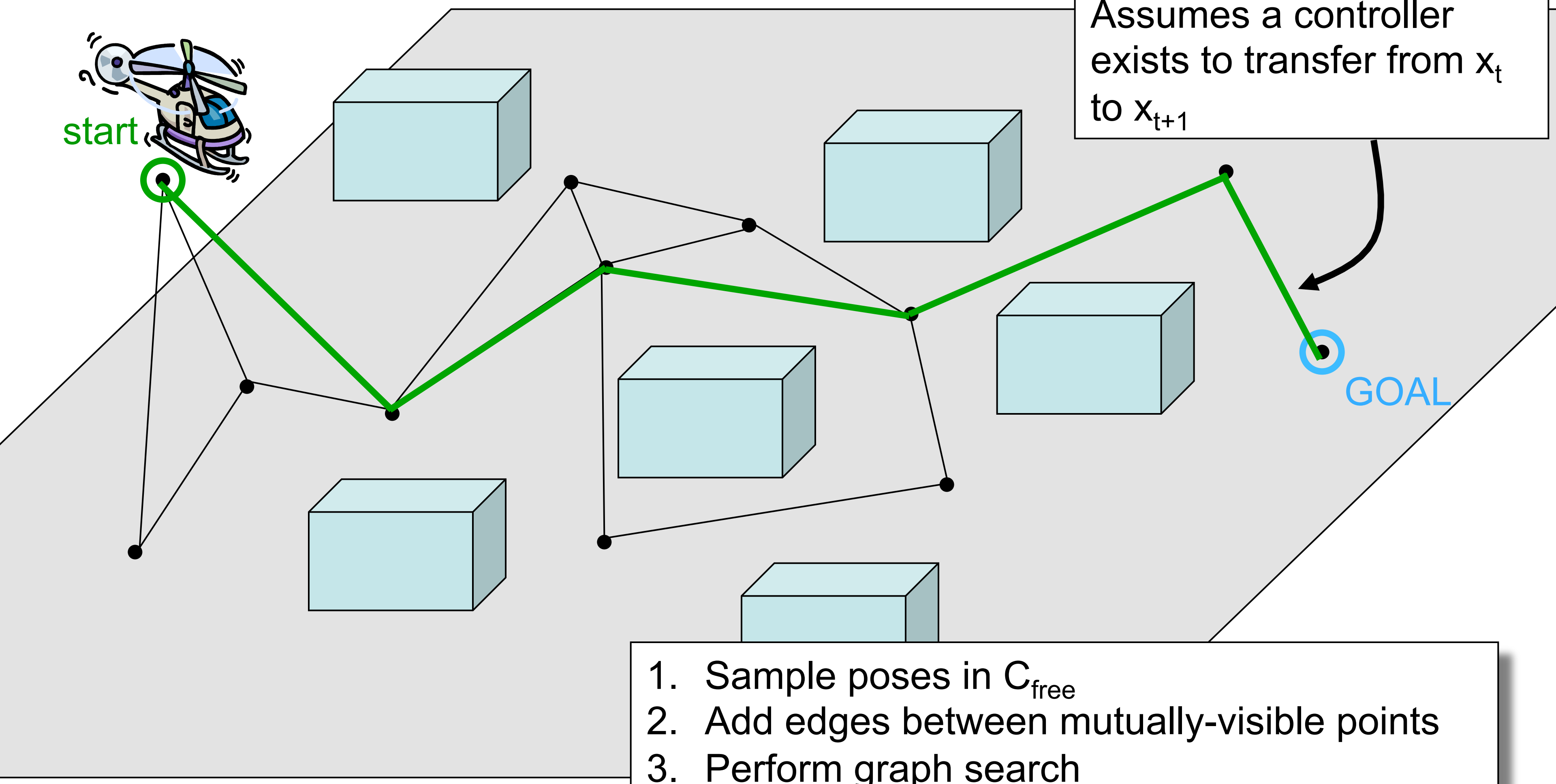
- Flight in GPS-denied environments
- Path planning

Motion Planning



Goal: shortest path, subject to kinematic and environmental constraints

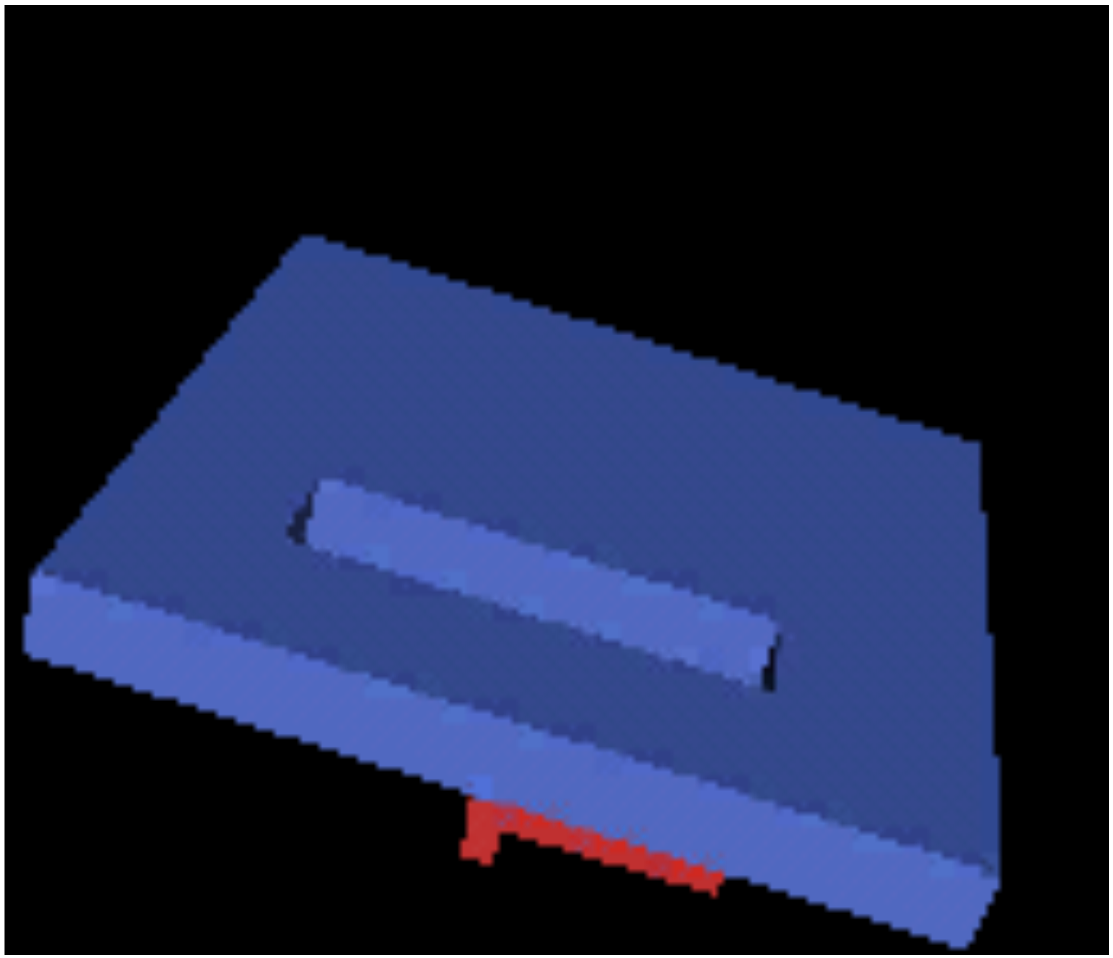
Motion Planning in High Dimensional Configuration Spaces



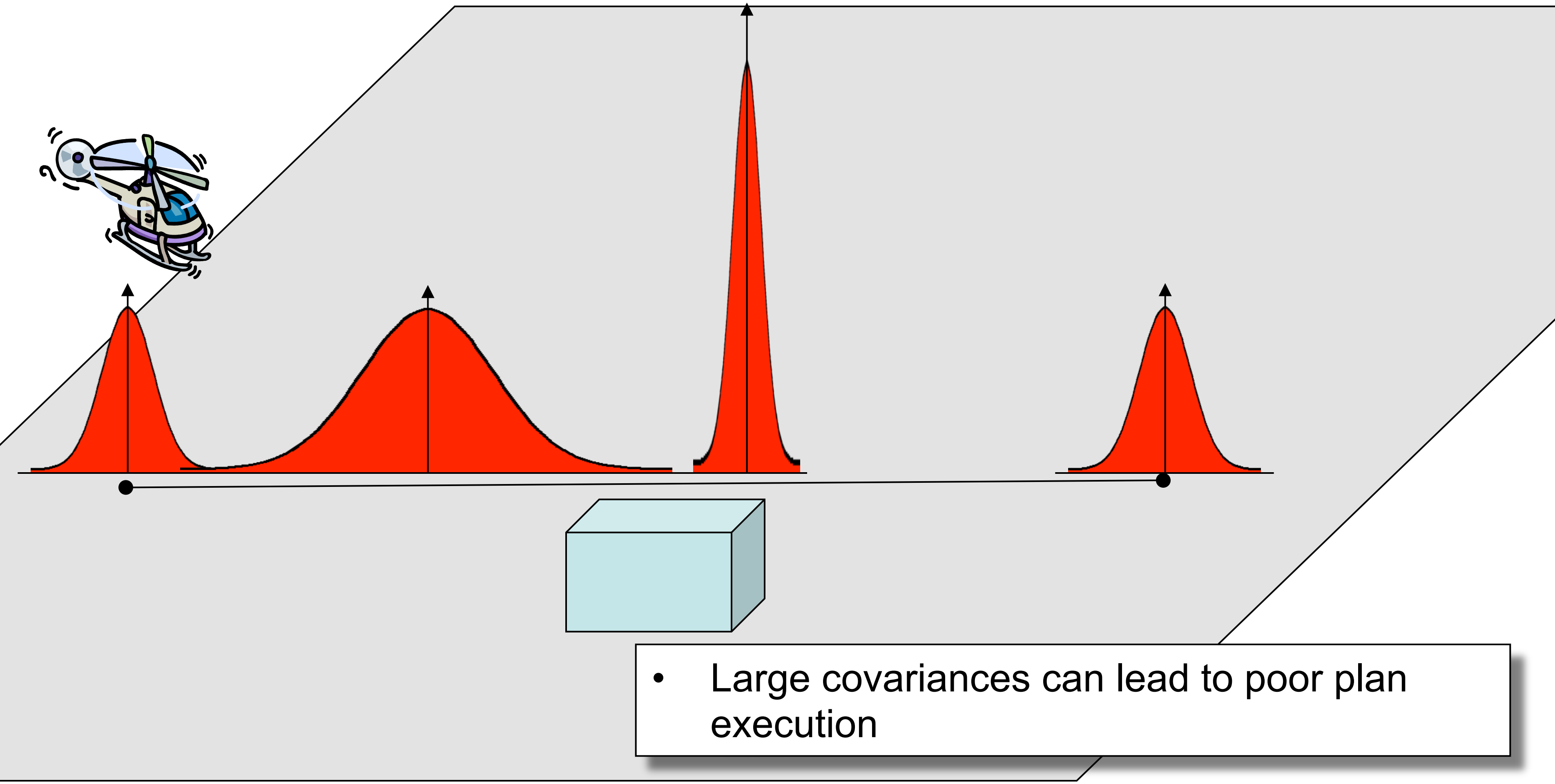
Assumes a controller exists to transfer from x_t to x_{t+1}

1. Sample poses in C_{free}
2. Add edges between mutually-visible points
3. Perform graph search

6DOF Planning

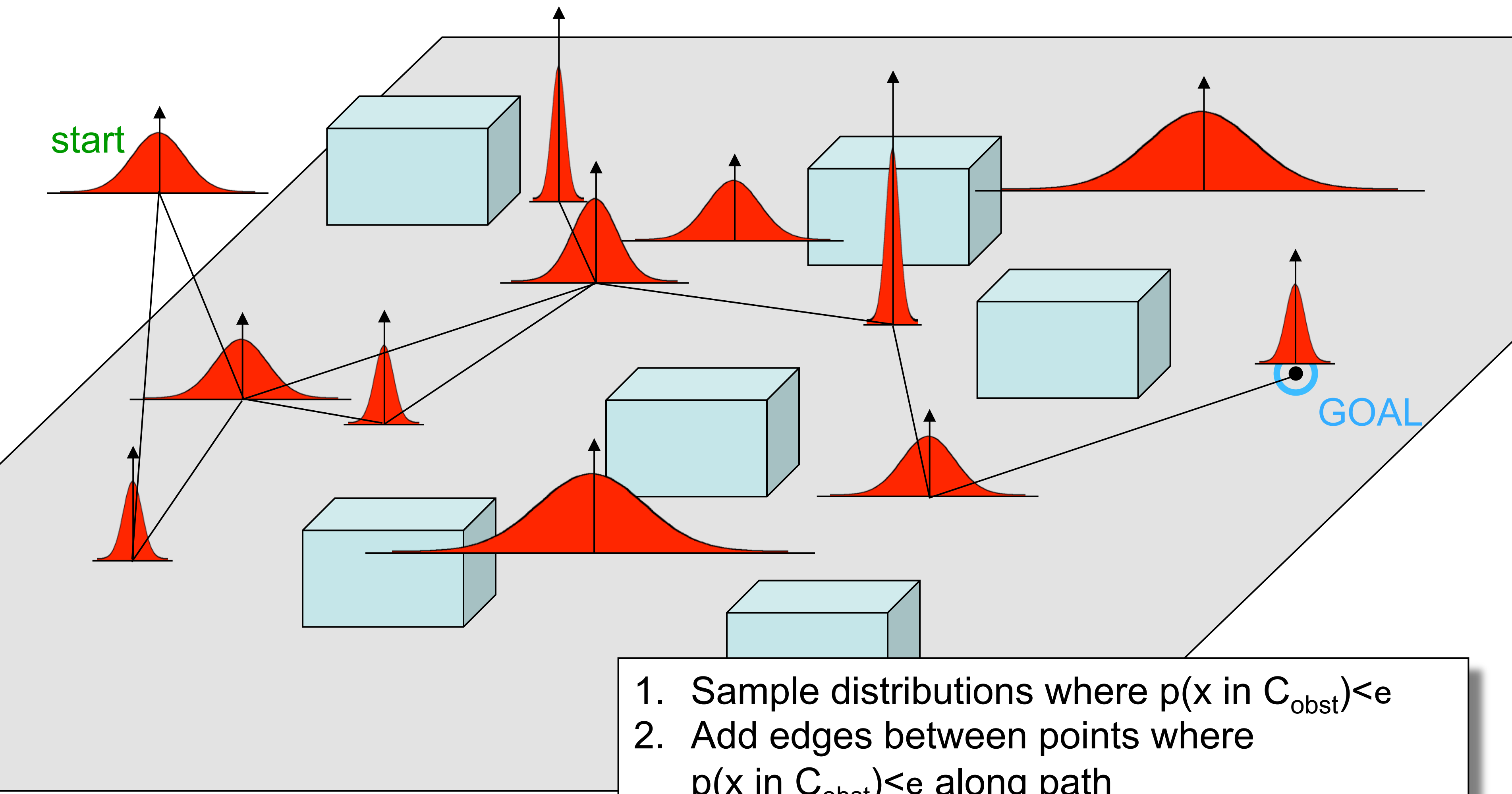


State vs. Information Space



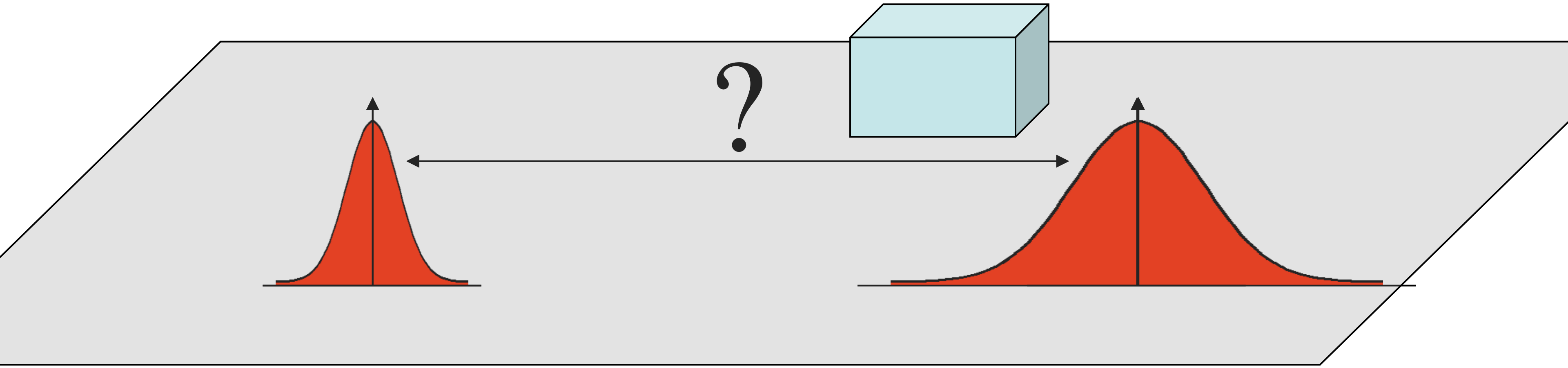
- Large covariances can lead to poor plan execution

Motion Planning in Information Space



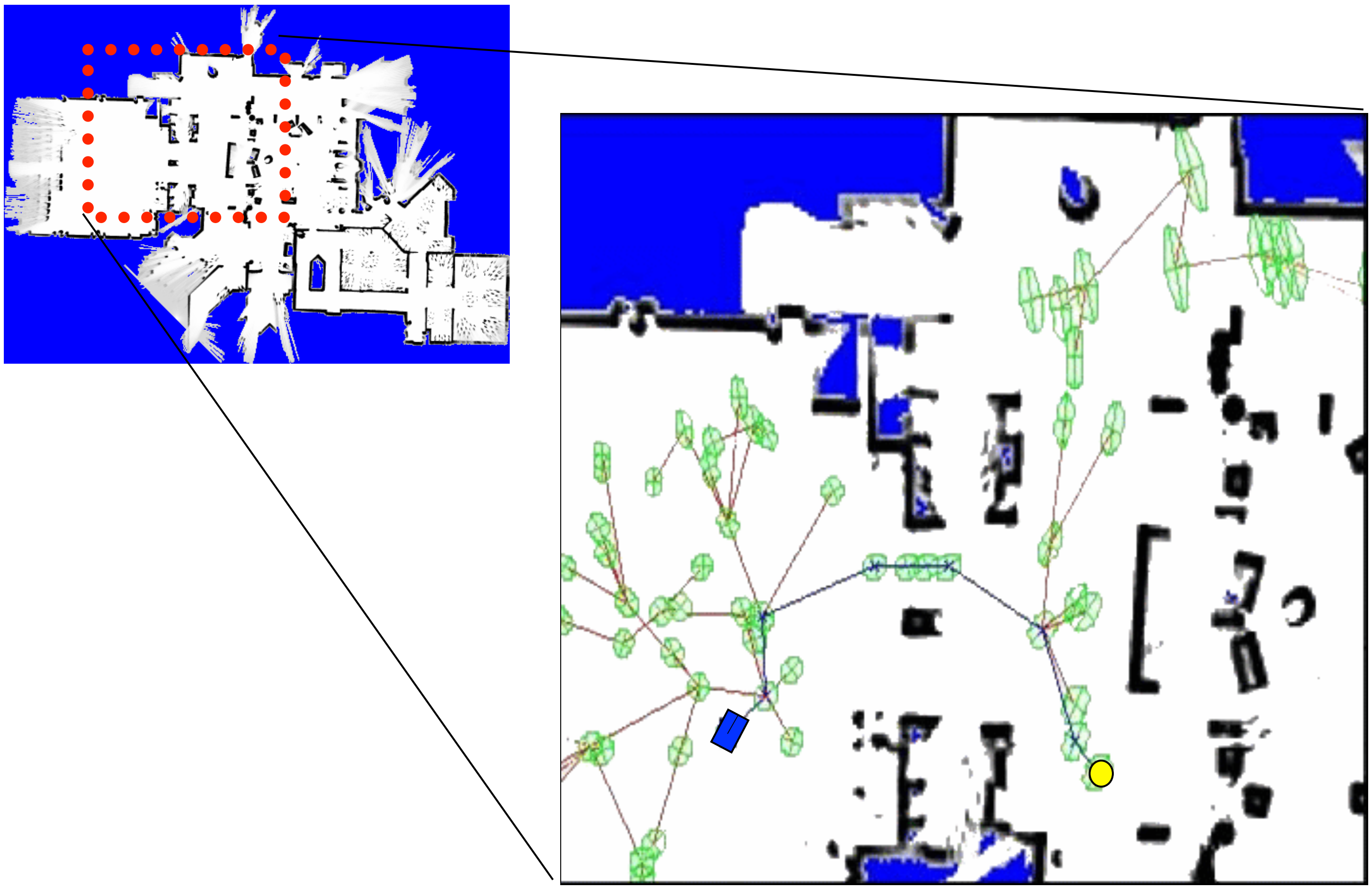
1. Sample distributions where p(x in C_{obst})<e
2. Add edges between points where p(x in C_{obst})<e along path
3. Perform graph search

Problem: Edge Construction

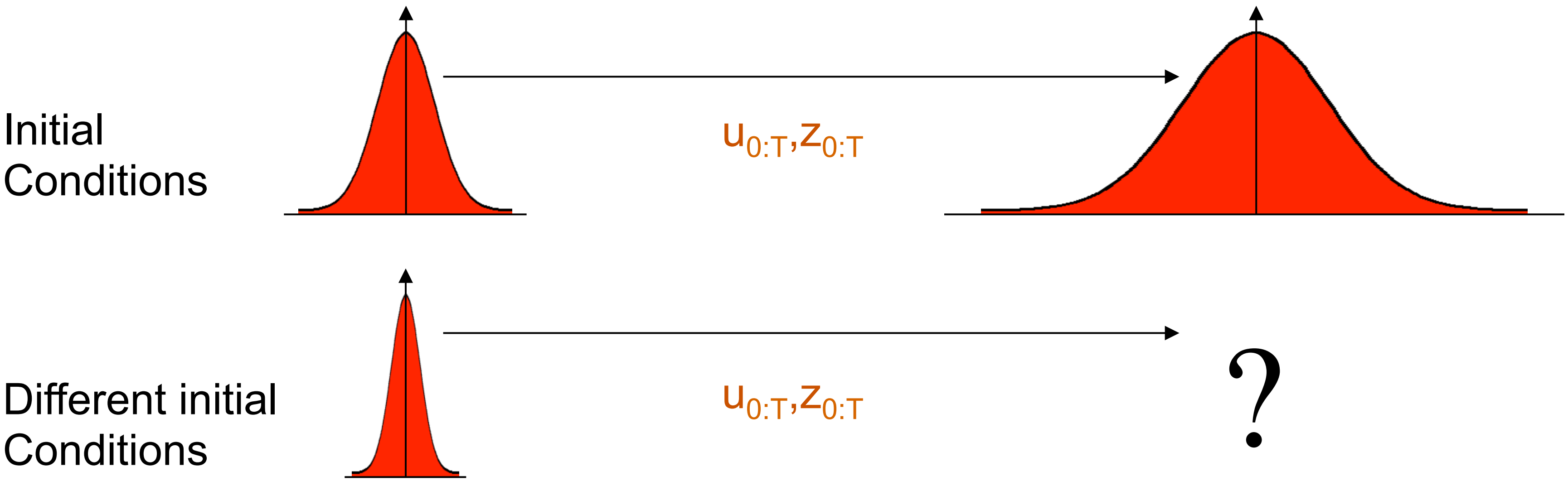


- Need $u_{0:T}$ such that $p(x|u_{0:T}) = p(x')$
- Possible solution: sample waypoints, use forward simulation to compute full posterior

Example Belief Roadmap



Problem: Edge Construction



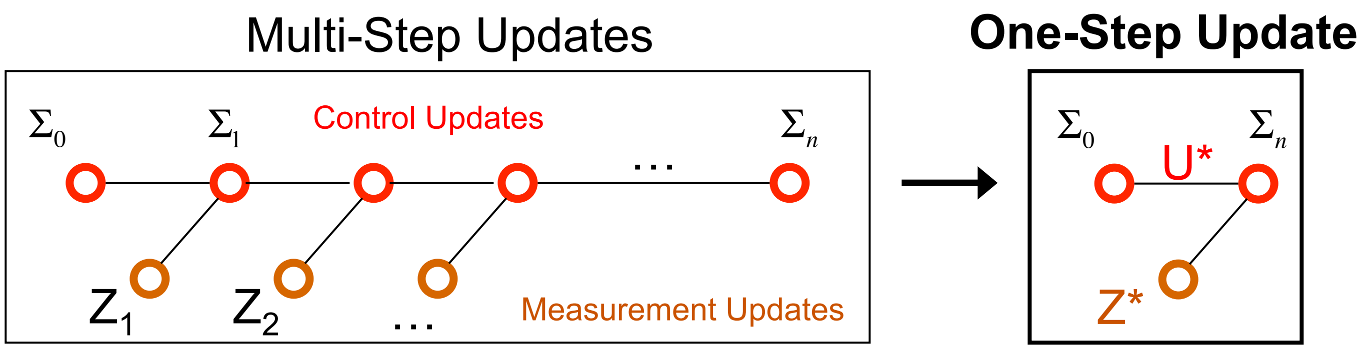
- Need to perform forward simulation (and belief prediction) along each edge for every start state
- Computing minimum cost path of 30 edges: ≈100 seconds

Multi-Step Update as One-Step

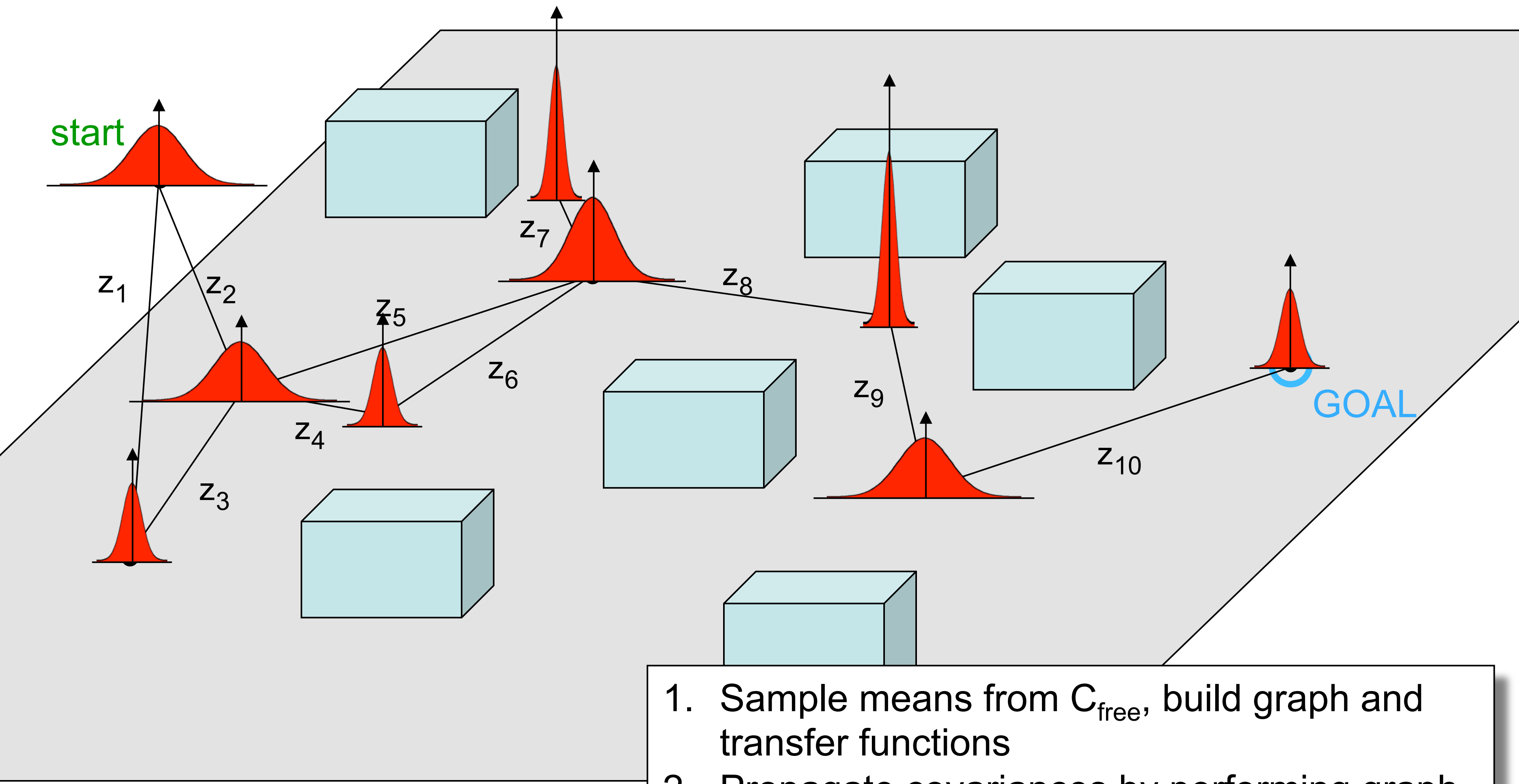
EKF Covariance Update

Control: $\bar{\Sigma}_t = G\Sigma_{t-1}G^T + R$

Measurement: $\Sigma_t = \left(\bar{\Sigma}_t^{-1} + HQ^{-1}H^T\right)^{-1}$

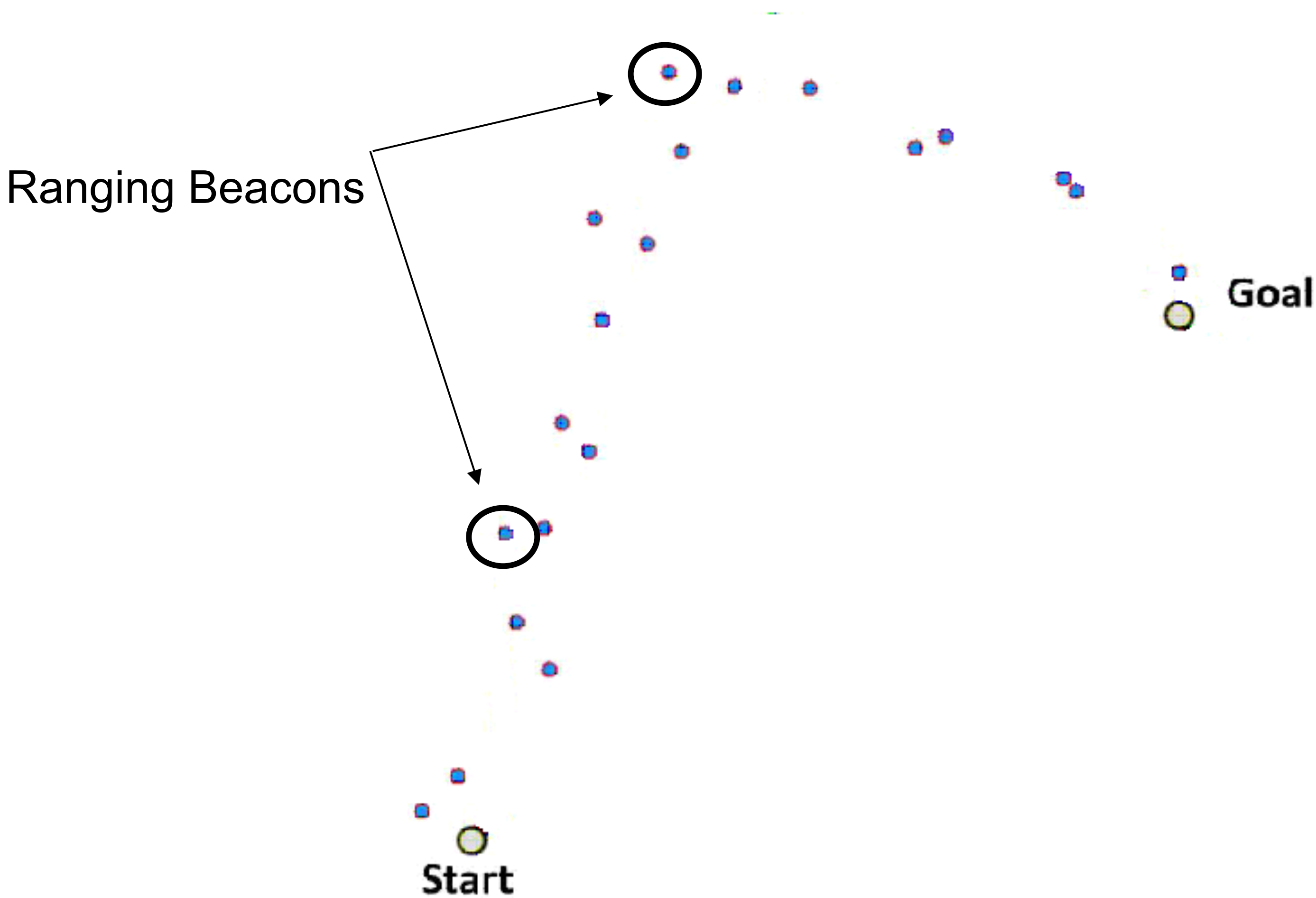


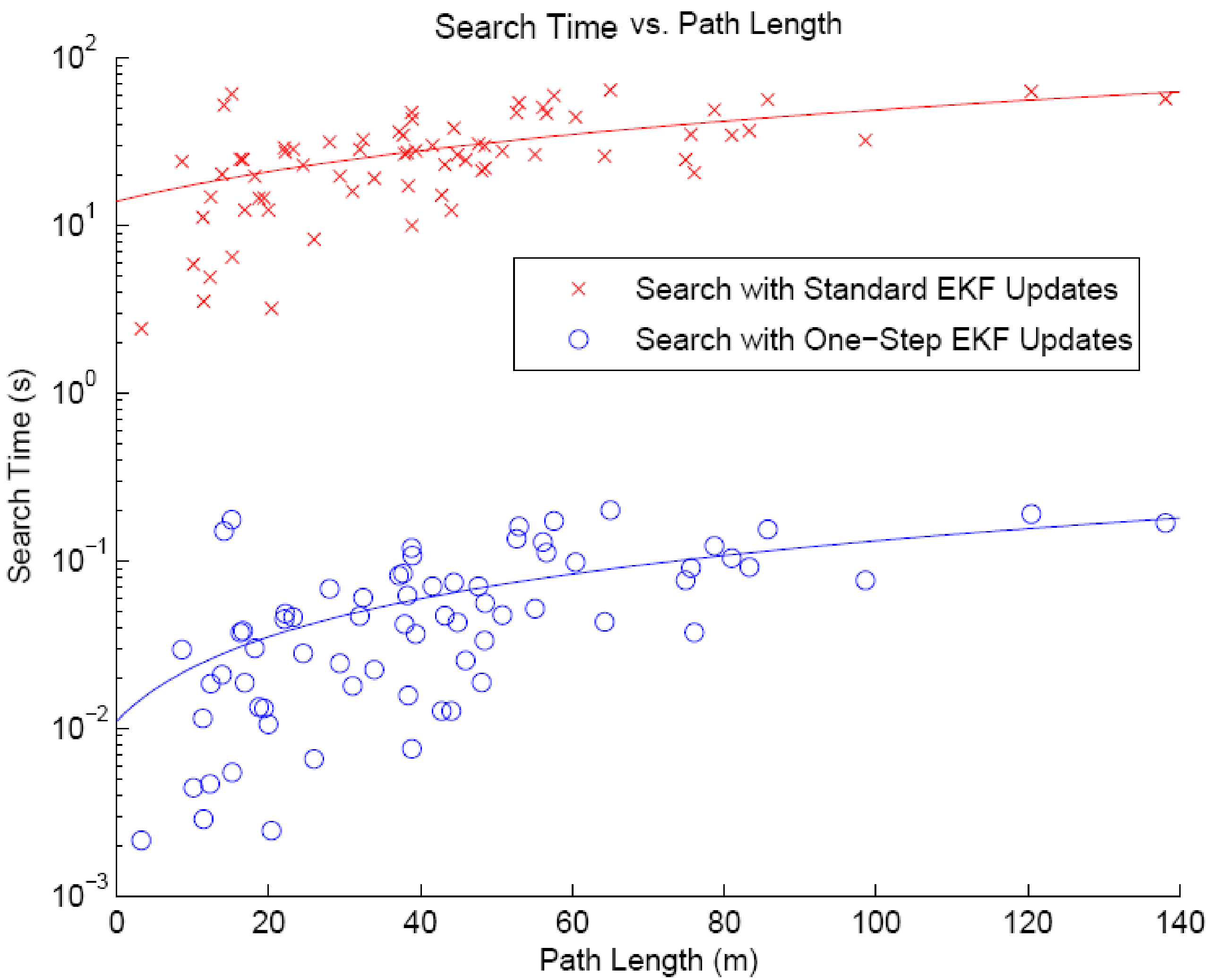
The Belief Roadmap Algorithm



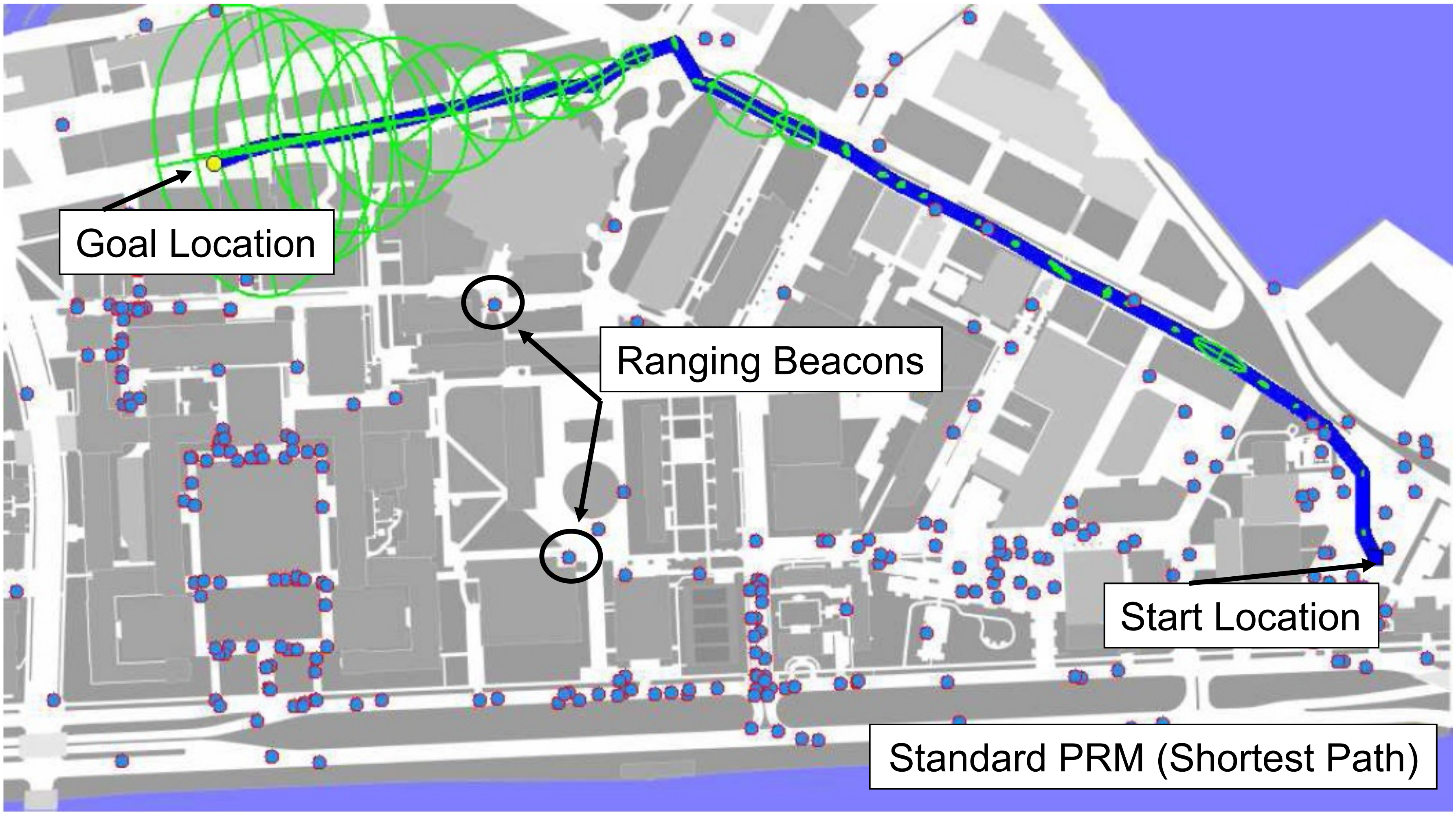
1. Sample means from C_{free}, build graph and transfer functions
2. Propagate covariances by performing graph search

Example

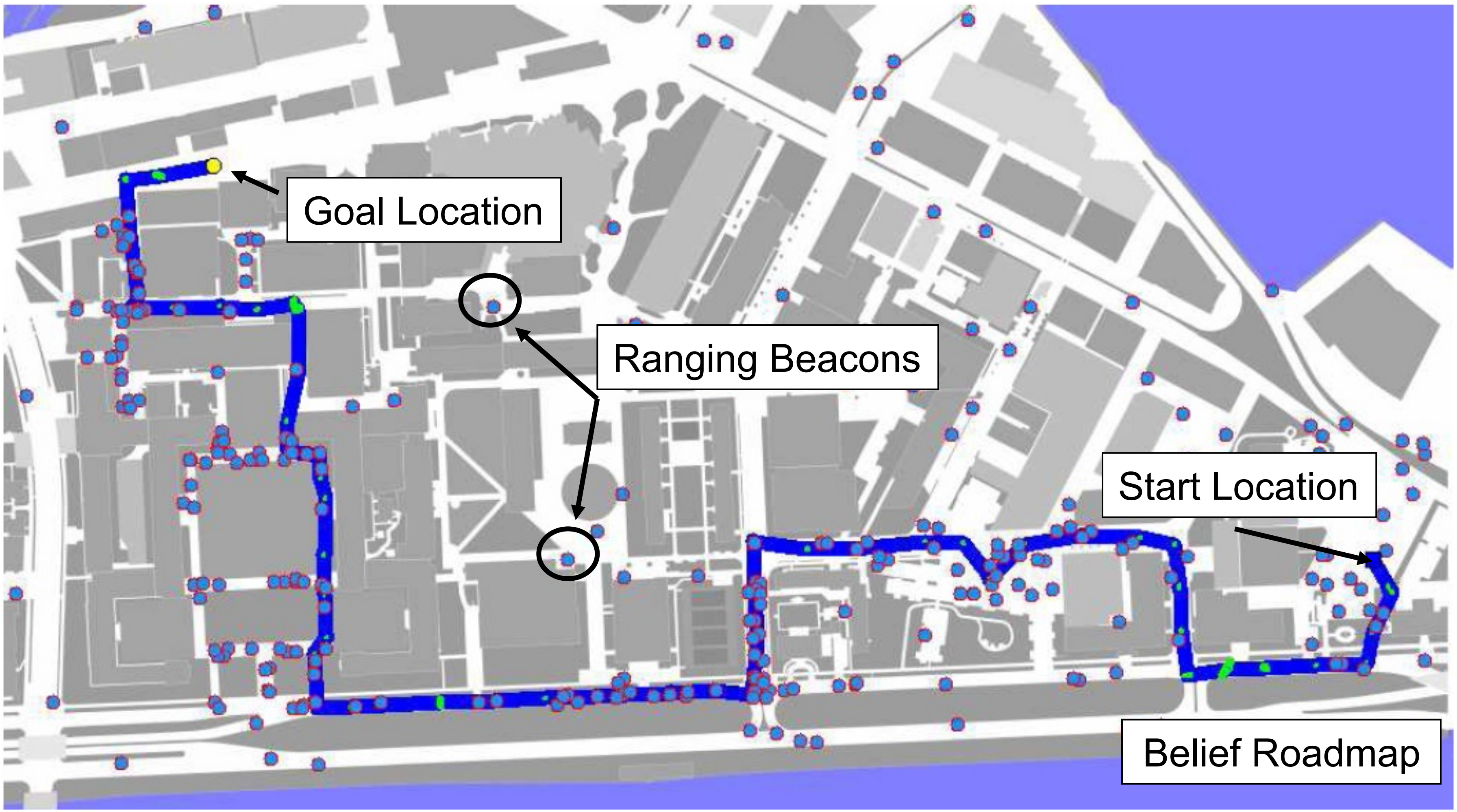



Search Time vs. Path Length
Search Time (s)
Path Length (m)
Search with Standard EKF Updates
Search with One−Step EKF Updates
10^2
10^1
10^0
10^-1
10^-2
10^-3
0
20
40
60
80
100
120
140

Simulated Ranging On MIT Campus

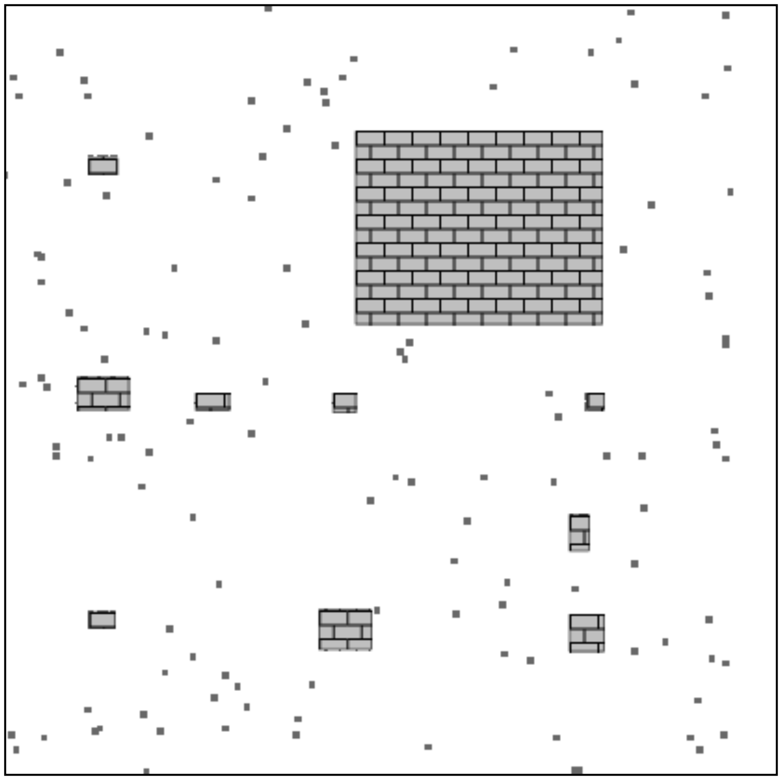


Simulated Ranging On MIT Campus

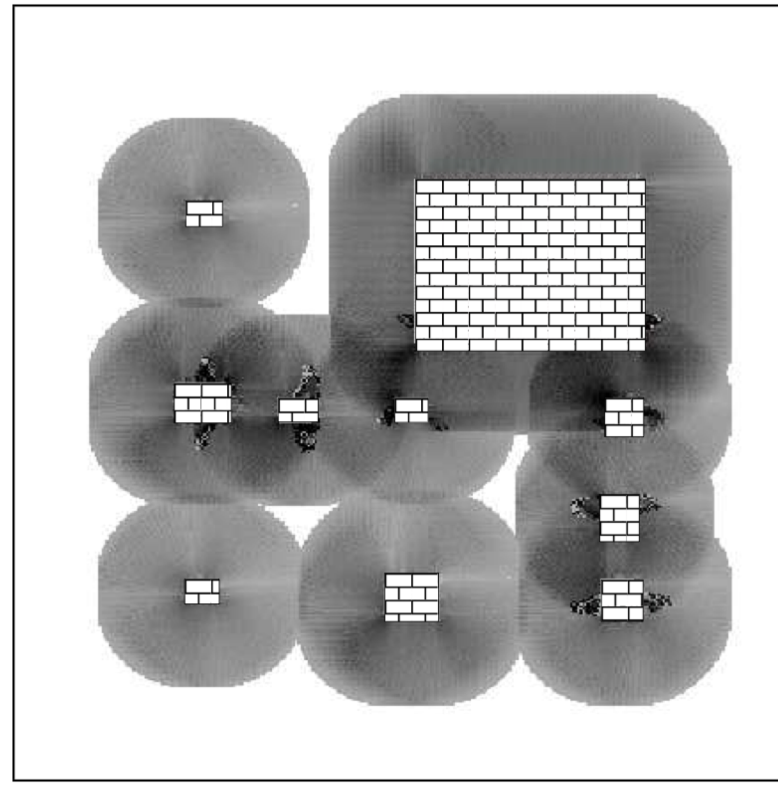



C

Improving Sampling

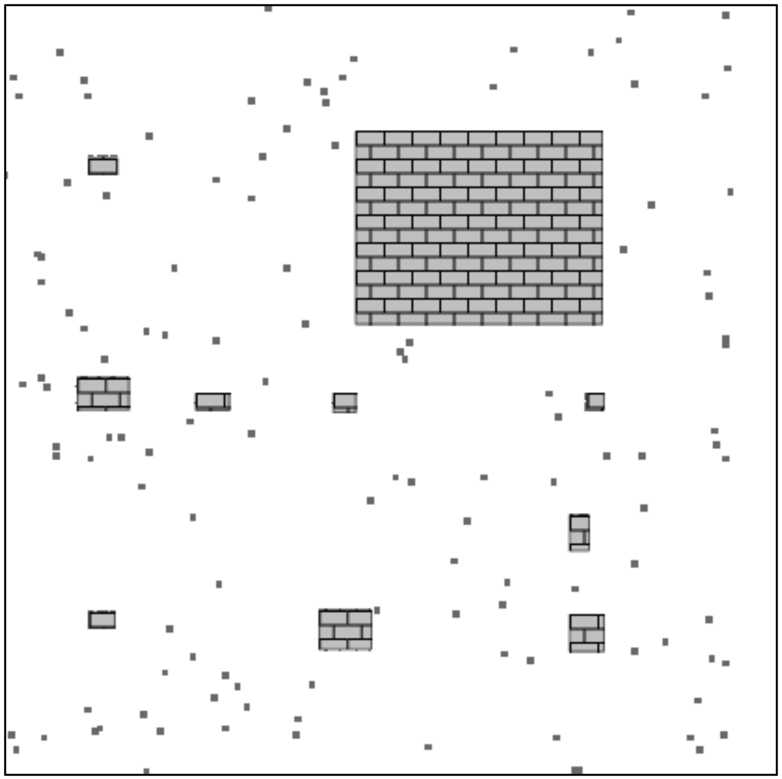


Uniform Sampling

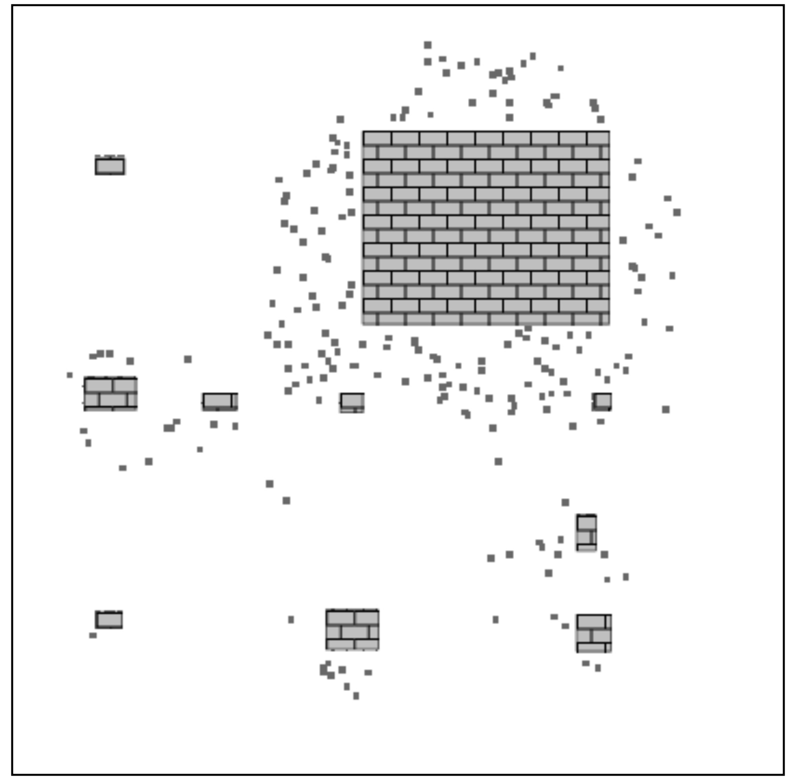


Sensor Uncertainty Field

Improving Sampling

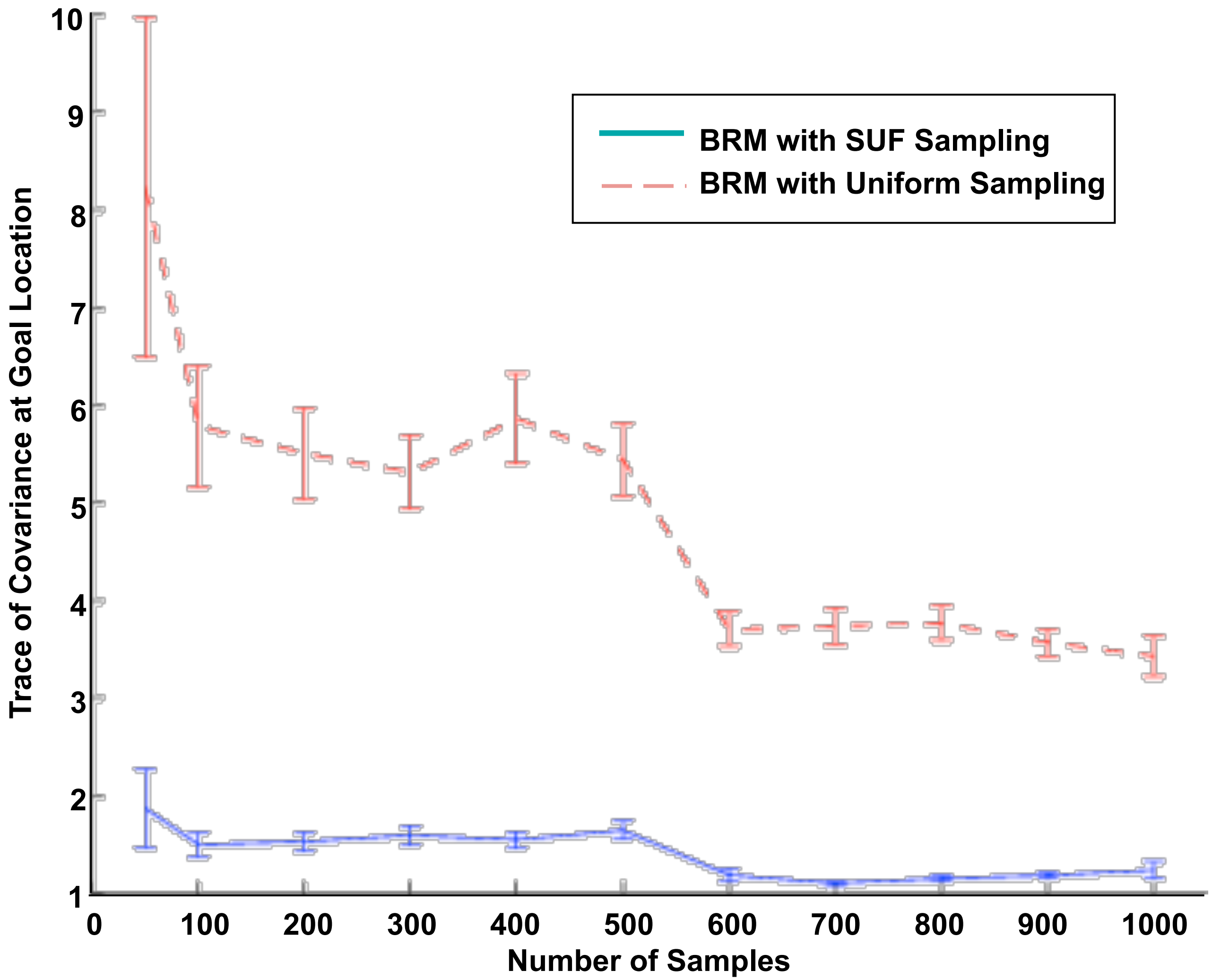


Uniform Sampling



Sensor-Uncertainty Sampling

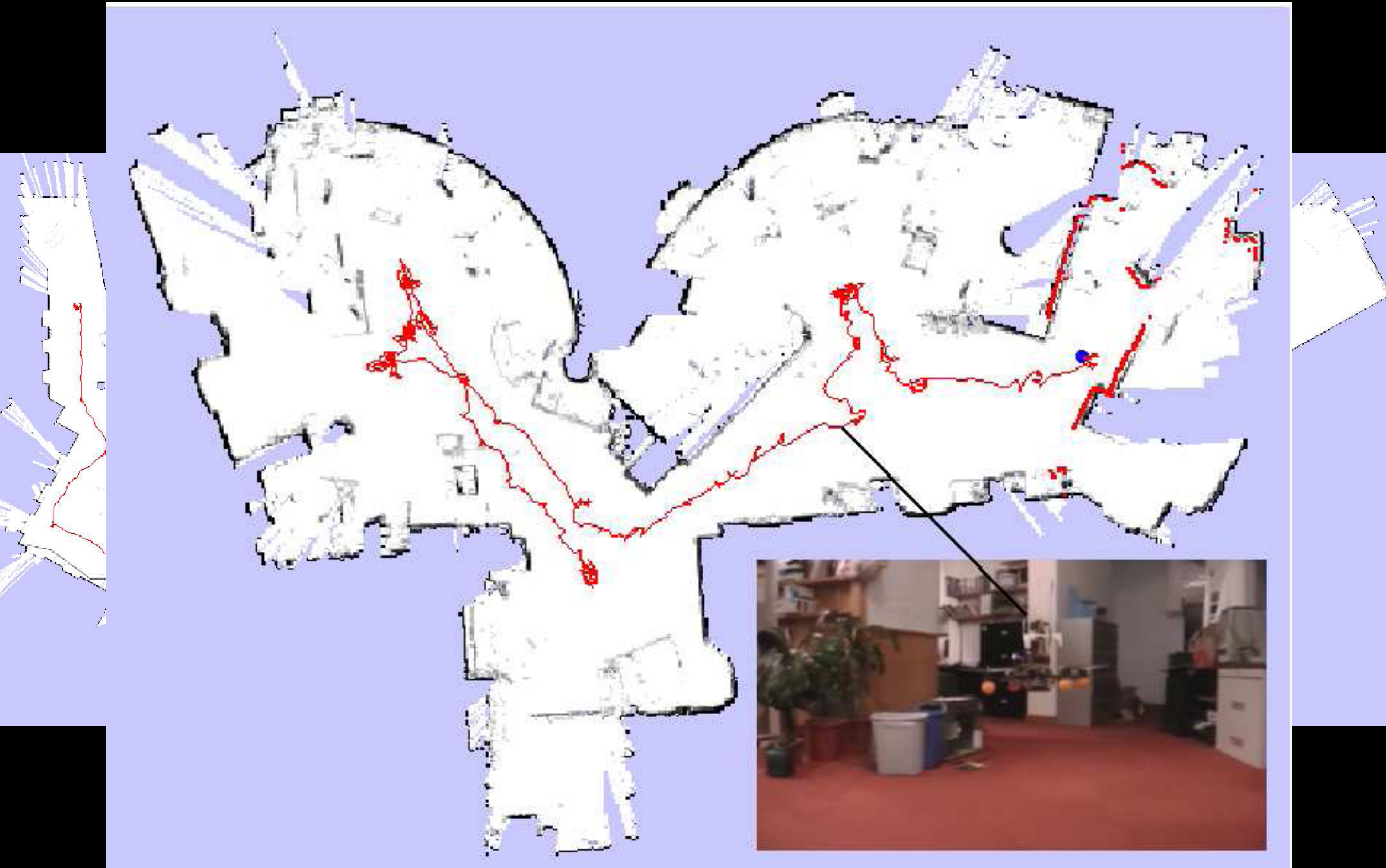
Improving Sampling

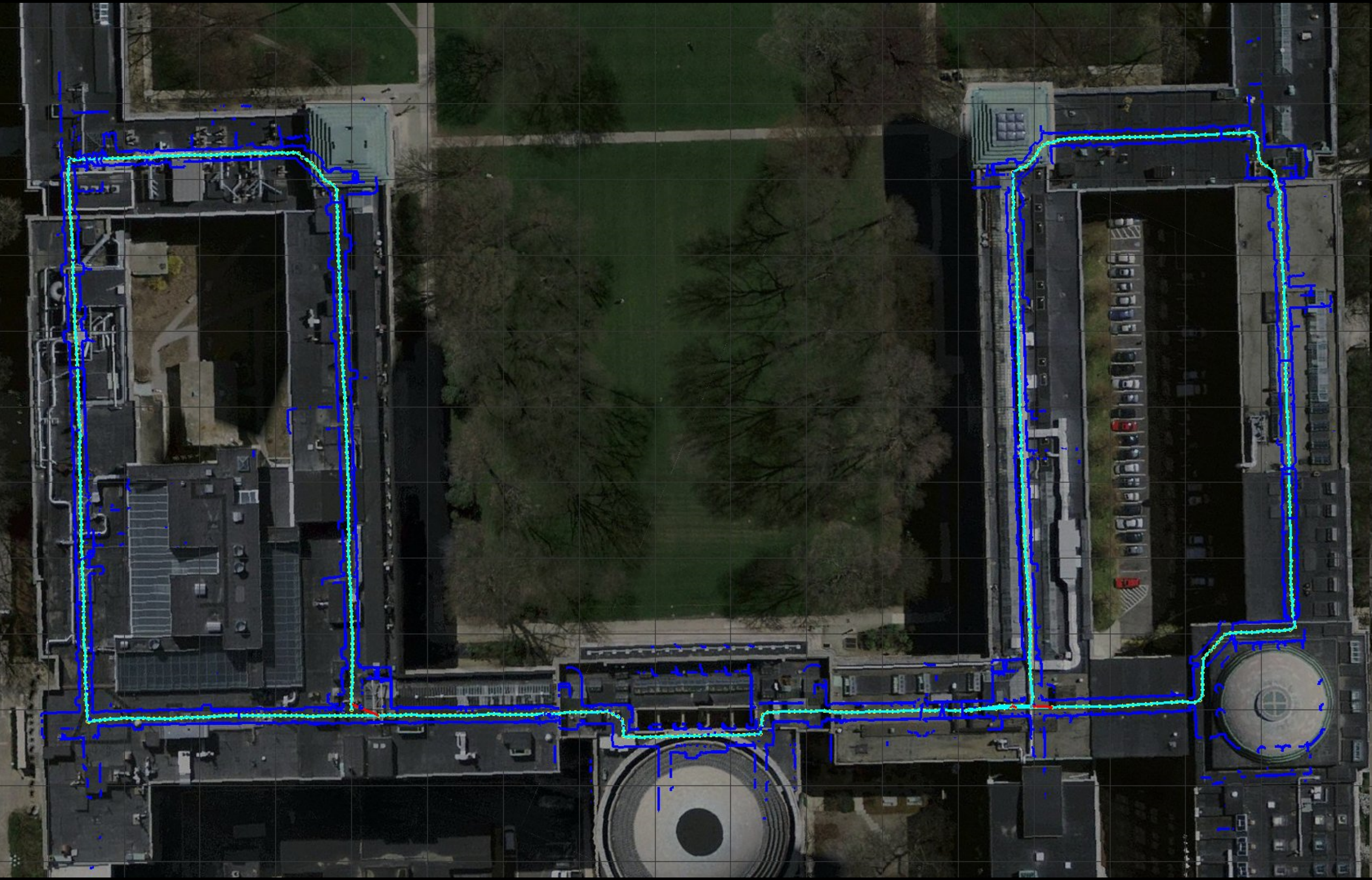


Overview

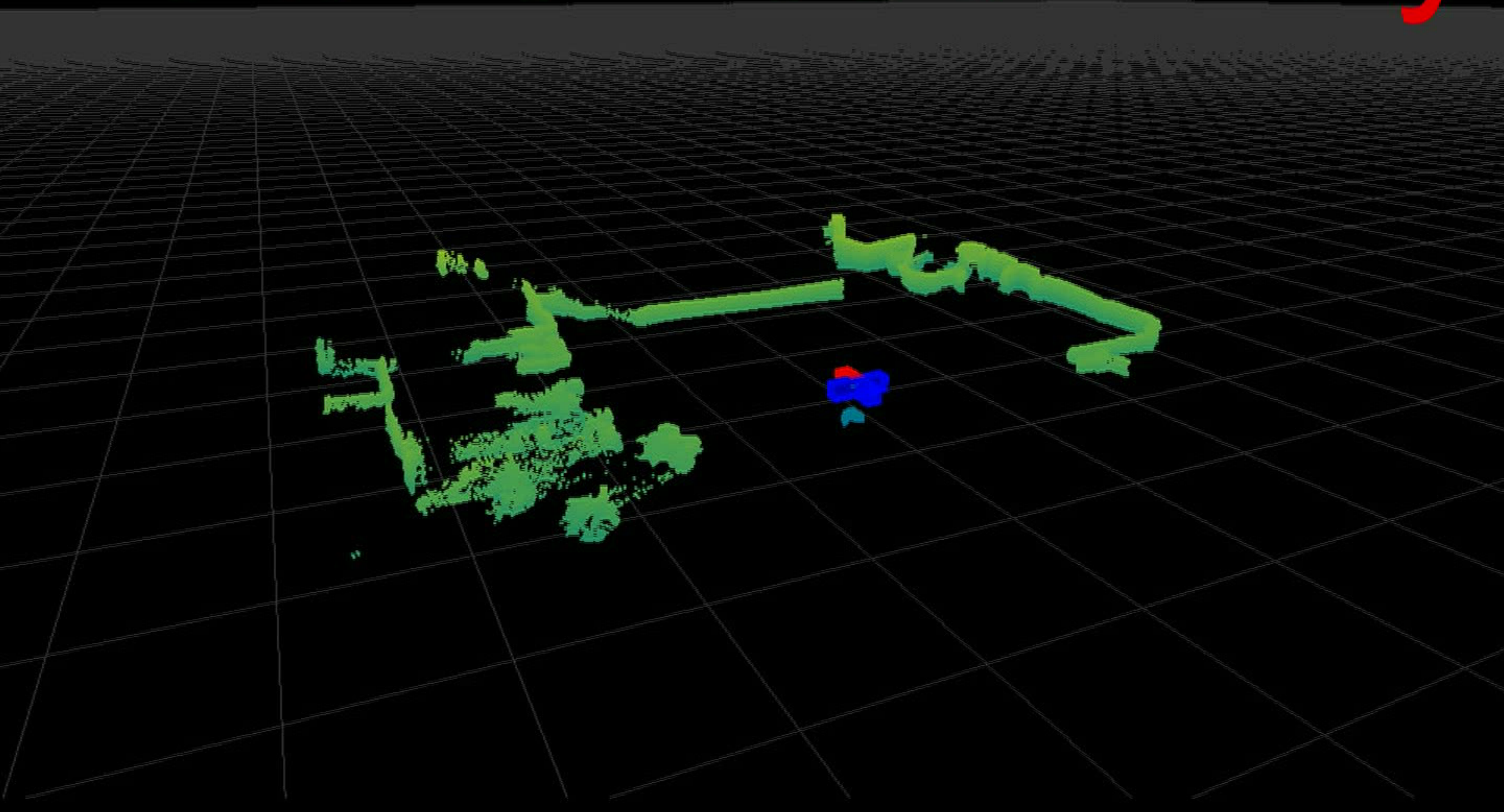
- Flight in GPS-denied environments
- Path planning
- Exploration

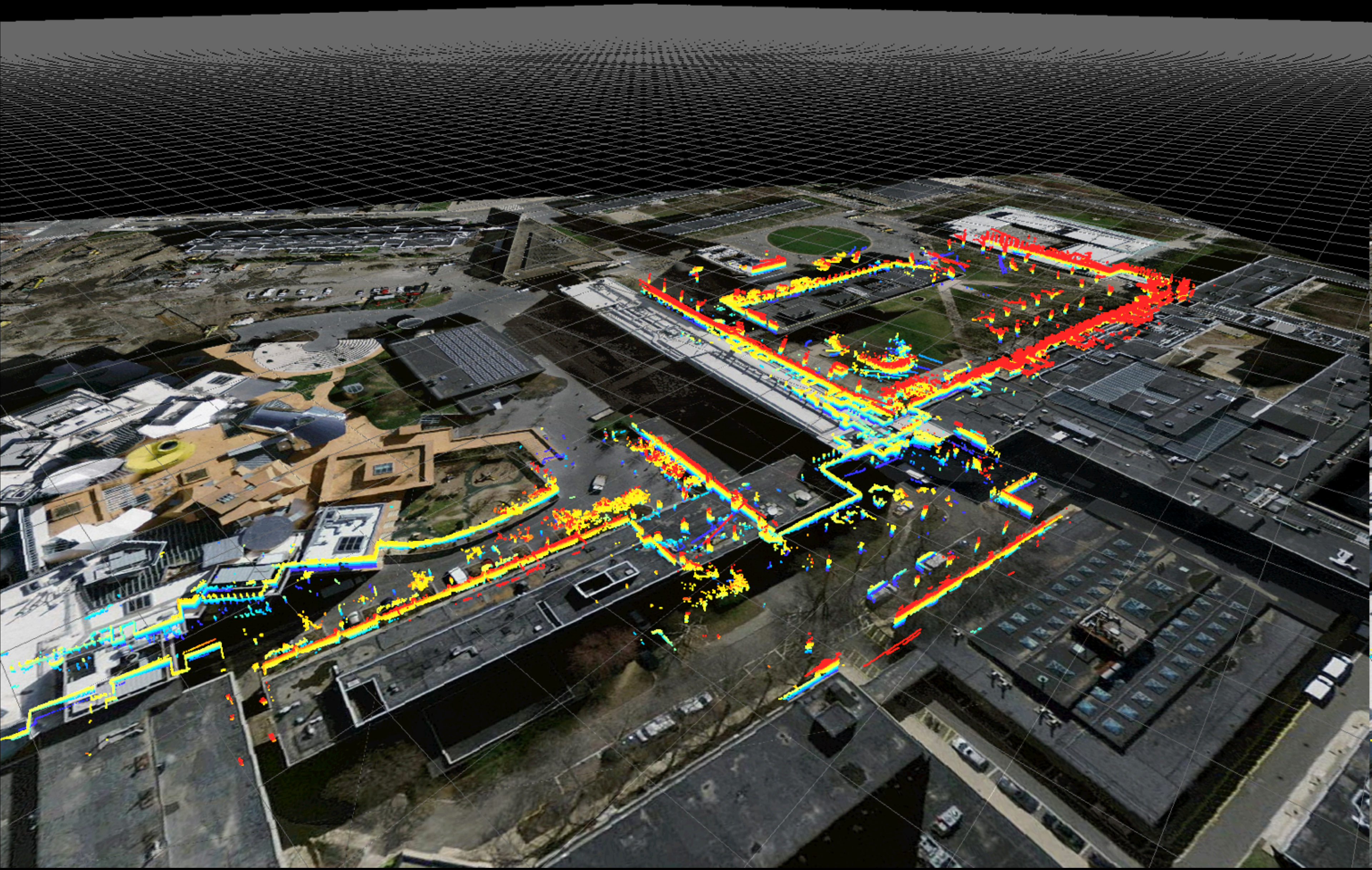

Autonomous
Navigation





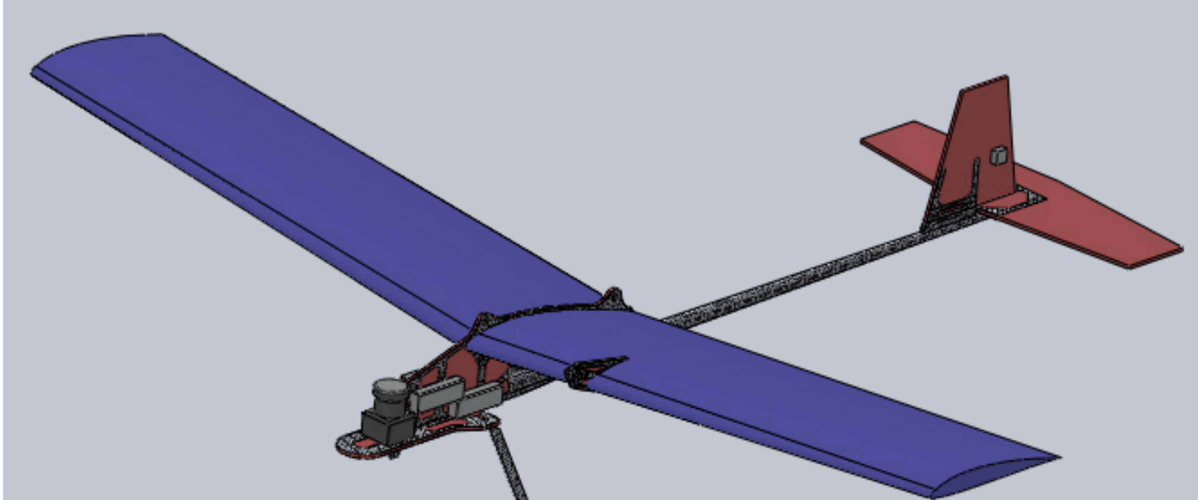
Autonomous Entry





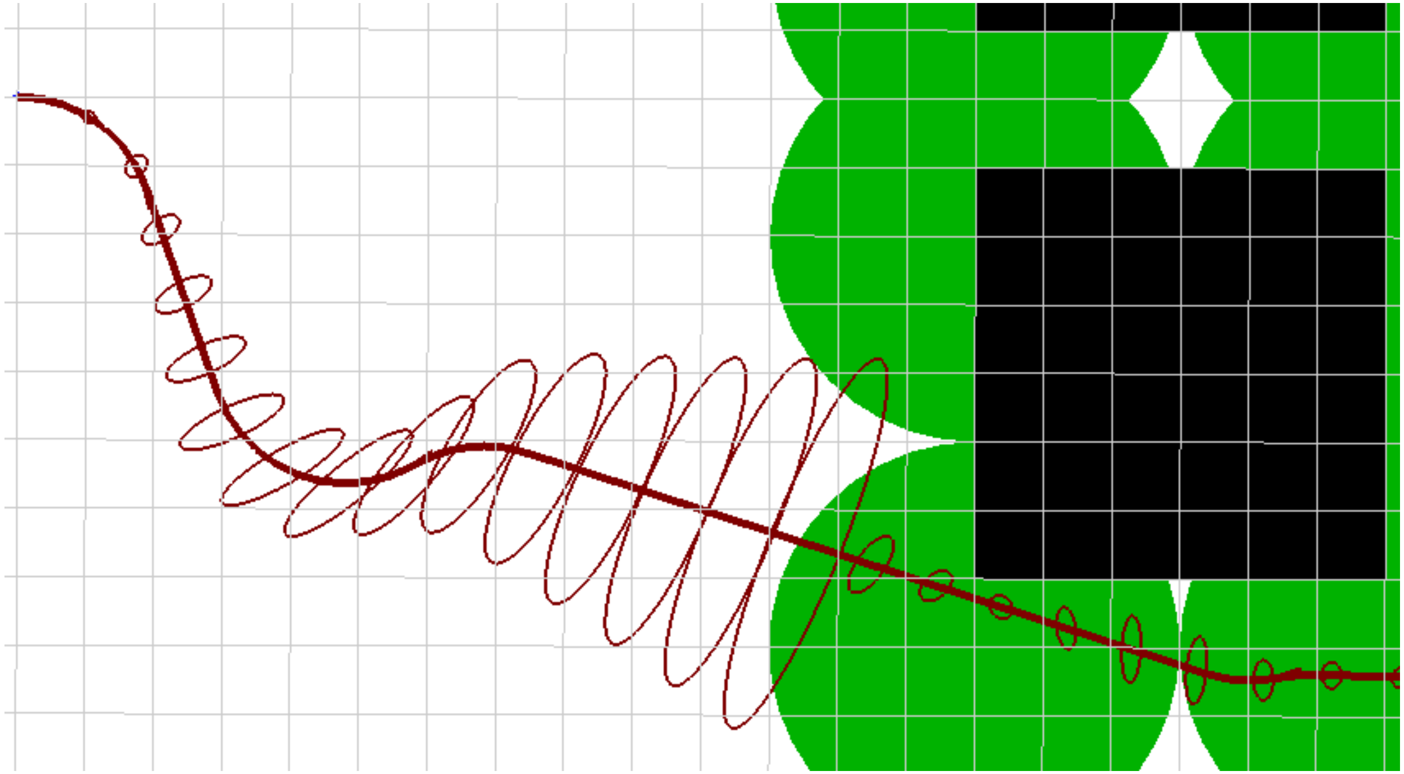
Overview

- Flight in GPS-denied environments
- Path planning
- Exploration
- Fixed-wing Flight



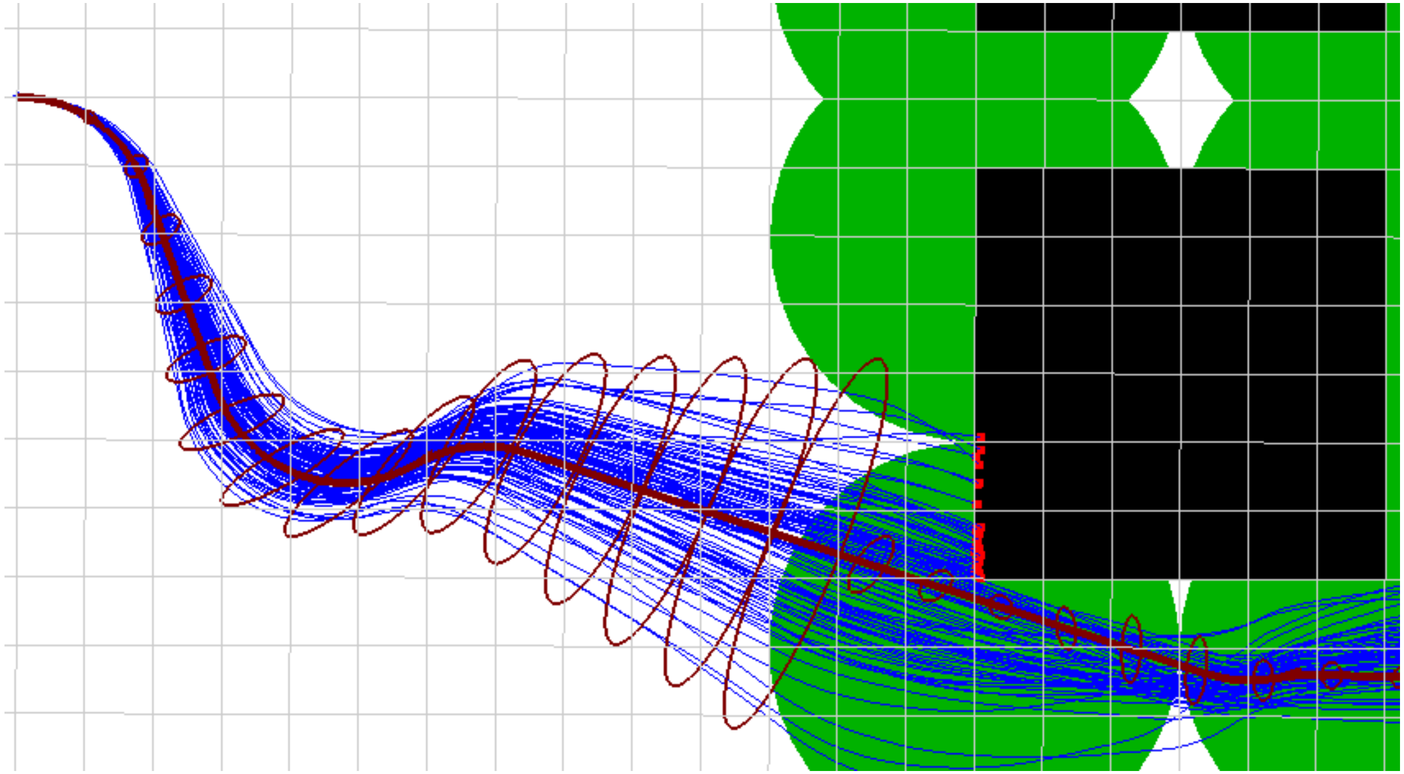

Predicting State Uncertainty

- Kalman covariance predicts uncertainty of posterior state estimate



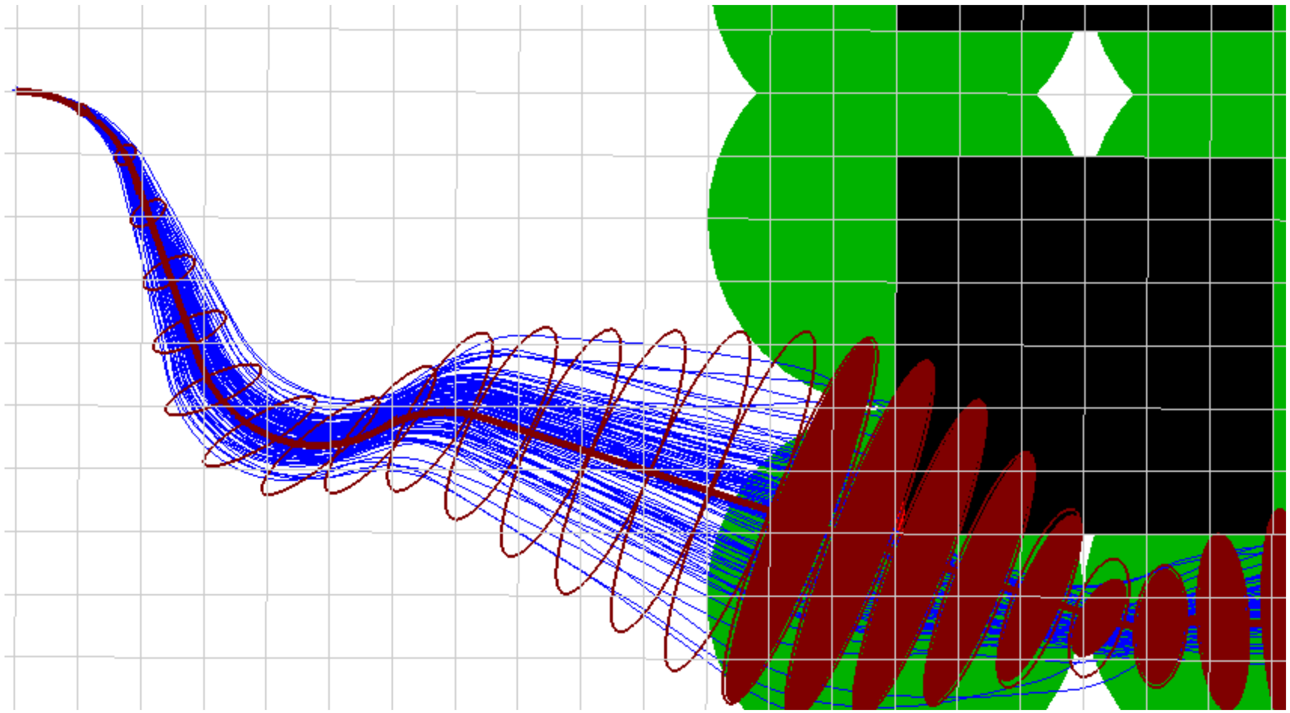
Predicting State Uncertainty

- Kalman covariance fails to predict full uncertainty

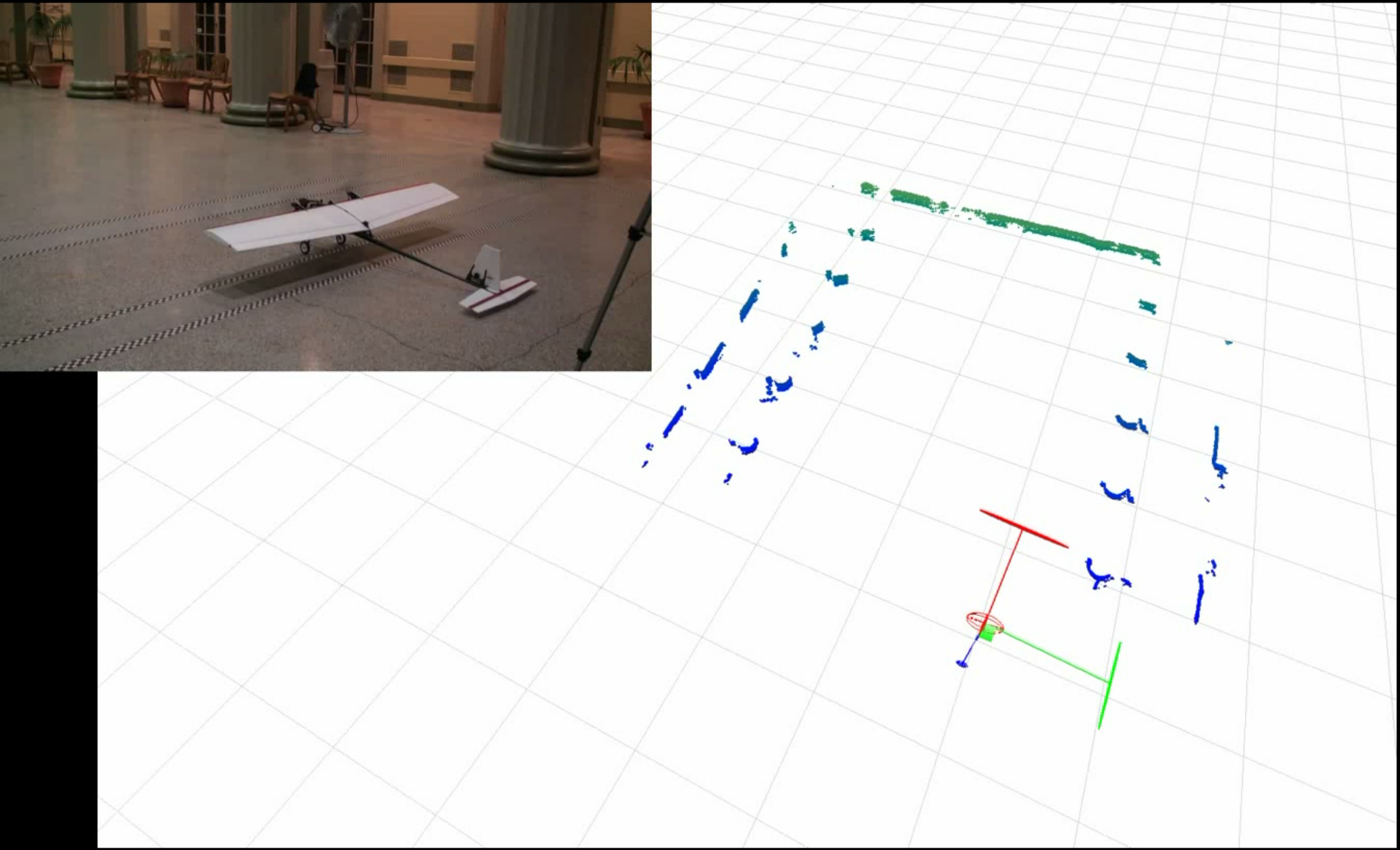


Predicting State Uncertainty Continued

- Gives us a distribution over trajectories for all realizations of process and sensor noise:



- “robot knows that it will know where it is, it just doesn’t know where that will be”



Summary

- Robust, long-term autonomy in large-scale environments
- Planning algorithms for worlds in which we have limited knowledge of the state, model of the system, or a map of the world
- Key Issue: Control of Information
- Technical approaches:
  - Understanding how information propagates
  - Machine learning