# AEROSPACE VEHICLE SENSING AND MAPPING

NONLINEAR DYNAMICS AND CONTROL LAB

Motivation

- Accurate estimates of relative pose and velocities between satellites are essential for safe and efficient docking, on-orbit refueling, and space debris removal
- Want to place fiducial markers in a way that maximizes estimate quality while considering surface area constraints (solar panels, antennae, etc.) and visibility constraints (shadowing, camera quality, etc.)
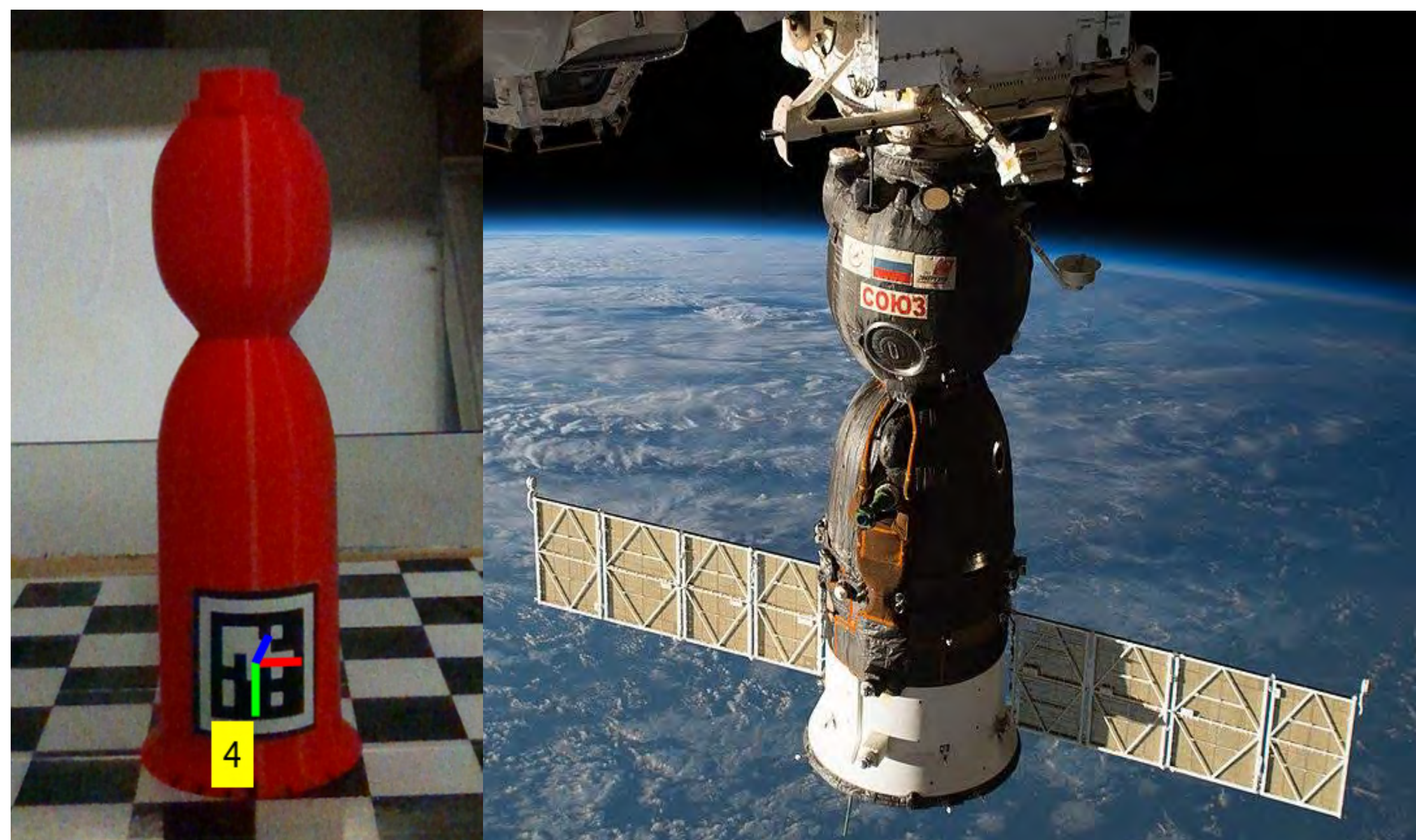
Fiducial Markers

- A single tag can provide a relative range and orientation measurement
- Using open-source AprilTag fiducial system developed out of the University of Michigan
- Tags are scalable to desired size and can easily be printed at home
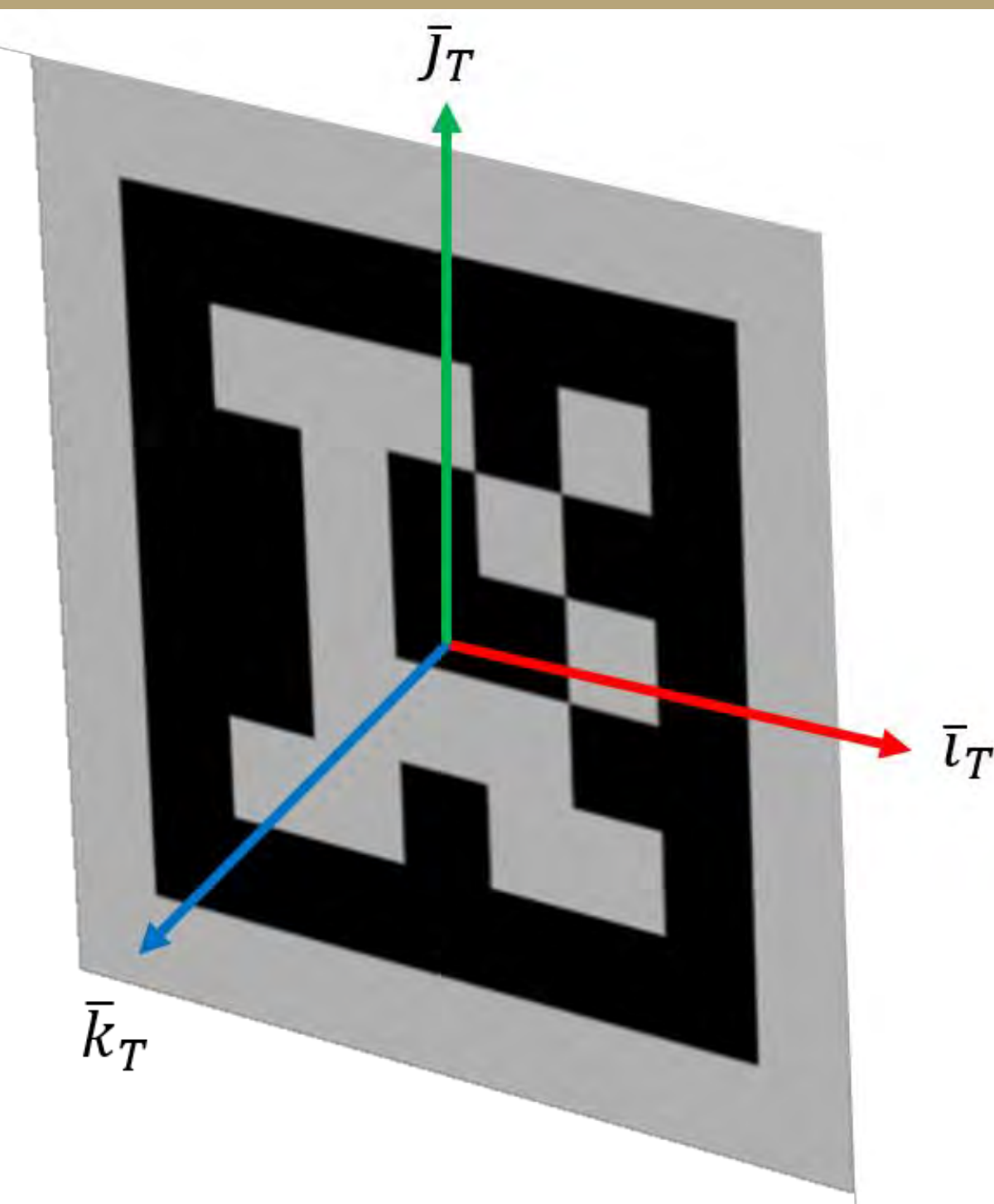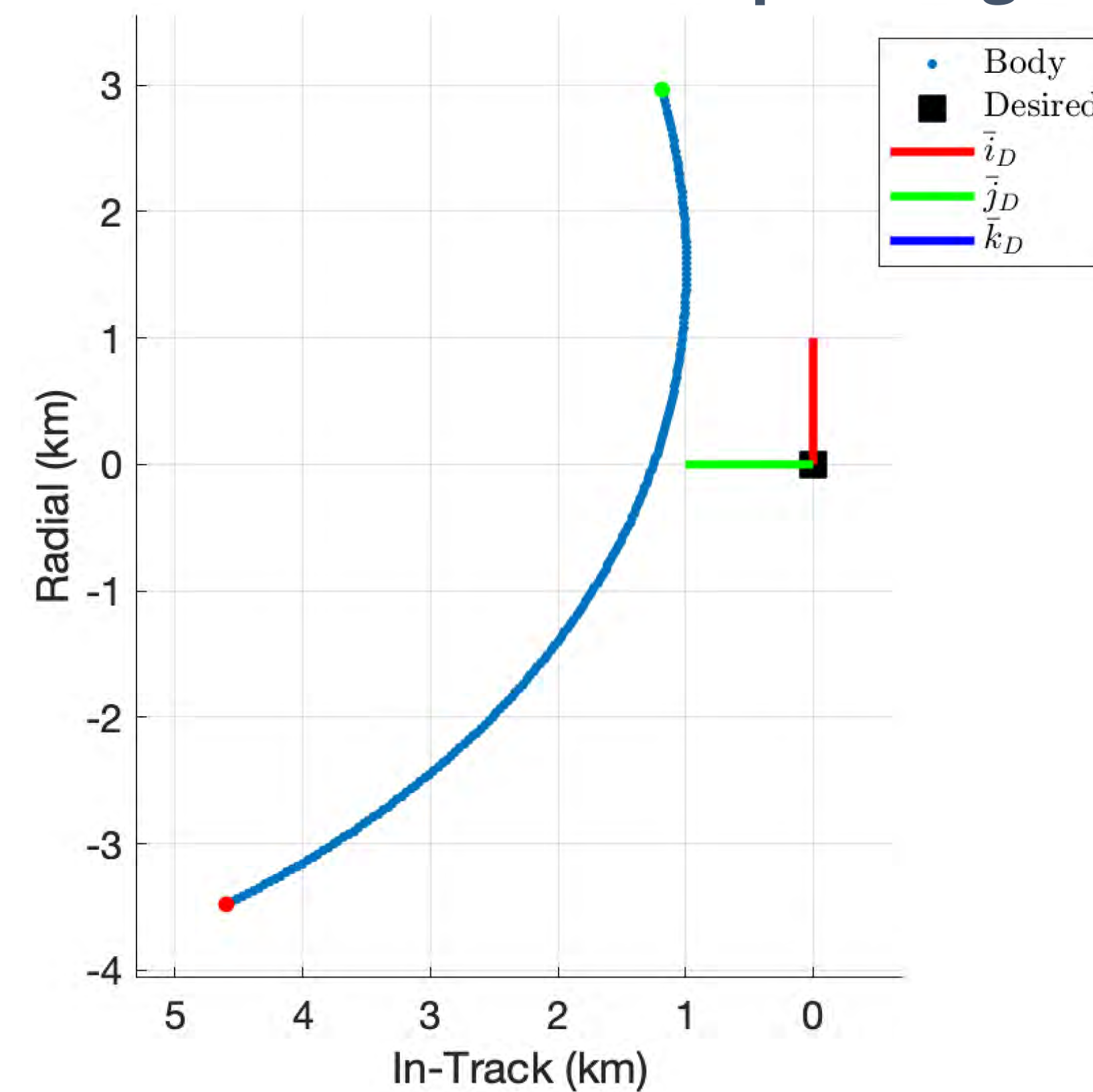

Optimal Sensor Placement

- A system is *observable* if the state can be uniquely determined from a set of measurements
- Empirical Observability Gramian is used to formulate sensor placement as a convex optimization problem that maximizes observability

Simulation Setup

- 3-hour geostationary flyby
- "Desired" satellite is fixed nadir pointing

- Candidate marker locations evenly spaced on "desired"
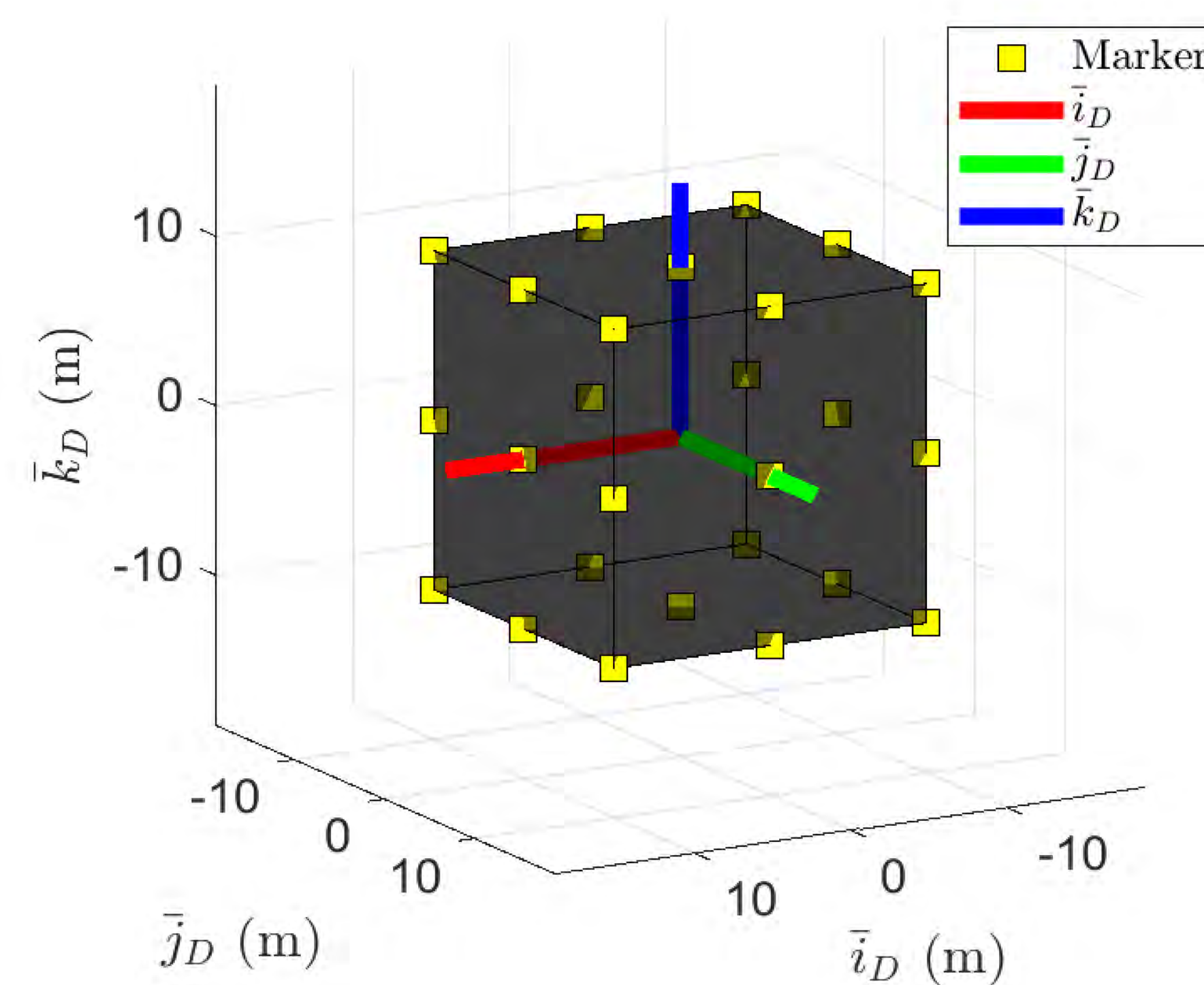
Simulation Results

- Optimal sets of 5 (left below) and 10 (right below)
- Solution spreads markers to maximize measurement differences
- Optimal markers are not necessarily those that are visible for longest duration
- Maximizing observability is synonymous with selecting sensors that are most sensitive to measuring changes in state
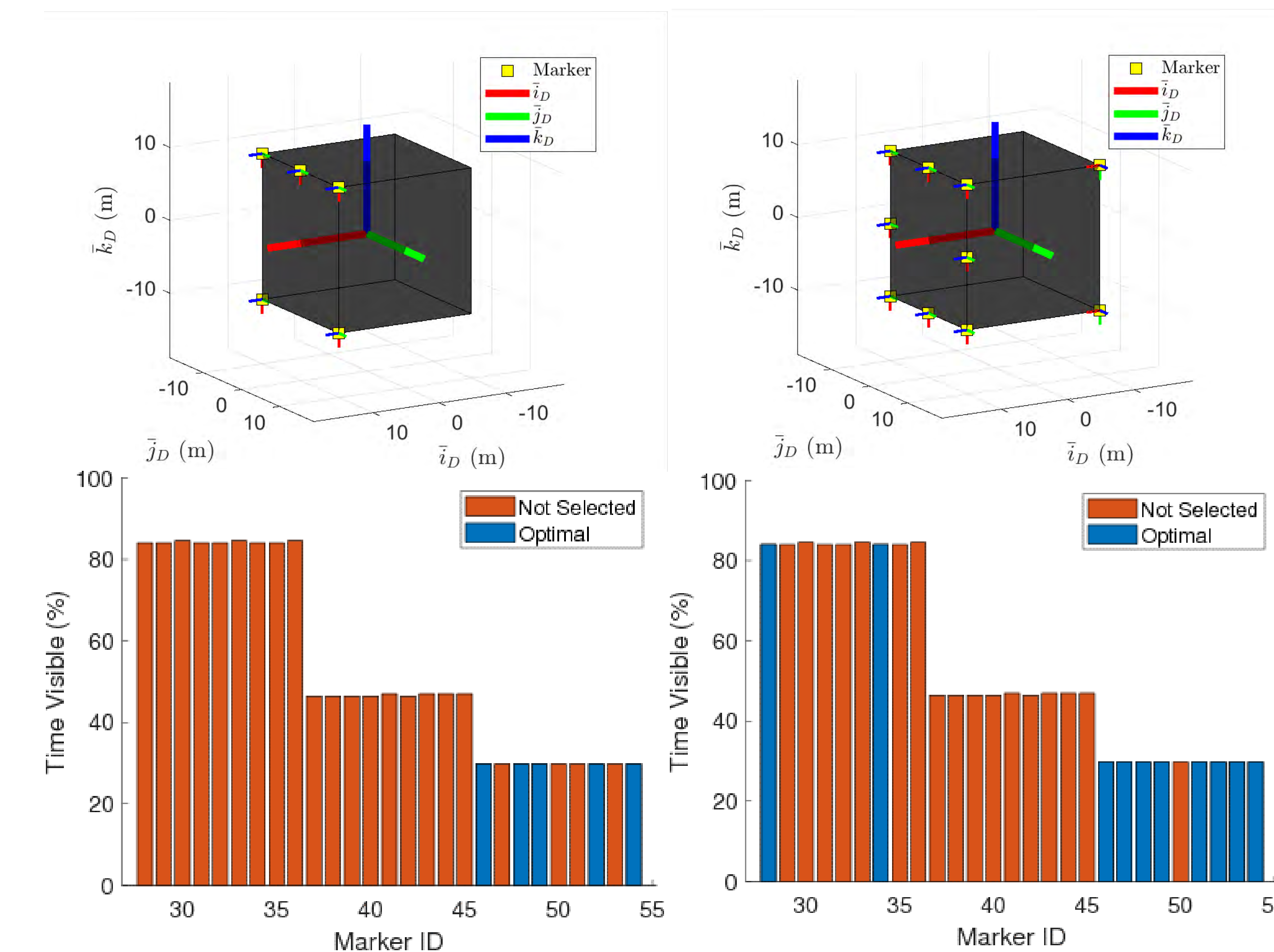
Acknowledgments

Faculty: Kristi Morgansen
Grad Students: Nick Andrews, Josh Cheng
Undergrads: Trail Sammarco, Marco Jawili, Celeste Yuan, Maya Morse