OPTIMAL FIDUCIAL MARKER PLACEMENT FOR SATELLITE PROXIMITY OPERATIONS **STUDENT(S): NICHOLAS ANDREWS**

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



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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



• Candidate marker locations evenly spaced on "desired"



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- differences
- visible for longest duration
- in state



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Simulation Results

 Optimal sets of 5 (left below) and 10 (right below) Solution spreads markers to maximize measurement

Optimal markers are not necessarily those that are

• Maximizing observability is synonymous with selecting sensors that are most sensitive to measuring changes

Acknowledgments