Near-Frictionless Test Bed for Satellite Maneuver Development

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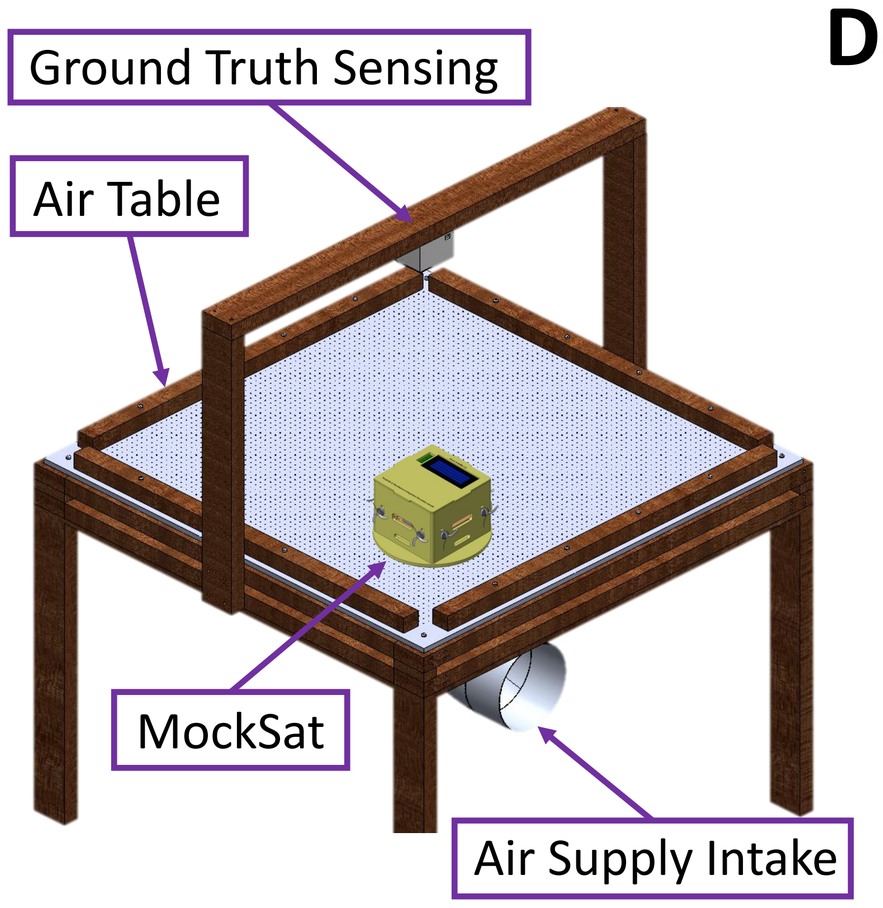
Purpose

Provide an on-campus testbed that allows students to develop, test, and validate space-vehicle guidance, navigation, and control techniques in a controlled environment.

Objectives

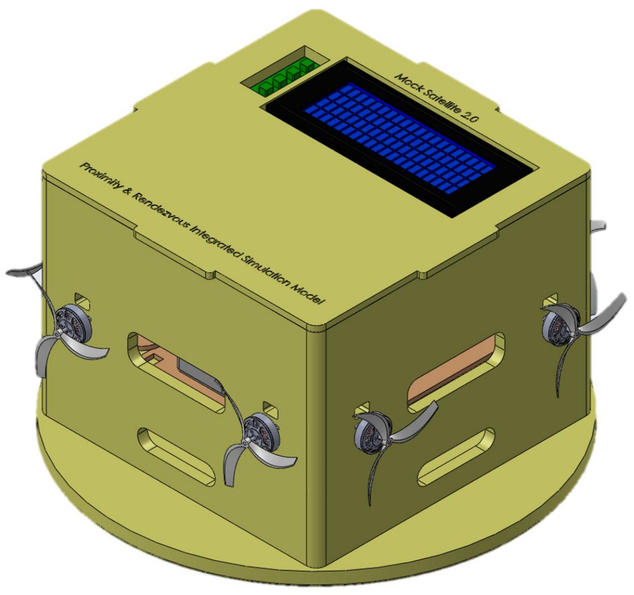
- Develop a **mock satellite** (MockSat) capable of precise translation and rotation with the capability to implement different control algorithms.
- Design and implement a **near-frictionless air lifted testing environment.**
- Establish a **control framework** that enables implementation and comparison of multiple maneuver **control algorithms.**



Design Overview

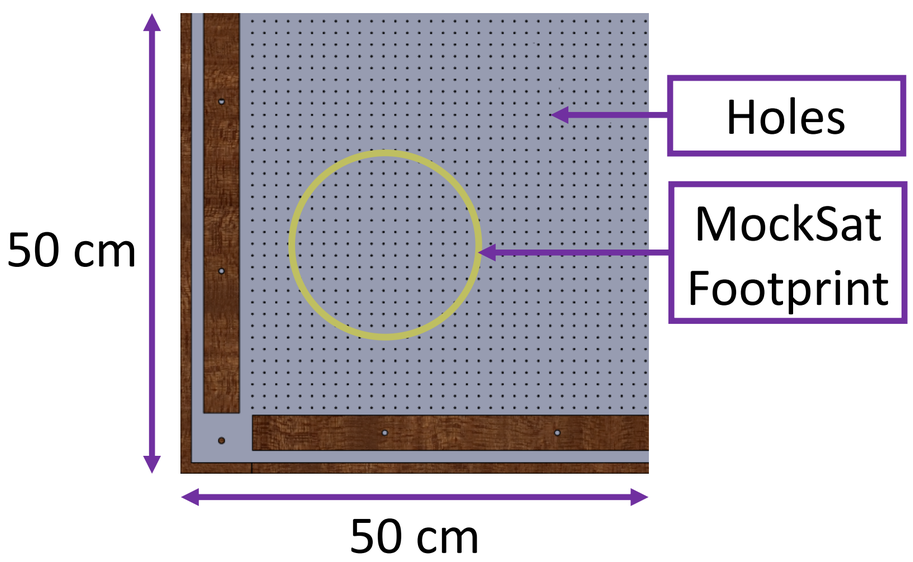
- The **Air Table** creates a smooth, low-friction surface using pressurized air, allowing the MockSat to move and rotate like a spacecraft in microgravity.
- The **MockSat** acts as the spacecraft model and uses onboard electronics and small motors to perform controlled movements.
- The **Ground-Truth Sensing System** tracks the MockSat using a camera and a visual marker to measure its motion.
- **Performance validation** is achieved by comparing the commanded motion, onboard sensor estimates, and external tracking data to confirm systems performance.

MockSat



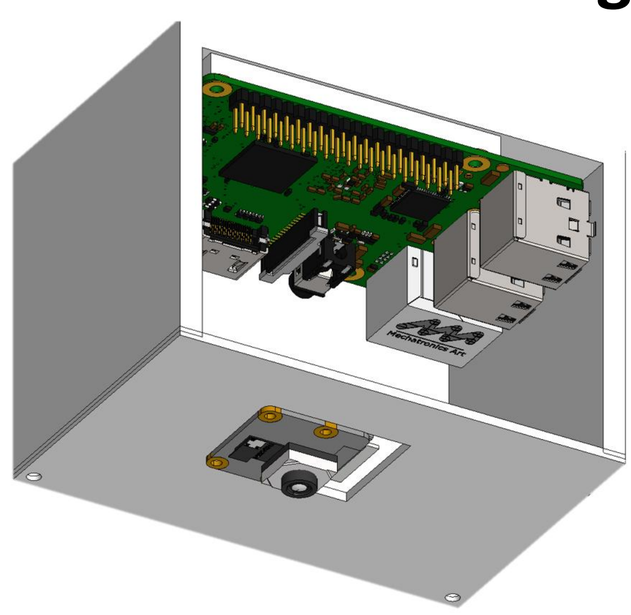
- **8 thrusters** (motors, propellers, ESCs) for angular & translational control
- 1 Pulse width modulation board + 3 LiPo batteries for power and actuation
- Onboard **motion sensors** provide speed and orientation feedback, while the **switch, buttons**, and **display** allow the operator to select control modes, adjust thrust settings, and start or stop tests.

Air Table



- **2.3 kW blower** pressurizes the table to generate an **air cushion**.
- Smooth aluminum surface and air exiting through surface holes create a **~0.5 mm** air cushion for lift and stable gliding.
- Provides near-frictionless motion while supporting **up to 5 kg over a 20 cm** diameter surface contact area, approximately **324 cm²**.

Ground Truth Sensing



- Uses AprilTag **QR codes** for visual **pose estimation**, developed by the APRIL Robotics Lab at the University of Michigan (Olson et al., 2011).
- AprilTags placed at each corner provide a **fixed global reference frame**.
- **Tracks position and attitude** (±5 mm, ±1° accuracy) with 120° Arducam mounted 0.5 m above table.