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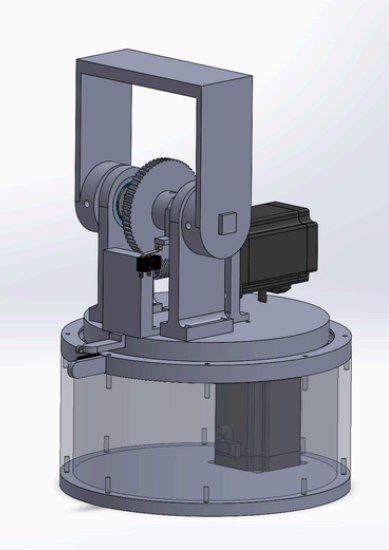
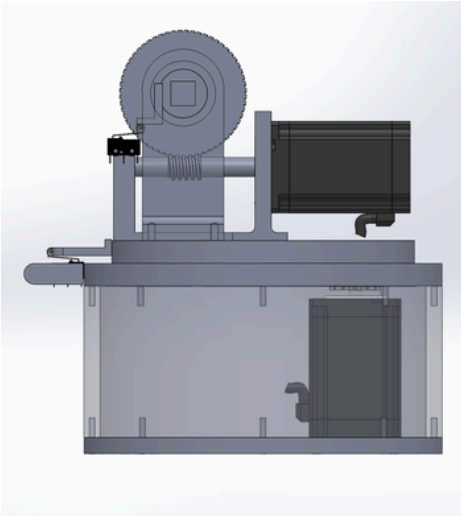
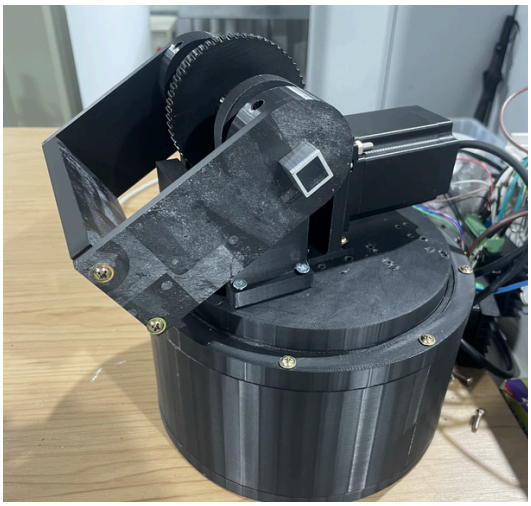
AEROSPACE ENGINEERING AT UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

MOTORIZED SATELLITE TRACKER - GROUND STATION







Situation:

- **Sun-Synchronous Orbit (SSO)** satellites require high-precision real-time tracking to maintain communication links.
- Satellite travel at approximately 7.5 km/s requiring **high-slew rate tracking** and precise pointing to maintain link.

Task

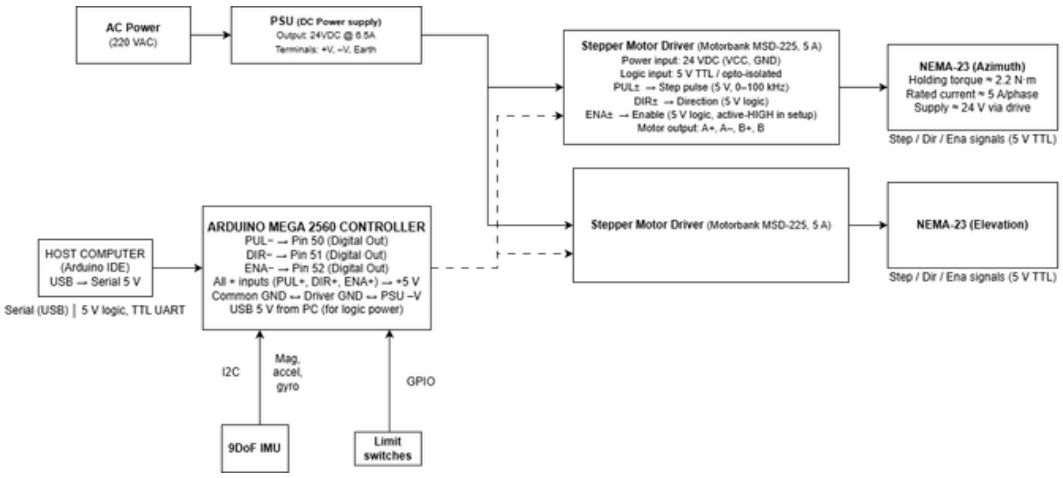
- Design and prototype a **dual-axis** (Azimuth-Elevation) motorized ground station capable of tracking satellites using real-time orbital data with stable dynamic response.
- The system needs to support a heavy **(1.5 kg)** Yagi antenna boom

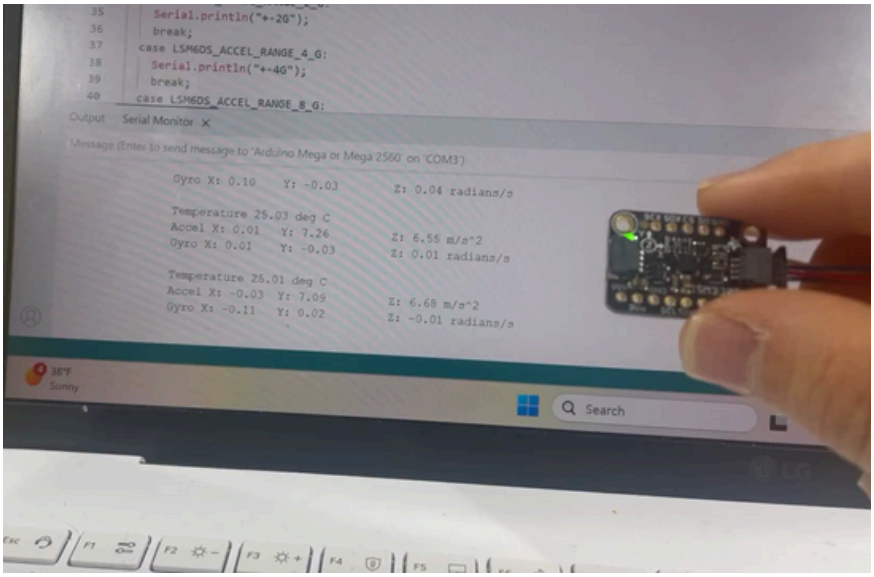
Action

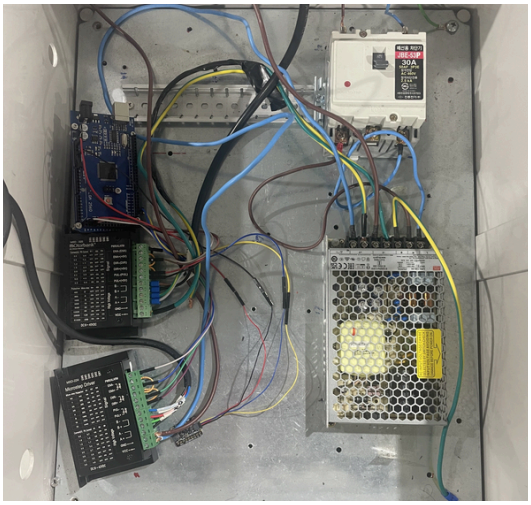
- **Mechanical Trade Study**: Performed a trade study analyzing bearing loads and required azimuth/elevation torque, which led to the selection of **NEMA-23 motors** with a **5:1 (Azimuth) gear and 60:1 (Elevation) worm gear reduction ratio** to ensure tracking stability under environmental disturbances.
- **Power & Logic Architecture**: Designed an electrical system converting **220 VAC to 24 VDC** to power **Motorbank MSD-225 drivers**. Used an **Arduino Mega 2560** to handle 5V TTL logic for PUL/DIR/ENA signals, ensuring electrical isolation between high-power motors and logic controllers.
- **Software**: Implemented orbital propagation algorithms in **C++/Arduino** to parse Two-Line Element (TLE) data, enabling the system to predict satellite passes and calculate real-time Azimuth and Elevation coordinates.
- **System Integration**: Applied **CAD** principles (**SolidWorks**) to rapid prototype and **3D printing** to ensure structural integrity.

Results

- **Dynamic Response**: Achieved stable, jitter-free movement by iteratively tuning Arduino algorithm and motor micro-stepping, which was verified visually through programmed test sequences.







Challenges and Improvements

- Cable twist risk
  - Current design limited to 360° azimuth rotation; future iteration will integrate a slip-ring assembly to allow continuous tracking of multi-orbit passes
- Current design does not account for variances in the weather
  - Weatherproofing and larger antenna support

CURRENT DEVELOPMENT: HIL GNC TEST RIG - ROBOT ARM

Mission Objective

- Develop a 4-to-6 DOF robotic arm capable of simulating spacecraft proximity maneuvers (e.g., docking or landing) in a **Hardware-in-the-Loop (HIL) environment.**
- The system is engineered to carry a **1.33 kg CubeSat** mockup. The arm must maintain high-precision positioning while managing the inertial moments of the 1.33 kg payload at the end-effector.

Project Roadmap (Current Status)

- **Phase 1 (In-Progress)**
  - **Mechanical Design & CAD**: Currently conducting mechanical trade study to create a **BOM** of parts and **CAD** of the prototype structure
- **Phase 2 (Upcoming)**
  - **Digital twin and simulation**: Develop a Deep Learning pipeline in NVIDIA Isaac Lab using synthetic data to perform 6D pose estimation of a 1U CubeSat.

Hardware Integration

- Utilizing MATLAB/Simulink for control design and **SolidWorks** for rapid prototyping of joint assemblies.