# CP301

## CONCEPT DESIGN AND PROTOTYPE DEVELOPMENT OF A UGV (UNMANNED GROUND VEHICLE)-UAV (UNMANNED AERIAL VEHICLE) TRANSFORMER

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# INTRODUCTION

Design and prototyping of a hybrid UGV-UAV Transformer enabling seamless ground-air transitions, inspired by nature and AI-driven robotics.

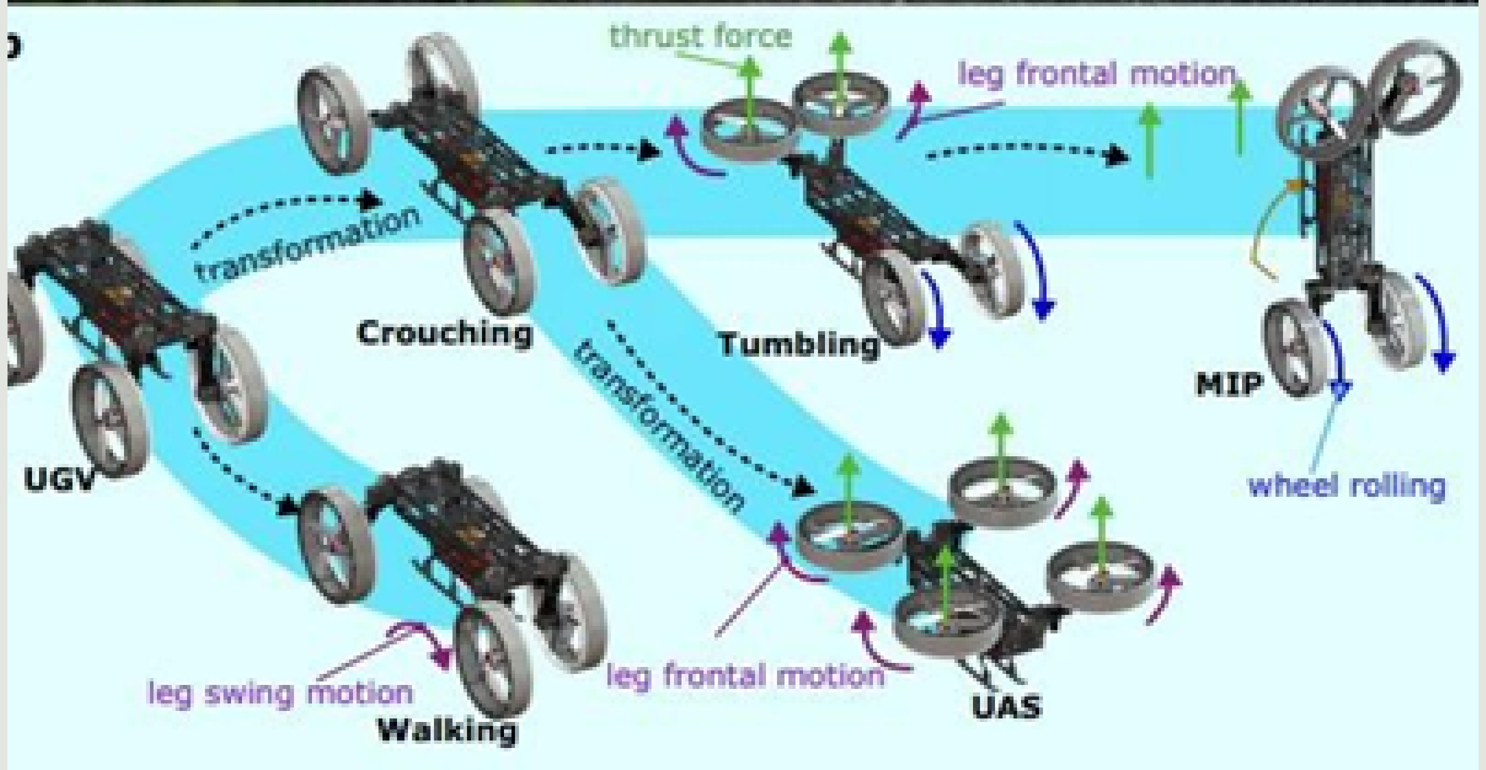
- Key Features:
  - BLDC motors + geared transmission for UGV
  - 2307 1400KV motors + 8045 props for UAV
  - Two-stage transformation: servo + linear actuator
  - Dual-mode control: PWM (UGV), SBUS (UAV)
- Control System:
  - ESP32 for UGV operations
  - SpeedyBee F405 FC (IMU, barometer, blackbox) for UAV
- Design Focus:
  - Modular integration · Power efficiency · Low-latency control
- Applications:
  - Reconnaissance · Environmental Monitoring · Disaster Assessment

# LITERATURE REVIEW

- M4 – Caltech (Sihite et al., 2023): Biologically inspired robot achieving rolling, crawling, crouching, and flying via appendage repurposing. Informed our actuator-based transformation strategy.

- GuLu·XuanYuan (Chen et al., 2023): Integrates humanoid, reptilian, and aerial modes with simplified transformation and minimal hardware redundancy. Guided our UGV-UAV structural integration

- UGV-UAV Transformer (Rechtin, 2024): Real-world demo emphasizing mechanical design, actuation reliability, and ESC-control synchronization. Shaped our practical design considerations.



# PROBLEM STATEMENT

Motivation & Proposed Solution

- Problem:
  - UGVs: Poor at obstacle navigation, terrain handling
  - UAVs: Limited flight time, low payload
- Solution:
  - UGV-UAV Transformer — a hybrid robot with dynamic ground-air switching
- Design Goals:
  - Real-time mechanical transformation
  - High-torque ground actuation
  - Quadcopter-based aerial mobility
  - Efficient control & power management
- Applications:
  - Agriculture · Logistics · Disaster Response · Industrial Inspection.

# METHODOLOGY

## Phase 1: Ground Mobility (UGV Mode

Chassis:

- Acrylic for strength-to-weight optimization
- Balanced weight distribution for transformation stability

Drive System:

- 2x IDUINO 5010-360KV BLDC motors (20:1 geared, 3.41 Nm torque/wheel)
- Differential drive for precise steering
- ESP32 + for PWM velocity/direction control
- Custom 3D-printed PLA wheels with high-traction treads

# METHODOLOGY

## Phase 1: Ground Mobility (UGV Mode)

Control Layer

- ESP32 interprets PWM from 4-channel RC receiver
- Channels mapped to throttle, steering, actuator, and servo
- Real-time analog stick control using 1–2 ms pulse widths

# METHODOLOGY

## Phase 2: Transformation Mechanism Integration

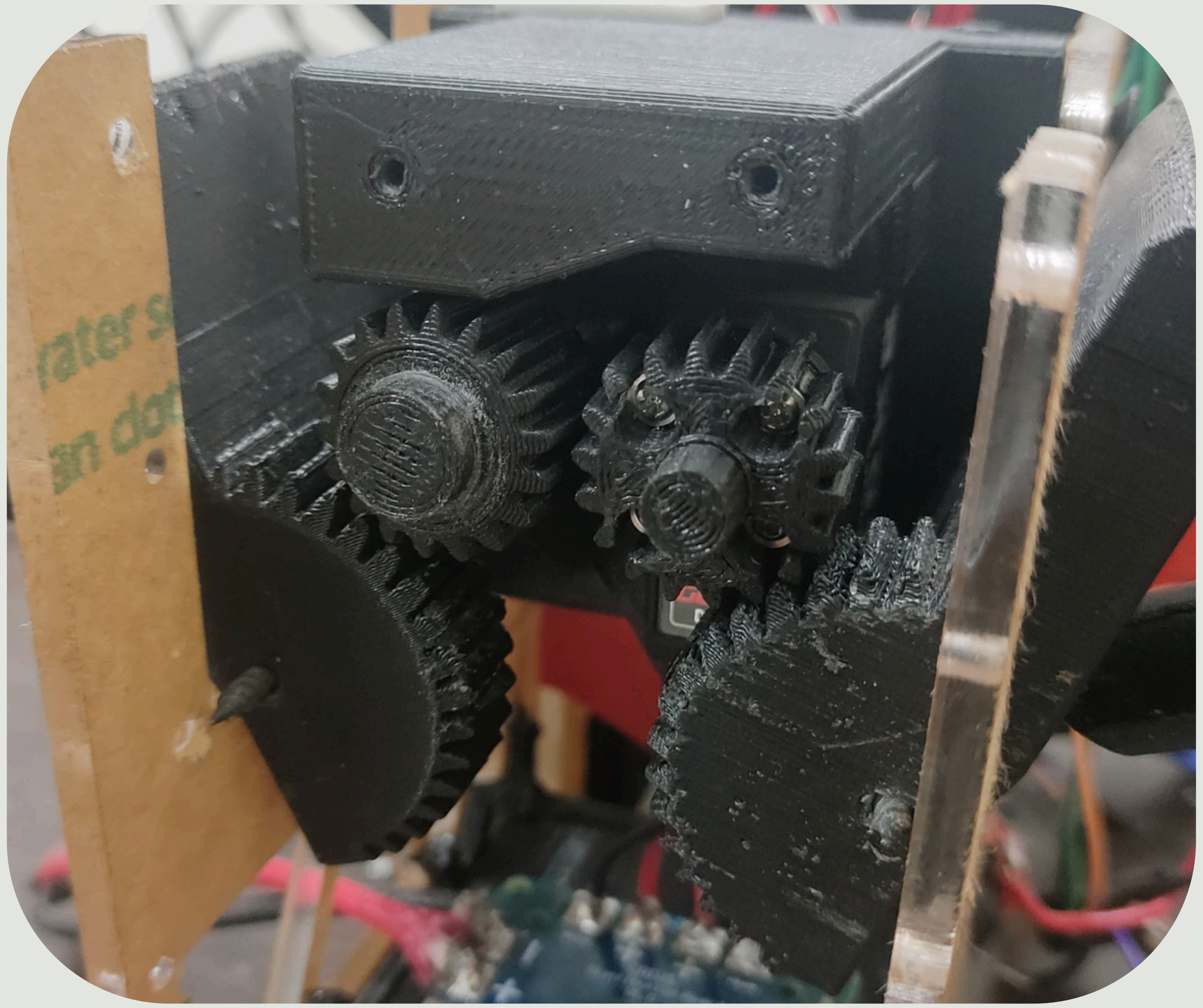
- Mechanical Design:
  - Two-stage actuation:
    - 25 kg·cm servo rotates rotor arms ~180°
    - 100 mm, 60 N linear actuators lock UAV configuration
  - Forms stable 4-bar linkage with telescopic motion and minimal CG shift

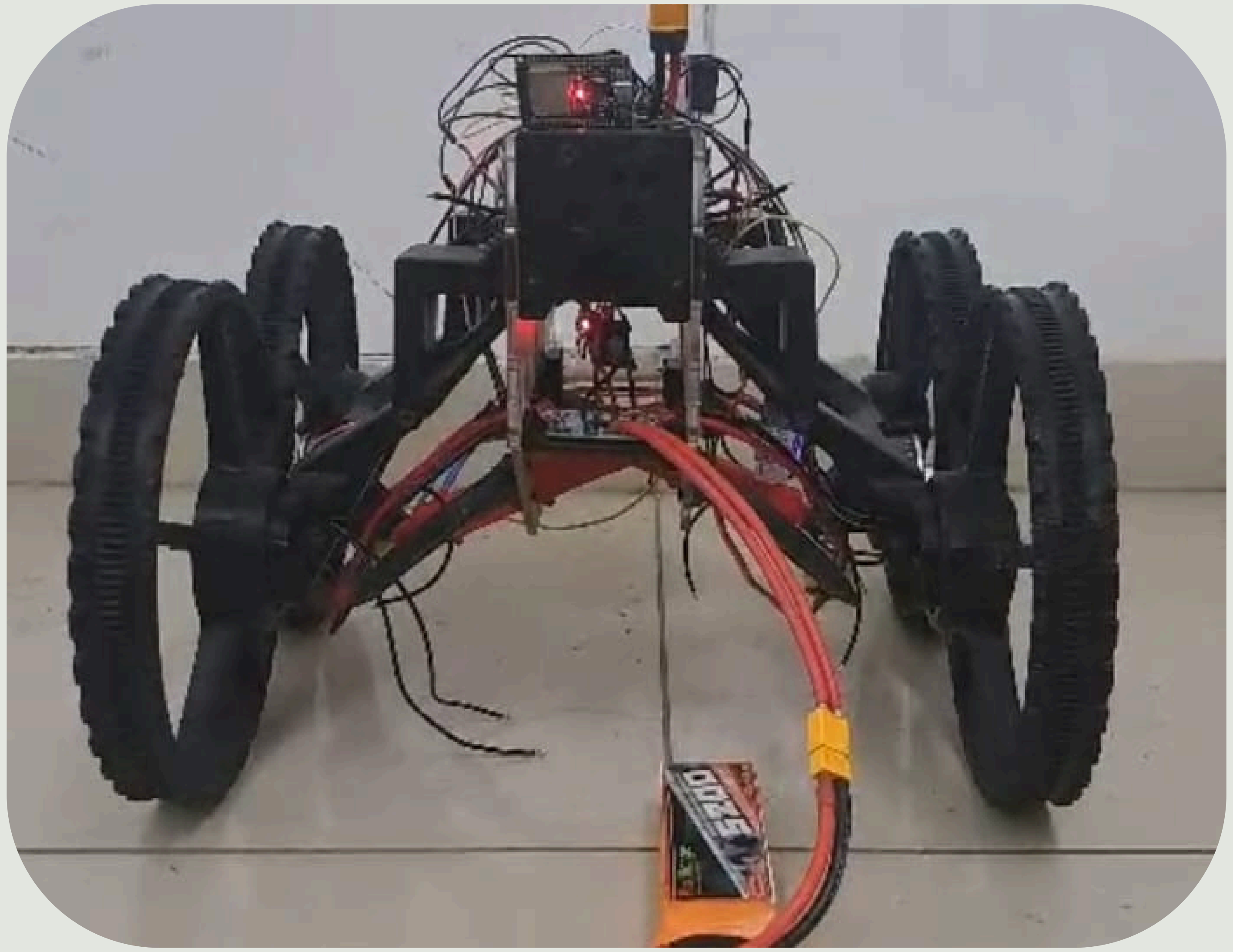
Control Logic:

- Wireless mode switching via transmitter switches
- PWM for ground mode, SBUS for flight mode
- Safety interlocks prevent simultaneous UGV/UAV motor activation

# METHODOLOGY

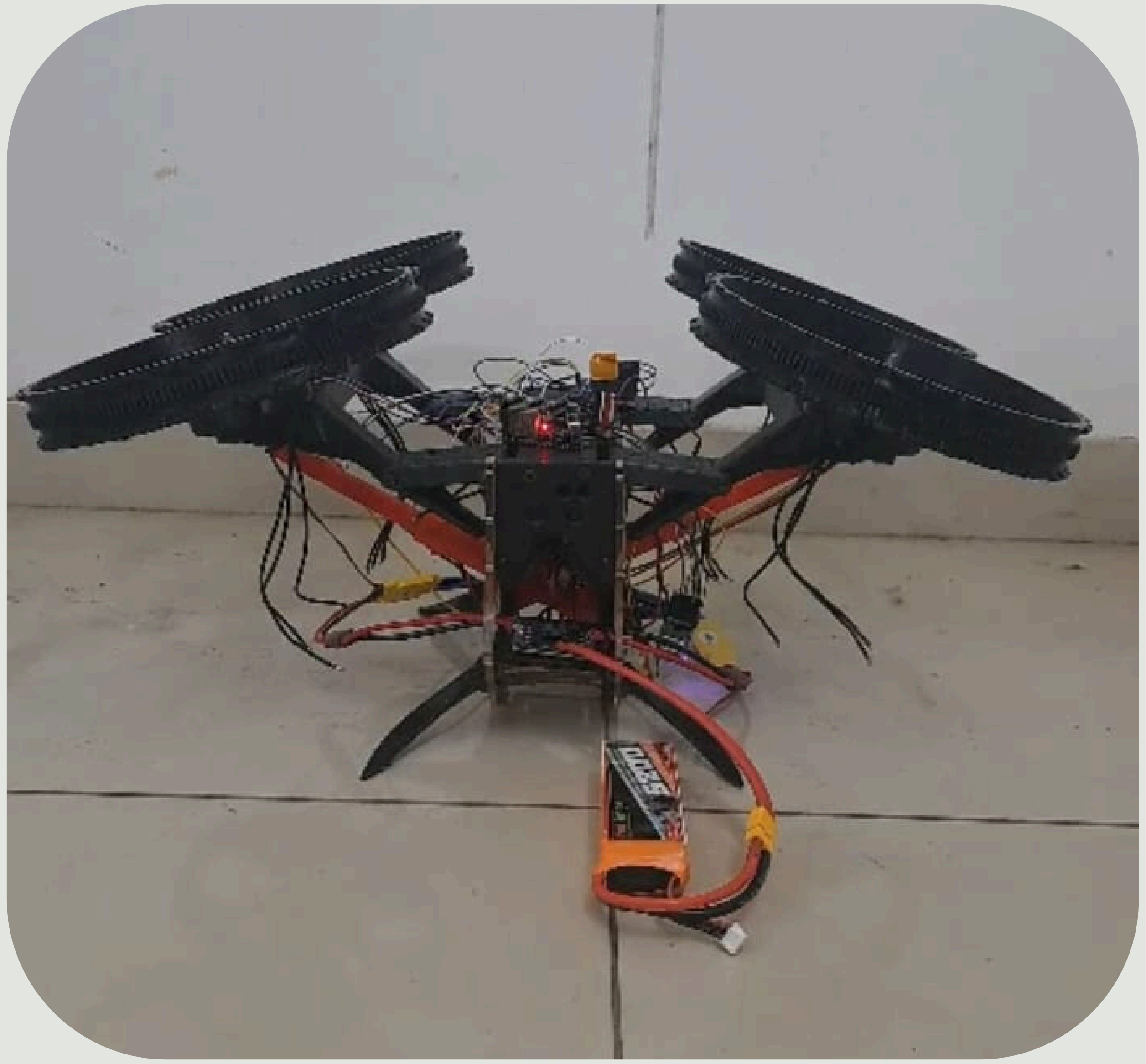
## Phase 2: Transformation Mechanism Integration





# METHODOLOGY

## Phase 2: Transformation Mechanism Integration



# METHODOLOGY

## Phase 3: Aerial Mobility Subsystem (UAV Mode)

- Propulsion System:
- 4x 2307 1400KV motors + 8045 props → ~34.7 N thrust (> system weight)
- Powered by 3S (11.1V) LiPo battery

ESCs:

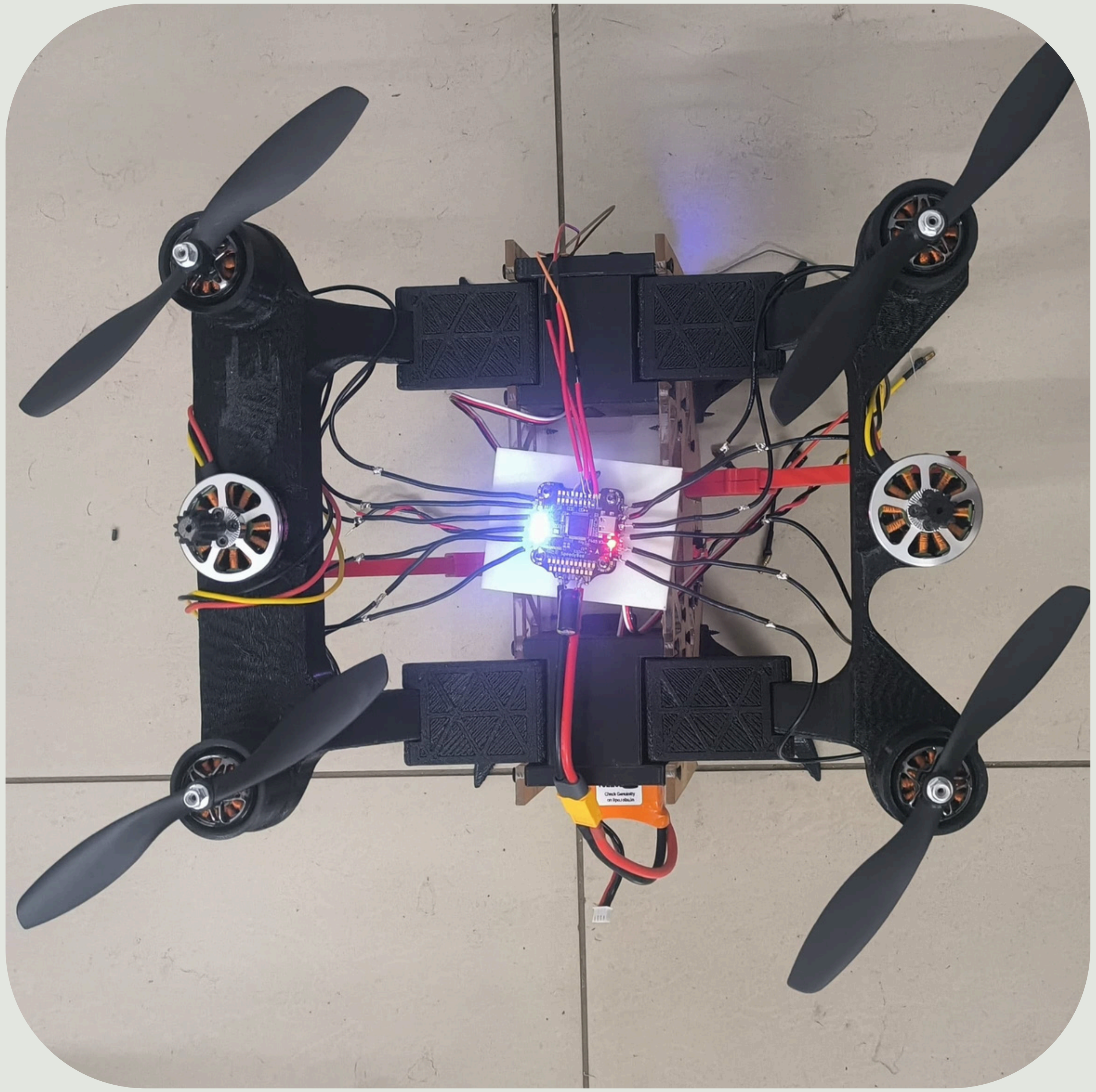
- 4-in-1 ORION 35A ESC for compact, synchronized control
- DSHOT600 support with RPM telemetry

# METHODOLOGY

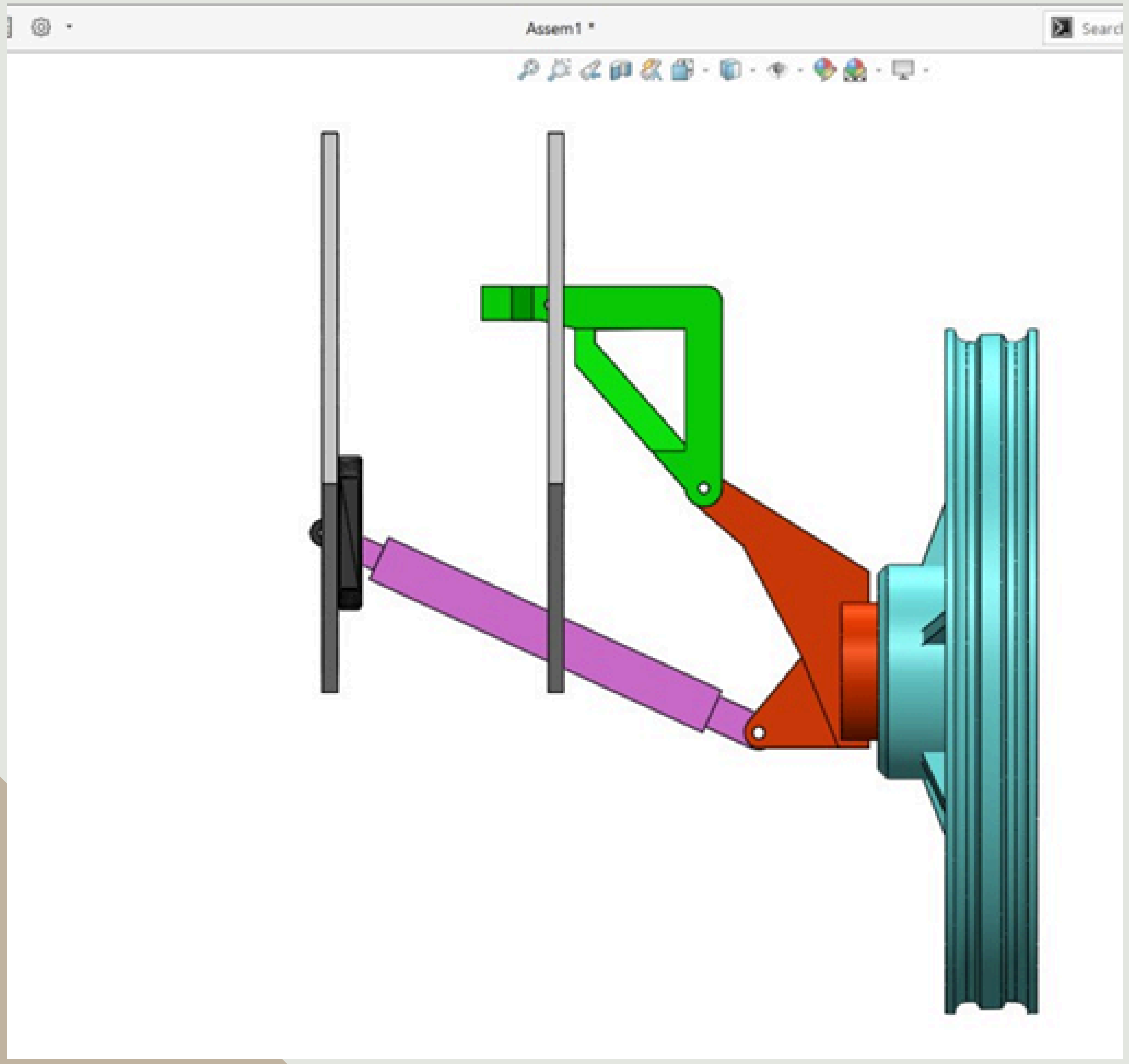
## Phase 3: Aerial Mobility Subsystem (UAV Mode)

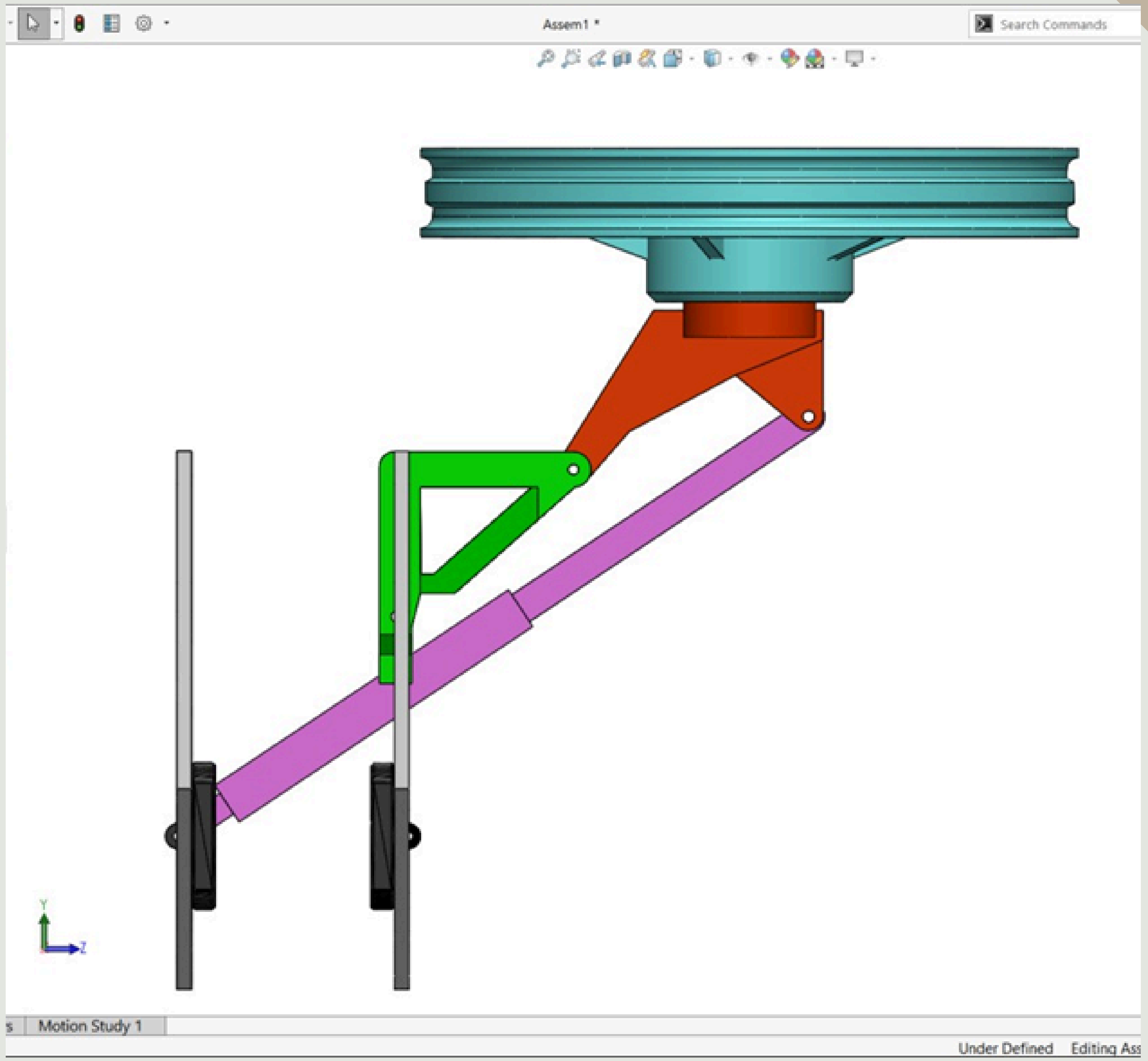
Flight Control System

- SpeedyBee F405 V3 FC with 6-axis IMU, barometer, OSD, blackbox
- Controlled via SBUS (16-ch) for low-latency mode switching
- Enables seamless transition between UGV and UAV modes



# SIMULATIONS



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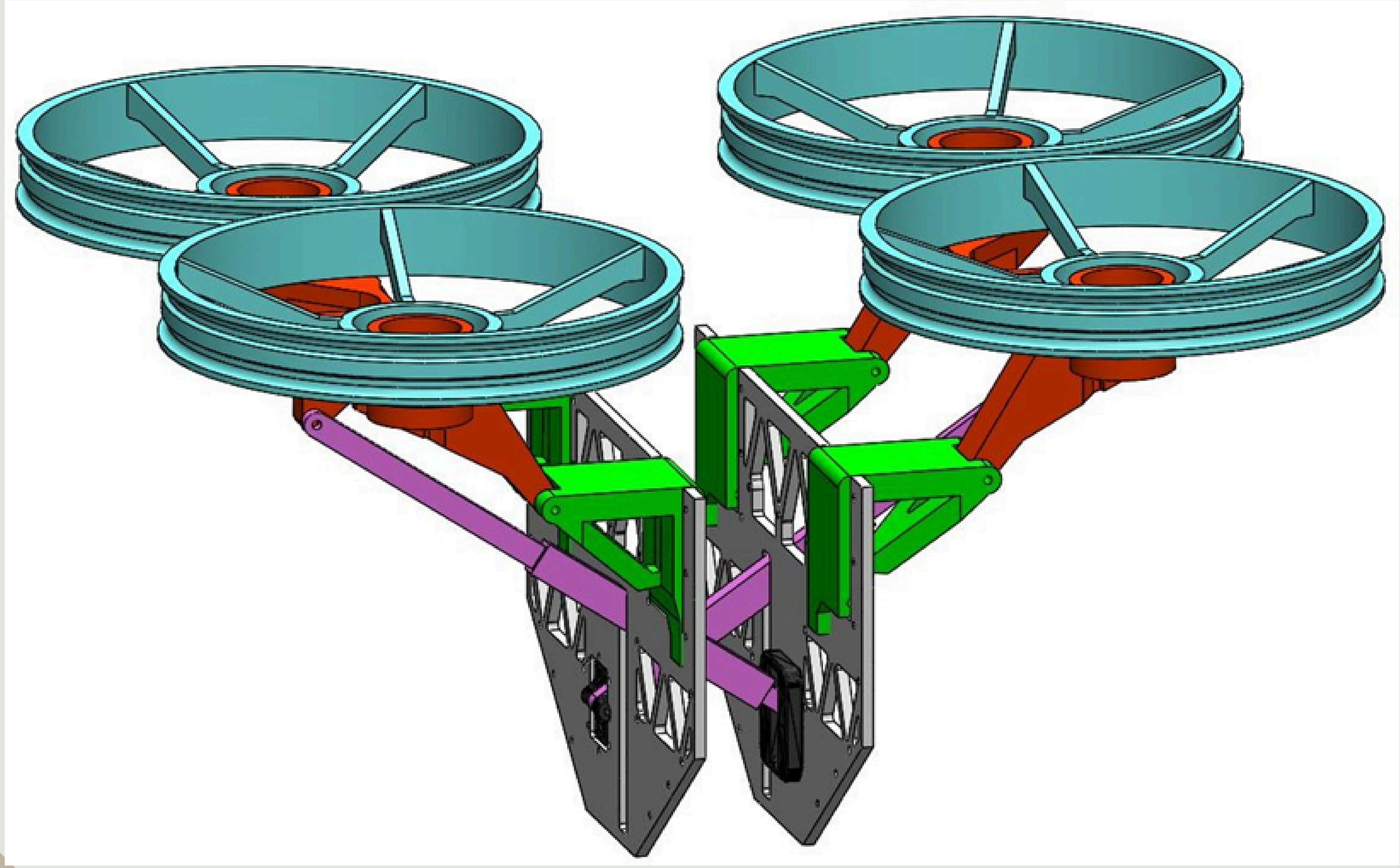

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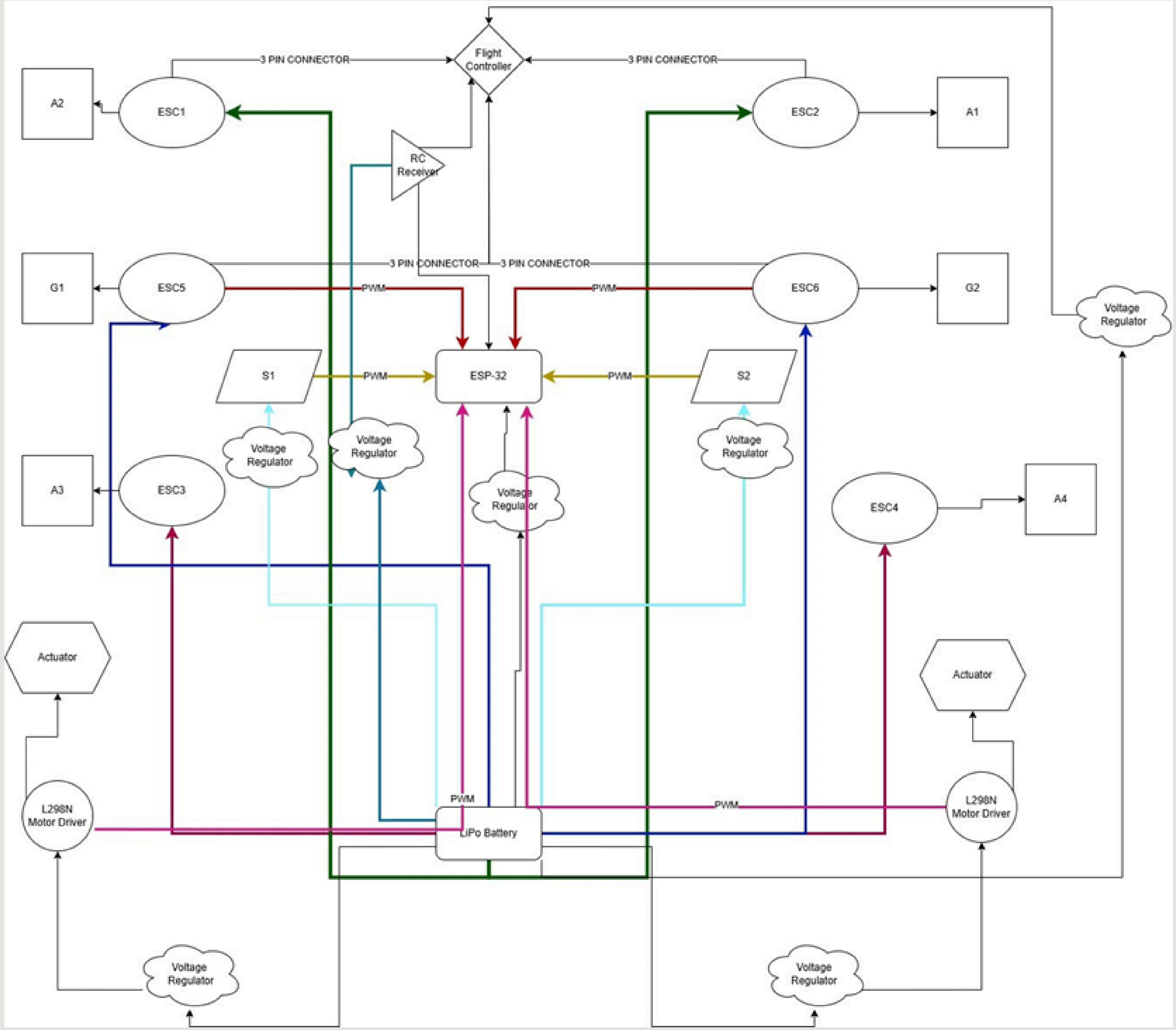
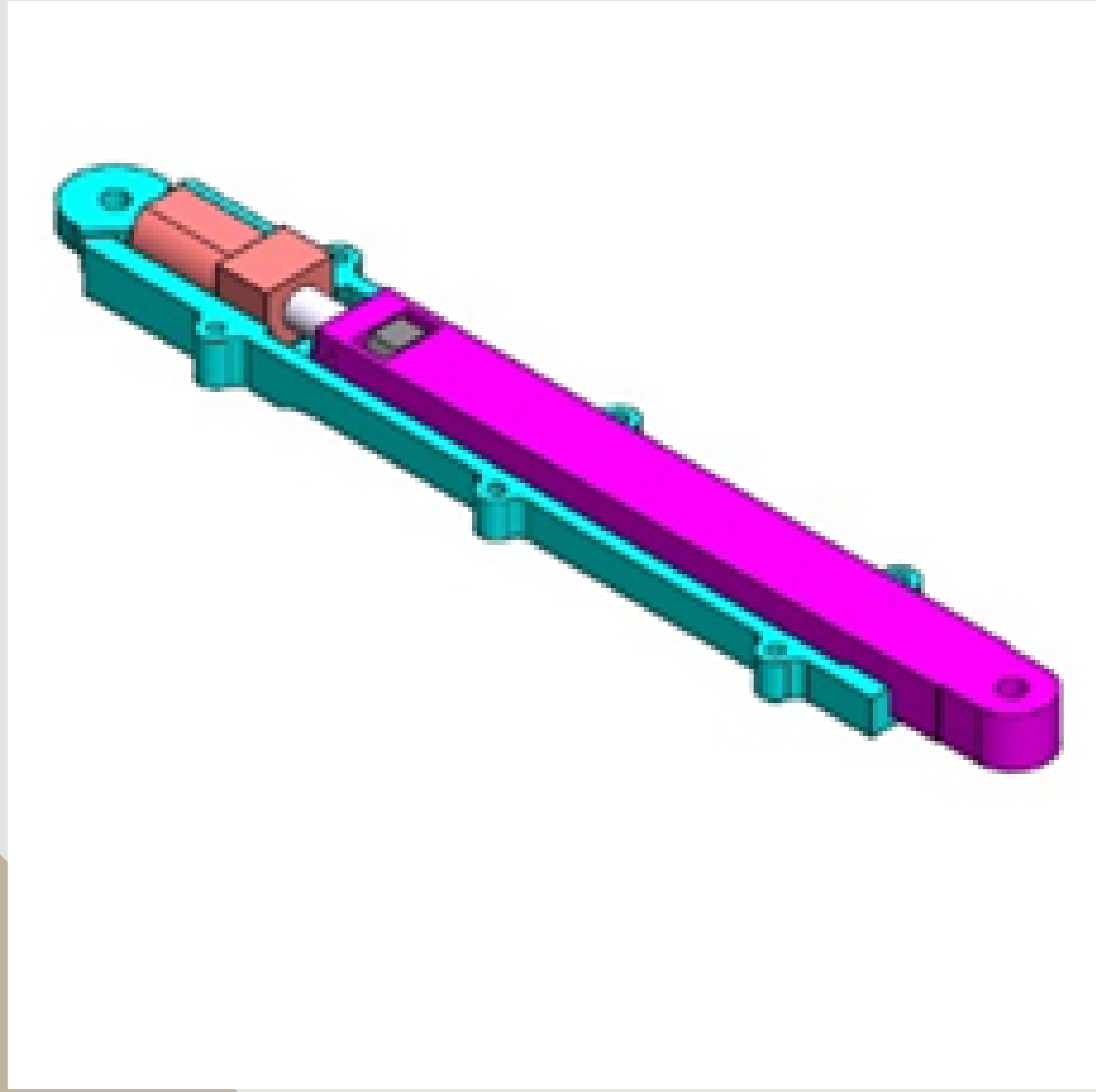
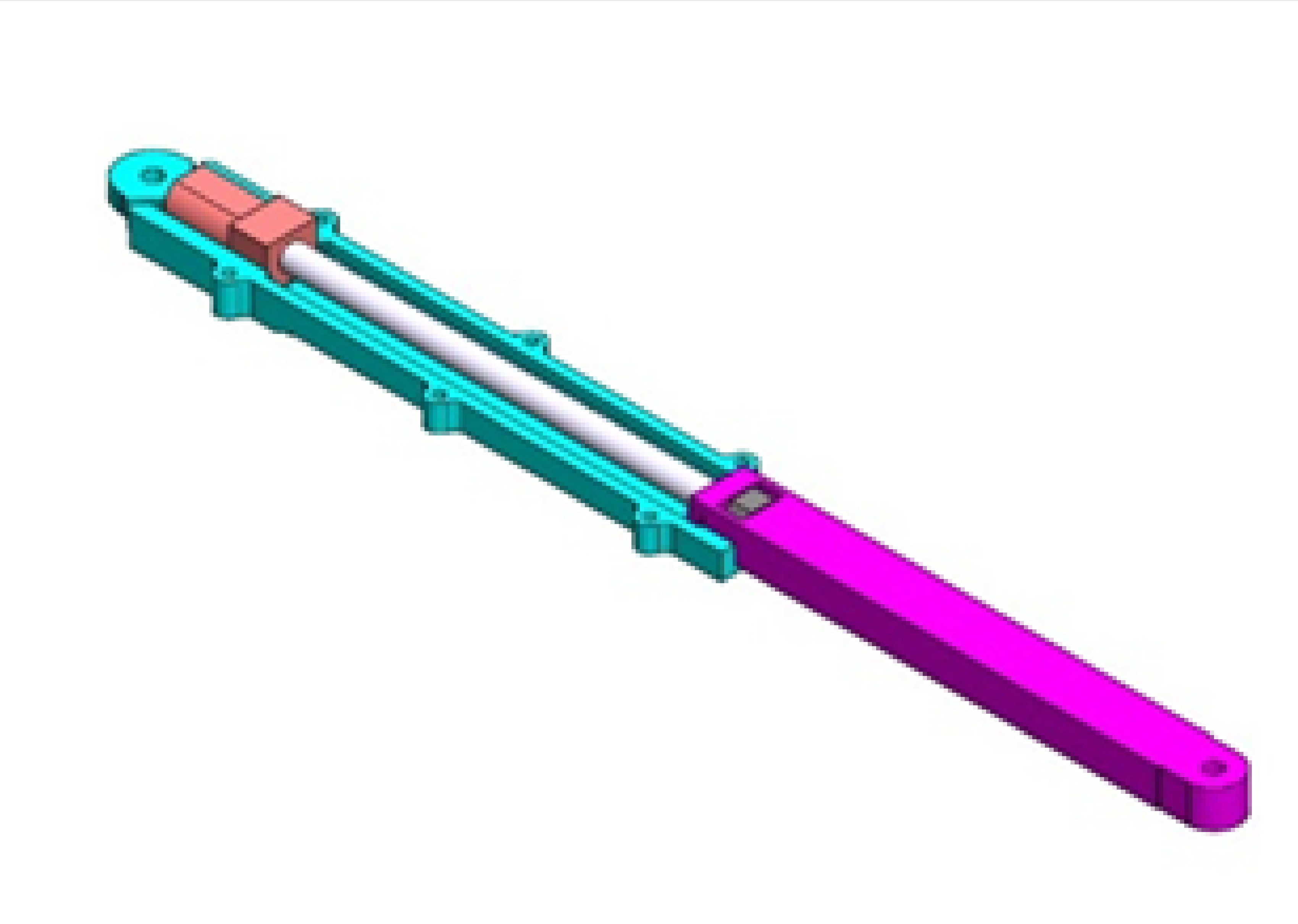


# SIMULATIONS

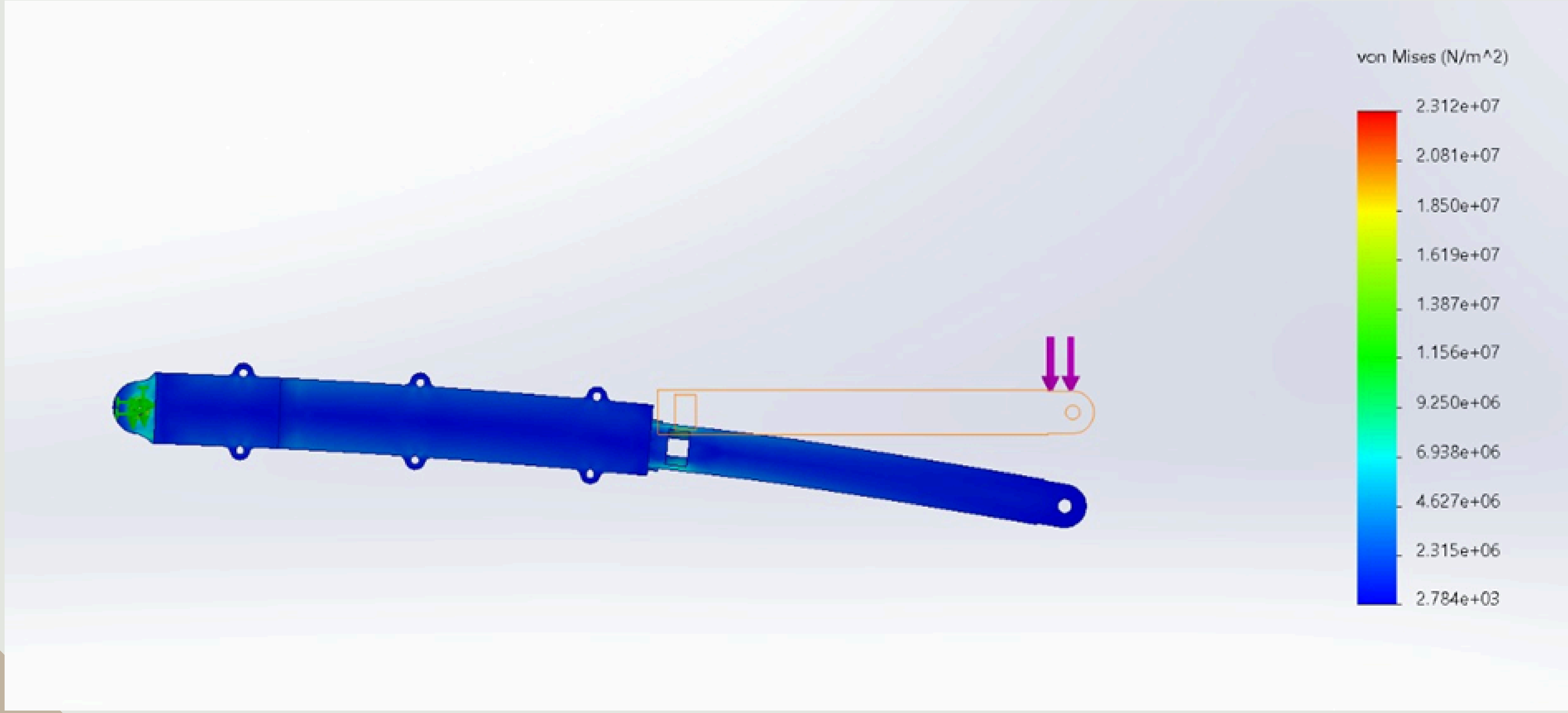
## ASSEMBLY VIEW OF THE LINEAR ACTUATOR





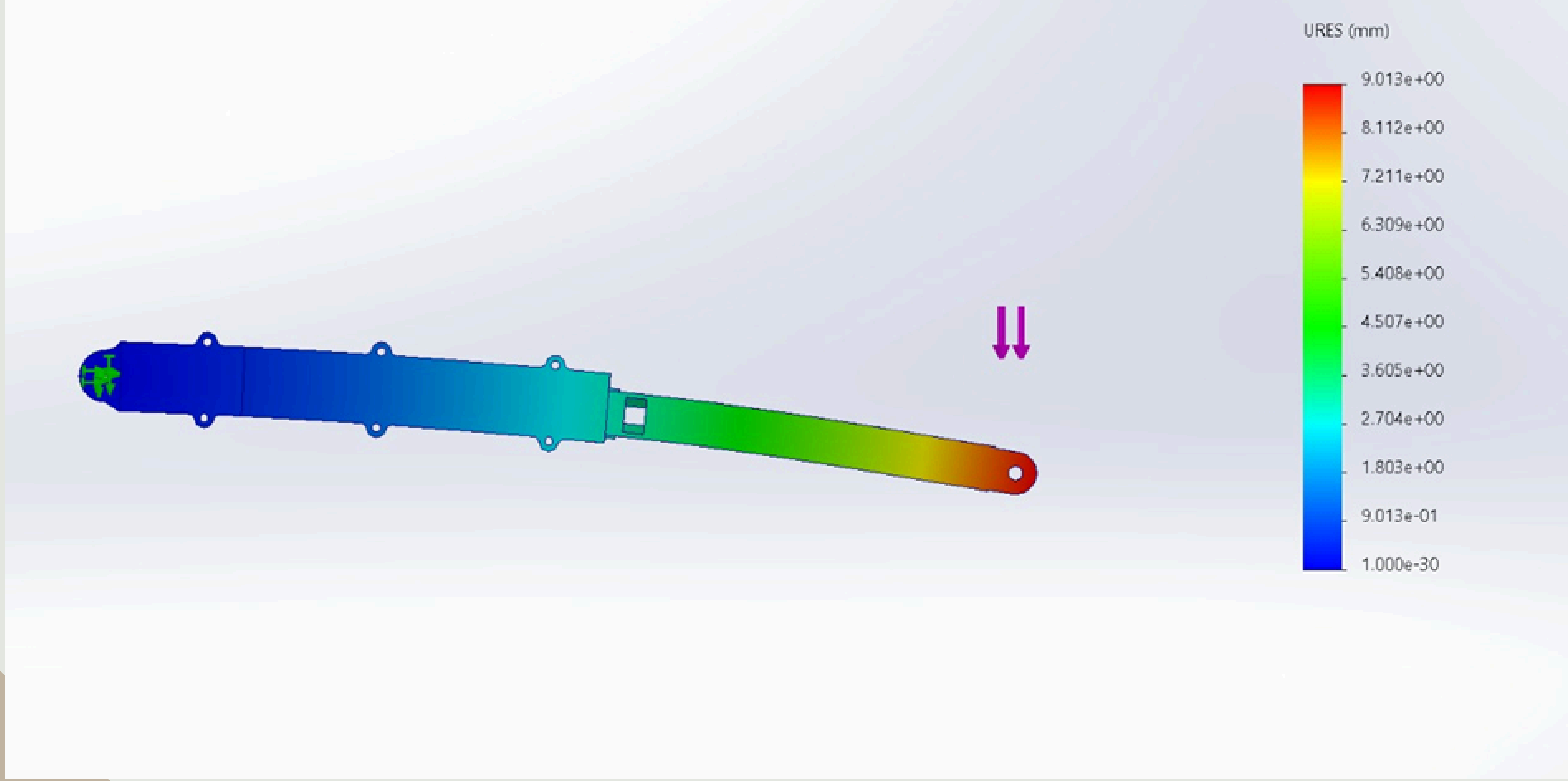
# SIMULATIONS

## VON MISES STRESS DISTRIBUTION ($N/M^2$)



# SIMULATIONS

## TOTAL DISPLACEMENT(URES)

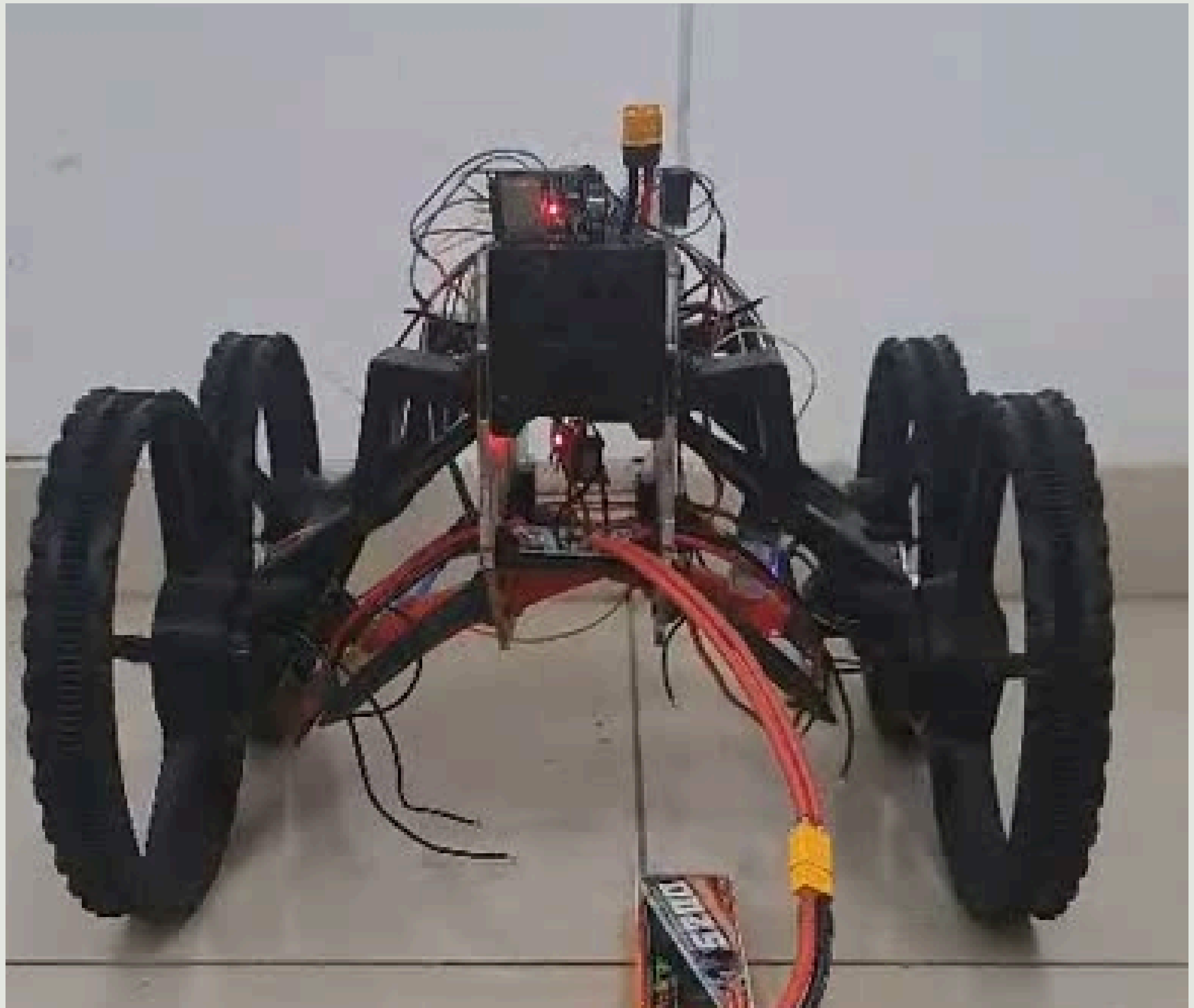


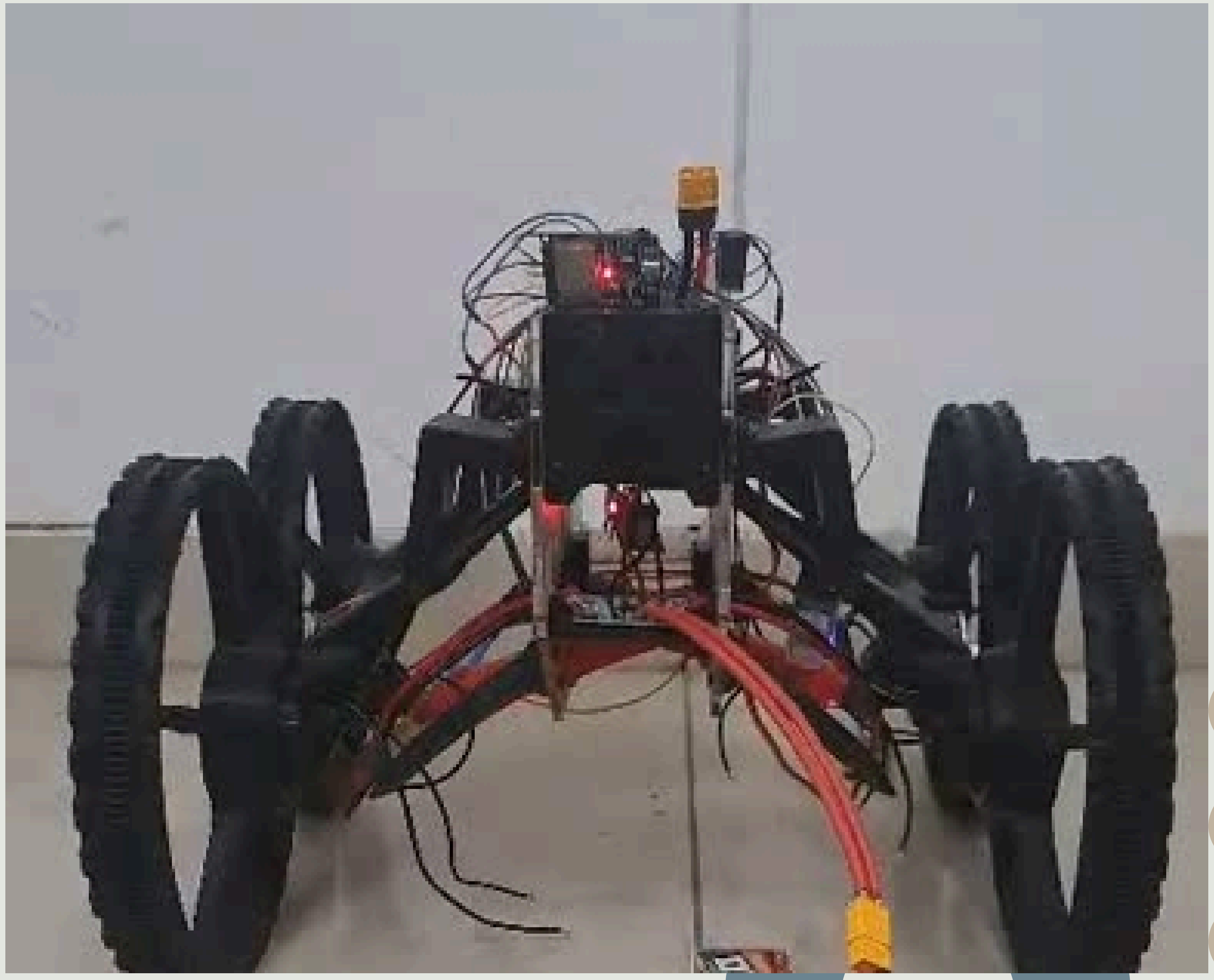
# RESULTS

## Phase 1: Ground Mobility (UGV Mode)

# RESULTS

## Phase 2: Transformation Mechanism Integration





# CONCLUSION

Project Summary:

- Successfully designed and partially fabricated a dual-mode UGV-UAV Transformer
- Servo + linear actuator-driven four-bar transformation
- Combines UGV endurance with UAV agility for adaptive deployment

Applications:

- Post-disaster navigation
- Ground + aerial inspection
- Reconnaissance in constrained terrains

# CONCLUSION

Future Directions:

- Autonomous Decision-Making: AI/ML-based mode selection & planning
- Energy Optimization: Load-adaptive control, hybrid energy (e.g., solar + LiPo)
- Swarm Coordination: Multi-agent navigation, payload sharing
- Modular Payloads: Swappable mission tools (e.g., thermal cam, sprayer)
- Planetary Exploration: Adaptation to variable gravity & extreme terrain

# Thank You