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MECHATRONICS ENGINEER

MECHANICAL DESIGN · ROBOTICS · PRODUCT DEVELOPMENT

CRAFTING INNOVATION
From Concept to Production-Ready Systems

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MECHANICAL DESIGN · ROBOTICS · PRODUCT DEVELOPMENT

SKILLS

- Design for manufacturing (FDM, injection molding, machining)
- Design for assembly
- design optimisation
- FEA- static stress analysis
- CAM simulation
- design cleaning for 3D printing

DESIGN SOFTWARE

- AUTODESK FUSION 360
- CATIA V5
- BLENDER
- SolidWorks
- CURA
- Creality

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ZAKARIA EL MLILAH

MECHANICAL DESIGN · ROBOTICS · PRODUCT DEVELOPMENT

WORK EXPERIENCE

- **VEHICLE CONFIGURATION AND TESTING ENGINEER**
  @ Ennopulse for FEV *since Jan 2026*
- **AUTOMOTIVE MECHANICAL DESIGNER**
  @ Ennopulse *since June 2025*
- **VEHICLE HARDWARE CONFIG TECHNICAL REFERENT**
  @ Ennopulse for FEV *July 2025 - Dec 2025*
- **VEHICLE HARDWARE CONFIGURATION ENGINEER**
  @ Ennopulse for FEV *July 2024 - June 2025*
- **POWERTRAIN CALIBRATION INTERN**
  @ FEV *Feb 2024 - June 2024*
- **ADAS SYSTEM ENGINEERING INTERN**
  @ Capgemini *Aug 2023 - Sep 2024*

SKILLS

- Design for manufacturing (FDM, injection molding, machining)
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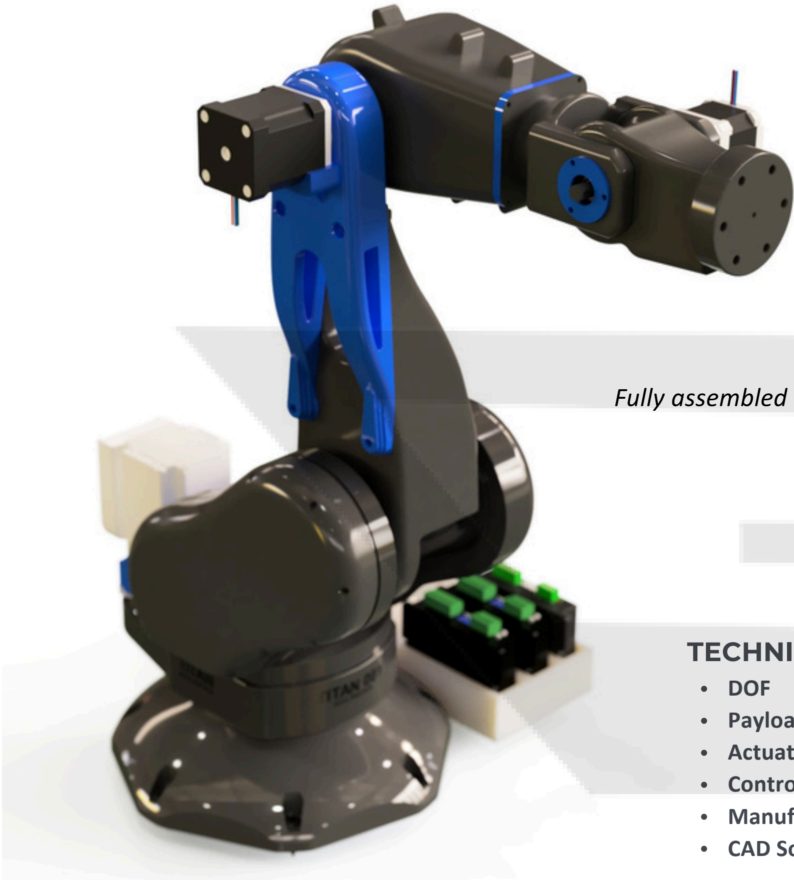
EDUCATIONAL 6-AXIS ROBOT ARM

System Architecture & Mechanical Design

DOF: 6 | Payload: ~1 kg | Manufacturing: FDM | Actuation: Servo + Stepper | Control: STM32 | Transmission: Belt / Pulley / Linkage



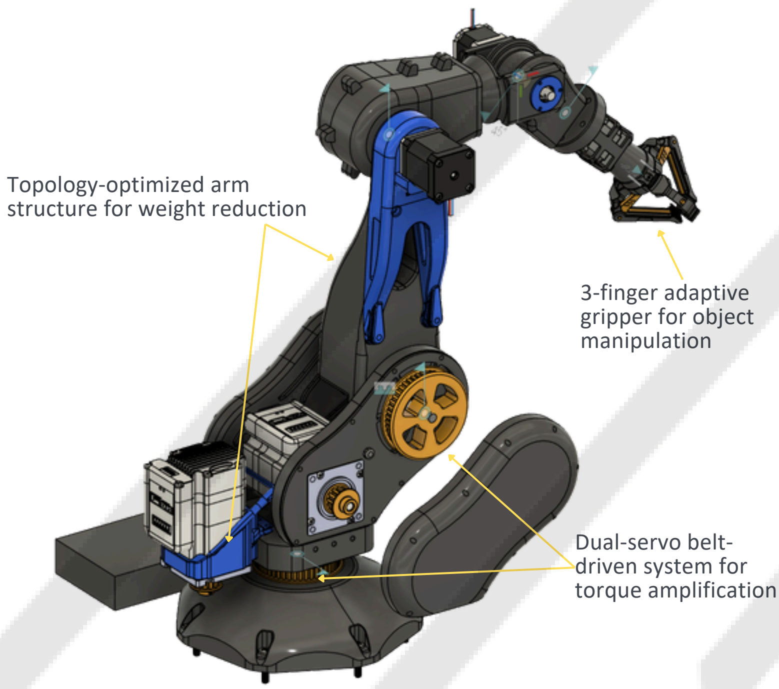
Fully assembled 6-DOF robotic manipulator

TECHNICAL SPECIFICATIONS

- **DOF** : 6
- **Payload** : ~1 kg
- **Actuation** : Servo + Stepper motors
- **Controller** : STM32 Nucleo
- **Manufacturing** : FDM 3D Printing (PLA, TPU)
- **CAD Software** : Autodesk Fusion 360

OBJECTIVE

Designed a fully articulated 6-DOF robotic manipulator for educational and rapid prototyping applications, demonstrating kinematics, actuation strategies, and mechanical power transmission.



ENGINEERING HIGHLIGHTS

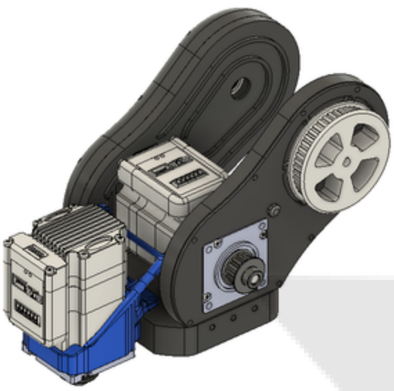
- Hybrid actuation strategy optimized for torque and speed distribution
- Belt & pulley transmission used for torque amplification and reduced motor load
- Modular architecture enabling simplified assembly and maintenance
- Lightweight structures optimized for additive manufacturing constraints

EDUCATIONAL 6-AXIS ROBOT ARM

Mechanical Components & Design Logic

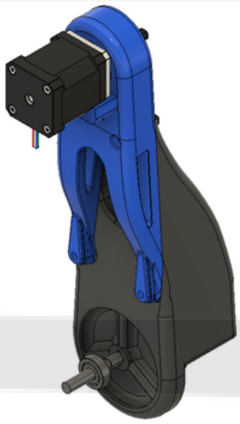
Detailed breakdown of the mechanical subsystems, highlighting design decisions, power transmission strategies, and structural optimization.

COMPONENTS SECTION



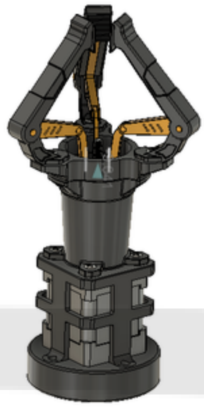
Shoulder

- **Role:** Primary load-bearing joint for arm elevation
- **Design Choice:** Belt-driven system to amplify torque
- **Key Feature:** Remote motor placement reduces inertia



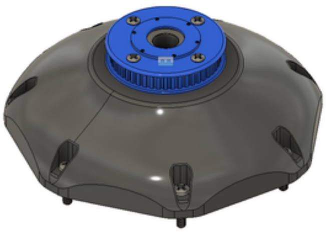
Arm

- **Role:** Load transmission between joints
- **Design Choice:** Split-body for printability
- **Key Feature:** Internal cable routing



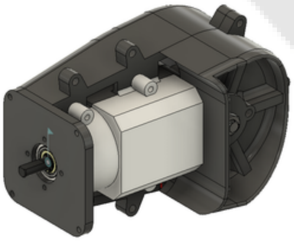
Gripper

- **Role:** Object manipulation
- **Design Choice:** 3-finger servo-actuated linkage
- **Key Feature:** Adaptive grip with distributed contact force



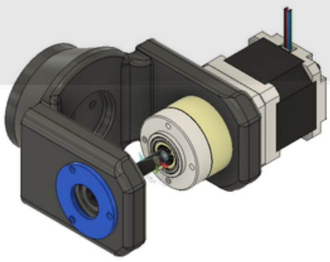
Base

- **Role:** Role: Structural support and system anchoring
- **Design Choice:** Belt-driven system to amplify torque
- **Key Feature:** Remote motor placement reduces inertia



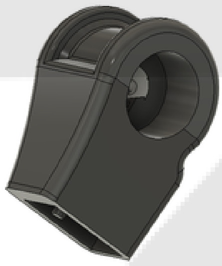
Elbow

- **Role:** Secondary articulation for reach extension
- **Design Choice:** Compact direct-drive stepper integration
- **Key Feature:** Compact direct-drive integration with reduced backlash and improved structural rigidity



Wrist

- **Role:** End-effector orientation control
- **Design Choice:** Compact multi-axis joint architecture
- **Key Feature:** Enables precise end-effector orientation with compact multi-axis integration



End Link

- **Role:** Structural link between joints
- **Design Choice:** Curved hollow geometry for stress distribution
- **Key Feature:** High stiffness-to-weight ratio

DESIGN ENGINEERING DECISIONS

- **Actuation Selection:**

Servo motors were selected for primary joints due to their compact size and precise position control. Stepper motors were integrated in smaller joints with gear reduction to provide higher torque and improved positional resolution. This hybrid approach achieves a balance between performance, precision, and cost.

- **Transmission Strategy:**

Belt and pulley systems were implemented to amplify torque without increasing motor size. This approach reduces weight and cost compared to traditional gearbox solutions while maintaining smooth motion transmission.

- **Mass Distribution:**

High-mass components strategically positioned near the base to minimize load on distal joints, reducing required torque and improving overall system stability

- **Modularity:**

Modular architecture enabling easy disassembly, maintenance, and part replacement using standardized fastening methods (bolted joints and snap-fit features).

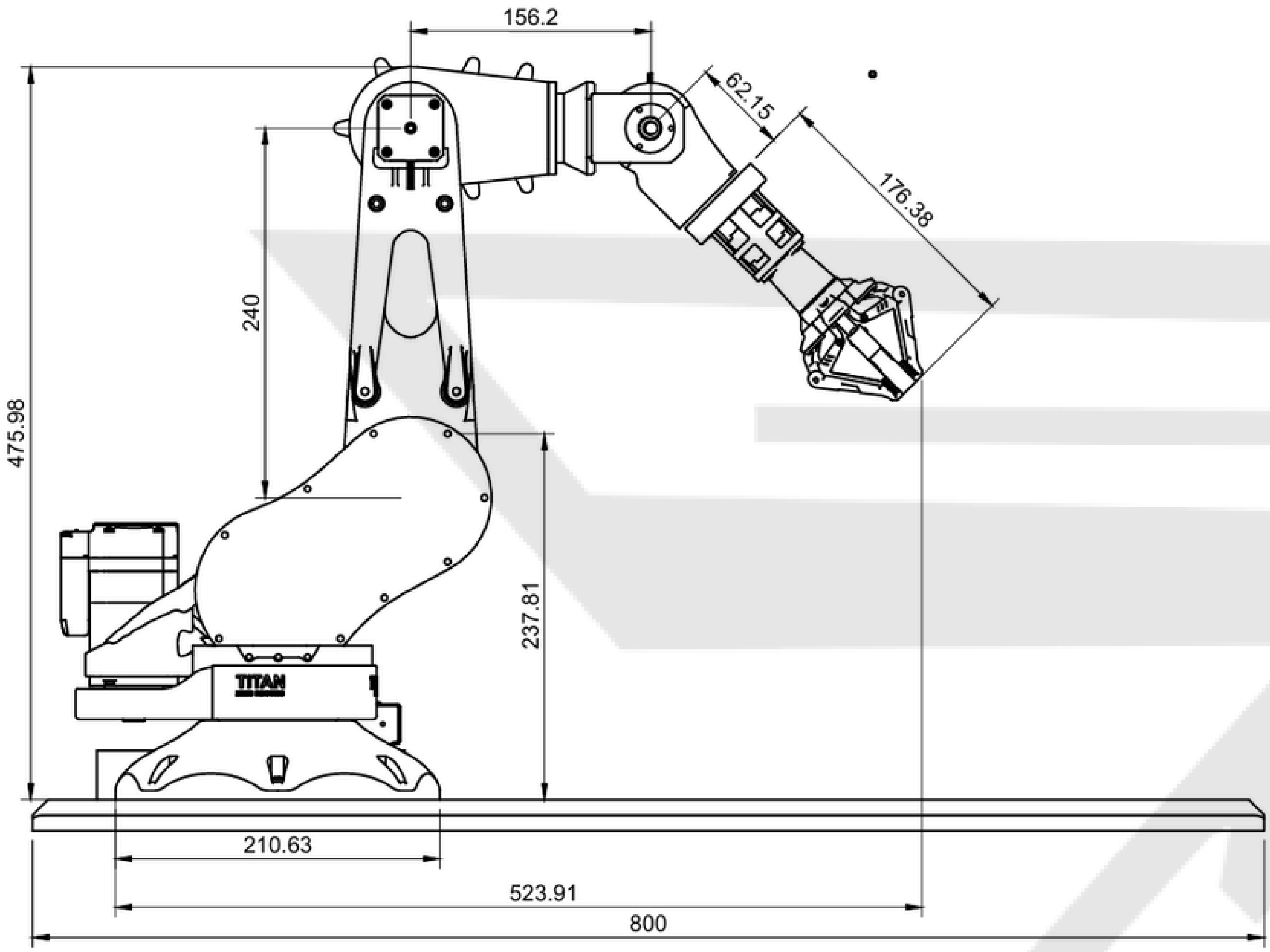
- **Manufacturing Constraints:**

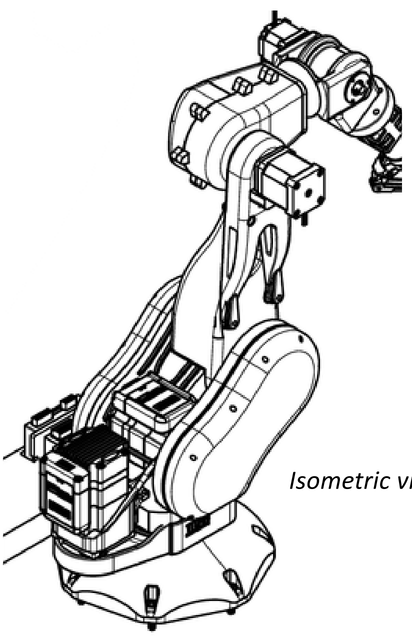
All components were optimized for FDM 3D printing, including support minimization, print orientation control, dimensional constraints within build volume, and tolerance adjustments based on material behavior (PLA, TPU).

EDUCATIONAL 6-AXIS ROBOT ARM

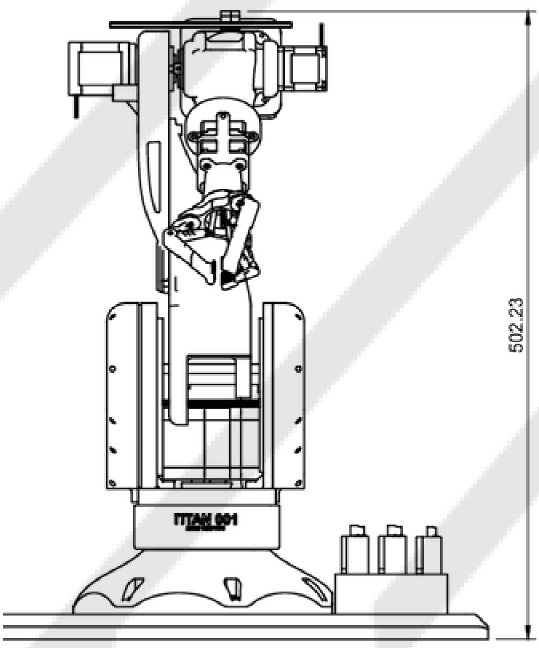
System Dimensions

CAD-derived technical drawing defining system dimensions, joint reach, and operational workspace envelope of the robotic arm.





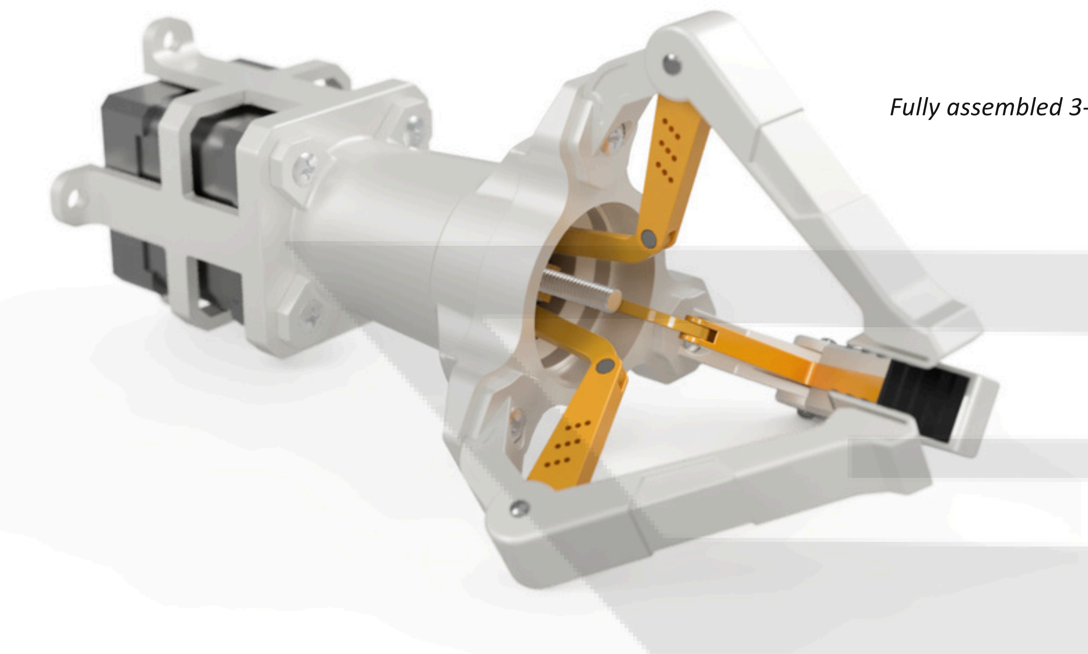
Isometric view of assembled system



3-FINGER ADAPTIVE GRIPPER

Mechanical Design & Actuation System

Actuation: Single Motor | Mechanism: Lead Screw + Linkage | Gripping: 3-Finger Adaptive | Manufacturing: FDM



Fully assembled 3-finger adaptive gripper

KEY FEATURES

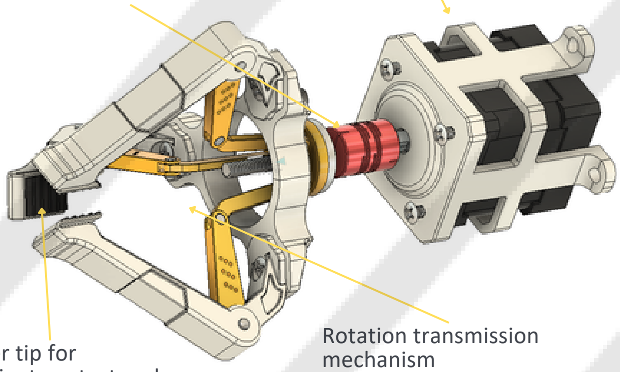
- Single actuator driving multiple fingers
- Symmetrical 3-finger configuration for stable grasping
- Linkage-based motion distribution across fingers
- Geometry optimized for compact packaging and manufacturability

OBJECTIVE

Design a compact robotic gripper capable of object handling using a single-actuator linkage system, ensuring balanced force distribution and reliable grasping.

ENGINEERING HIGHLIGHTS

- Linkage-based force distribution ensuring balanced gripping across fingers
- Centralized actuation reducing system complexity and weight
- Three-point contact improving grasp stability on irregular objects
- Compact mechanism enabling integration with robotic manipulators



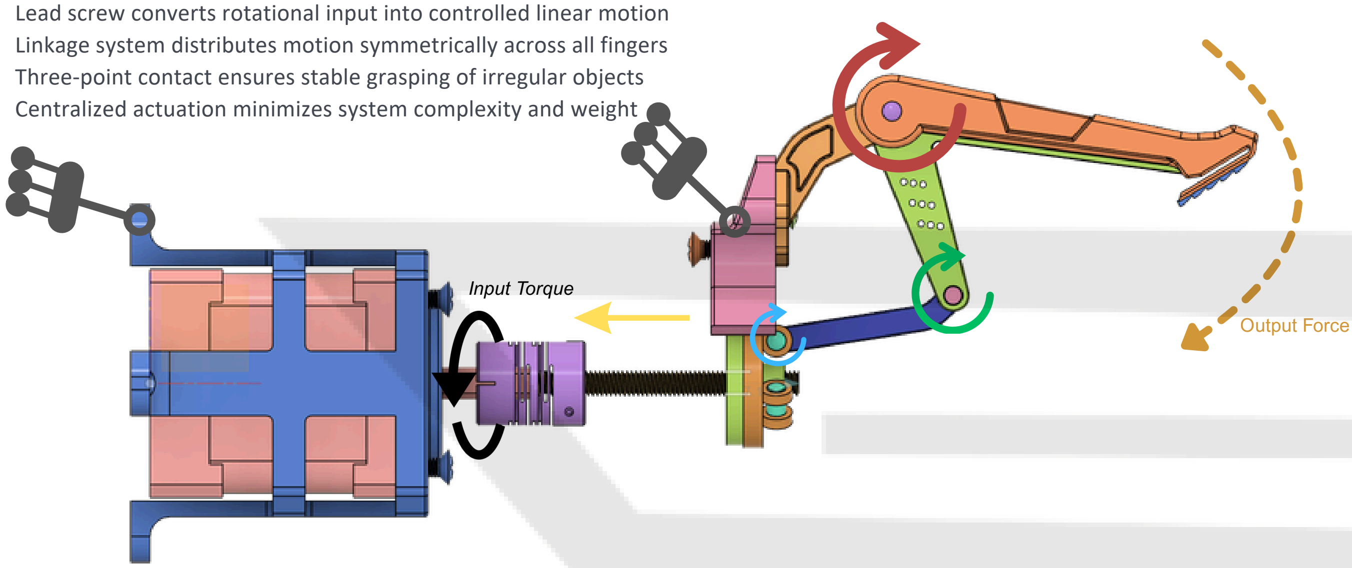
3-FINGER ADAPTIVE GRIPPER

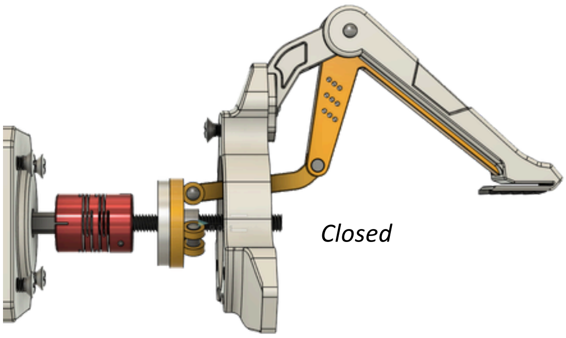
Actuation Mechanism & Linkage System

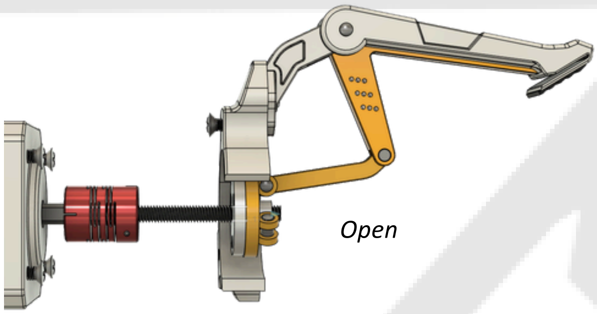
Actuation: Single Motor | Mechanism: Lead Screw + Linkage | Gripping: 3-Finger Adaptive | Manufacturing: FDM

ACTUATION MECHANISM & MOTION ANALYSIS

- Lead screw converts rotational input into controlled linear motion
- Linkage system distributes motion symmetrically across all fingers
- Three-point contact ensures stable grasping of irregular objects
- Centralized actuation minimizes system complexity and weight

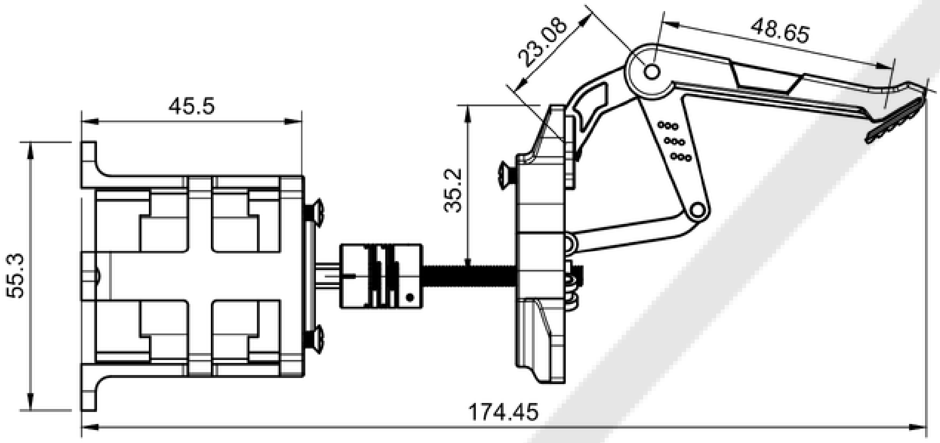


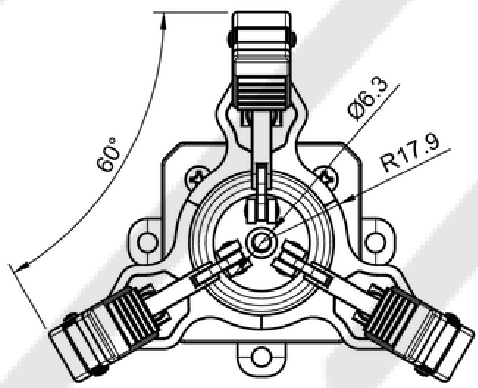




TECHNICAL DRAWING

CAD-derived drawing illustrating key dimensions, motion envelope, and actuation mechanism behavior.



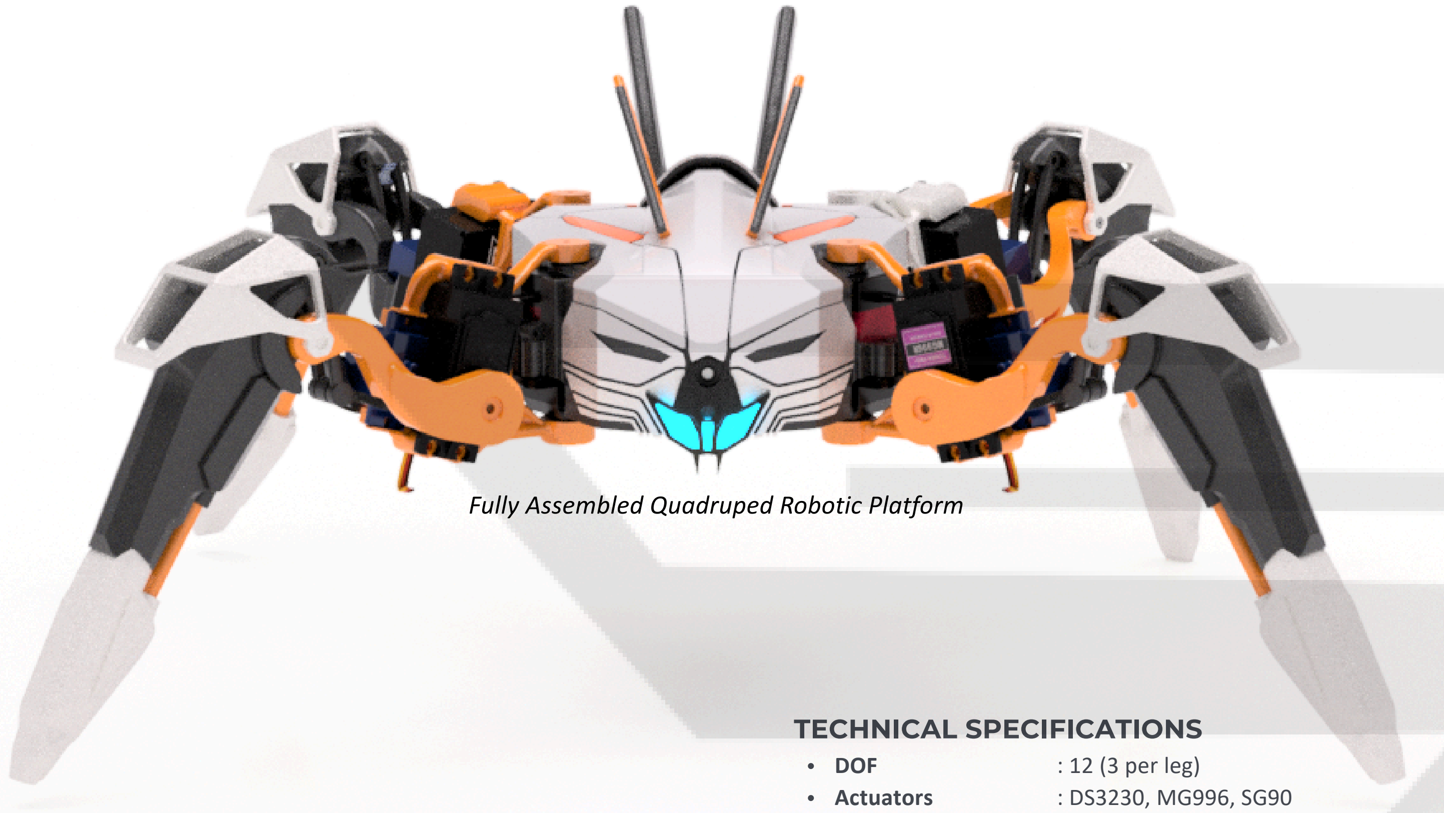


QUADRUPED ROBOTIC PLATFORM

MECHANICAL & SYSTEM DESIGN (PHASE 1)

Mechanical Architecture & System Design

Legs: 4 | DOF: 12 | Actuation: Servo-Based | Control: ESP32 / Raspberry Pi | Gait: Crawl / Walk | Application: Surveillance / Interaction



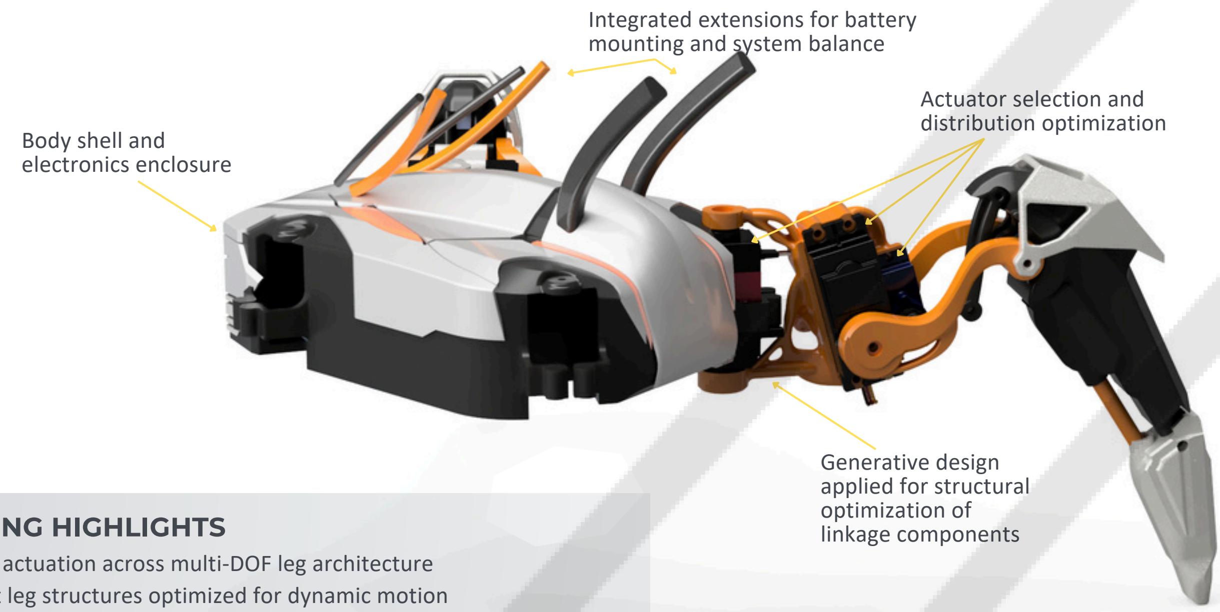
Fully Assembled Quadruped Robotic Platform

TECHNICAL SPECIFICATIONS

- **DOF** : 12 (3 per leg)
- **Actuators** : DS3230, MG996, SG90
- **Control** : ESP32 (future Raspberry Pi)
- **Sensors** : Camera, ultrasonic (planned)
- **Manufacturing** : FDM 3D Printing

OBJECTIVE

Designed a quadruped robotic platform for stable locomotion, modular expansion, and future integration of vision and autonomous behaviors.



ENGINEERING HIGHLIGHTS

- Distributed actuation across multi-DOF leg architecture
- Lightweight leg structures optimized for dynamic motion
- Modular system architecture enabling payload and electronics integration
- Designed for real-world interaction beyond simulation environments

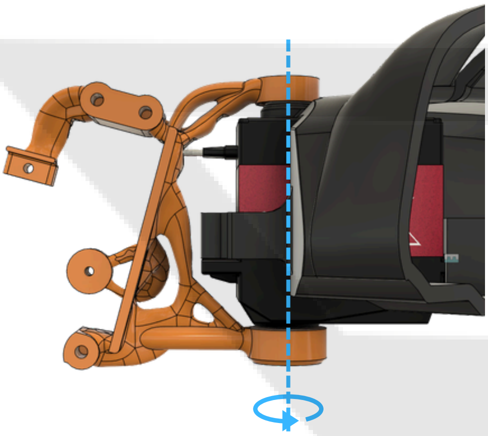
QUADRUPED ROBOTIC PLATFORM – MECHANICAL & SYSTEM DESIGN (PHASE 1)

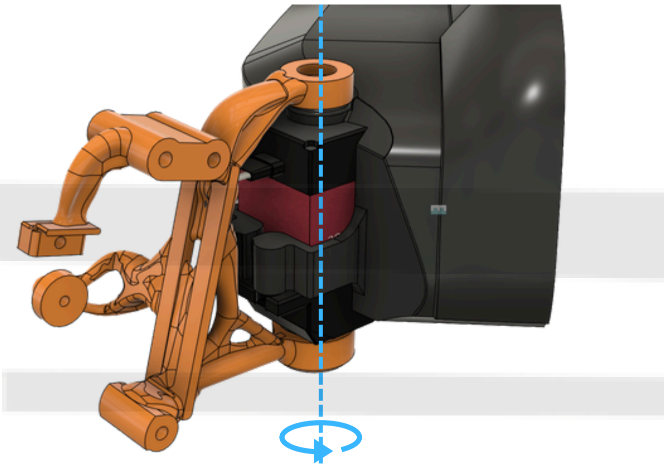
Actuation & Joint Mechanism Design

Legs: 4 | DOF: 12 | Actuation: Servo-Based | Control: ESP32 / Raspberry Pi | Gait: Crawl / Walk | Application: Surveillance / Interaction

HIP YAW JOINT – BASE ROTATION AXIS

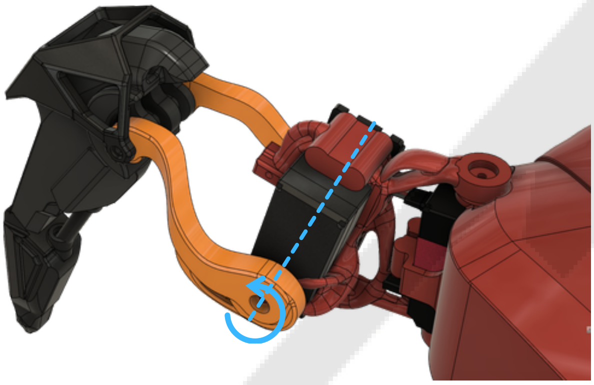
- **Role** : Provides horizontal rotation of the leg
- **Actuator** : DS3230 - high torque servo 30 kg·cm
- **Design Choice :** Direct-drive configuration with reinforced mounting interface for high torque transmission
- **Key Feature** : High torque capacity for full leg orientation





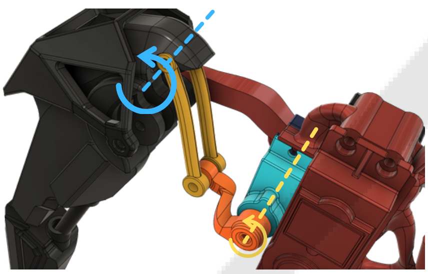
HIP PITCH JOINT – LOAD-BEARING AXIS

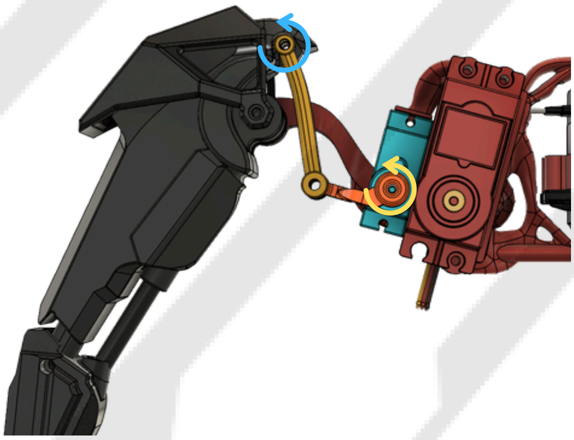
- **Role** : Supports vertical movement and main load transfer
- **Actuator** : MG996 - High torque servo (12Kg/cm)
- **Design Choice** : Servo positioned close to body to reduce moment arm
- **Key Feature** : Optimized for high torque transmission and structural rigidity



KNEE JOINT – DISTAL ARTICULATION

- **Role** : Controls leg extension and ground interaction
- **Actuator** : MG90S - Metal gears servo 2.3 kg·cm
- **Design Choice** : Lightweight distal joint to minimize inertia
- **Key Feature** : Compact integration enabling fast response and reduced inertia

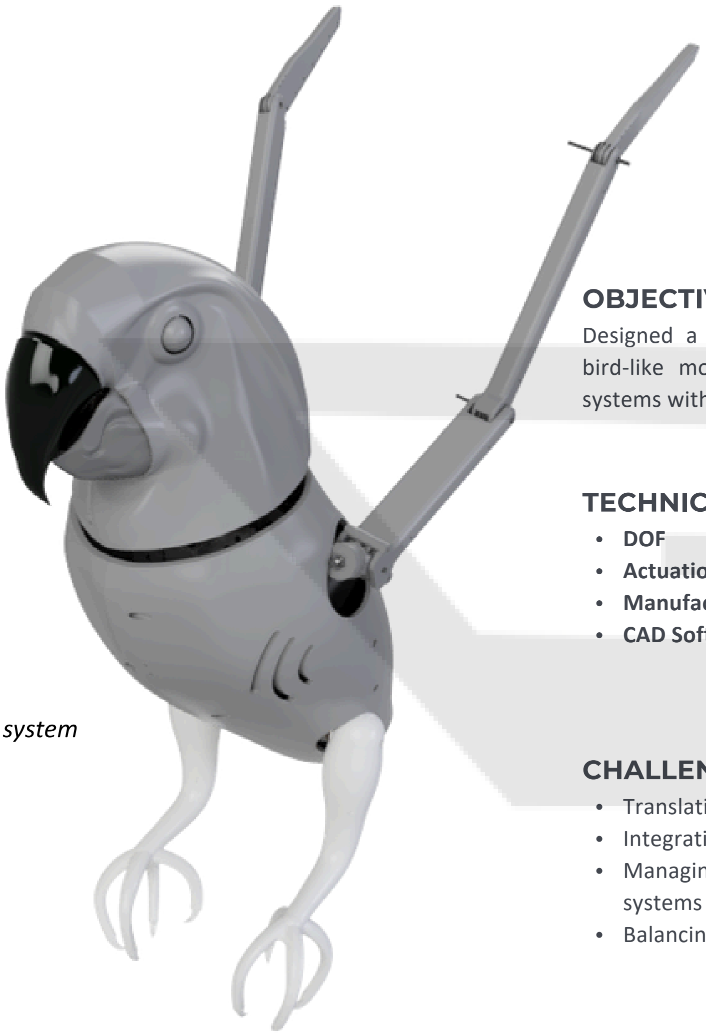




ANIMATRONIC BIRD SYSTEM (CONFIDENTIAL PROJECT)

Biomimetic Motion & Compact Mechanism Design

DOF: 12 | Actuation: Servo Motors | Manufacturing: FDM | Transmission: Linkage + Cable Systems | Application: Animatronics



Fully assembled animatronic bird system

OBJECTIVE

Designed a compact animatronic system capable of replicating bird-like motion through integrated mechanical and actuation systems within constrained volume.

TECHNICAL SPECIFICATIONS

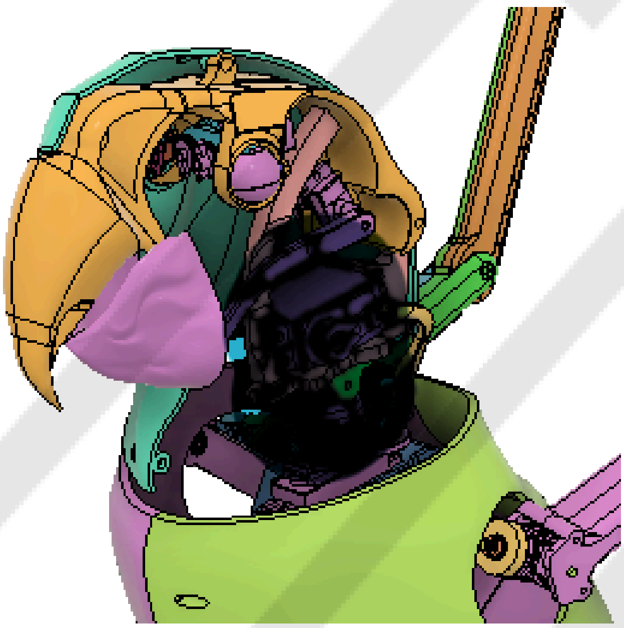
- **DOF** : 12
- **Actuation** : Servo motors
- **Manufacturing** : FDM 3D Printing (PLA, TPU)
- **CAD Software** : Autodesk Fusion 360 & Blender

CHALLENGES

- Translating organic motion into rigid mechanical systems
- Integrating multiple actuators within a constrained volume
- Managing cable-driven and linkage-based transmission systems
- Balancing visual realism with mechanical feasibility

ENGINEERING HIGHLIGHTS

- Biomimetic geometry translated into manufacturable mechanical structures
- Hybrid actuation strategy based on torque and motion requirements
- Cable-driven and linkage-based motion transmission
- Compact actuator integration within constrained internal volume
- Optimized structure for additive manufacturing

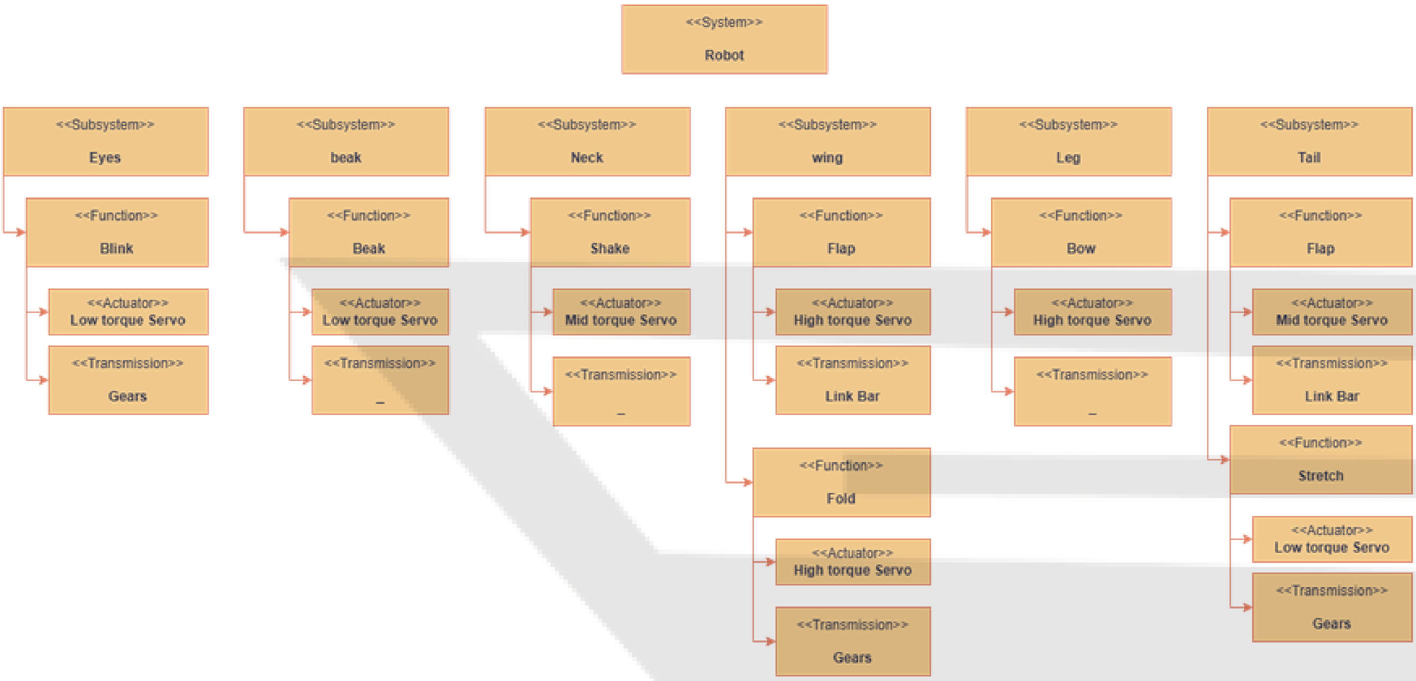


ANIMATRONIC BIRD ROBOT (CONFIDENTIAL PROJECT)

Motion System Architecture (Abstracted)

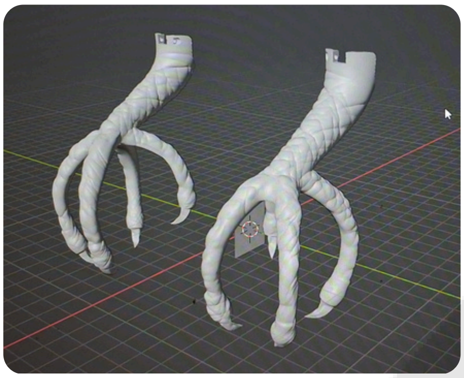
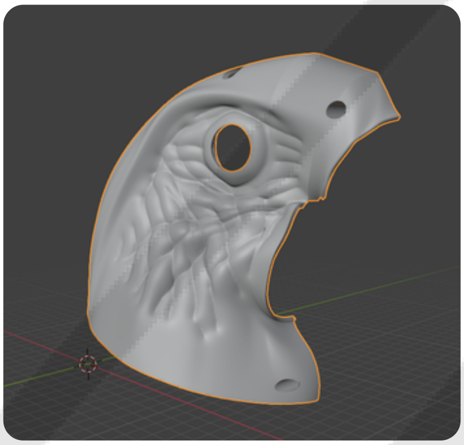
DOF: 12 | Actuation: Servo Motors | Manufacturing: FDM | Transmission: Linkage + Cable Systems | Application: Animatronics

SYSTEM DECOMPOSITION



BIOLOGICAL REFERENCE

Biological structures were analyzed and translated into mechanical systems, balancing realism, manufacturability, and functional actuation.

Real Part	**CAD Design**	**Printed result**
		
		

ANIMATRONIC BIRD ROBOT (CONFIDENTIAL PROJECT)

Compact System Integration & Packaging Strategy

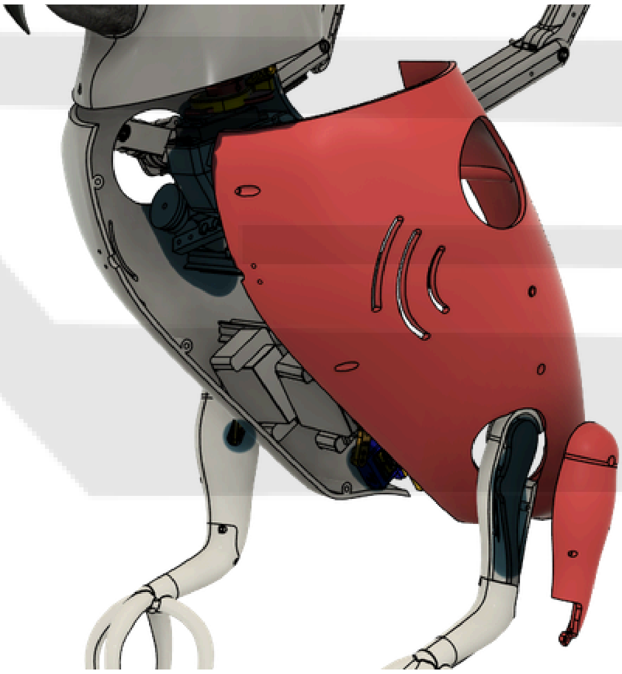
DOF: 12 | Actuation: Servo Motors | Manufacturing: FDM | Transmission: Linkage + Cable Systems | Application: Animatronics

PACKAGING OBJECTIVES

- Integrate multiple actuators within constrained internal volume
- Maintain accessibility for assembly and maintenance
- Prevent interference between moving subsystems through spatial separation
- Ensure sufficient clearance for cable routing and motion

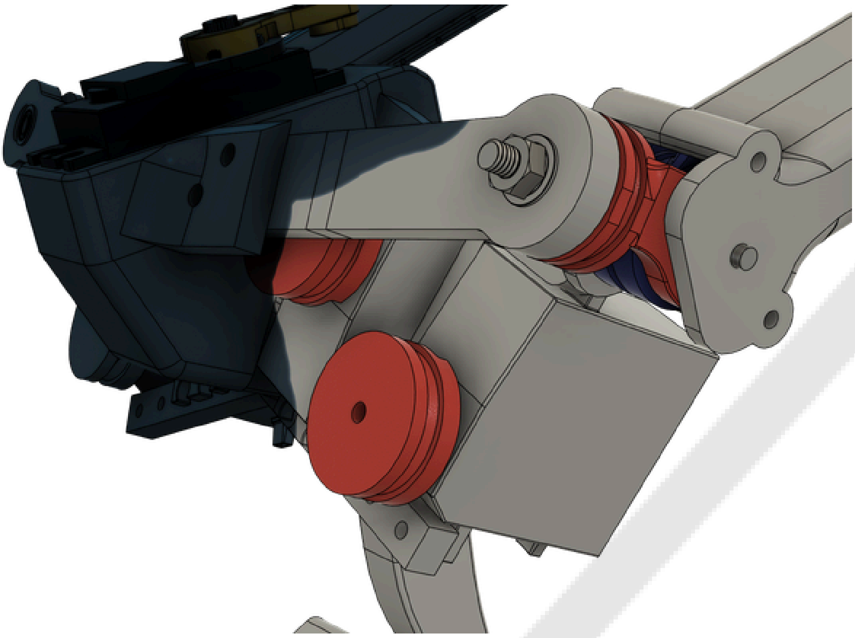
INTEGRATION STRATEGY

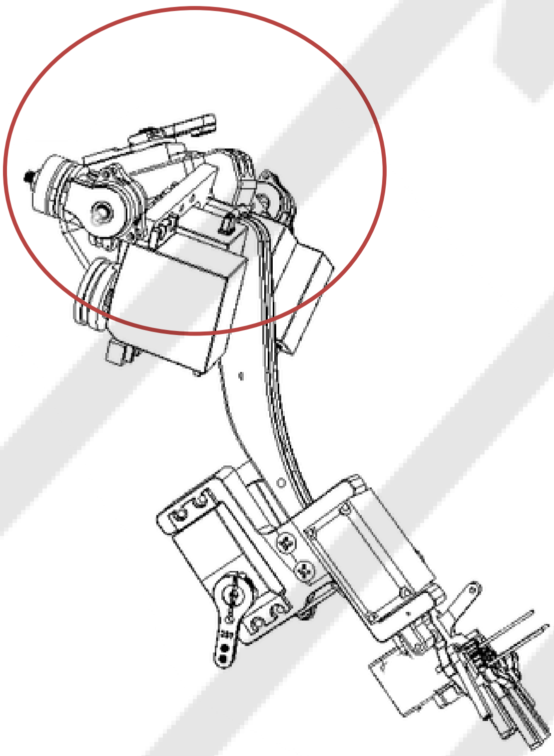
- Centralized actuator zones for efficient packaging and load distribution
- Defined internal routing paths for cable management
- Separation of moving subsystems to avoid mechanical interference



KEY DESIGN DECISIONS

- Prioritized compactness while maintaining functional accessibility
- Used remote transmission systems to reduce distal mass
- Allocated internal volume for future system adjustments and integration



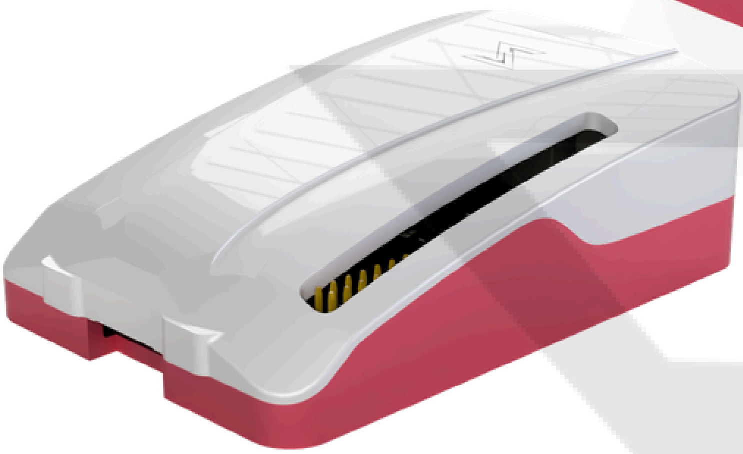


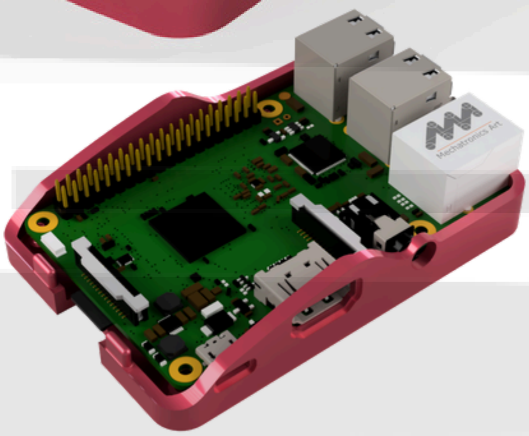
ELECTRONIC ENCLOSURE DESIGN

Functional Design & Product Integration

RASPBERRY ENCLOSURE

- Designed to house a single-board computer (SBC) and peripheral interfaces
- Integrated port openings and internal mounting features
- Optimized for rapid prototyping using FDM processes
- Compact internal layout with basic thermal considerations





INTERACTIVE DEVICE ENCLOSURE WITH DISPLAY INTERFACE

- Integrated LED indicators and LCD display interface
- Slide-to-open mechanism enabling user access to internal components
- Internal architecture designed for PCB placement and cable routing
- Ventilation and interface accessibility considered in design

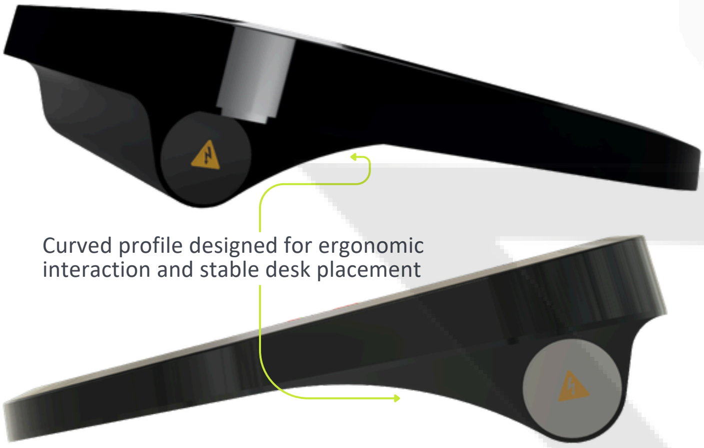
Internal architecture was defined prior to external geometry, ensuring proper component integration, clearance management, and manufacturability.

TOUCH INTERFACE DEVICE ENCLOSURE

Capacitive Input & Compact System Integration

PROJECT OBJECTIVE

Designed a compact electronic enclosure integrating capacitive touch inputs, optimized for internal packaging, user interaction, and manufacturability.



DESIGN ENGINEERING DECISIONS

- Capacitive touch interface integrated beneath glass surface for clean user interaction
- Layered architecture separating user interface and electronics
- Internal clearances defined for PCB placement and wiring
- Compact packaging using a multi-part assembly strategy

EXPLODED VIEW

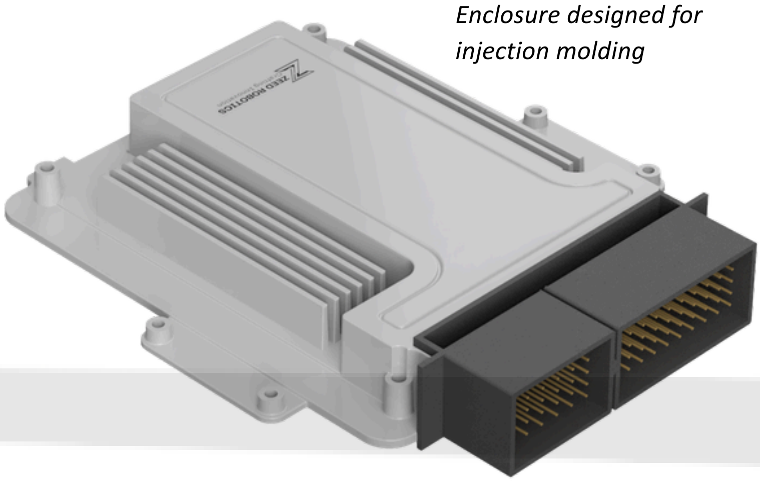
INJECTION MOLD DESIGN

& MANUFACTURING DEVELOPMENT

DFM, Tooling Strategy & Machining Simulation

INJECTION-MOLDED ENCLOSURE DESIGN

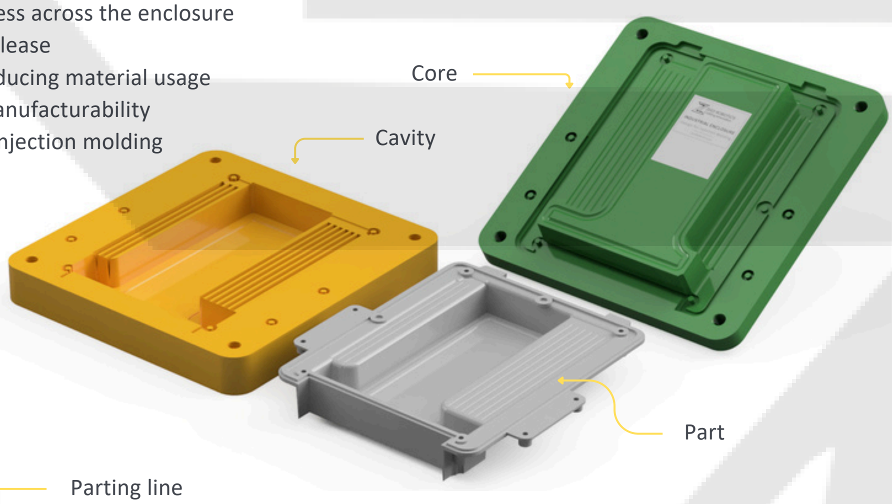
- Designed for industrial enclosure applications
- Geometry optimized for injection molding
- Internal ribs and supports for structural integrity
- Part split defined for manufacturability

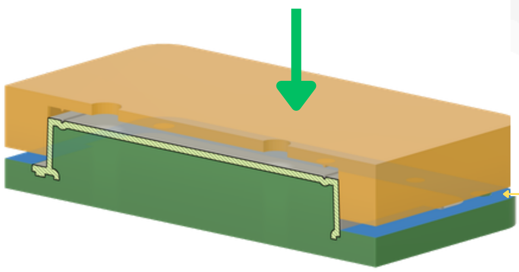


Enclosure designed for injection molding

DESIGN FOR MANUFACTURING (DFM)

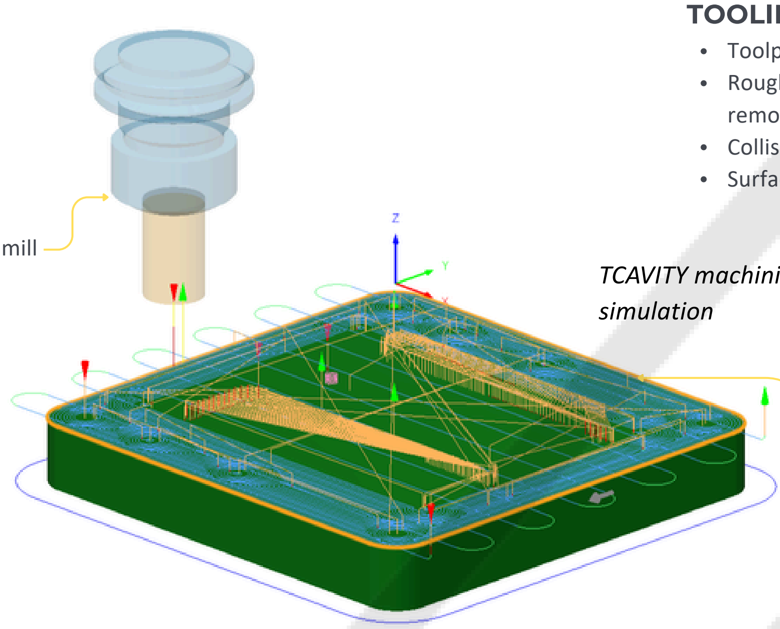
- Geometry adapted to ensure uniform wall thickness across the enclosure
- Draft angles integrated to enable reliable mold release
- Rib structures used to maintain stiffness while reducing material usage
- Parting line selected to balance aesthetics and manufacturability
- Design adapted for transition from prototype to injection molding production.





TOOLING & MACHINING SIMULATION

- Toolpath generation for cavity machining operations
- Roughing and finishing strategies defined for material removal optimization
- Collision-free machining validated through simulation
- Surface finish optimized for final mold quality



TCAVITY machining toolpath simulation

AUTOMOTIVE AIR VENT ASSEMBLY

Reverse Engineering & Functional Mechanism Design

OBJECTIVE

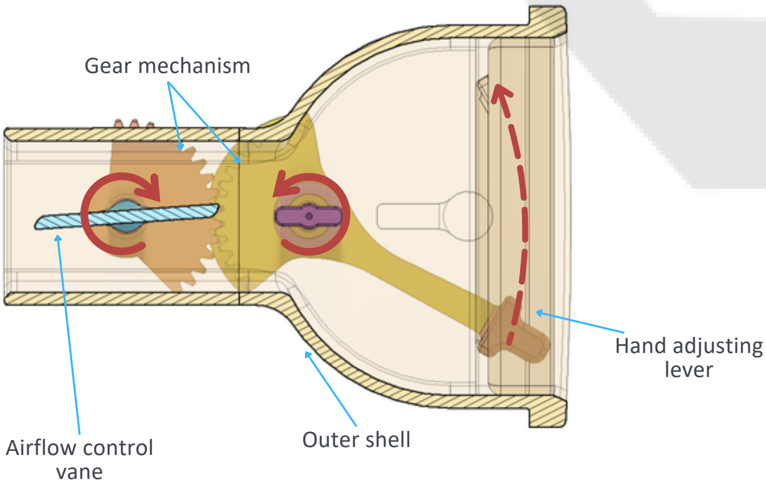
Reverse engineered and redesigned an automotive air vent assembly, focusing on functional accuracy, mechanical reliability, and manufacturability using additive processes.

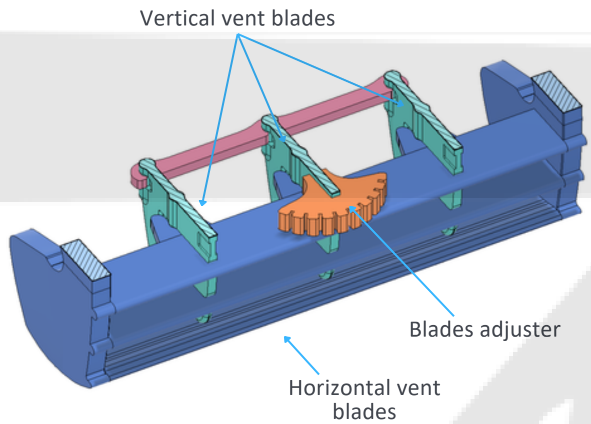
KEY ENGINEERING FEATURES

- Functional airflow direction control mechanism with multi-axis adjustment
- Synchronized blade system for consistent airflow direction
- Manual actuation through integrated control mechanism
- Validated through physical prototyping using 3D printing

MECHANISM BREAKDOWN

Reverse engineering and redesign of an automotive air vent assembly, focusing on functional accuracy, mechanical reliability, and manufacturability using additive processes.





ADDITIVE MANUFACTURING CONSIDERATIONS

- Adjusted tolerances to account for FDM printing limitations
- Optimized print orientation to minimize support structures
- Surface finishing considered to ensure smooth mechanical motion
- Functional validation through physical prototype testing

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