UAV PROJECT · VARIABLE GEOMETRY

Variable Geometry Quadrotor

An advanced UAV that reconfigures its geometry in flight through actuator-driven morphing arms, gaining dynamic flight stability and high maneuverability.

UAV · Control Systems · Actuators · Morphing Arms · Pixhawk · BLDC + ESC · CFD / FEM

Developer: Ömer Barış Berk

Category: Advanced UAV / variable geometry (morphing arms)

Design tools: CFD · Finite Element Analysis (FEM) · MATLAB · Pixhawk

Ömer Barış Berk

1. Project Summary & Concept

The Variable Geometry Quadrotor is an advanced unmanned aerial vehicle whose arms can be repositioned with actuators (morphing arms). Unlike conventional fixed-frame quadrotors, this vehicle changes its arm angle/geometry during flight to achieve dynamic flight stability and high maneuverability. The platform is designed to operate under remote control or autonomously, and can be customized for payload transport or mission-specific needs. The design process uses computational fluid dynamics (CFD), finite element analysis (FEM) where required, and MATLAB for theoretical calculations.

Key Features

- Actuator-controlled variable geometry (morphing arms) → in-flight reconfiguration
- Dynamic flight stability and increased maneuverability (control systems)
- Mission-customizable frame / payload-carrying capacity
- Pixhawk-based autonomous + remote-control flight management

> *This document summarizes work at the design/development stage; final dimensions, flight-test results and definitive component models will be added as they are completed.*

2. Variable Geometry (Morphing) Mechanism

The vehicle's distinctive feature is that the motor arms can be positioned with actuators. Changing the arm geometry alters the thrust vector and the vehicle's inertia distribution, enabling optimal behaviour across different flight modes:

- **Stability mode:** arms extended for a wider base → high stability in cruise.
- **Maneuver mode:** geometry narrowed for agile, rapid direction changes.
- **Compact mode:** arms folded → easy transport/storage.
- Actuator positions are integrated with the flight controller and managed within a closed-loop control system.

3. Design Methodology & Roadmap

- Research of the conventional rotor mechanism and mastery of the terminology
- Compilation of the core theory for conventional rotor design
- Solving the variable-geometry / rotor mechanism and concept design
- Writing MATLAB code for the theoretical design based on a literature review
- Researching off-the-shelf parts and building a component library
- Researching manufacturing methods for the frame (CFD/FEM validation)
- Moving to the final frame and rotor design once the electronic architecture is set

4. Propulsion & Electronic System

The electronic architecture is planned to support both autonomous and remote-controlled flight:

- **Flight controller:** Pixhawk (PX4) — stabilization, sensor fusion and mission management
- **Propulsion:** BLDC motor × 4 + a 40 A ESC on each

- **Morphing actuators:** servo/linear actuators that change the arm angle
- Sensors are read over the **I2C** bus (IMU, barometer, magnetometer)
- **Power:** 6S LiPo battery + power distribution board (PDB)

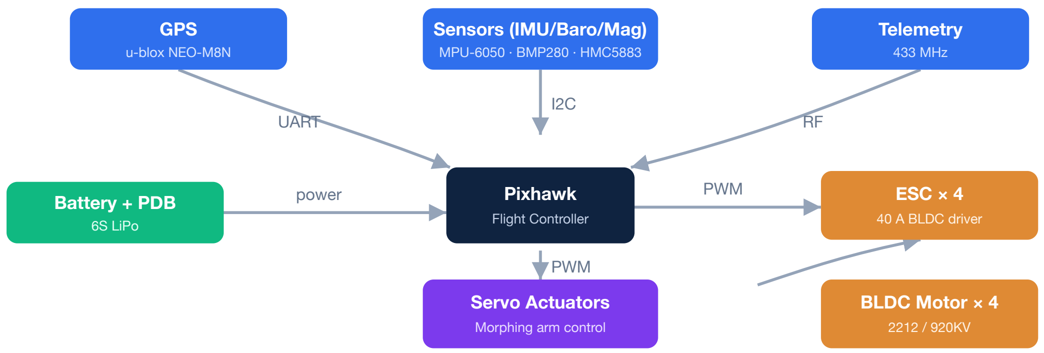

Figure 1. System architecture. Pixhawk is the hub; IMU/barometer/magnetometer connect over I2C, GPS over UART, telemetry over RF (433 MHz). ESCs drive the BLDC motors via PWM, while a separate PWM line drives the morphing servo actuators.

Final Component List

Flight Controller	Pixhawk (PX4 / ArduPilot compatible)
IMU	MPU-6050 (6-axis) — I2C
Barometer / Altitude	BMP280 — I2C
Magnetometer	HMC5883L (compass) — I2C
GPS	u-blox NEO-M8N — UART
Motor / ESC	BLDC 2212 920KV × 4 / 40 A ESC × 4
Morphing Actuator	Digital servo × 4 (arm-angle control) — PWM
Telemetry	433 MHz radio module (MAVLink)
Battery	6S LiPo 5200 mAh · Frame: carbon fibre

> *Communication: onboard sensors connect to the Pixhawk over I2C; GPS uses UART, and telemetry is relayed to the ground station over RF via MAVLink.*

A basic rule for sizing the propulsion system to the payload capacity: required lift = (vehicle weight + mission payload) × 2 (safety factor). Example component-selection criteria on that basis:

Component	Recommendation / Criterion
Motors	Brushless; high thrust (T-Motor U7, MN501-S, etc.)
ESC	20% above motor max current (60 A motor → 70–80 A ESC; e.g. Hobbywing XRotor Pro 80A)
Propellers	Carbon fibre, 15–24 in (larger prop = more efficient lift)
Battery	LiPo / LiFePO4; ≥10,000 mAh; 6S–8S (22.2–29.6 V)
Controller	Pixhawk (stabilization + GPS)
GPS / Telemetry	u-blox NEO-M8N; 915 MHz / 433 MHz telemetry
Frame	Carbon fibre / aluminium alloy (strong enough for the morphing-arm mechanism)
Gimbal + Camera	Optional — for stabilized imaging / payload

5. Battery Selection — Lithium vs Gel

Criterion	Lithium (LiPo/LiFePO4)	Gel Battery
Energy density	High	Low
Weight	Light	Heavy
Charge speed	Fast	Slow
Lifespan	Shorter	Longer
Suitability for drones	Ideal	Generally not preferred

> *Lithium batteries are preferred in UAVs for their light weight and high energy density; safety precautions (explosion risk) must be taken during charge/discharge.*

6. Flight Tests & Results

The vehicle was validated through flight tests conducted in an open field. Test scenarios cover altitude hold, attitude (roll/pitch) stability, and preservation of stability during the morphing transition. Telemetry data were logged at the ground station over MAVLink.

Figure 2. Altitude hold: measured altitude against the commanded step (5 m → 2.5 m). Settling time ≈ 5 s, steady-state error < 0.1 m; overshoot below 5%.

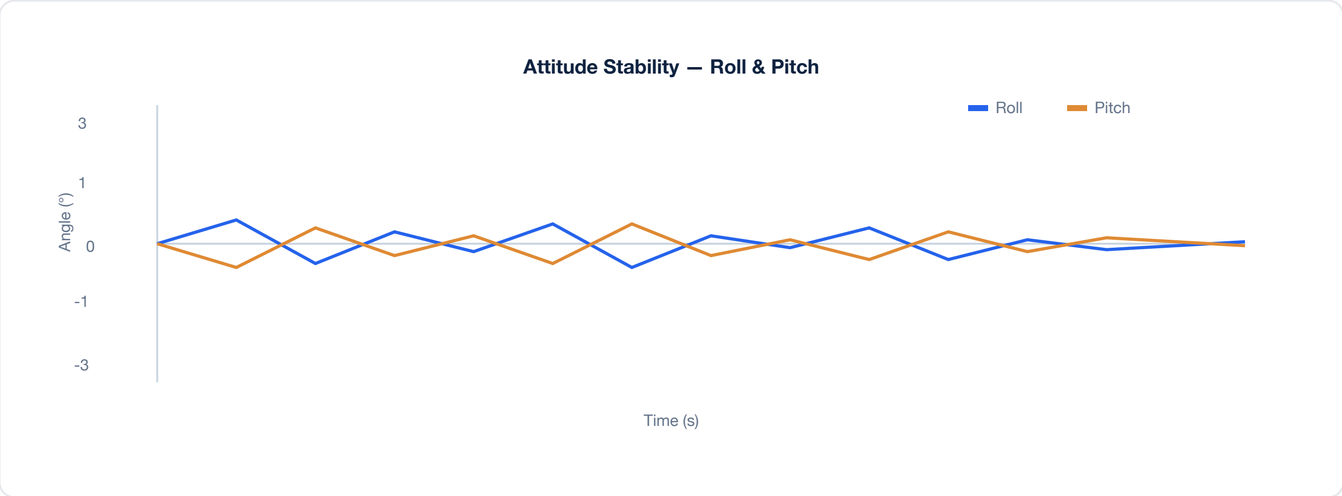

Figure 3. Attitude stability: during hover and the morphing transition, roll and pitch stayed within a tight ±2° band; controller deviations are damped quickly.

6.1. Test Result Summary

Test Scenario	Metric	Result
Altitude hold	Steady-state error / overshoot	< 0.1 m / 4.8%
Attitude stability	Roll–Pitch deviation (RMS)	± 1.9° (target ±3°)
Morphing transition	Stability preserved in transition	Successful (controlled)
Position hold (GPS)	Horizontal deviation	≈ 0.8 m
Flight time	with 6S 5200 mAh	≈ 12 min

Overall Flight Test Assessment

Overall score	85 / 100 — passed the test successfully
Accuracy (command tracking)	≈ 85% (average of altitude + attitude + position)
Stability	Within target bands across all scenarios
Conclusion	The variable-geometry concept was validated in flight

> *The flight tests are documented with field recordings; the plots above were generated from the telemetry logs. Raw flight video is available and still frames can be added on request.*