



CP-302

Capstone Project

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Objective

The objective of this project is to simulate a realistic 4-BLDC motor quadcopter in MATLAB to understand its flight dynamics and control. The study shows how motor thrust, drag, and 6-DOF motion affect the movement of the quadcopter.

It demonstrates how changes in motor speeds control altitude, direction, and rotation of the drone.

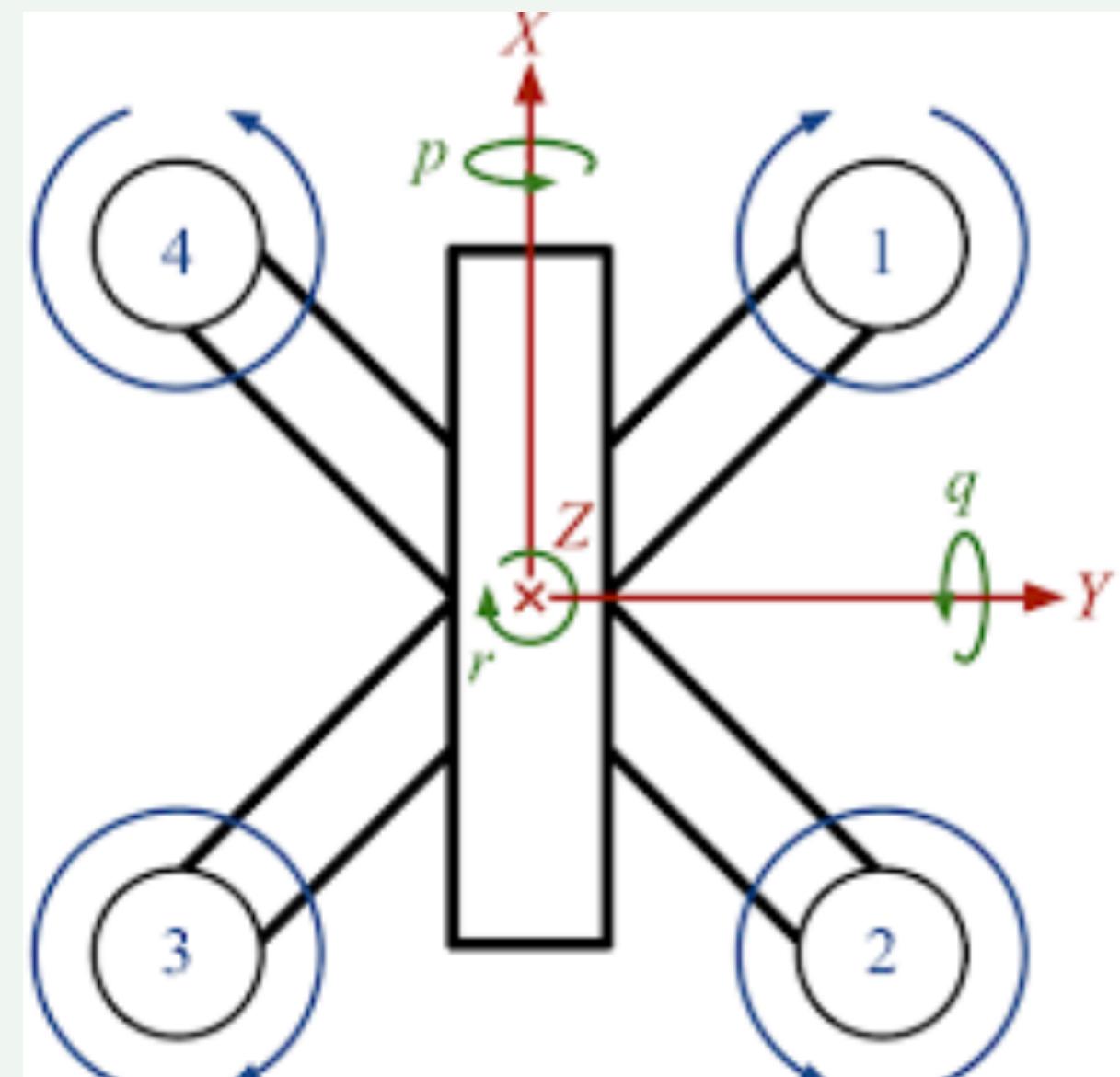


Translational and Rotational Dynamics of a Quadcopter

A quadcopter moves in 6-DOF, consisting of

- a)** 3 translational motions (u, v, w)
- b)** 3 rotational motions (p, q, r).

These describe how the aircraft translates and rotates in space.



Translational Velocities (u, v, w)

These describe how the aircraft moves linearly along its body axes.

1. u – Forward/Backward Velocity

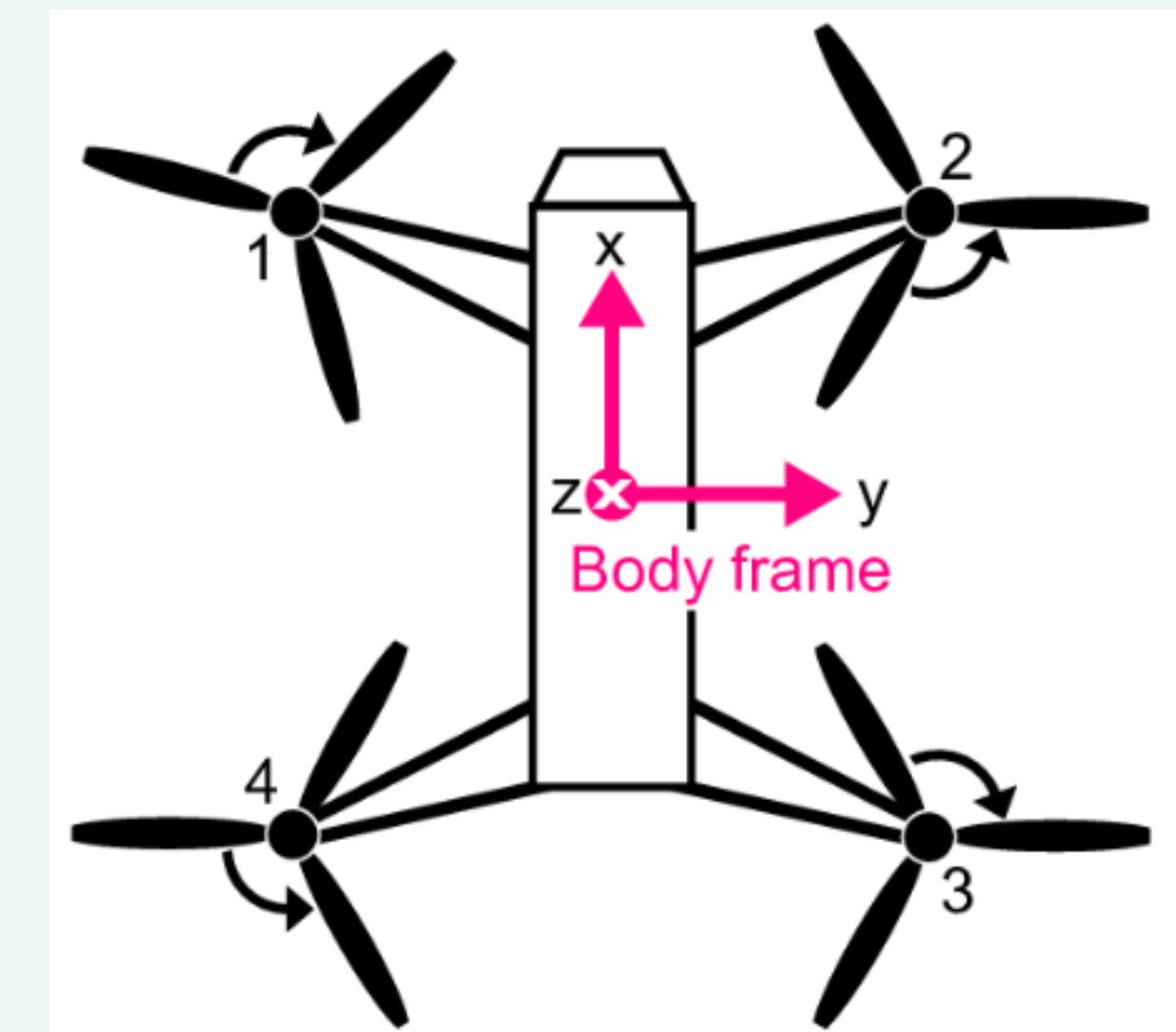
- Velocity along the x-axis of the body frame (forward direction)
- Positive $u \rightarrow$ aircraft moves forward

2. v – Left/Right Velocity

- Velocity along the y-axis of the body frame (sideways direction)
- Positive $v \rightarrow$ aircraft moves to the right

3. w – Up/Down Velocity

- Velocity along the z-axis of the body frame (vertical direction)
- Positive $w \rightarrow$ aircraft moves upward



Rotational Motions (p,q,r)

These describe how the aircraft changes its orientation in space

1. p – Roll Rate

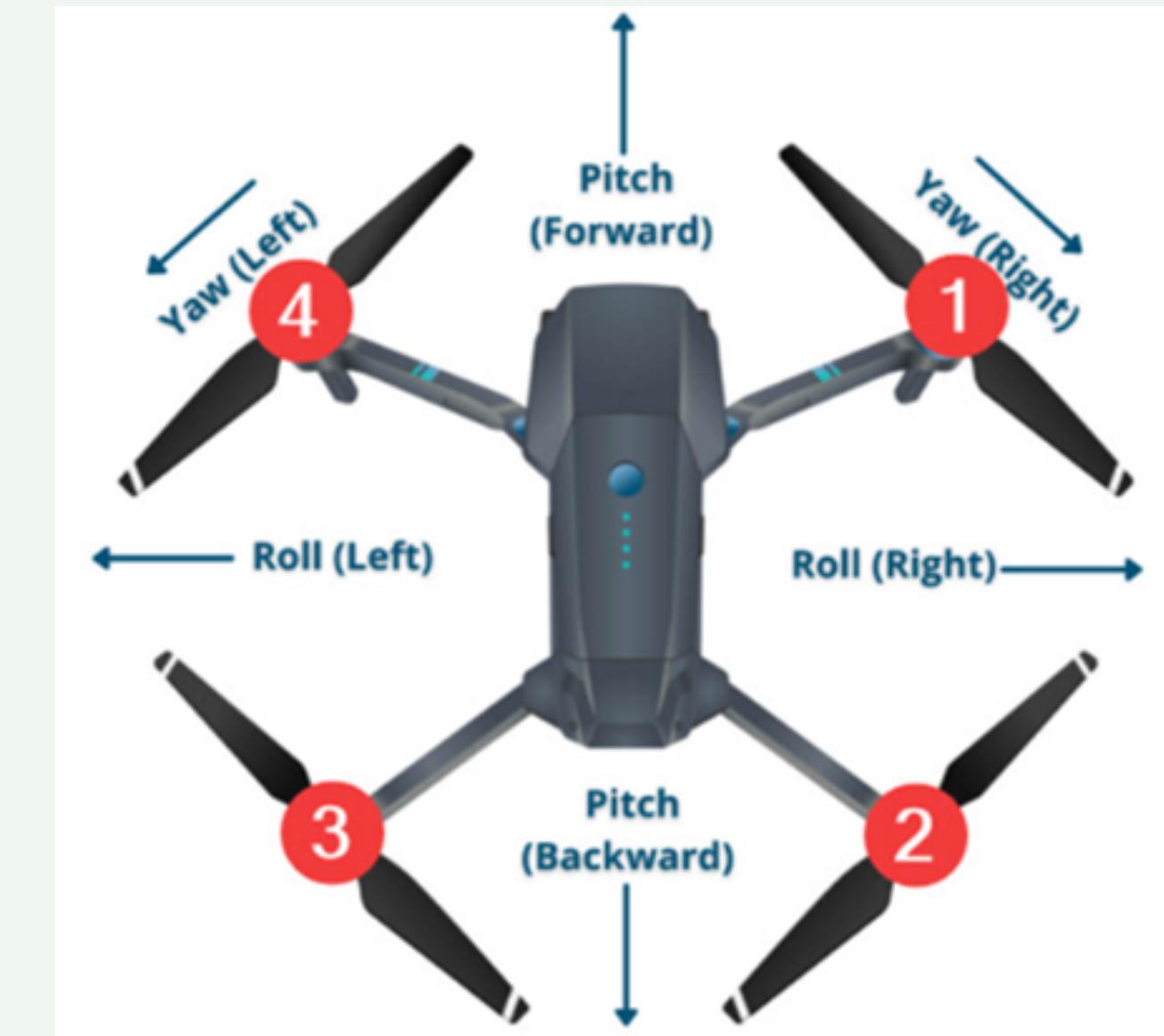
- Rotation about the X-axis
- Defines the drone tilting left/right.

2. q – Pitch Rate

- Rotation about the Y-axis
- Defines nose up/down motion.

3. r – Yaw Rate

- Rotation about the Z-axis
- Defines turning left/right



Effect of Motor Voltage on 6-DOF Aircraft Motion

1. u – Forward/Backward Velocity (X-axis translation)

a). Forward ($u \uparrow$)

Back motors increase, front decrease

\uparrow Motors: 2, 3

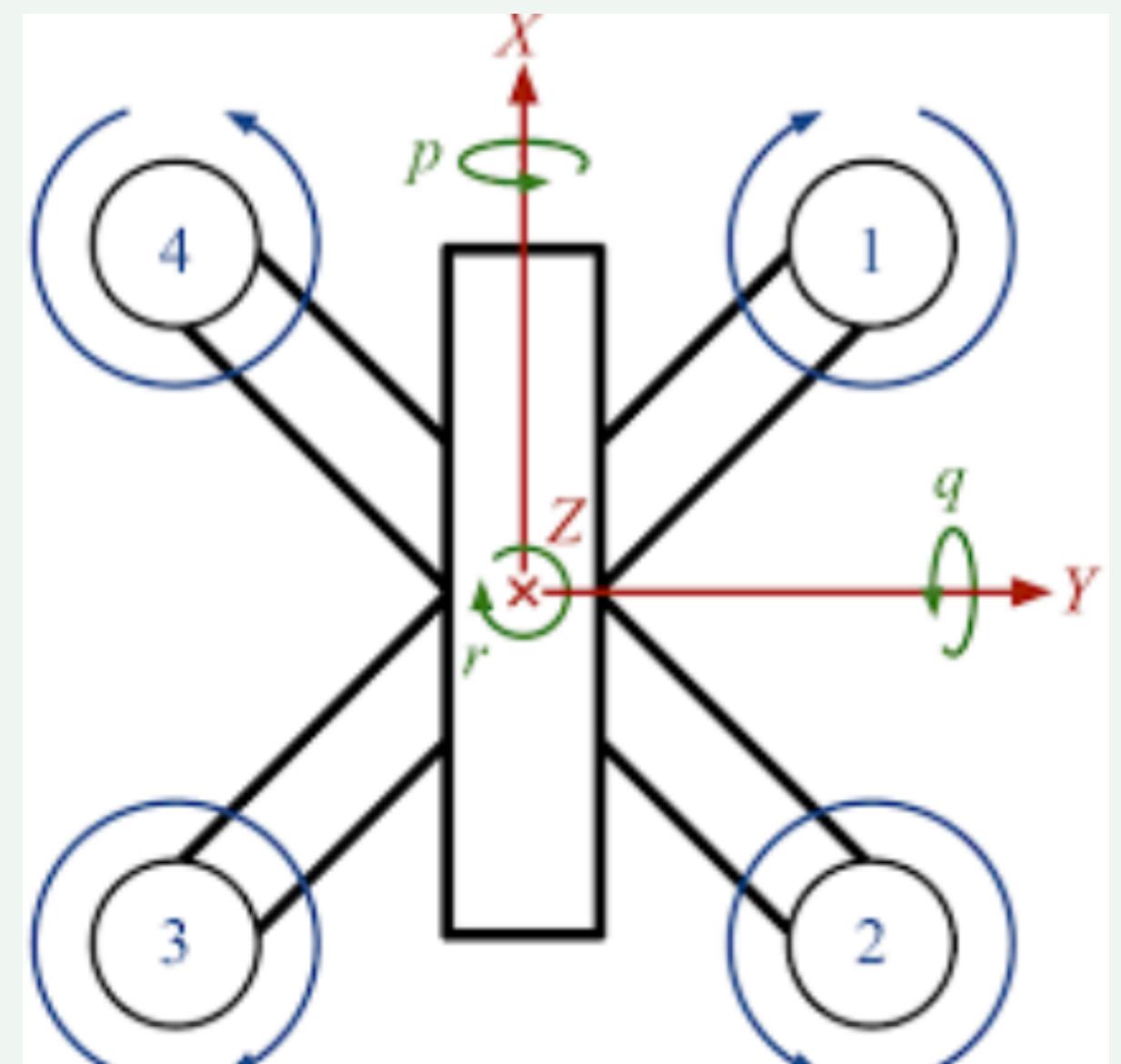
\downarrow Motors: 1, 4

b). Backward ($u \downarrow$)

Front motors increase, back decrease

\uparrow Motors: 1, 4

\downarrow Motors: 2, 3



Effect of Motor Voltage on 6-DOF Aircraft Motion

2. v – Right/Left Velocity (Y-axis translation)

a). Right ($v \uparrow$)

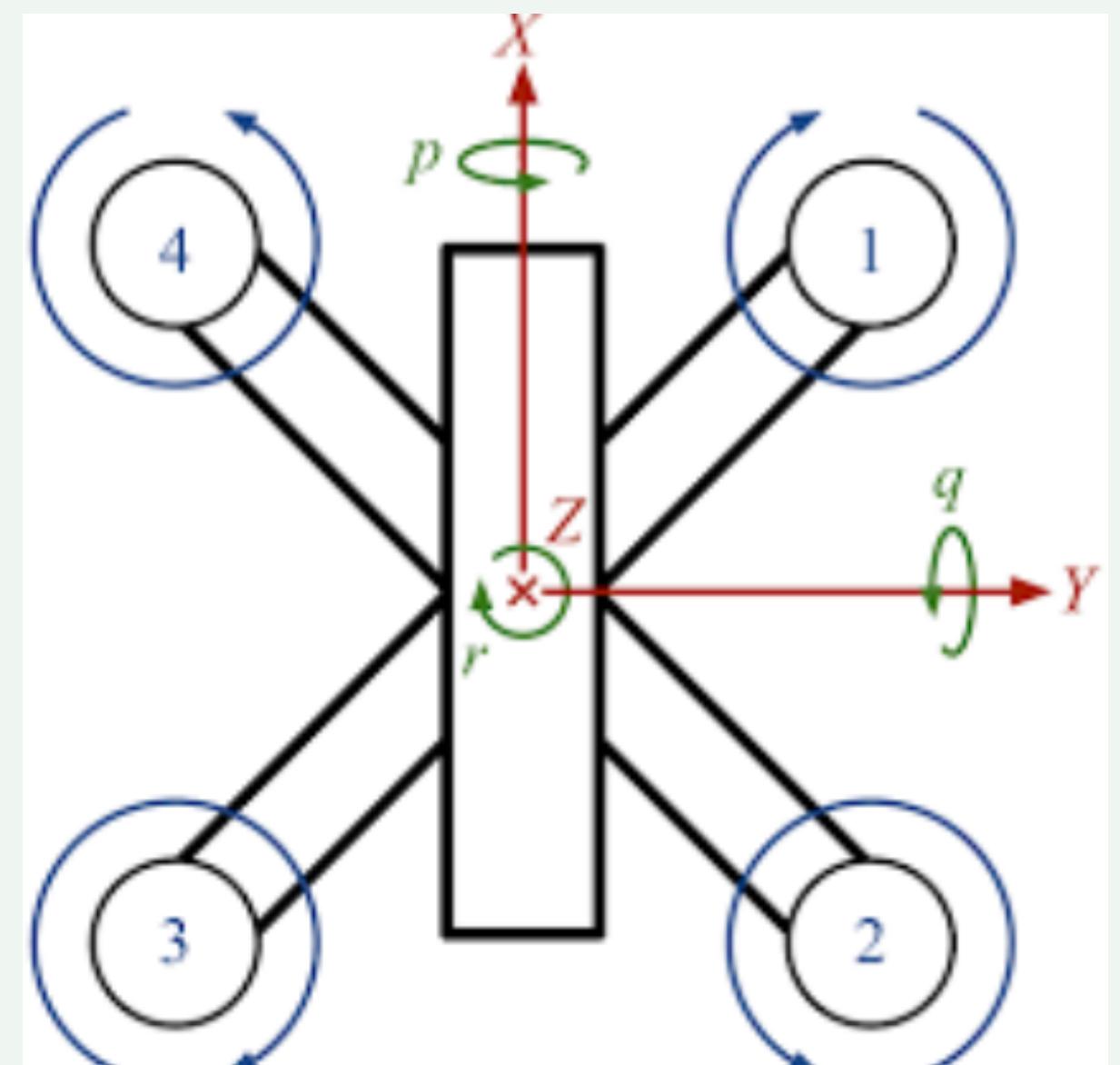
Left motors increase, right decrease

- \uparrow Motors: 4, 3
- \downarrow Motors: 1, 2

b). Left ($v \downarrow$)

Right motors increase, left decrease

- \uparrow Motors: 1, 2
- \downarrow Motors: 4, 3



Effect of Motor Voltage on 6-DOF Aircraft Motion

3. w – Up/Down Velocity (Z-axis translation)

a). Up ($w \uparrow$)

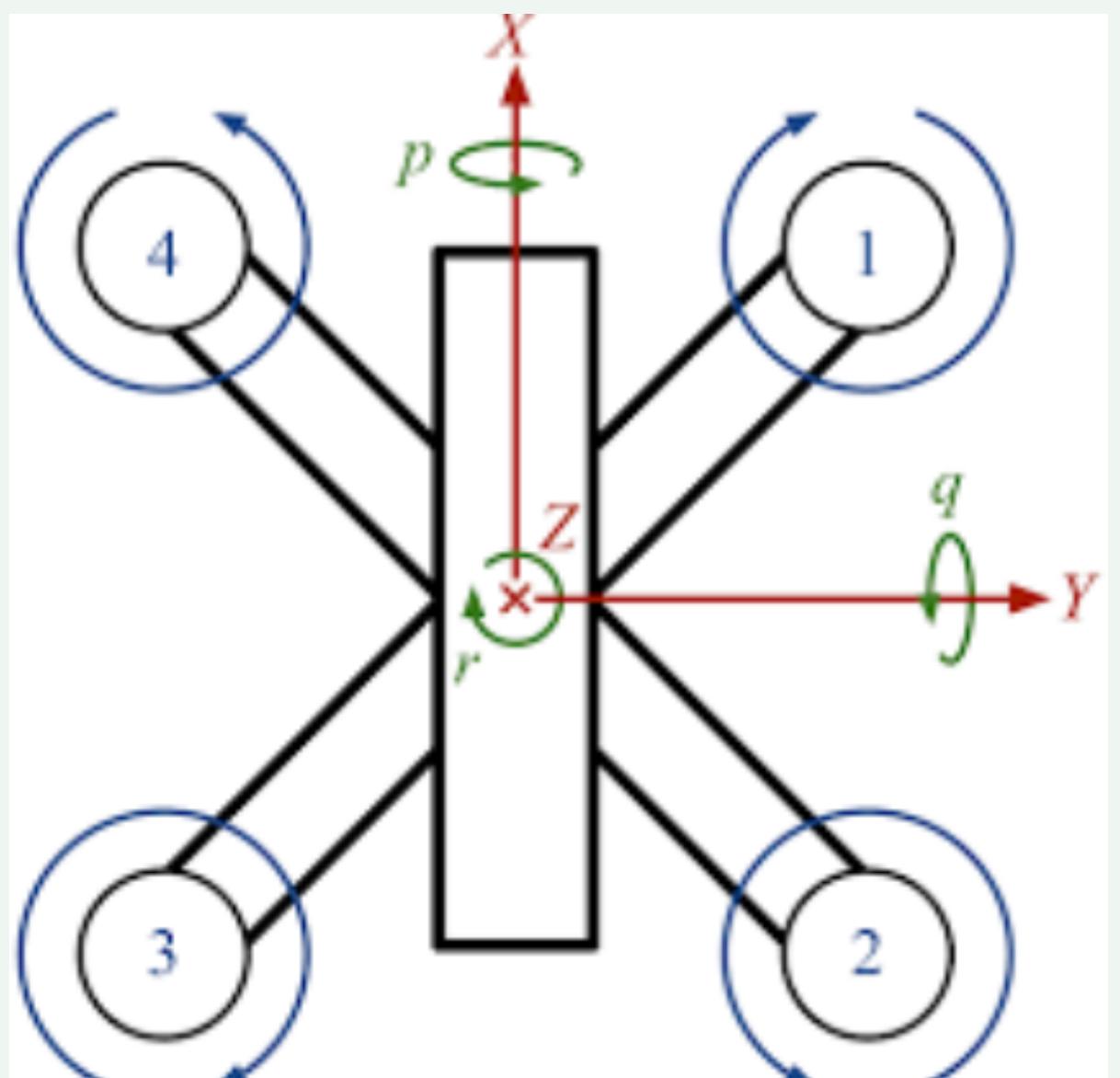
All motors increase

- \uparrow Motors: 1, 4, 3, 2

b). Down ($w \downarrow$)

All motors decrease

- \downarrow Motors: 1, 4, 3, 2



Effect of Motor Voltage on 6-DOF Aircraft Motion

4. p – Roll Rate (Rotation about X-axis)

a). Roll Right ($p \uparrow$)

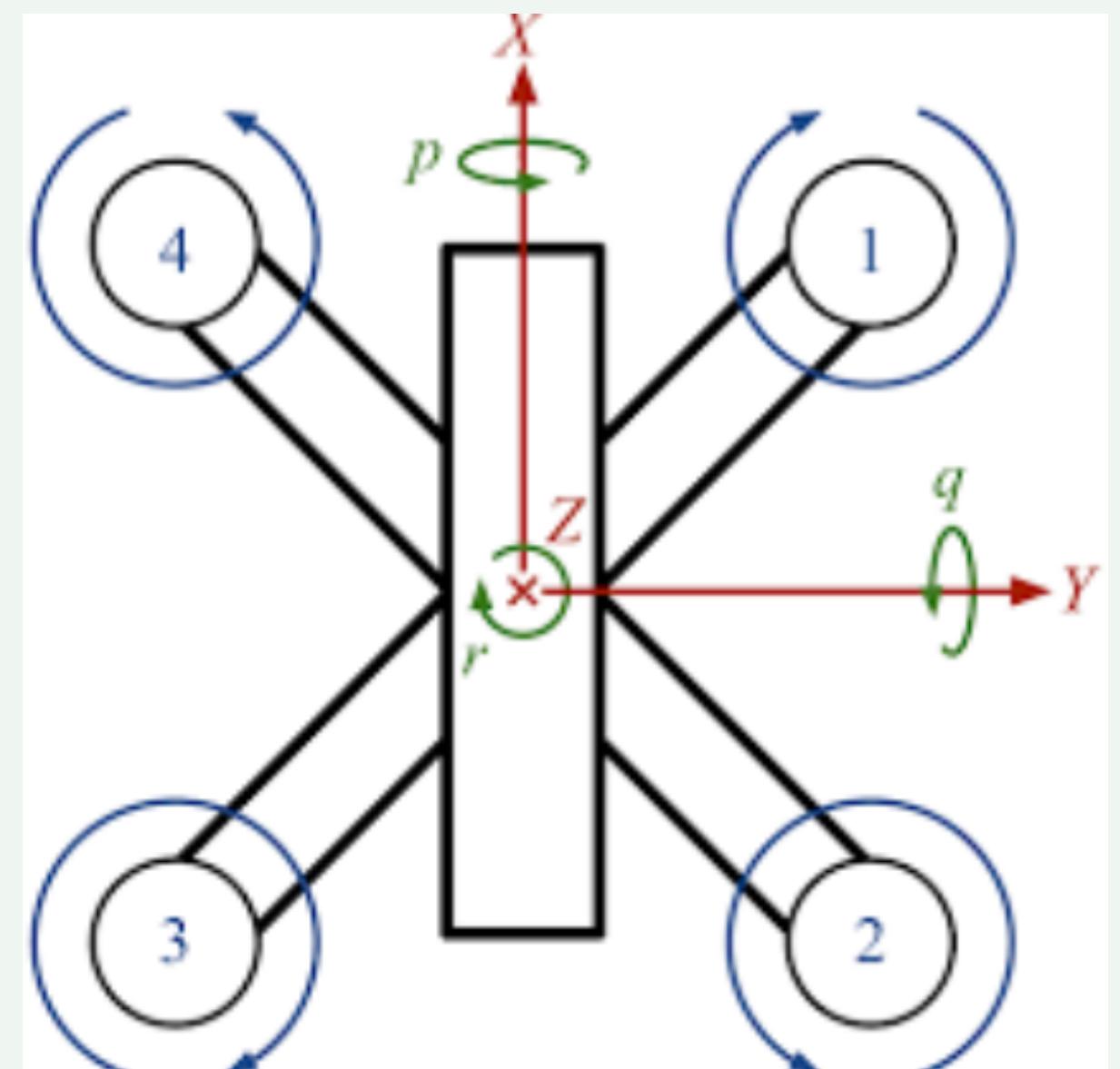
Left motors increase, right decrease

- \uparrow Motors: 4, 3
- \downarrow Motors: 1, 2

b). Roll Left ($p \downarrow$)

Right motors increase, left decrease

- \uparrow Motors: 1, 2
- \downarrow Motors: 4, 3



Effect of Motor Voltage on 6-DOF Aircraft Motion

5. q – Pitch Rate (Rotation about Y-axis)

a). Pitch forward ($q \uparrow$)

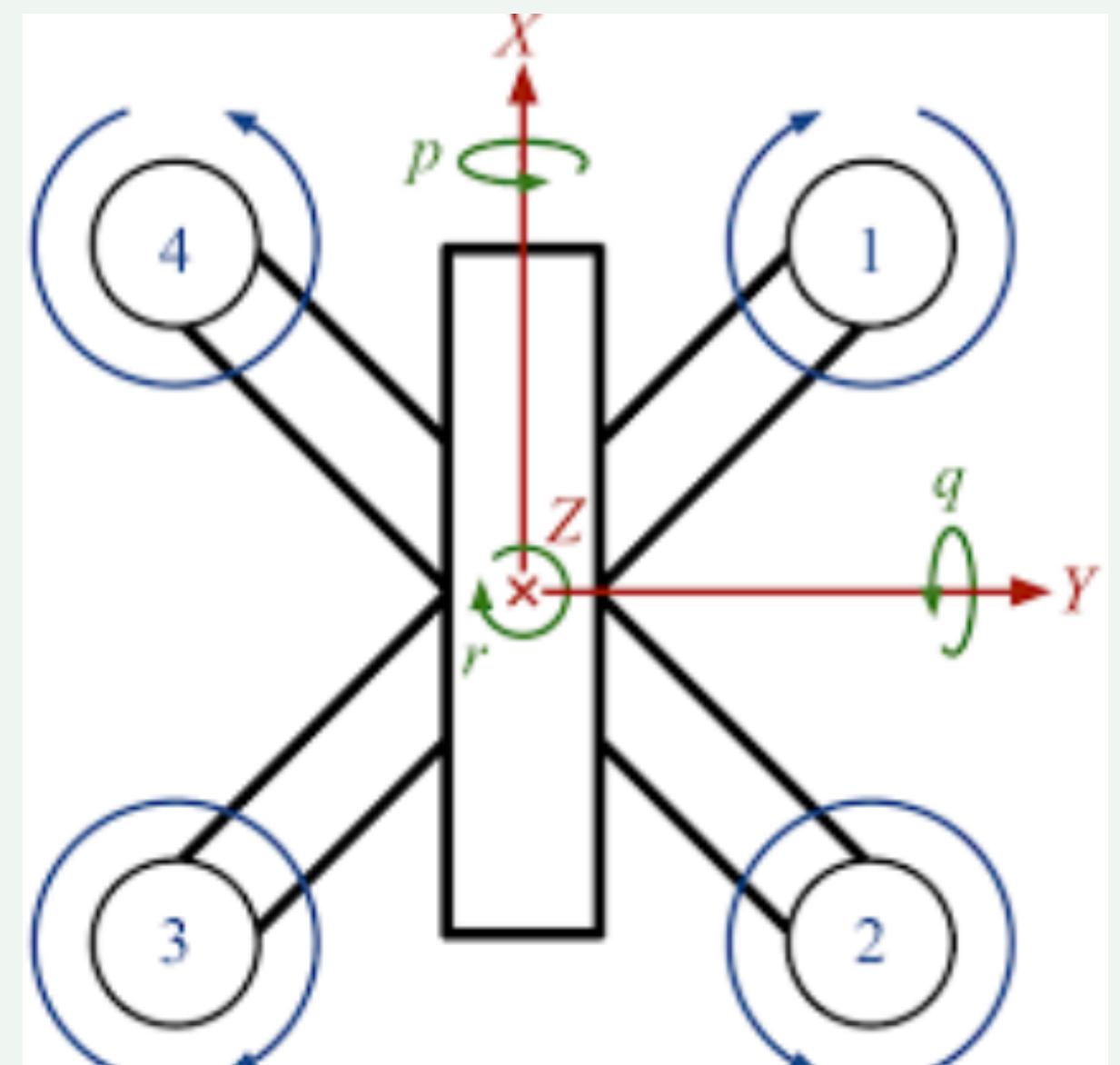
Back motors increase, front decrease

- \uparrow Motors: 2, 3
- \downarrow Motors: 1, 4

b). Pitch backward ($q \downarrow$)

Front motors increase, back decrease

- \uparrow Motors: 1, 4
- \downarrow Motors: 2, 3



Effect of Motor Voltage on 6-DOF Aircraft Motion

6. r – Yaw Rate (Rotation about Z-axis)

Assuming standard directions:

- CW motors: 1, 3 CCW motors: 4, 2

a). Yaw Right ($r \uparrow$)

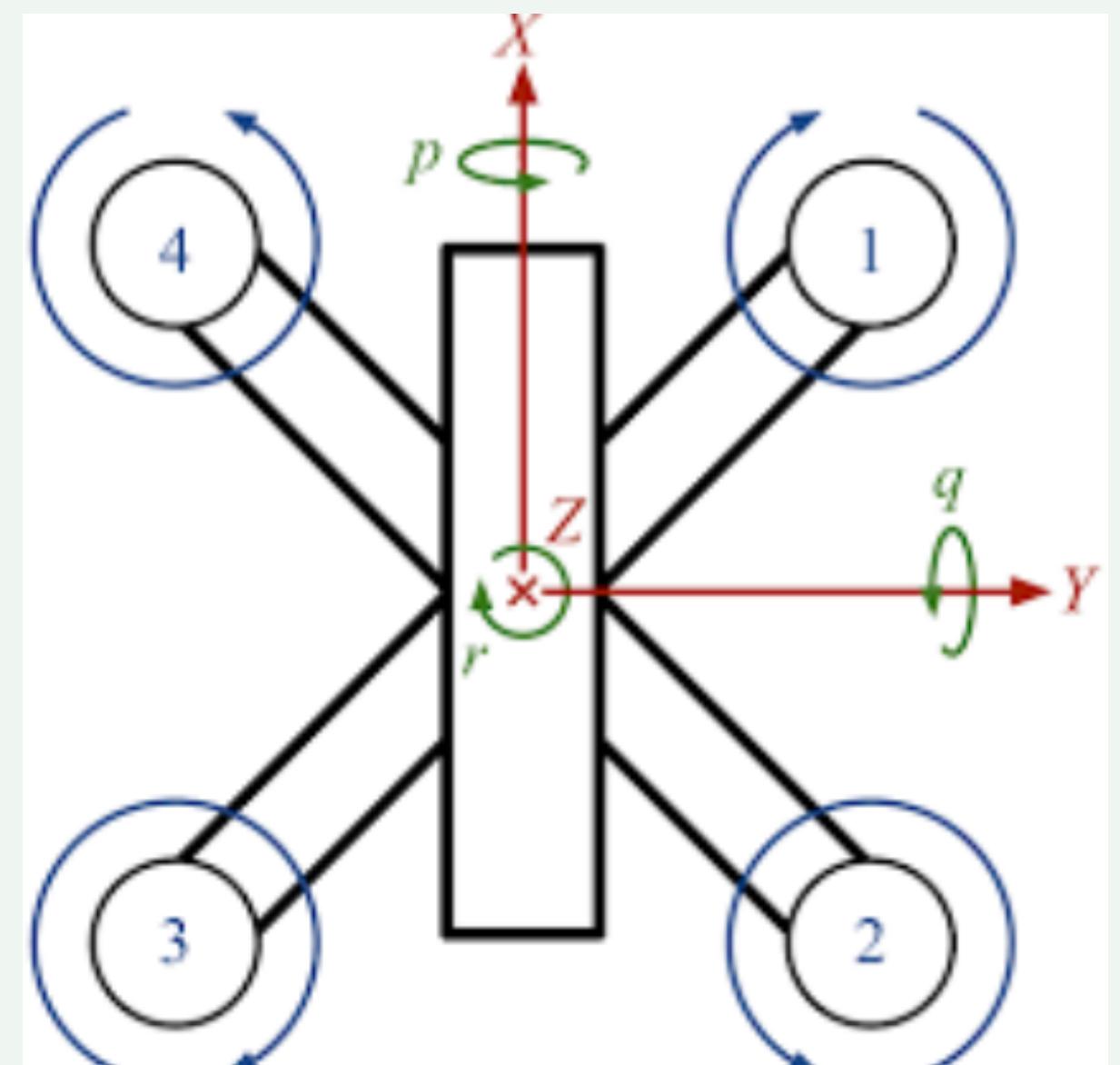
Increase CCW motors OR decrease CW motors

- \uparrow Motors: 4, 2
- \downarrow Motors: 1, 3

b). Yaw Left ($r \downarrow$)

Increase CW motors OR decrease CCW motors

- \uparrow Motors: 1, 3
- \downarrow Motors: 4, 2



Input and Parameters

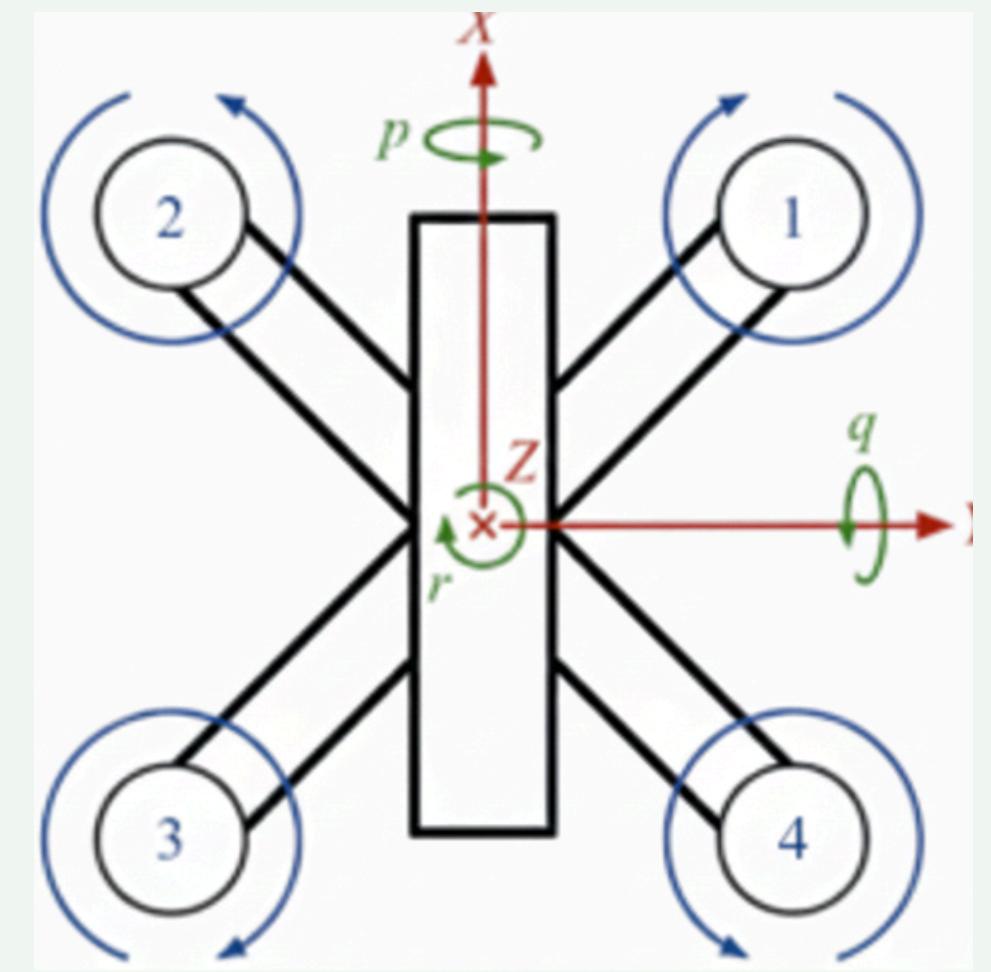
Motor Specifications (BLDC Motor)

1. Motor KV: 1200 RPM/V
2. Motor resistance: 0.1Ω
3. Motor inductance: 0.01 H
4. Maximum voltage: 12 V
5. Maximum RPM: 14400 RPM
6. Thrust coefficient: $kt = 1.8 \times 10^{-6} \text{ N}\cdot\text{s}^2/\text{rad}$

Input and Parameters

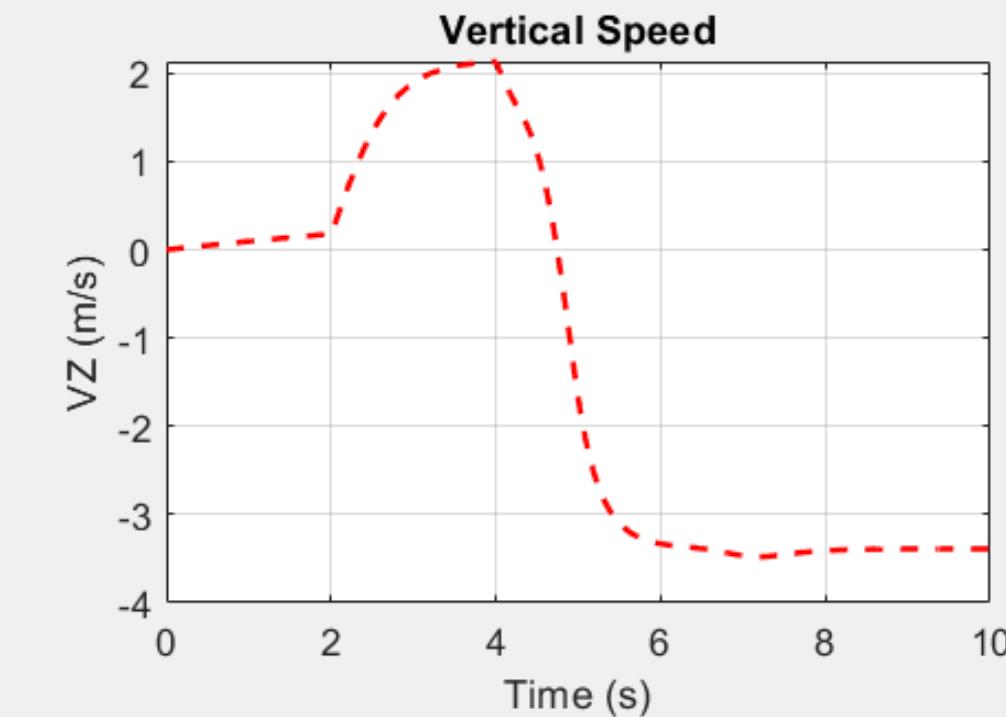
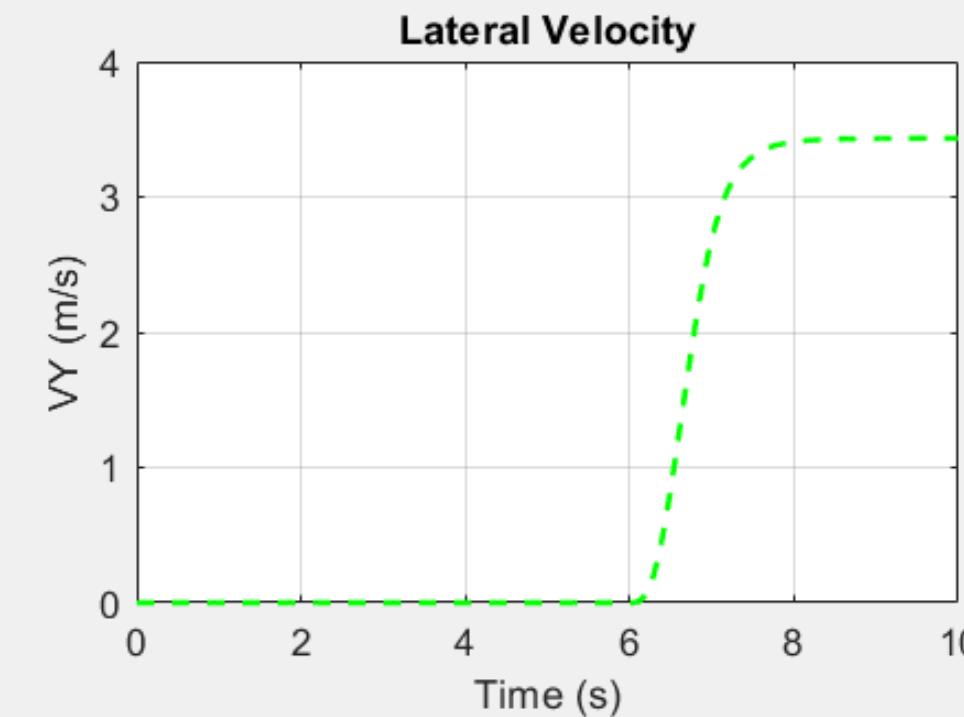
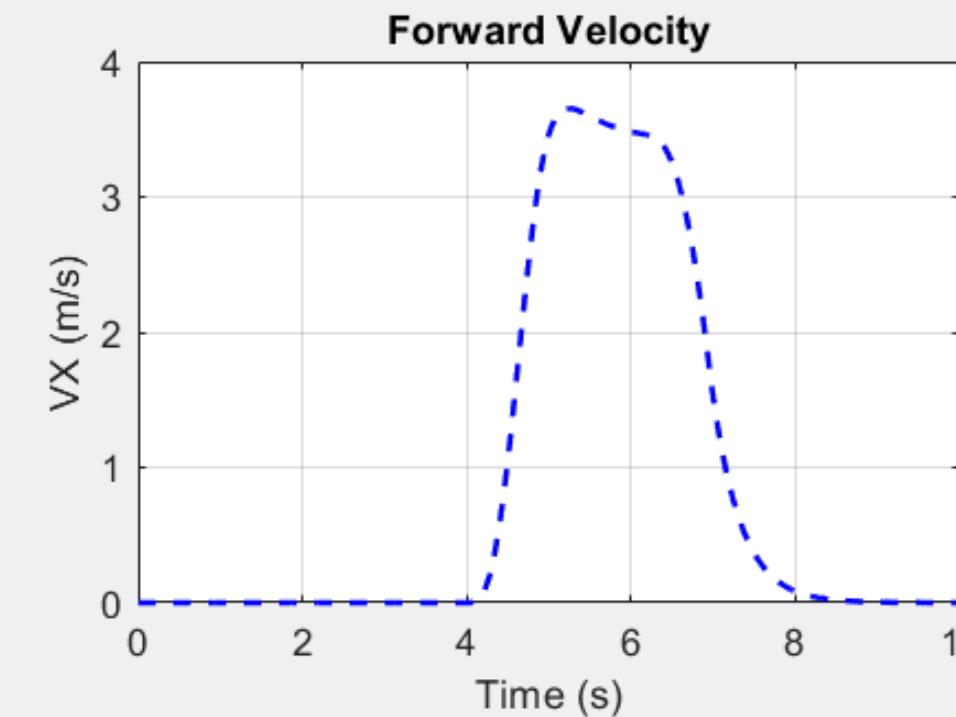
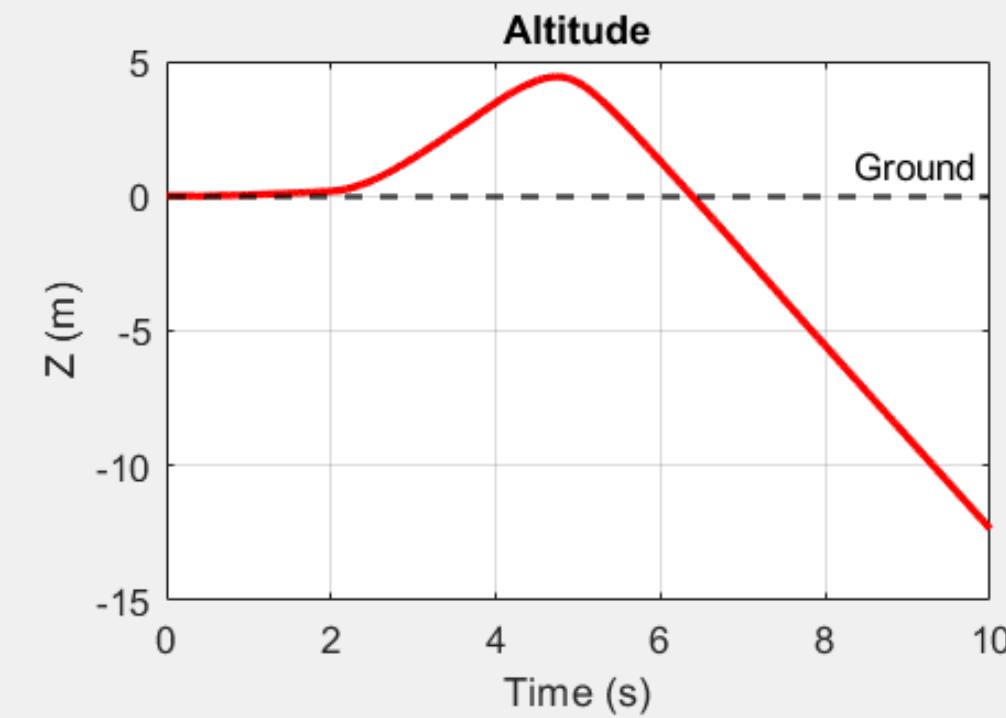
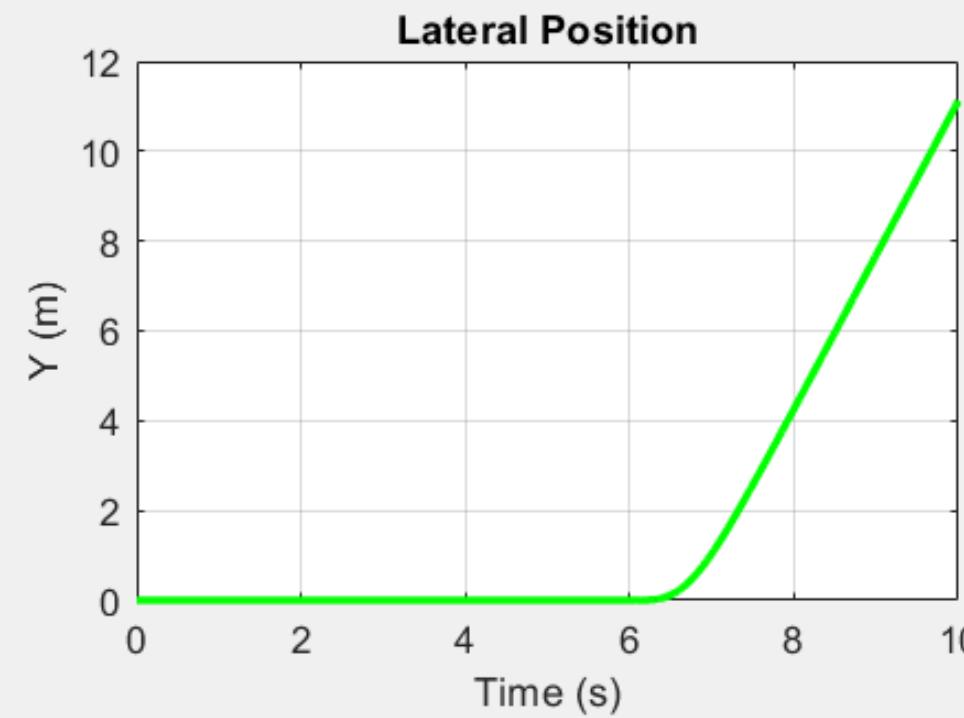
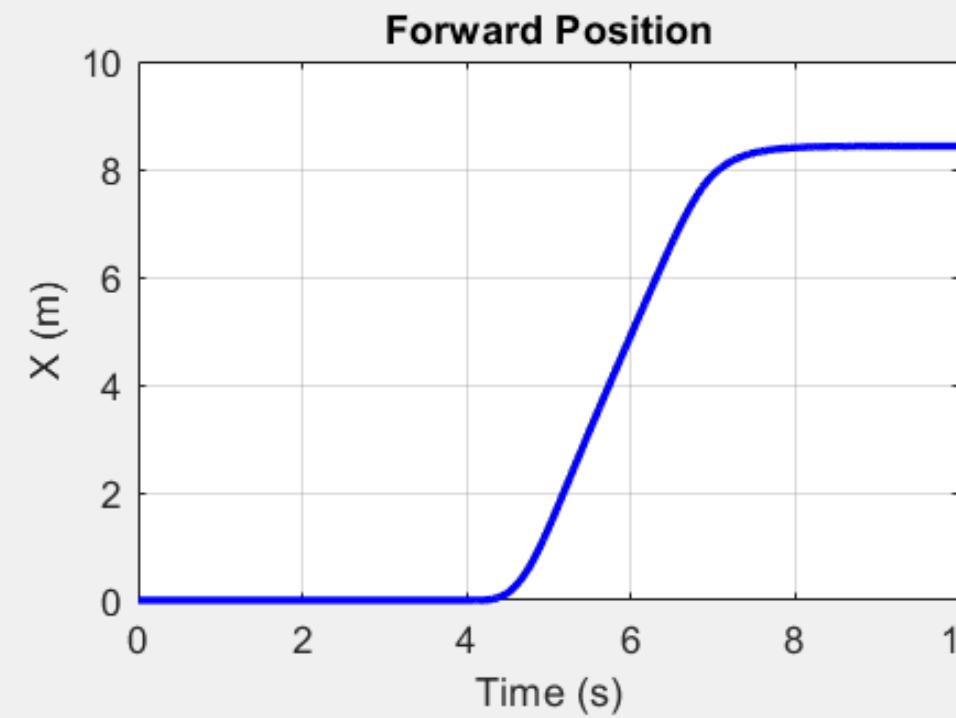
Aircraft Specifications (Quadcopter)

1. Mass: 0.5 kg
2. Gravitational acceleration: 9.81 m/s^2
3. Arm length: 0.12 m (distance to motors)
4. Moment of inertia: $I_{xx} = 0.01 \text{ kg}\cdot\text{m}^2$,
 $I_{yy} = 0.01 \text{ kg}\cdot\text{m}^2$,
 $I_{zz} = 0.02 \text{ kg}\cdot\text{m}^2$
5. Drag coefficient: $C_d = 0.3$



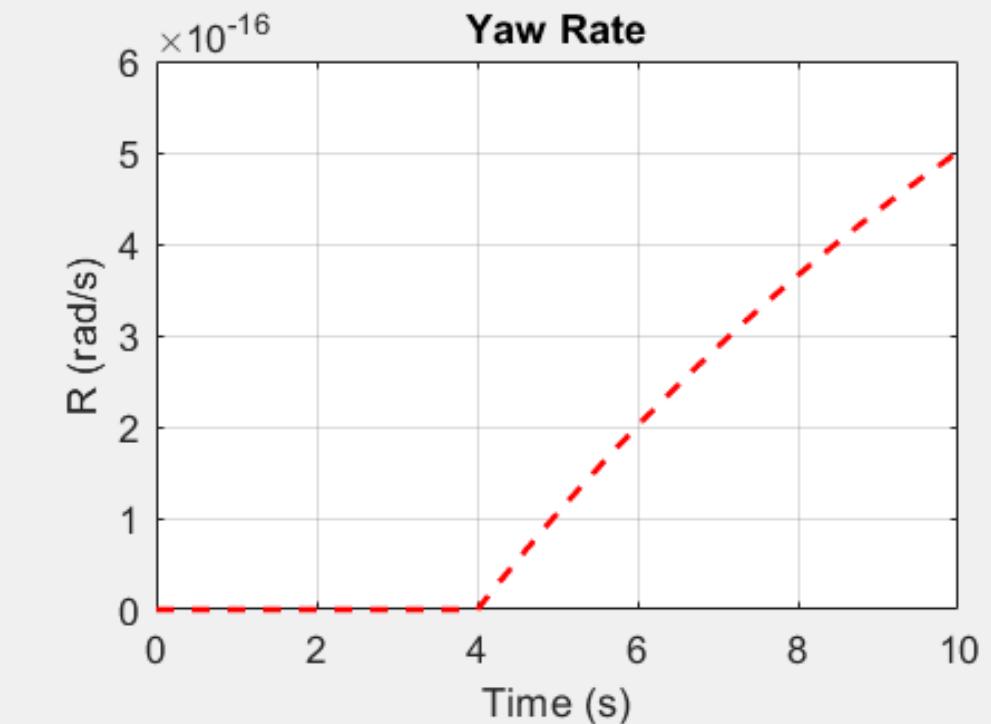
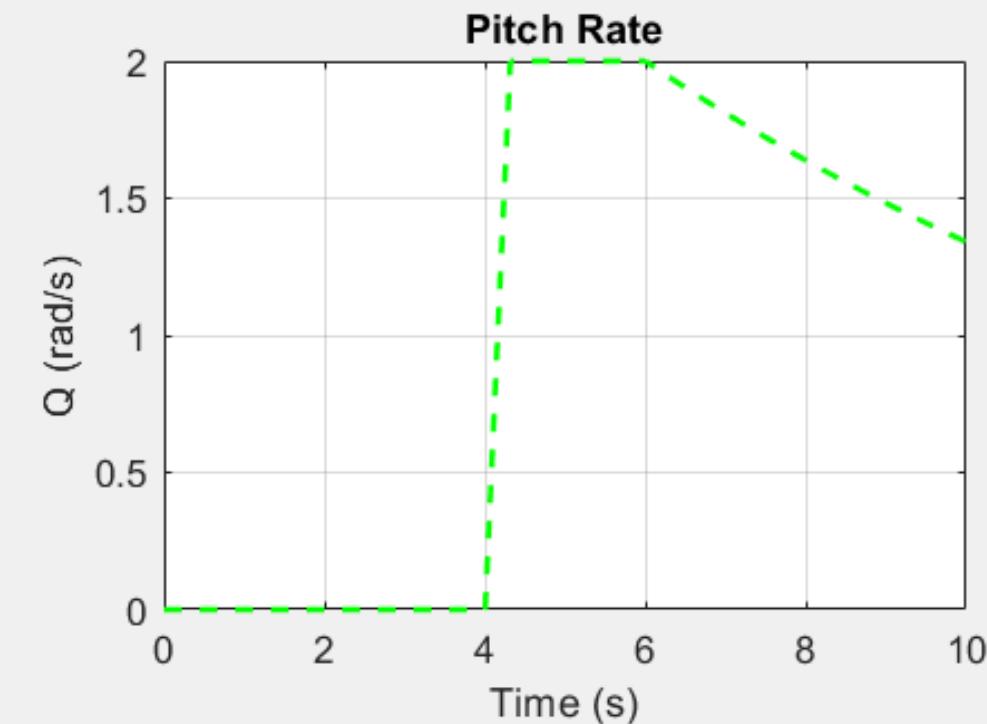
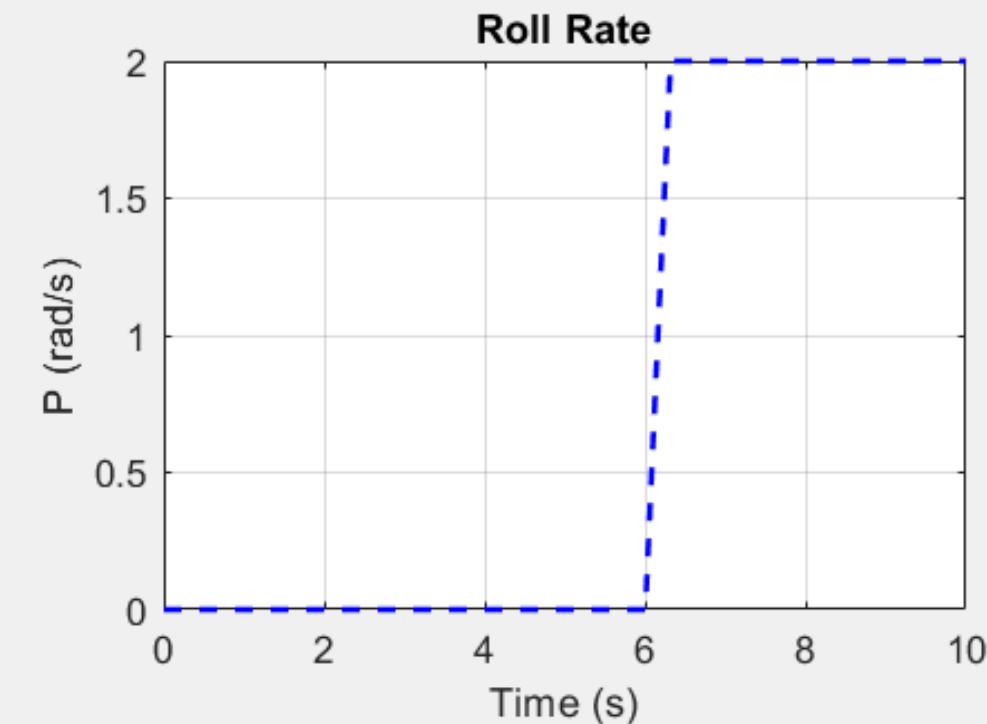
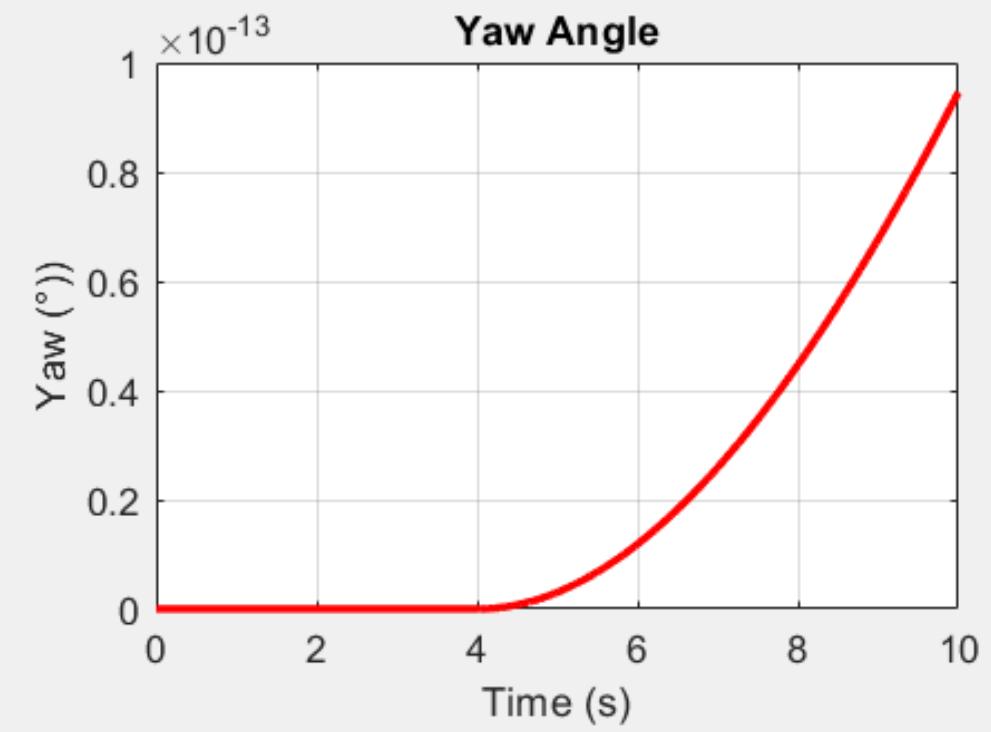
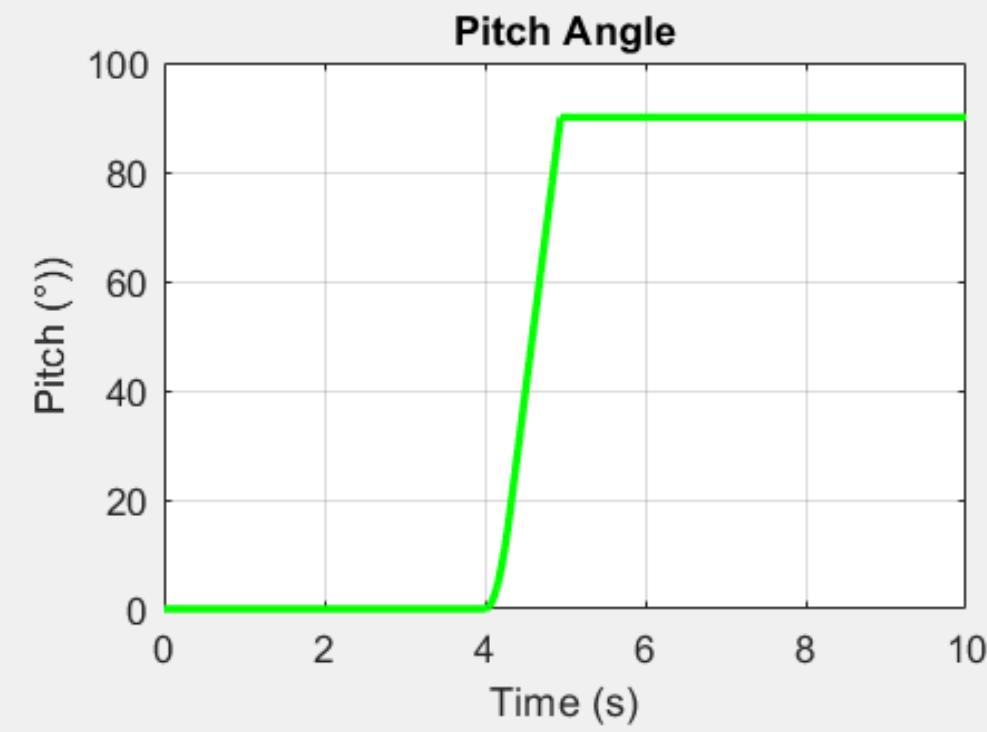
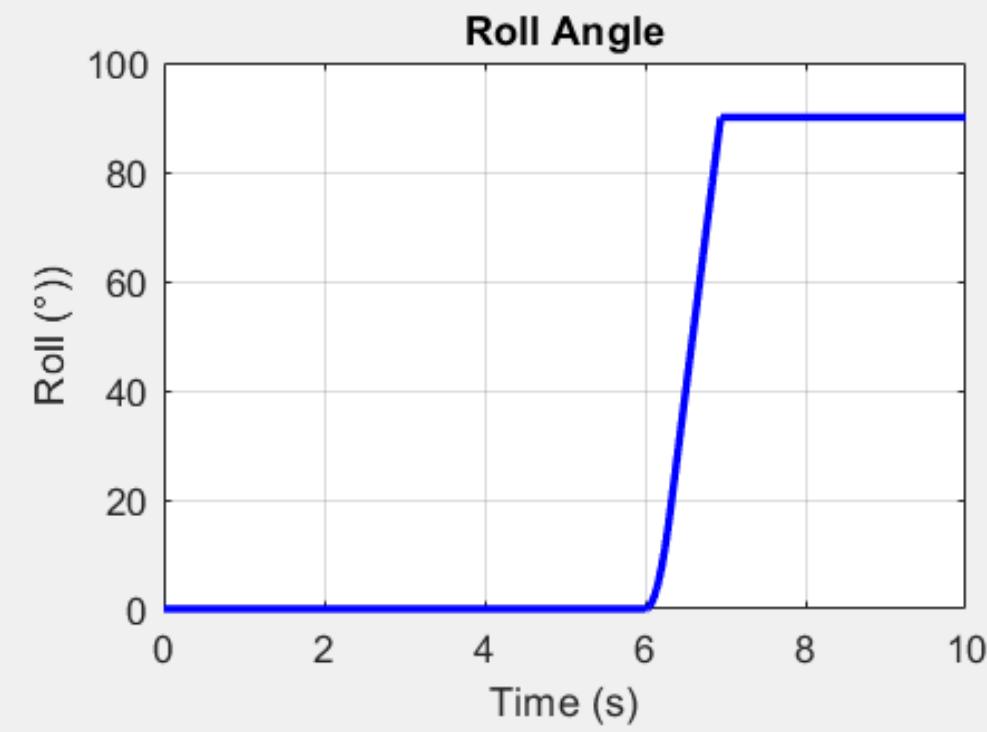
Output

TRANSLATION DYNAMICS (3DOF) - REALISTIC



Output

ROTATION DYNAMICS (3DOF) - REALISTIC



Output

FINAL AIRCRAFT STATE:

Position: [8.428, 11.121, -12.3] meters
Velocity: [0.000, 3.432, -3.389] m/s
Attitude: [1.57, 1.57, 0.00] radians
Altitude: [90.0°, 90.0°, 0.0°]

MOTOR PERFORMANCE SUMMARY:

Motor 1 - Max RPM: 8928 | Max Thrust: 1573.40g (1.573N)
Motor 2 - Max RPM: 8928 | Max Thrust: 1573.40g (1.573N)
Motor 3 - Max RPM: 8928 | Max Thrust: 1573.40g (1.573N)
Motor 4 - Max RPM: 8928 | Max Thrust: 1573.40g (1.573N)

THRUST ANALYSIS:

Total Thrust - Max: 6294g (6.3N) | Hover: 4905g
Aircraft Weight: 4905g (4.905N)
Max Thrust-to-Weight Ratio: 1.3

6DOF PERFORMANCE:

1. X Position: [0.00 - 8.43] m
2. Y Position: [0.00 - 11.12] m
3. Z Altitude: [-12.34 - 4.4] m
4. Roll: [0.0 - 90.0] °
5. Pitch: [0.0 - 90.0] °
6. Yaw: [0.0 - 0.0] °

Thank You