LOCOMOTIONS (AR): KEY DESIGN ISSUES, ATTRIBUTES, BASIC THEORETICAL MODEL, PAYLOAD.

MUHAMMAD FARID BIN JAFRI (2111633)

LOCOMOTION MECHANISMS

1. Fixed-Wing
   - Generates lift through forward motion and wing aerodynamics.
   - High endurance, large range.
   - Requires a runway or catapult for takeoff.
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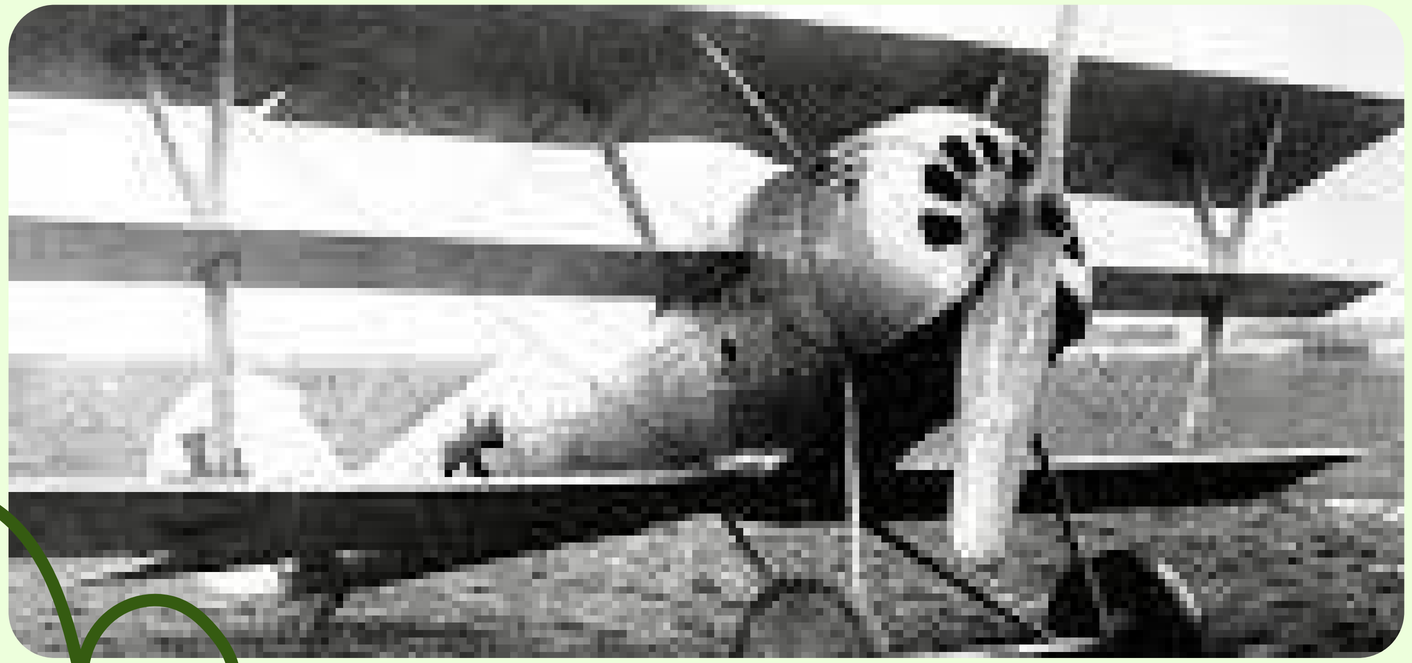

2. Rotary-Wing (Multirotor)
   - Vertical lift through spinning rotors.
   - It can hover and take off/land vertically.
   - Lower endurance than fixed-wing.

3. Flapping-Wing (Ornithopter)
   - Mimics bird/insect flight via wing flapping.
   - Highly maneuverable, very small scale.
   - Low payload and endurance.

4. Hybrid VTOL
   - Combines rotary and fixed-wing.
   - Vertical takeoff + long-distance flight.
   - Complex control system.

KEY DESIGN ISSUES

KEY DESIGN	EXPLAINATION
Weight and Lift Balance	• Must ensure total lift ≥ total weight. • Trade-off between structural strength and weight reduction.
Power Management	• Batteries limit endurance. • Design must optimize for energy efficiency and rechargeability. • Integration of solar or hybrid power in some systems.
Flight Stability and Control	• Need for real-time dynamic stabilization via sensors (IMU, gyroscope). • Handling disturbances (wind gusts, obstacles).
Environmental Adaptability	• Operating altitude, wind resistance, and weatherproofing. • Temperature/humidity tolerance affects electronics and lift.

ATTRIBUTES OF AERIAL ROBOTS

Common Attributes:

Degrees of Freedom (DOF): Typically 6 (x, y, z, pitch, yaw, roll)

Autonomy Levels:

- Manual (RC)
- Semi-autonomous (waypoint following)
- Fully autonomous (adaptive navigation)

Sensors:

- Inertial Measurement Unit (IMU)
- GPS / RTK
- Cameras (optical, IR)
- LIDAR/radar

Communications:

- Line-of-sight (radio)
- Beyond Visual Line of Sight (BVLOS) via satellite/5G

Real-Time Feedback:

- Telemetry data for monitoring and diagnostics

THEORETICAL MODEL OF AERIAL ROBOT

Quadrotor Case

Physical Model Assumptions:

- Rigid body, symmetrical structure.
- Actuation through four rotors with known thrust/torque constants.

Translational Dynamics:

- Based on Newton's Second Law:
  - $m\ddot{x} = -mgz + RFt$
- where R is the rotation matrix from the body to the inertial frame.

Rotational Dynamics:

- Euler's Equations:
  - $I\dot{\omega}+\omega\times(I\omega)=\tau$
- where τ is the net torque from rotors.

Control Inputs:

- Thrust (up/down), pitch (forward/back), roll (left/right), yaw (rotation).
- Differential speeds on rotors allow complete control in 3D space.

PAYLOAD CONSIDERATIONS

What is Payload?

- The additional equipment/mass carried by the aerial robot beyond its own structure and propulsion.

Factors Affecting Payload Capacity:

- Rotor thrust and motor power
- Battery capacity and flight duration
- Center of gravity and aerodynamic stability

Types of Payload:

- Sensing: Cameras, LIDAR, multispectral sensors
- Delivery: Parcels, emergency supplies
- Communication: Relays, antennas
- Weapons (military use): Guided munitions, surveillance pods

Trade-off:

- Higher payload reduces flight time and maneuverability.
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DJI MATRICE 300 RTK

- **Type:**
  - **Multirotor hexacopter**
- **Applications:**
  - **Industrial inspection, public safety, and agriculture**
- **Payload Capacity:**
  - **Up to 2.7 kg**
- **Key Features:**
  - **AI tracking**
  - **Dual operator mode**
  - **RTK GNSS precision (cm-level accuracy)**
  - **Max flight time ~55 minutes**

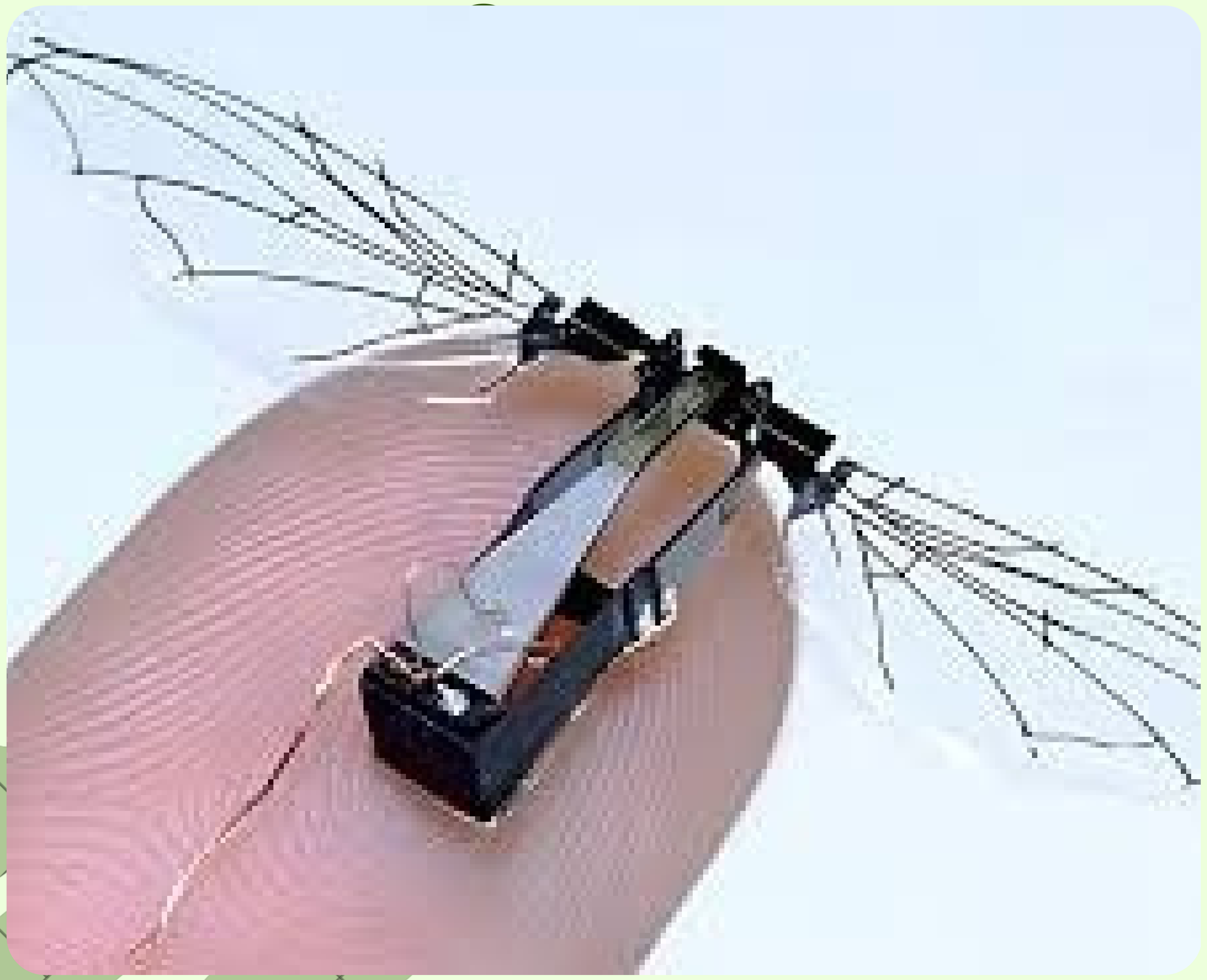
MQ-9 REAPER

- Type:
  - Fixed-wing, long-endurance UAV
- Use Case:
  - Military surveillance and strike
- Payload:
  - Up to 1700 kg (missiles, sensors, fuel)
- Key Features:
  - Satellite communications for BVLOS control
  - Endurance: 27+ hours
  - Altitude: Up to 50,000 ft
  - EO/IR and synthetic aperture radar (SAR)

PARROT ANAFI AI

- **Type:**
  - **Multirotor**
- **Application:**
  - **3D mapping, construction inspection**
- **Payload:**
  - **Integrated 48 MP camera with 6x zoom**
- **Key Features:**
  - **4G LTE connectivity for long-range control**
  - **Autonomous flight planning**
  - **Real-time terrain following**

ROBOBEE (HARVARD)



- **Type:**
  - **Flapping-wing micro aerial vehicle**
- **Purpose:**
  - **Research, insect-mimic flight**
- **Payload:**
  - **Minimal (lightweight sensors)**
- **Key Features:**
  - **Weighs ~80 mg**
  - **Electrostatic adhesion for vertical landing**
  - **High maneuverability in confined spaces**

WINGCOPTER 198

- **Type:**
  - **Hybrid VTOL fixed-wing**
- **Application:**
  - **Medical delivery, remote logistics**
- **Payload:**
  - **Up to 5 kg**
- **Key Features:**
  - **3-package system, dynamic release**
  - **Range: Up to 75 km**
  - **Weather-resistant design**
  - **VTOL takeoff and landing**

CONCLUSION

- Aerial robots exhibit diverse locomotion systems tailored to specific missions.
- Design involves trade-offs between payload, flight time, and maneuverability.
- Real-world examples show how ARs are solving modern challenges in military, logistics, industry, and research.
- Understanding theoretical models aids in building control systems and flight algorithms.
- Future work includes swarming, AI-enhanced autonomy, and extended endurance systems.

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THANK YOU