SYSTEM ARCHITECTURE (AR): COMPONENTS, COMMUNICATIONS, GROUND CONTROL STATION.

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SYSTEM ARCHITECTURE IN AERIAL ROBOTICS

System architecture in aerial robotics refers to the structural framework that governs the interaction between an aerial robot's subsystems. It encompasses the design, integration, and functionality of the robot's components—sensors, actuators, processors, communication systems, and software algorithms—that enable autonomous or semi-autonomous operation. The effectiveness of the system architecture influences a UAV’s reliability, scalability, control efficiency, and mission adaptability.

FUNDAMENTAL COMPONENTS OF AR SYSTEMS

- Flight Management Unit
  - Brain of the UAV; controls navigation, stability, and mission execution
- Sensor Suite
  - IMUs, GPS, cameras, barometers, and other tools for orientation and data sensing
- Actuation Subsystem
  - Includes motors, servos, propellers, and control for mobility
- Power Supply
  - Battery systems, fuel cells, or hybrid generators to energize all subsystems
- Payload Interface
  - Mounts and integrates mission-specific tools or cargo
- Communication Stack
  - Handles data transfer, remote command, telemetry, and inter-UAV networking
- Computing Unit
  - Processes sensor data and supports autonomous navigation and decision-making

COMMUNICATION INFRASTRUCTURE

Communication ensures operational control, real-time monitoring, and safe data exchange between the aerial robot and human operators or other robots. Key communication layers include:

- Control Link: Securely transmits flight commands using RF protocols (e.g., 2.4/5.8 GHz)
- Telemetry Channel: Reports aircraft status and sensor data to the ground station
- Video/Data Link: Transfers live video or survey data in real-time (typically HD downlink)
- Beyond Visual Line of Sight (BVLOS): Employs SATCOM, LTE/5G for remote missions
- Fail-safes: Redundant links and return-to-home triggers ensure mission resilience

GROUND CONTROL STATION (GCS)

Ground Control Stations serve as the human interface for monitoring, command issuance, and mission planning. GCS platforms include:

Platform	Functions
Handheld GCS	Suitable for commercial drones; integrates touch controls and telemetry
Laptop/Desktop Systems	Runs mission software (e.g., QGroundControl, DJI Pilot, FreeFlight)
Mobile Tactical Units	Used for military UAVs with dual operator interfaces and secure networks
Cloud-Based Systems	Web-accessible dashboards for multi-UAV coordination and real-time analytics

DJI MATRICE 300 RTK

- Architecture Highlights:
  - Advanced dual-redundant flight controller
  - RTK-GPS integration for high-precision navigation
  - Versatile payload ports supporting AI and LIDAR tools
- Communications:
  - OcuSync Enterprise: HD, low-latency control up to 15 km
  - Auto-hopping between 2.4/5.8 GHz with AES-256 encryption
- GCS:
  - Enterprise-grade Smart Controller with RTK compatibility
  - Supports automated flight paths and live sensor feed display

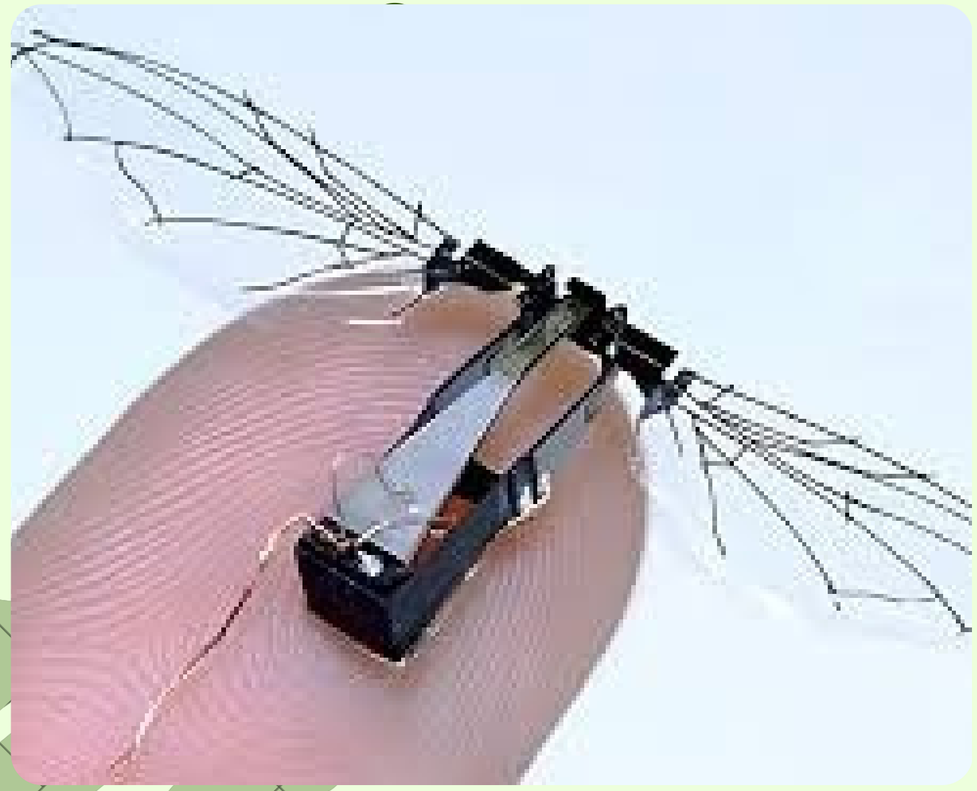
MQ-9 REAPER

- Architecture Highlights:
  - Triple-redundant onboard avionics and mission-specific payload bays
  - Sensor fusion with EO/IR, radar, and SIGINT capabilities
- Communications:
  - Global SATCOM for BVLOS operations
  - Encrypted data links with military-grade protocols
- GCS:
  - Aircrew-style console with pilot and payload control stations
  - Integrated data analysis, target acquisition, and mission control

PARROT ANAFI AI

- Architecture Highlights:
  - Embedded edge-AI processor for onboard scene interpretation
  - RTK GNSS for geospatial applications
- Communications:
  - Native 4G LTE module enabling BVLOS ops
  - Wi-Fi fallback mode with IP-based encryption
- GCS:
  - FreeFlight 7 app featuring photogrammetric and AI flight modes
  - Real-time sync with Pix4Dcloud for data analysis

ROBOBEE (HARVARD)



- Architecture Highlights:
  - Piezoelectric wing actuators
  - Ultra-lightweight frame with micro-scale sensors
- Communications:
  - Tethered wired setup for power and command
  - IR-based optical link under development for swarm control
- GCS:
  - Laboratory interface using Simulink and motion capture inputs
  - GUI-based flight path programming and real-time feedback

WINGCOPTER 198

- Architecture Highlights:
  - Hybrid VTOL with tilt-rotor vector thrust control
  - Supports triple-drop payload for logistics missions
- Communications:
  - Redundant telemetry with LTE/5G options
  - Satcom readiness for long-distance delivery
- GCS:
  - Wingcopter Control Center for fleet and mission scheduling
  - Web-based GUI with payload verification and delivery updates

CONCLUSION

The system architecture of aerial robots dictates their reliability, communication robustness, and functional specialization. Platforms such as the MQ-9 Reaper and DJI Matrice 300 RTK showcase robust multi-redundant architectures with advanced sensing and secure long-range communications. In contrast, research UAVs like RoboBee prioritize miniaturization and precise control over durability and scale. This diversity reflects the adaptability of system architecture in serving varied domains—military, research, logistics, and geospatial mapping.

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