DRONE TECHNOLOGY & ROBOTICS

DIPLOMA WALLAH

OPEN ELECTIVE

Jharkhand University Of Technology (JUT)

Unit-V – Avionics Hardware of Drones

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1. Autopilot (Flight Controller)

Explanation:
The autopilot (also called flight controller) is effectively the "brain" of the drone. It runs real-time software on dedicated hardware (microcontroller or embedded computer) to stabilise the aircraft, execute flight commands, follow waypoints, and interface with sensors and actuators. (PX4 Docs) It receives inputs from accelerometers, gyros, magnetometer, barometer, GNSS, etc., processes them to compute attitude, position and other flight parameters, then outputs commands to the motors/servos (via Electronic Speed Controllers or servo drive units). Many modern autopilots also support advanced features such as obstacle avoidance, mission scripting, telemetry, and even companion computing. (Unmanned Systems Technology) During design you must ensure the autopilot hardware supports required vehicle type (multirotor, fixed-wing, VTOL) and meets embedded constraints (weight, power, EMI, redundancy). (PX4 Docs)
Key Points:

- Autopilot = flight controller + firmware + sensor fusion.
- Must support vehicle configuration (e.g., multicopter, plane, VTOL).
- Real-time OS or firmware (often RTOS) to manage fast loops for attitude control. (PX4 Docs)
- Sensor fusion: gyros + accelerometers + magnetometer + GNSS to estimate flight state.

- Managing communication with ground station (telemetry), managing failsafe (return-home) and modes (manual, assisted, autonomous).
  Example:
  The open-source PN4 (PX4) flight stack runs on hardware boards like Pixhawk; it supports multicopter, fixed-wing, VTOL, and uses sensor fusion, safety features, mission planning tools. (Wikipedia)
  Hinglish Summary:

Autopilot ya flight controller drone ka dimaag hota hai — sensors se information leke, motors/servos ko commands deta hai. Manual mode se autonomous mode tak kaam karta hai.

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2. Sensors: Accelerometer, Gyros, Pressure Sensors (AGL), etc.

Explanation:
Sensors form the "eyes and ears" of the drone's avionics. Common ones include:

- **Accelerometer/Gyro (IMU):** Measures linear acceleration and angular rates. Essential for attitude and motion estimation.
- **Magnetometer/Compass:** Provides heading reference.
- **Barometer/AGL (Altitude) sensor / Pressure sensor:** Measures altitude or vertical changes via air pressure differences.
- **GNSS (GPS/GLONASS/RTK):** Provides position, velocity, time.
- **Other sensors:** Air-speed (for fixed-wing), range-finder/ lidar/sonar (for altitude hold/terrain following), temperature, vibration monitoring.
  The avionics must integrate these sensors, ensure calibration (bias, scale, alignment), manage noise filtering, and feed data into the autopilot for state estimation and control. Without reliable sensors, control instability or drift can occur. Advanced systems also include sensor redundancy and fault detection.
  Key Points:
- IMU (accelerometer + gyro) provide core state data for attitude control.

- Pressure/AGL sensor gives altitude or height above ground.
- GNSS gives absolute position; important for waypoint/navigation.
- Calibration and proper mounting (minimising vibration) are critical.
- Redundancy and sensor fusion improve reliability and safety.
  Example:
  A drone uses IMU + GNSS to maintain a hover at given altitude; if GNSS fails, the autopilot falls back on IMU + barometer for short time.
  Hinglish Summary:

Sensors drone ka "feeling" system hain — jaise accelerometer/gyro mo-motion bataate hain, pressure sensor altitude, GPS location. Proper setup ke bina stability nahi milegi.

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3. Servos / Actuators / Actuation Systems

Explanation:
Actuators are the mechanical devices that convert electrical signals (from the autopilot) into motion — e.g., controlling motor speeds via ESCs (Electronic Speed Controllers) or moving control surfaces via servos or linear actuators. (Unmanned Systems Technology) In fixed-wing UAVs/control surface drones, actuators move ailerons, elevators, rudders. In multirotors, ESCs control brushless motors. Servos may also be used for camera gimbals or payload release mechanisms. Actuation systems must respond rapidly, smoothly, and reliably; they require correct linkage, neutral positions, safe torque limits, and often redundancy in safety-critical drones.
Key Points:

- Actuators = ESCs for motors (multirotor) or servos for control surfaces.
- Must be selected for correct torque/force, speed, resolution and reliability.
- Must integrate with autopilot commands and feedback (if closed-loop).

- In safety-critical systems, actuators often have redundancy or fail-safe (e.g., shear screw on servo). (dynonavionics.com)
- Actuator mounting and alignment (gear linkage) affect performance and reliability.
  Example:
  In a survey drone with tiltable camera, servos are used to pan/tilt the camera smoothly; autopilot sends position commands, feedback improves accuracy.
  Hinglish Summary:

Actuators ya servos wahi parts hain jo autopilot ke commands ko motion me badalte hain — motor speed badh-ghataana, control surface hilaana. Sahi selection aur mounting bahut maayne rakhte hain.

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4. Power Supply & Processor Systems

Explanation:
The power supply subsystem delivers stable and appropriate power voltages and currents to avionics, sensors, actuators, and payload. It includes batteries (Li-Po, Li-Ion), power distribution boards, voltage regulators, switches, fuses, monitoring. The processor system (flight controller + companion computer) must have sufficient computational power, low power consumption, thermal management, and reliable connectivity/communications. Proper power and processor design ensure reliability, minimal risk of brown-out or electromagnetic interference, and enable extension for additional payloads/mission modules. (PX4 Docs)
Key Points:

- Batteries must match endurance, current draw of motors/actuators + avionics + payload.
- Power distribution must handle peak loads (e.g., motor startup) without voltage drop.
- Processors must run flight-stack software, sensor fusion, mission logic. Some drones include companion computers for vision/AI.

- EMI/EMC, grounding, filtering must be handled to prevent sensor noise and control issues.
- Thermal management: processors and power electronics must remain within safe temperature.
  Example:
  A delivery drone uses a Li-Po battery pack sized for 30 minutes flight; power distribution board splits power to motors (via ESCs) and to autopilot + sensors via 5 V/12 V regulators; companion computer (e.g., NVIDIA Jetson) handles vision payload; power monitoring reports battery state to ground station.
  Hinglish Summary:

Power supply aur processor system drone ka backbone hote hain — battery, regulators, distribution board sab sahi tarah design karna zaroori hai. Processor ko sensors + actuators + mission logic chalana hota hai, isliye compute aur cooling ka bhi khayal rakhna padta hai.

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5. Integration, Installation & Configuration

Explanation:
Integration involves putting all avionics hardware together — mounting the flight controller, sensors, actuators, wiring, power modules, and configuring software parameters. Installation concerns physical mounting (vibration isolation, proper alignment of IMU, GPS clear sky view, avoiding electromagnetic interference). Configuration includes flight-controller firmware-flashing, parameter tuning (PID gains, sensor calibration, motor direction, ESC calibration), setting failsafe modes, geofencing, telemetry links, mission planning software setup. Proper integration ensures that all subsystem modules communicate, are correctly powered and aligned, and that the drone is safe and stable. Improper installation/configuration is a frequent cause of failure. (PX4 Docs)
Key Points:

- Physical installation: ensure IMU is level, GPS has clear sky, vibration isolation for sensors, wires neat and secure.

- Wiring: power and signal wires must be separated to reduce noise, ensure correct ground referencing.
- Firmware & parameter configuration: update software, calibrate sensors (gyro, accel, compass, baro), configure ESCs, set failsafe.
- Testing: pre-flight checks, motor direction check, control surface movement check, telemetry link, ground station communication check.
- Safety: set return-home, low battery thresholds, geofence, emergency switch, event logging.
  Example:
  Before first flight, an operator mounts the Pixhawk flight controller on foam pads to reduce vibration, ensures GPS antenna is placed on a stalk clear of electronics, wires ESCs with separate ground path, configures parameters in QGroundControl, calibrates compass/IMU/ESC, sets geofence for the local zone.
  Hinglish Summary:

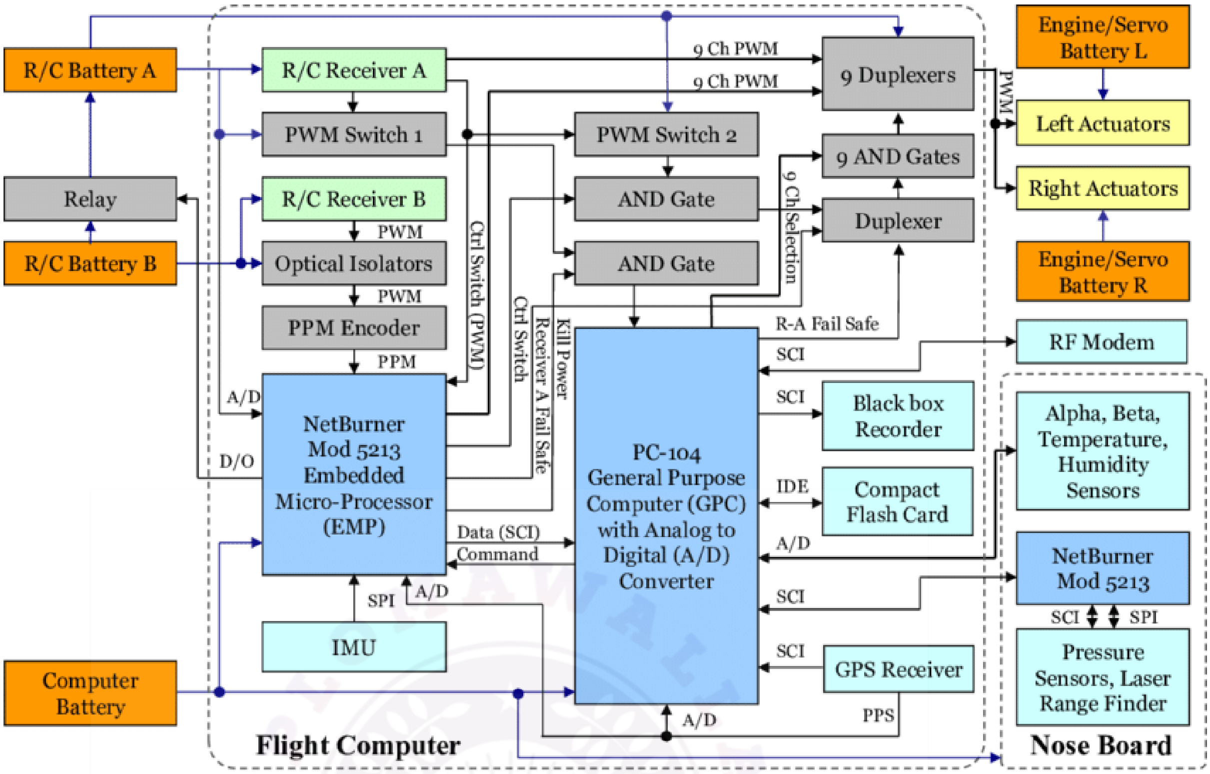
Integration aur installation step me sab components ek saath jode jaate hain — sensors mount, wiring set, firmware update, calibration, safety modes set — tabhi drone safe aur reliable fly karega.

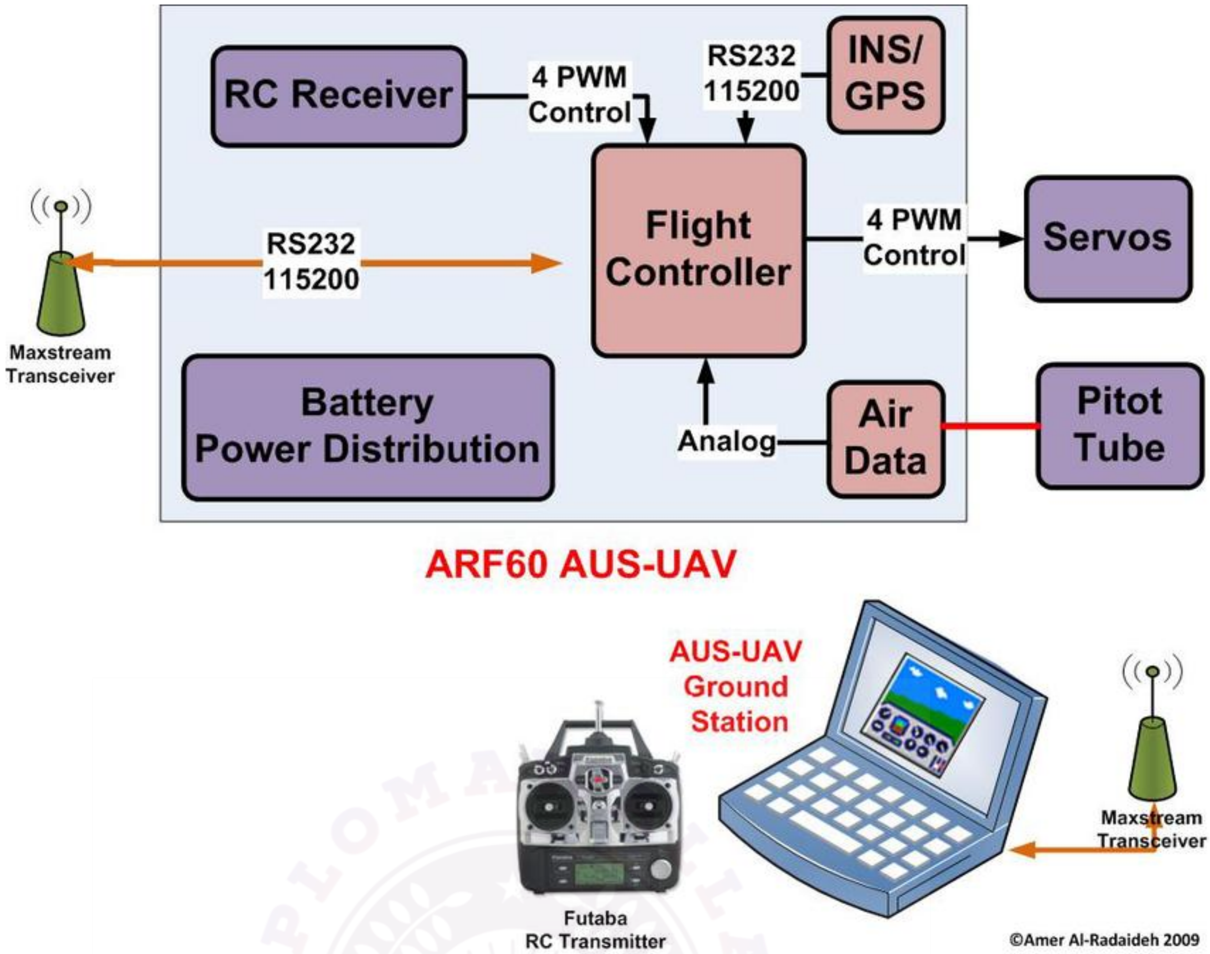
✅ Summary

- Avionics hardware of drones includes autopilot (brain), sensors (feelings), actuators/servos (motion parts), power & processor systems (energy + compute), and integration/installation/configuration (putting it all together).
- Each subsystem must be selected and designed carefully: reliability, weight, power consumption, vibration isolation, EMI/EMC, calibration.
- Real-world good design and installation reduce failures, improve stability, increase mission reliability.
- Human read-out: *"Sensors tell the autopilot what's happening; autopilot thinks; actuators do; power & compute enable; integration makes it all work."*

Short Revision

🧠 Advanced Explanation of Avionics Hardware of Drones

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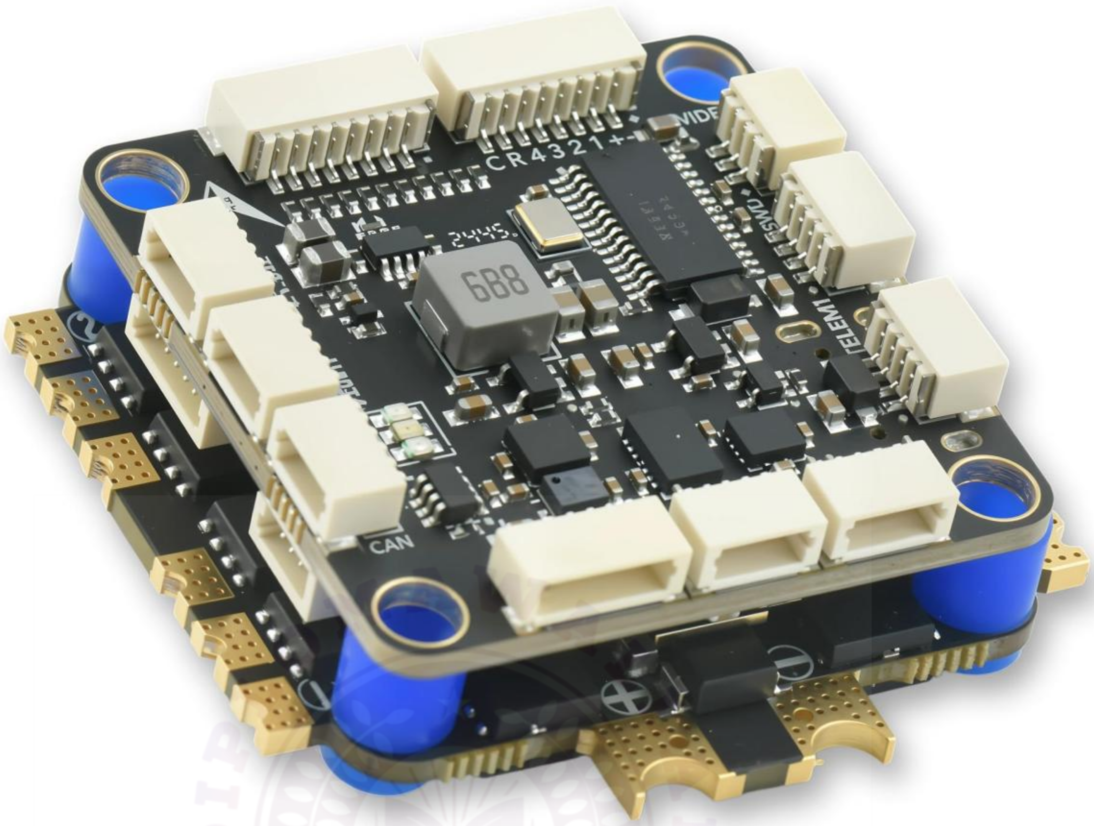
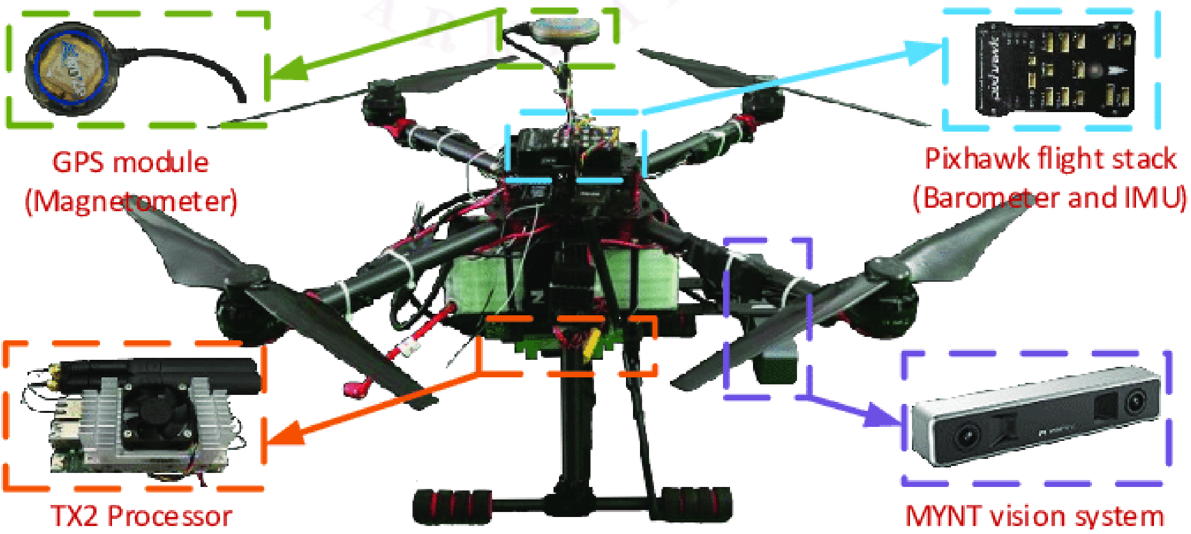
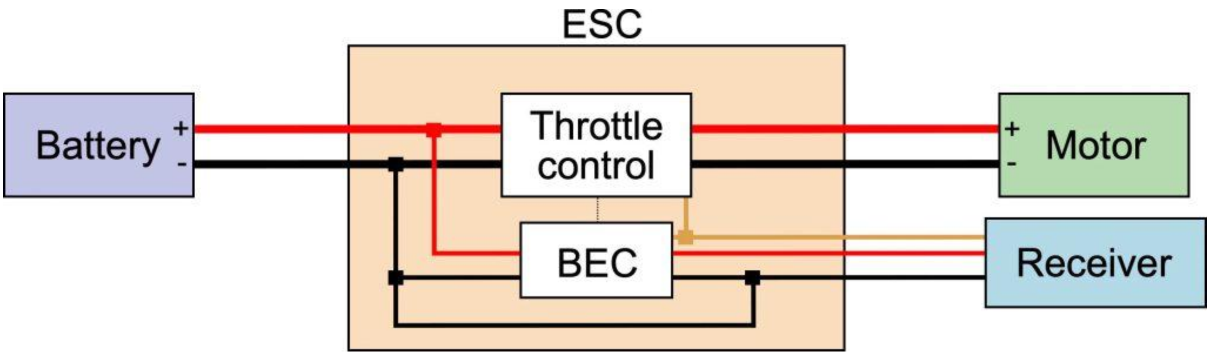
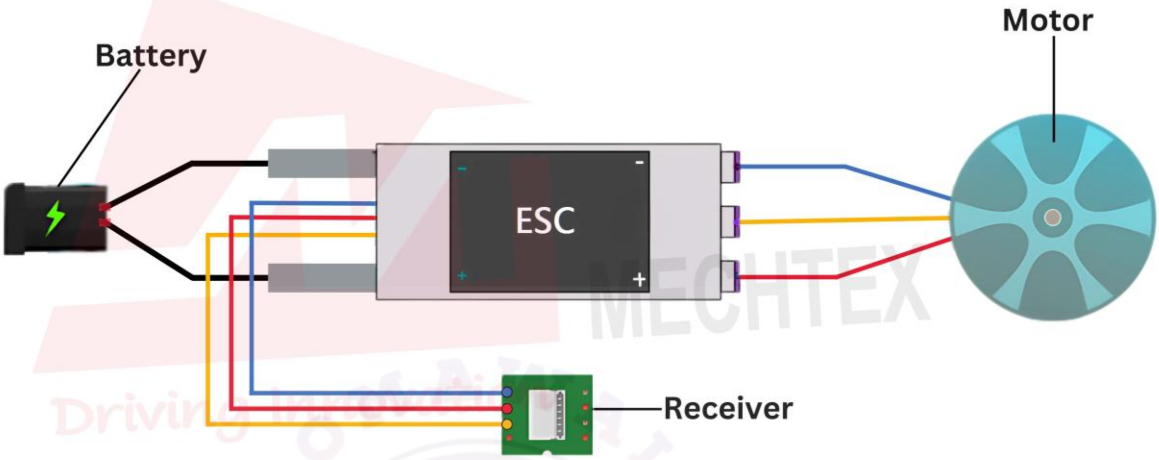



GPS module
(Magnetometer)
Pixhawk flight stack
(Barometer and IMU)
TX2 Processor
MYNT vision system





Working of Electronic Speed Controller (ESC)

Here's a deeper, exam-friendly breakdown of the avionics hardware in drones — explained in simpler language, but with advanced ideas for full understanding.

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1. What is "Avionics Hardware" in Drones?

- Avionics here means all the electronic and electrical components that allow the drone to *sense*, *think*, *decide*, and *act*.
- Unlike just the air-frame and motors, avionics covers sensors (gyro, accelerometer, barometer), flight controller (processor + firmware), actuators/servos/ESCs (electronic speed controllers), power supply, wiring/integration.
- The performance and reliability of a drone depend heavily on these subsystems working together seamlessly.

- For example: Without correct avionics, the drone might drift, lose control, or fail mid-mission — even if the air-frame and motor are perfect.

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2. Flight Controller (Autopilot) – The Brain

Detailed View:

- The flight controller is a specialised embedded computer with sensors built in (typically an IMU: gyroscope + accelerometer; sometimes magnetometer, barometer). (Oscar Liang)
- It *fuses* data from sensors to estimate the drone's state (orientation, angular rate, acceleration). Then it uses control algorithms (often PID, or more advanced) to determine how each motor/thrust/servo should act. (fusion.engineering)
- It handles modes: manual control, assisted hovering, autonomous waypoint navigation, return-home.
- Key considerations: processing speed (real-time loops), sensor noise filtering, firmware reliability, fail-safe logic, compatibility with vehicle type (multirotor vs fixed-wing vs VTOL).
  Exam tip: Remember: "Sensors → state estimation → control commands → actuators".

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3. Sensors: IMU, Barometer (AGL/Altitude), Pressure Sensors, GPS, etc.

Detailed View:

- **IMU (Inertial Measurement Unit):** Contains gyroscope (measures angular rate) + accelerometer (measures linear acceleration). These give high-rate raw data so the controller can stabilise. (mwrona.com)
- **Barometer / Pressure sensor / AGL sensor:** Measures ambient air pressure to infer altitude (or height above ground) — essential for altitude hold or terrain-following.

- **GPS/GNSS module:** Provides position (latitude/longitude), velocity, and sometimes heading — necessary for waypoint navigation and autonomous flight.
- **Other sensors:** Magnetometer (compass), range-finder (sonar/laser for ground or obstacle), air-speed sensor (fixed-wing).
- Calibration and mounting matter: e.g., IMU must be isolated from vibration; barometer must be away from heat sources.
  Exam tip: Think of sensors as the drone's 'perception system'.

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4. Actuators / ESCs / Servos – The Motion Systems

Detailed View:

- **Electronic Speed Controllers (ESC):** For brushless motors common in drones. The flight controller sends throttle signals, ESCs regulate current/voltage to motors. (JOUAV)
- **Servos / Linear Actuators:** In fixed-wing or hybrid drones, control surfaces (ailerons, rudder, elevator) are moved by servos in response to flight-controller commands.
- Selection criteria: torque/speed of servo, current rating of ESC, proper PWM or digital signal protocol, and mechanical linkage.
- Motor/prop design: combined with ESC must handle peak loads, startup, and continuous flight.
  Exam tip: "Actuators = the muscles of the drone."

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5. Power Supply & Processor System

Detailed View:

- The power supply includes battery pack (Li-Po, Li-Ion, sometimes hybrid fuel-electric), power distribution board (PDB), voltage regulators (to supply 5 V, 12 V to sensors/flight controller), and wiring/fuses.
- The processor system: flight controller + sometimes a companion computer (if advanced payloads like vision, AI). Must manage

compute load, thermal issues, EMI (electromagnetic interference), and power stability.

- Important trade-offs: battery weight vs endurance; size of wires vs voltage drop; EMI isolation to avoid sensor error.
  Exam tip: In design questions, mention "ensure clean power, minimal voltage drop, isolated sensor ground".

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6. Integration, Installation & Configuration

Detailed View:

- Physical installation: flight controller must be mounted level and at drone's centre of gravity (ideally); vibration isolation is key for IMU accuracy.
- Wiring: separate power and signal wires, ensure good grounding, avoid loops that pick up interference.
- Configuration: after hardware installation you must calibrate IMU (gyro/accel), compass, ESCs (throttle range), barometer, ground station telemetry settings. Flight-controller firmware must match vehicle type (multirotor, fixed-wing, VTOL). (hakrc.com)
- Testing: pre-flight check list includes motor direction test, failsafe test (loss of link), GPS fix, return-home altitude, battery health.
  Exam tip: In "design" or "installation" questions, include "vibration isolation, sensor alignment, wiring cleanliness, calibration".

✅ **Summary (Exam-Style, Easy Language)**

• Sensors tell the drone *what's going on*.
• Flight controller decides *what to do*.
• Actuators make it *happen*.
• Power supply keeps everything alive.
• Integration/installation ensures all parts work together smoothly.
You should be able to explain each subsystem, mention key

selection/design factors (weight, power, reliability), and talk about trade-offs (more sensors = heavier; bigger battery = less agility; better ESC = more cost).
In exam questions, you could be asked: “Design the avionics subsystem for a 2 kg UAV with 30 min endurance for aerial inspection—state components and justify selection.” Use the above structure to answer.

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