UNMANNED AERIAL VEHICLE

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MCTE 4362 Robotic Hardware Systems

UAV

1. Unmanned Aerial Vehicle (UAV) or commonly called as drone is an aircraft that is are either remotely or autonomously controlled from a computer, mobile device or controller. It does not involve any crew onboard hence the name unmanned.
2. UAV has a variety of uses some of which are:

- Industrial and Environmental Applications: UAVs are used in infrastructure inspection, agricultural monitoring, and wildlife tracking, deforestation monitoring, providing critical data quickly and safely.
- Emergency and Delivery Services: UAVs support disaster response by delivering aid, surveying damage, and search and rescue operations. They're also being developed for urban package delivery, reducing delivery times and emissions.

HULL DESIGN

1. The term "hull design" in UAV usually refers to the airframe or fuselage design rather than a traditional hull as seen in the USV.
2. The criteria that come in choosing the frames of UAV are:
   1. Aerodynamics: The hull's shape and materials are optimized for efficient lift and reduced drag, enabling stable and agile flight.
   2. Modularity: The design must allow for easy customisation and be easy to reconfigure to suit different missions
   3. Durability: The frame must be lightweight yet strong enough to withstand the stresses of flight, wind, and potential impacts.
3. The UAV are generally classified based on the shapes of its wings and rotors, with specific shapes being suitable for their respective missions.

DESIGN	DESCRIPTION	CHARACTERISTICS	APPLICATIONS
FIXED-WING 	Similar to traditional aircraft design with a fuselage and two wings.	• Requires runway or a launcher for takeoff and landing. • High fuel Efficiency • high endurance, long range	Surveillance, mapping
MULTIROTOR 	Involves multiple rotor arranged symmetrically (eg. quadcopters= 4 rotors, hexacopters=6 rotors)	• Capable of vertical takeoff and landing (VTOL) • High maneuverability • stable hovering • high energy consumption	Aerial photography, inspection, agriculture spraying

HULL DESIGN

DESIGN	DESCRIPTION	CHARACTERISTICS	APPLICATIONS
SINGLE-ROTOR HELICOPTER 	Resembles a traditional helicopter with one main rotor and a smaller tail rotor.	• Capable of VTOL • Efficient in carrying heavier payloads • complex machenics	Cargo transport, missions with llong hover times
HYBRID (VTOL FIXED-WING) 	Combines fixed-wing and multirotor elements	• Versatile; able to take off and land in confined spaces but also • High long-distance flight. • Higher Endurance • Complex Design	Mapping, surveying, search and rescue, and remote area delivery.
BLENDED WING BODY (BWB) 	Similar to the fixed wing, but with a more defined central fuselage that blends smoothly into the wings.	• Excellent lift-to-drag ratio • Energy efficient • Large internal space • Less maneuverable • More complex to control	High-endurance flights, large payload missions, military reconnaissance, and environmental monitoring.

HULL DESIGN

DESIGN	DESCRIPTION	CHARACTERISTICS	APPLICATIONS
BLIMP 	Non-rigid airships where the structure is filled with helium to maintain buoyancy	• High Payload efficiency • Lower Operating costs • Involve less power • Lower Crash impact • Capable of Vertical takeoff and landing • Accessible to large spaces	Indoor monitoring, Surveillance, Cargo transports, Gas-source localization

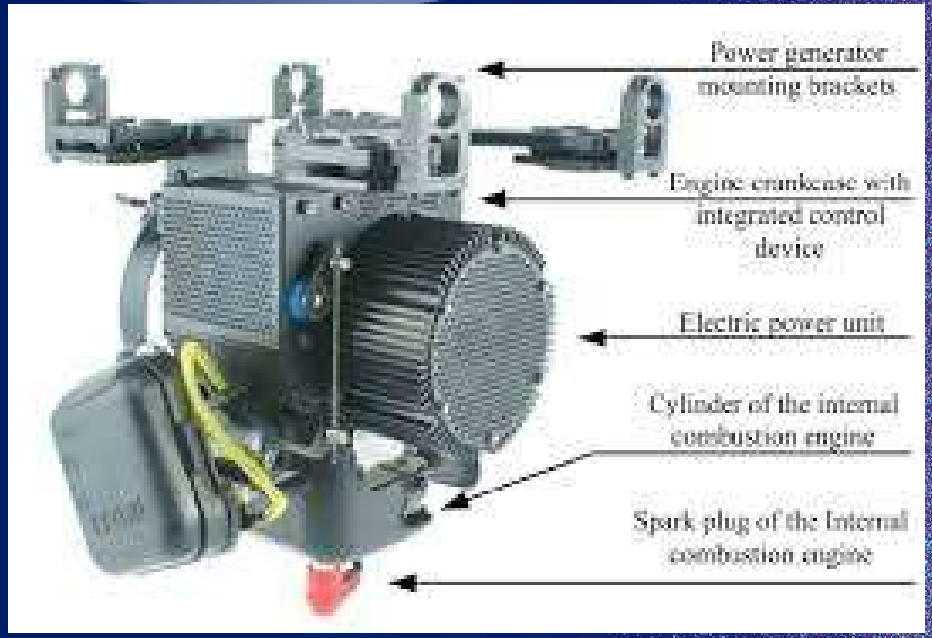
PROPULSION SYSTEMS

1. Propulsion systems are the core of a UAV's power and determine its ability to complete tasks.
2. The type of propulsion system used in a UAV can affect its flight time, reliability, and environmental impact. Similar to USV, choosing the propulsion systems would depend on the mission requirements of the UAV.
3. The most common propulsion systems used would be the electrical propulsion systems as they are efficient, reliable, and produce little noise. They are also well-suited for smaller aircraft and multirotor UAVs, which require precise control and a quick response time. However, batteries have a lower energy-to-weight ratio than fuel, so they limit flight time.
4. Other propulsion systems would include:

ELECTRIC PROPULSION

INTERNAL COMBUSTION ENGINE (ICE)

SOLAR POWER



HYBRID PROPULSION (ELECTRIC+ECE)

PROPULSION SYSTEMS

PROPULSION SYSTMES	DESCRIPTION	ADVANTAGES	DISADVANTAGES
ELECTRIC PROPULSION	Uses electric motors powered by rechargeable batteries	• Quiet and low vibration • Lightweight • Eco-friendly	• Limited flight time due to battery capacity • Longer recharging time
INTERNAL COMBUSTION ENGINE (ICE)	Uses gasoline or methanol engines, similar to traditional aircraft engines.	• Higher power output • Longer flight endurance	• Noisy • Higher maintenance • Heavier and less eco-friendly
SOLAR POWER	Uses solar panels to generate electricity to power the motor or recharge batteries.	• Unlimited duration with ample sunlight • Lightweight	• Limited power output • Ineffective at night or in poor sunlight
FUEL CELL	Uses hydrogen fuel cells to generate electricity through an electrochemical reaction.	• High energy density • Quiet and eco-friendly	• Requires hydrogen infrastructure • Complex storage

PROPULSION SYSTEMS

PROPULSION SYSTMES	DESCRIPTION	ADVANTAGES	DISADVANTAGES
HYBRID PROPULSION (ELECTRIC+ECE)	Combines ICE with an electric motor for recharging or additional thrust.	• Extended range • Option for silent electric operation	• Complex design • Higher cost and weight
JET TURBINE ENGINE	Small-scale jet engines designed for high-speed UAVs.	• High-speed capability • High thrust-to-weight ratio	• High fuel consumption • Noisy • High maintenance

NAVIGATION SYSTEMS & CONTROL

1 Navigation and control systems are essential for UAVs to perform autonomous or semi-autonomous operations. These systems are crucial in ensuring the UAV maintains stable flight, follows a planned route, avoids obstacles, and reaches its destination accurately.

SYSTEM	DESCRIPTION	FUNCTION	ADVANTAGES	APPLICATIONS
VISUAL NAVIGATION	Uses cameras and LiDAR to create maps and locate the UAV in real-time.	Enables real-time obstacle detection and navigation in GPS-denied areas.	Effective in indoor and GPS-denied environments	Indoor UAVs, delivery drones, exploratory missions
ULTRASONIC AND INFRARED SENSORS	Uses sound waves or infrared light to detect nearby obstacles.	Provides obstacle detection and safe distance maintenance.	Lightweight, cost-effective, short-range obstacle detection	Precision landings, low-altitude flights, obstacle avoidance
AUTOPILOT SYSTEMS	Onboard computers for autonomous flight control.	Manages speed, altitude, heading; follows pre-programmed path.	Reduces human intervention; enables autonomous flights	Surveying, mapping, long-endurance missions

NAVIGATION SYSTEMS & CONTROL

SYSTEM	DESCRIPTION	FUNCTION	ADVANTAGES	APPLICATIONS
GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)	Satellite-based positioning system	Provides location, altitude, and velocity data.	High accuracy and global coverage	Route navigation, waypoint navigation, geofencing
INERTIAL NAVIGATION SYSTEM (INS)	Uses accelerometers and gyroscopes to measure movement and orientation.	Measures orientation, speed, and direction for stability.	Works without external signals; resists jamming	GNSS-denied environments, paired with GNSS for accuracy
RADIO FREQUENCY (RF) AND REMOTE CONTROL	Communication link between UAV and ground control station for real-time control.	Enables manual/semi-autonomous control and telemetry feedback.	Allows precise control and emergency override	Line-of-sight operations, recreational drones
GROUND CONTROL STATION (GCS)	Remote station to monitor, control, and communicate with UAV	Allows operators to control and monitor UAV in real-time	Complete mission control, real-time adjustments	Military surveillance, environmental monitoring, search and rescue

DATA COLLECTION

1. Similar to USV, UAV may be used as an alternative to collect data from areas that may be hard to reach. With the application of UAV in industry has increased, the technological improvements that have been made to efficiently complete these missions has also mproved tremnedously these past few year.

2. In summary, the three components that have been used most commonly in collecting data are camera, LiDAR and sensors. However, the variety of apparatus that can be chosen depends on the mission.

DATA COLLECTION SYSTEM	DESCRIPTION	FUNCTION	ADVANTAGES	APPLICATIONS
OPTICAL CAMERAS 	High-resolution cameras (RGB or multi-spectral) for capturing images and video.	Captures visual data for imaging, mapping, and surveillance.	High-resolution images; versatile	Aerial photography, mapping, surveillance
THERMAL CAMERAS 	Infrared sensors detect heat signatures and temperature variations.	Detects heat differences for thermal imaging and analysis.	Operates in low-visibility conditions; identifies heat sources	Search and rescue, agriculture, industrial inspection

DATA COLLECTION

DATA COLLECTION SYSTEM	DESCRIPTION	FUNCTION	ADVANTAGES	APPLICATIONS
LIDAR (LIGHT DETECTION AND RANGING)	Uses laser pulses to measure distance and create 3D point clouds.	Provides accurate distance measurements and topographic mapping.	High precision, works in low-light conditions	Terrain mapping, forestry, infrastructure inspection
HYPERSPECTRAL SENSORS	Captures a wide spectrum of light wavelengths for detailed spectral analysis.	Provides information on material composition and vegetation health.	Detailed spectral data, valuable for material identification	Agriculture, environmental monitoring, mineral exploration
ULTRASONIC AND SONAR SENSORS	Uses sound waves to measure distances and detect underwater or surface obstacles.	Provides distance measurements and obstacle detection.	Works in low visibility; effective for underwater mapping	Marine UAVs, obstacle avoidance, surface mapping
RADAR SENSORS	Uses radio waves to detect objects, measure distance, and map terrain.	Provides data on object distance, speed, and terrain mapping.	Works in poor visibility; effective for long-range detection	Obstacle detection, weather monitoring, search and rescue

DATA TRANSMISSION

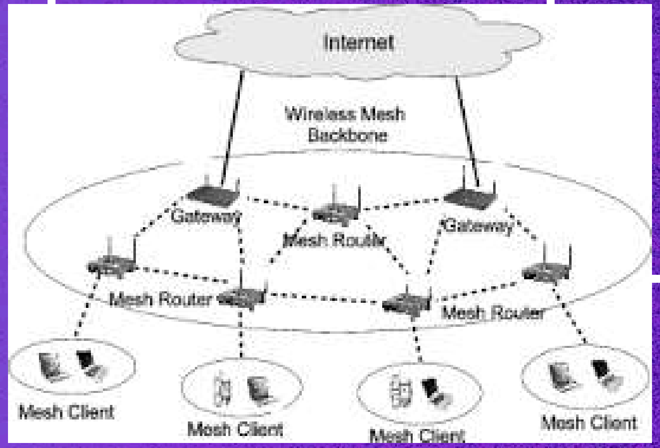
1

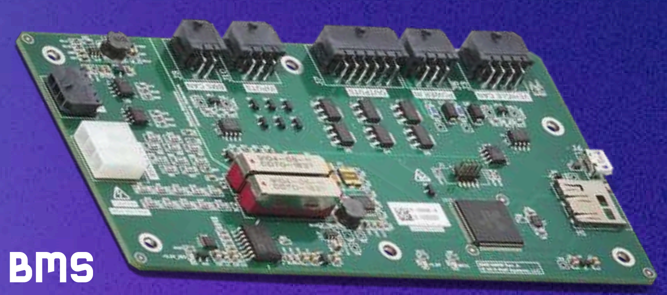
Data transmission between USV and UAV vary slightly primarily due to the different operational environments, range requirements, and connectivity challenges. UAV data transmission must account for altitude and terrain interference, whereas USVs contend with water reflection and marine conditions. Furthermore, UAVs often require high bandwidth and low latency for real-time applications, especially in surveillance. USVs, in contrast, can often manage with slightly lower bandwidth and prioritize stable communication. Finally, UAVs are typically more constrained by power capacity than USVs, which can impact the choice of data transmission system due to the need to reduce weight to increase flight time and constrained payload capacity.

DATA TRANSMISSION SYSTEM	DESCRIPTION	FUNCTION	ADVANTAGES	APPLICATIONS
SATELLITE COMMUNICATION (SATCOM)	Uses satellites to communicate with the ground station for long-distance and remote UAV operations.	Provides data transmission over long distances and in remote areas.	Global coverage, ideal for beyond visual line of sight (BVLOS)	Military UAVs, environmental monitoring, remote sensing
CELLULAR NETWORK (4G/5G)	Utilizes existing cellular networks to transmit data and maintain UAV connectivity.	Provides data transfer and live streaming capabilities.	High-speed data rates, good for urban areas	Delivery drones, urban surveillance, emergency response

DATA TRANSMISSION

DATA TRANSMISSION SYSTEM	DESCRIPTION	FUNCTION	ADVANTAGES	APPLICATIONS
RADIO FREQUENCY (RF) LINK	Uses radio waves for communication between UAV and ground station.	Real-time data transmission, control signals, and telemetry feedback.	Reliable for short- to mid-range communication; low latency	Short-range UAVs
WI-FI	Short-range wireless communication, typically using 2.4 GHz or 5 GHz bands.	Enables data transfer and control within short distances.	High data rates; ideal for indoor or close-range operations	Indoor UAVs, industrial inspection, recreational drones
MESH NETWORKING	Uses a network of interconnected nodes to create a decentralized communication system.	Allows multiple UAVs to relay data and extend transmission range.	Extends range and enables multi-UAV coordination	Swarm drones, search and rescue, complex surveillance tasks





BMS

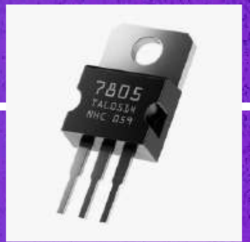
POWER MANAGEMENT

PDB

A UAV power management system (PWMS) controls the power sources of a UAV to generate power based on the needs of the mission, power supply and demand, and environmental conditions.

Functions of PWMS:

1. Power Distribution: Ensures that each component, including sensors, cameras, and motors, receives the appropriate power.
2. Battery Monitoring and Safety: Monitors voltage, current, temperature, and charge cycles to prevent battery failures and optimize battery life.
3. Redundancy Management: Ensures backup power sources are available in case of primary power failure, increasing mission reliability.
4. Real-Time Monitoring: Tracks power usage to optimize flight efficiency and provide alerts when the UAV is low on power.

COMPONENT	DESCRIPTION	FUNCTION	ADVANTAGES	APPLICATIONS
BATTERY MANAGEMENT SYSTEM (BMS)	Monitors and manages battery health, charging, and discharging processes.	Prevents overcharging/discharging; ensures battery longevity.	Extends battery life; improves safety	Small electric powered UAV
POWER DISTRIBUTION BOARD (PDB)	Distributes power from the main source to other components.	Supplies power to motors, ESCs, and onboard electronics.	Simplifies wiring; ensures reliable power flow	Multirotor drones
VOLTAGE REGULATORS 	Converts voltage from the main power source to appropriate levels for subsystems.	Protects sensitive electronics by providing stable voltage output.	Reduces risk of voltage fluctuations or surges	All types of UAV

THANK YOU!