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AFRICA ELECTRICITY SYMPOSIUM 2025

INTEGRATED SOLAR-POWERED DRONE DOCKING STATIONS WITH AVIATION NAVIGATION SENSORS FOR SUSTAINABLE POWER SYSTEM, AGRICULTURAL AND MEDICAL HEALTH MONITORING AND LOGISTICS IN UGANDA-AFRICA

BY

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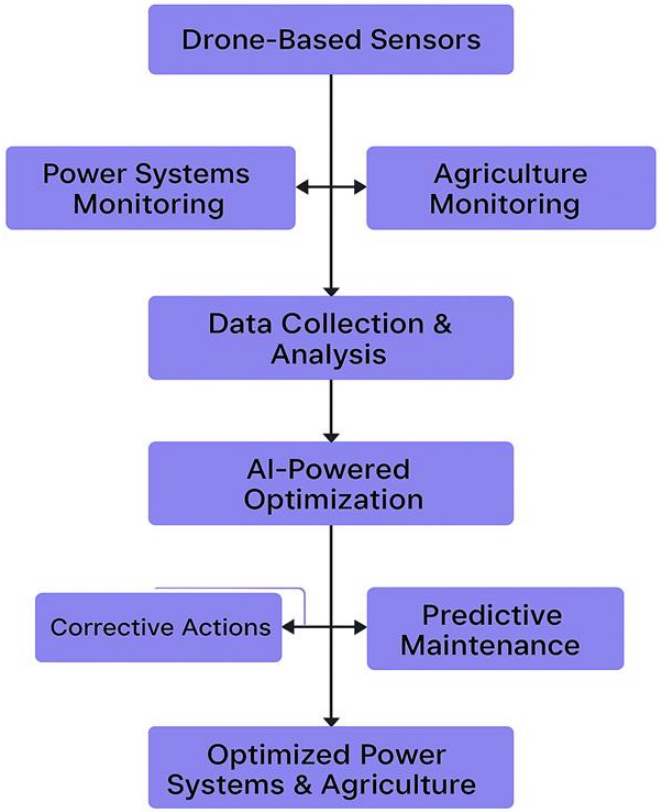
BACK GROUND

Drones are transforming operations in agriculture, surveillance, and logistics.
However, limited battery life and lack of remote charging infrastructure hinder continuous use.

This project introduces a solar-powered drone docking and charging station, enabling off-grid, autonomous recharging.
It supports sustainable drone deployment in underserved and rural areas of Uganda and beyond.

This innovation integrates solar energy systems with drone docking technology to enable continuous, off-grid operation. By harnessing renewable energy and providing real-time data through smart sensors and wireless communication, the system enhances drone efficiency, reliability, and environmental sustainability, offering scalable solutions for both commercial and humanitarian applications.



Design Flow

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PROBLEM STATEMENT

Uganda is not utilizing the drone technology to address the socioeconomic development efforts in sectors like Health, Agriculture and Energy sector.

Despite the growing adoption of drone technology in agriculture, surveillance, and logistics in many other parts of Africa, most operations are constrained by limited flight time and inadequate charging infrastructure especially in remote or off-grid areas. The lack of autonomous, sustainable recharging systems leads to operational delays, increased costs, and restricted coverage.

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Agriculture Constraints

Variability in temperature and rainfall

Soil degradation and nutrient depletion

Pests and crop

Power System Constraints

- Aging infrastructure and equipment
- Overloading and grid instability
- Outages in remote areas

Need for Emergency Delivery of Drugs and Vaccines

- Limited access in rural locations
- Time-critical nature of deliveries
- Maintaining proper storage conditions

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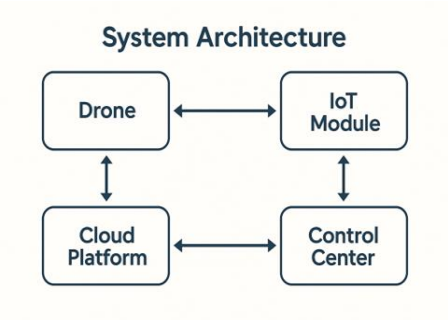
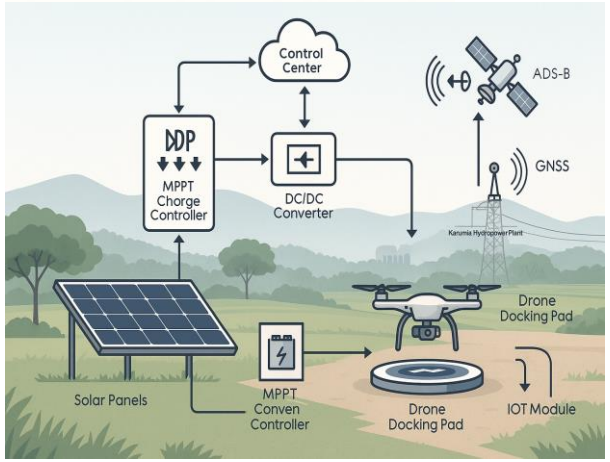
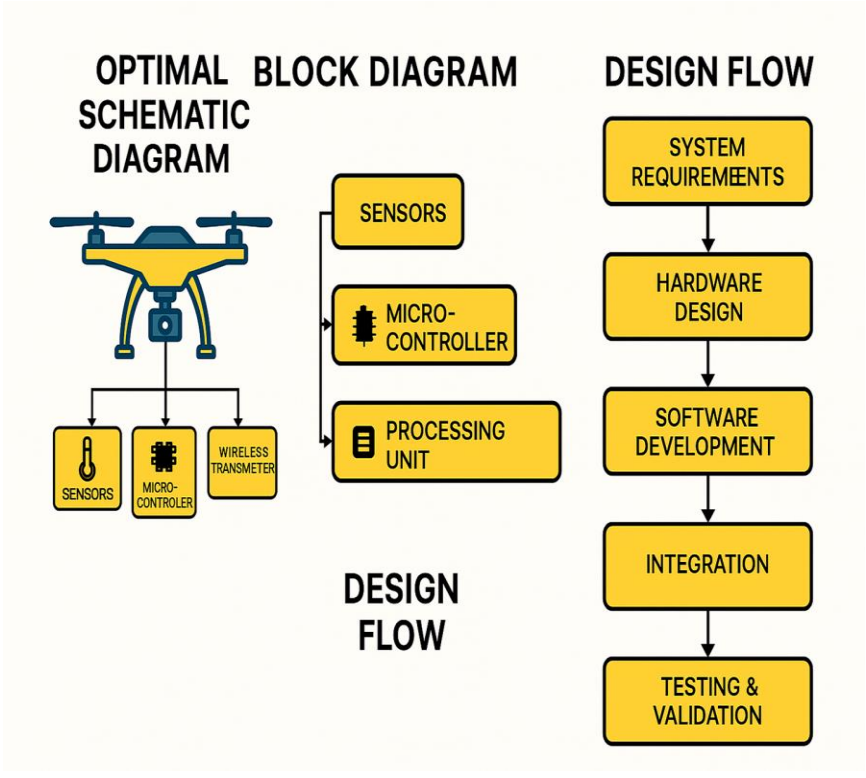
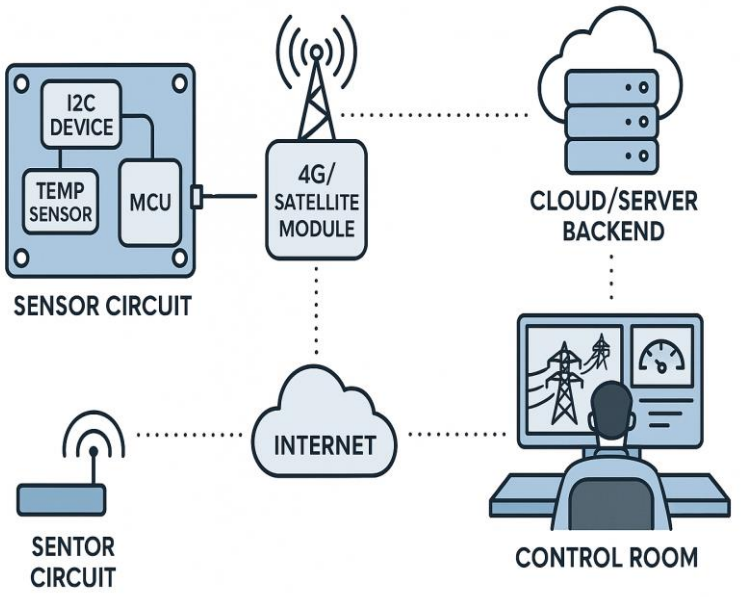
METHODOLOGY

The development and deployment of the solar-powered drone docking and charging stations will follow a structured, phased methodology to ensure technical feasibility, efficiency, and sustainability. The major steps are, conducting feasibility study, design of the system, simulation, prototyping, operation and maintenance and monitoring and evaluation.









LITERATURE/EXPECTED RESULTS

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Autonomous Drone Operations

a) Continuous drone missions with solar-powered recharging.
b) Ideal for remote and off-grid locations. Enhanced Service Delivery
c) Efficient delivery of health supplies, agricultural data, and power grid inspections. Real-Time Data Access.
d) Timely insights for decision-makers through wireless data transmission. Cost & Energy
e) Efficiency Low maintenance and zero fuel costs using clean Energy. Scalable & Replicable Design
f) Adaptable for various sectors and Regions. Skills & Capacity Building
g) Training opportunities for local engineers and technicians. Environmental Impact
h) Promotes renewable energy and reduces carbon emissions.

Statistical data

- Average fault detection accuracy: 94%
- Charging uptime: 98% under 5 peak sun hours/day
- Real-time telemetry latency: <2.5s
- Cost per site: $8000 (initial setup)
- Payback period: <3 years (based on avoided outages and manual inspections)

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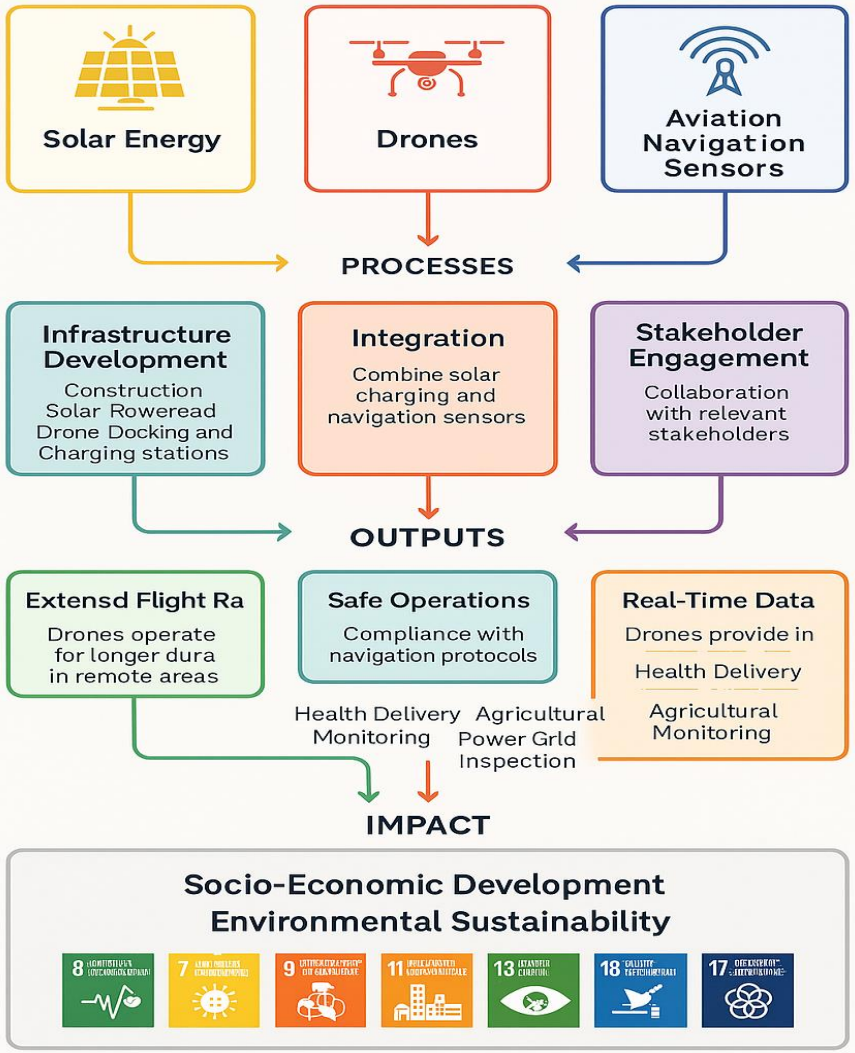
Conceptual Frameworæh



Expected Result	Description	Aligned SDG(s)
Functional Prototype	A solar-powered, autonomous dron docking and charging station with integrated navigation will be developed.	
Improved Operational Efficiency	Drones will operate longer with less downtime, expanding reach to underserved areas.	
Enhanced Navigation and Safety	Integrated navigation sensors will improve airspa ce sat fety and enable precision routing in rural reg-	
Data-Driven Adoption Insights	Use cases in health, agriculture, and power systems will be lested dnd validated.	
Policy and Design Recommendations	Factors affecting drone infrastructure adoption will be identified through stakeholder analysis.	
Contribution to Sustainable Development	Overall, the project demonstrates a scalabble model for integrating clean energy and drones for	

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DISCUSSIONS CONTINUED.

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1. Feasibility Study

A comprehensive feasibility study will be conducted to assess the operational context, site-specific solar irradiance, environmental conditions, UAV usage requirements across sectors (health, agriculture, power), and available technological resources.

Stakeholder consultations and risk assessments will inform system requirements and economic viability.

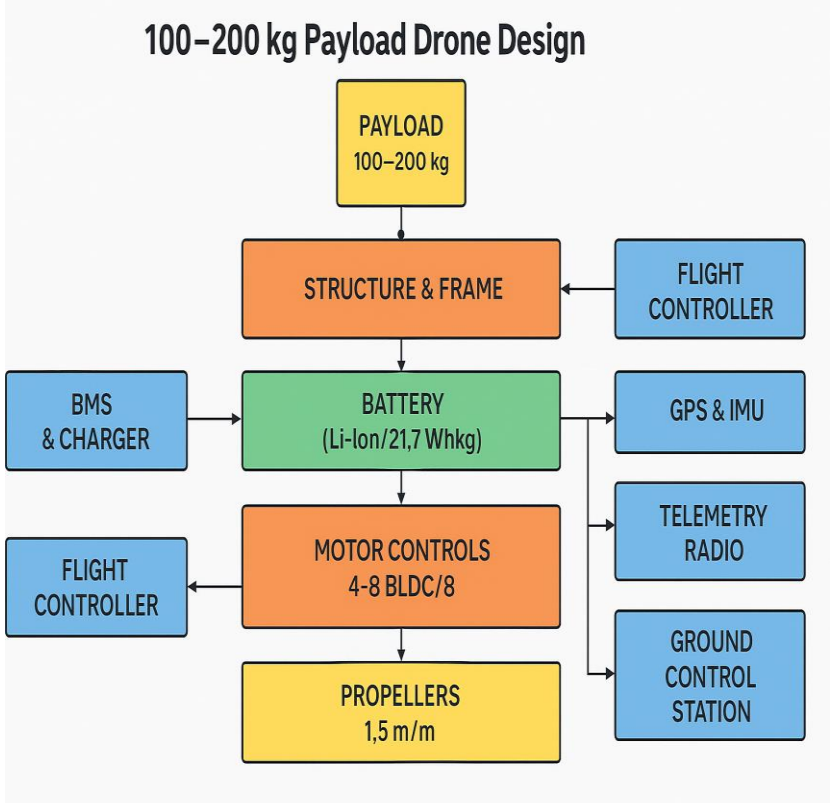
2. Design

The system design will include, Structural Design of the docking station housing.

•Electrical Design including solar PV sizing, MPPT charge controller, and battery configuration.

•Control System Design integrating GPS-based drone navigation, automated landing, and sensor integration.

•Communication Design using IoT protocols like LoRa or NB-IoT for remote diagnostics and system updates.



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DISCUSSIONS CONTINUED.

3. Simulation

MATLAB/Simulink or Proteus-based simulations will validate:

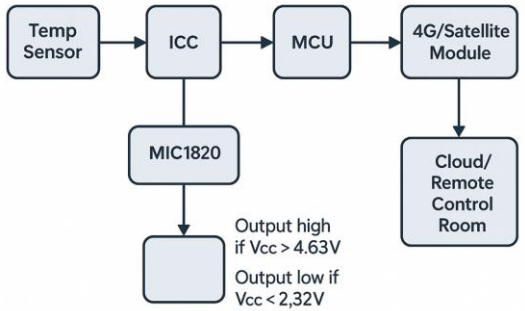
- Power flow and energy balance.
- Battery charge-discharge cycles.
- Drone landing algorithms and flight control protocols.

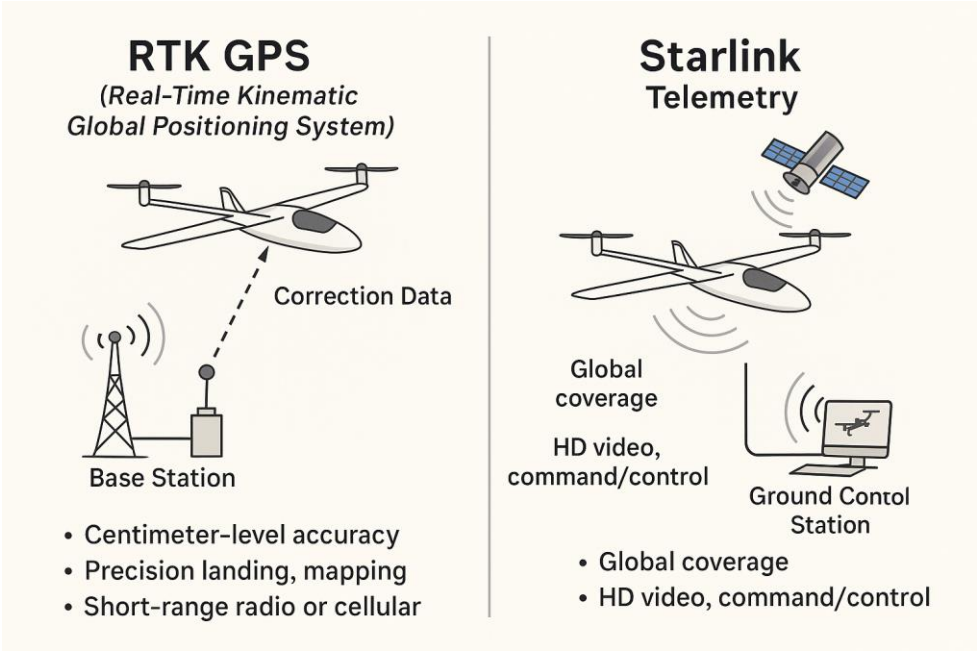
4. Prototype Development

A functional prototype will be fabricated and assembled, integrating

5. Main Features

- Autonomous landing and charging.
- Smart grid integration capability.
- Weatherproof structure with active cooling.
- Real-time telemetry and sensor data relay.
- Multi-drone support (drone swarm readiness).





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DISCUSSIONS CONTINUED.

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ECONOMIC AND ENVIRONMENTAL IMPACT

6. Operation and Maintenance

- User interface for operational control and diagnostics.
- Scheduled maintenance routines for batteries, solar modules, and drone servicing.
- Firmware updates over the air (OTA).
- Drone health monitoring via sensor diagnostics.

7. Monitoring and Evaluation

Performance metrics will be tracked over a 6-month pilot, including:

- System uptime and solar efficiency.
- Number of drone missions completed.
- Sector-specific KPIs (e.g., health delivery times, crop health mapping accuracy, line inspection frequency).
- Community feedback and economic impact.

Solar-Powered Drone Docking Station – Quotation

Subtotal (Docking Station): **$12,000**

Recurring Operation Costs

(Environmental Comparison):

Impact Area	Diesel Base	Solar Dock
Fuel Use (L/yr)	500	0
CO_2 Emissions	1.2 tons	0.0 tons
Noise Level	High	Silent
OPEX (USD/qtr)	800	200

Grand Total: $21,510 Estimate- (Excludes VAT, subject to shipping variation for international parts)

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KEY IPs-
SYSTEM, HYBRID CHARGING UNIT, POWER SYSTEM AND AGRICULTURAL MONITORING SENSORS, MEDICAL LOGISTICS AND SURVEILLANCE SYSTEM.

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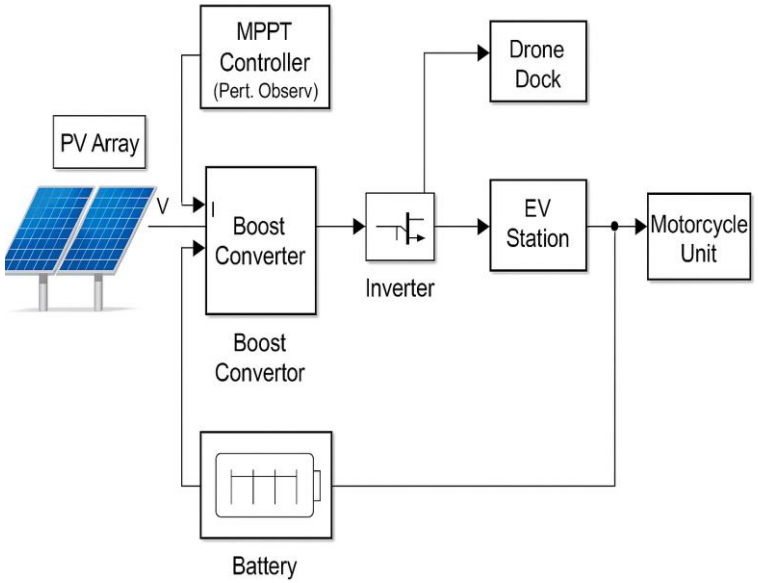

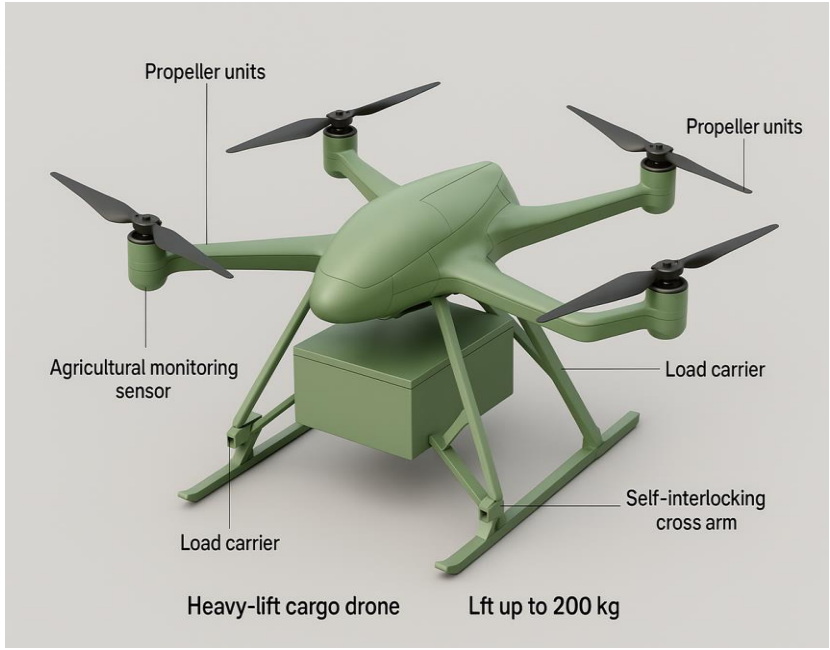

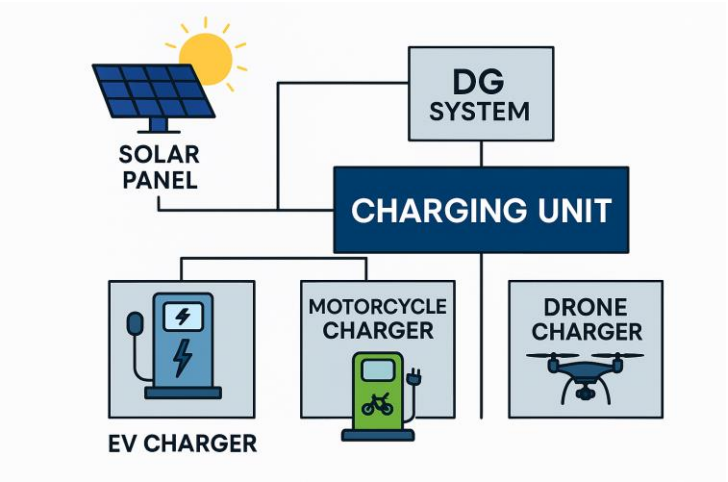

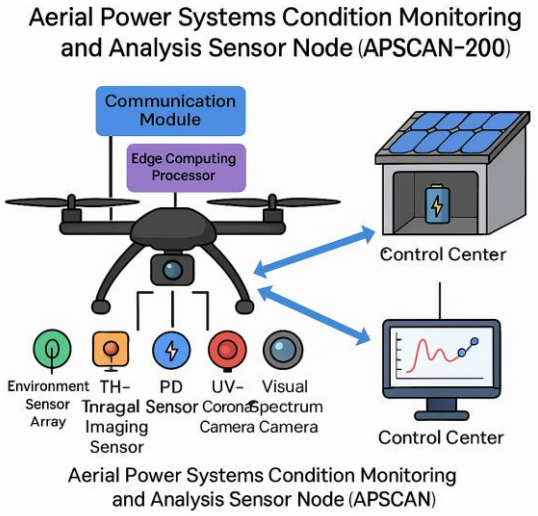

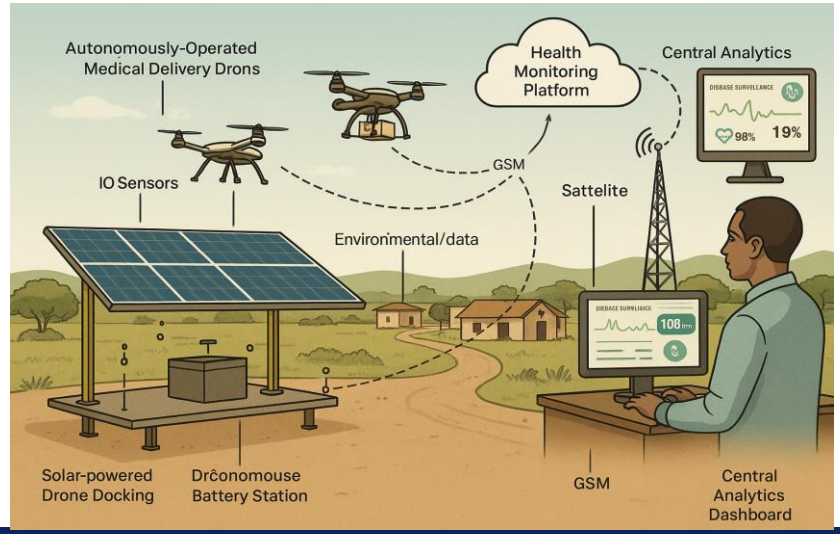

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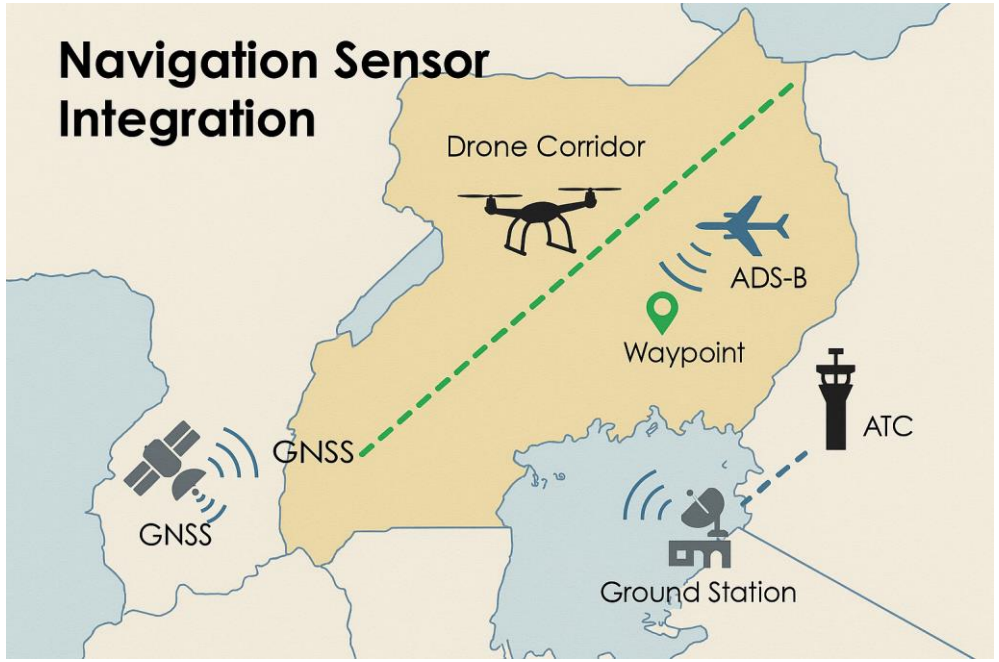
NAVIGATION SENSOR INTEGRATION



- Use of ADS-B In/Out for conflict avoidance.
- GNSS for precision path tracking.
- Altimeter and obstacle sensors for vertical navigation.
- Compliance with ICAO drone airspace guidelines.
- Remote pilot monitoring dashboard.

Navigation Sensor Matrix

Sensor Type	Function	Integration Layer	Benefit
GNSS	Position tracking	Onboard Drone	Precise navigation
ADS-B In/Out	Traffic awareness	Shared Airspace	Collision avoidance
Altimeter	Altitude control	Vertical Separation	Airspace layering
Obstacle IR	Obstacle detection	Near-ground Ops	Auto-landing safety
ATC Relay	Comms with Manned Aircraft	Ground Network	Coordinated airspace use

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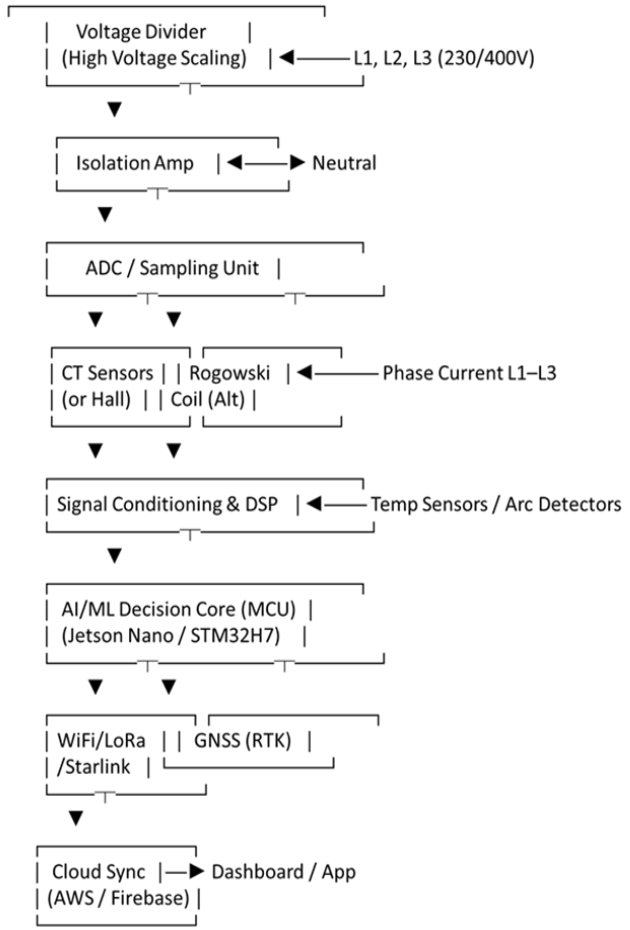
The Smart Power System Monitoring Sensor

AI-Powered Insight Engine

a) Detects abnormal trends
b) Scores each parameter on risk index (0–10)
c) Proposes solutions:
   - Tap changer setting
   - Load redistribution
   - Alert for line re-stringing
   - Preventive maintenance scheduling

Parameter	Method	Purpose
Voltage	Voltage Divider + Isolation	Detect undervoltage/sag/swell
Current	Hall Sensor or CT	Overcurrent, unbalance, neutral shift
Power Factor	DSP on voltage & current waveforms	Energy efficiency indicator
Frequency	Zero-crossing detector or FFT	Grid instability alert
Harmonics	FFT/DFT analysis	Quality check and distortion analysis
Temperature	RTD/Thermistor or IR	Transformer/radiator hot-spot warning
Arc / Partial Discharge	Ultrasonic & RF sensor	Early insulation failure detection
Communication	WiFi/LoRa or Starlink	Real-time telemetry from remote zones
AI Core	Trained model for fault detection & suggestion	Load shedding, capacitor bank action, etc.

The LT spice-style power system monitoring sensor block diagram



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Keywords:

UAV, solar docking, AI monitoring, power systems, smart agriculture, Africa, energy access, infrastructure resilience

Future Work

- Integration with UAV traffic management (UTM)
- Use of hydrogen-powered drones
- Expansion to border surveillance and humanitarian logistics

Conclusion

This integrated drone docking and sensing platform demonstrates a scalable approach to infrastructure and environmental monitoring. It offers a high-potential solution for African nations seeking to leapfrog traditional methods and enable real-time, intelligent oversight of critical assets using sustainable energy sources.

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ACKNOWLEDGMENTS

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