INNOVATIVE DRONE FOR CLEANING SOLAR PANELS AND HIGH-RISE BUILDINGS

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Introduction:

Aerial manipulators combine drone agility with manipulator dexterity to perform complex tasks in challenging environments. This H-frame drone is designed for high-rise building and solar panel cleaning, featuring a sprayer system and servo-based sweeping mechanism for efficient, uniform coverage. The H-frame structure enhances stability and wind resistance, making it ideal for high-altitude use.

An onboard cleaning tank enables continuous operation, boosting efficiency for large-scale tasks. The servo mechanism ensures precise, wide area sweeping. By eliminating the need for manual cleaning at extreme heights and in unpredictable weather, the drone enhances safety and reliability.

It reduces human risk, improves accuracy, and offers a cost-effective alternative to traditional labour methods. With extended flight capacity and high payload support, it suits long-duration tasks while minimizing downtime and maintenance costs. Its adaptable design supports various industrial cleaning and inspection applications.

Future upgrades may enable coordinated deployment of multiple drones for large-scale operations. This innovation advances automation of hazardous, repetitive tasks and paves the way for broader use of aerial manipulators in high-risk industries.

Objectives:

- Aerial Platform Design
- Manipulator Integration
- Prototype Testing
- Stability and Wind Resistance
- Safety and Efficiency

Methodology and Design:

The H-Frame aerial manipulator is built for automated cleaning of high-rise buildings and solar panels, offering enhanced stability, efficiency, and adaptability. Its lightweight carbon fiber frame provides high durability and maneuverability without sacrificing strength. A coaxial quad setup with eight brushless motors increases payload capacity and aerodynamic performance for stable flight in windy conditions.

High-efficiency ESCs and a 6S 6800mAh LiPo battery deliver long-lasting, reliable power. A dual servo-actuated custom manipulator ensures uniform spray coverage and maintains flight balance. The Pixhawk 2.4.8 flight controller enables precise hovering near surfaces, while an Arduino Nano controls the sprayer servos for accurate operation.

The H-frame offers 30% more stability than X-frames, ideal for stationary tasks. Its symmetrical design reduces drag and allows flexible mounting for tools and sensors. Simulation and testing will fine-tune flight dynamics and validate system efficiency, positioning the H-frame drone as a scalable, safe, and cost-effective solution for urban and renewable energy cleaning.

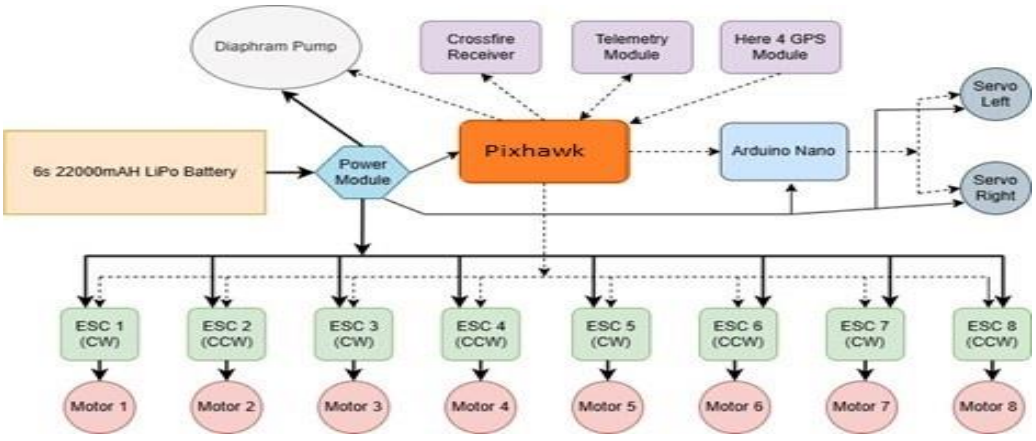

Figure 1: Control and Power flow Block Diagram

Result and Conclusion:

Flight tests showed square cross-sectional tubes outperform round ones, offering greater structural strength and preventing twisting from high-torque motors. A coaxial design nearly doubled thrust while keeping the frame compact for higher load capacity.

The drone achieved 12 minutes of flight without the sprayer and 6–7 minutes with it. The 1-liter tank empties in a minute, making the available flight time sufficient. It remained stable in high winds and performed tasks successfully.

With proven stability, the drone can now be tethered for water and power, enabling longer commercial operations. Future upgrades with AI, stereo and thermal cameras, and proximity sensors will enable full autonomy and swarm deployment for large-area coverage.

Figure 2: Drone Cleaning a Window

Project Outcome & Industry Relevance:

The H-Frame aerial manipulator provides a stable, efficient, and automated solution for high-rise maintenance and solar panel cleaning. It combines advanced flight control, adaptive manipulators, and a precision sprayer to perform tasks in unsafe or hard-to-reach areas. Its lightweight build and optimized payload handling support extended operations, reducing downtime and boosting productivity.

This innovation offers a cost-effective, safer alternative to manual labor in urban maintenance and renewable energy sectors. By lowering human risk and maintenance

costs, it addresses key industry needs. Its modular design supports future scalability, making it valuable across various industrial applications.

Working Model vs. Simulation/Study:

This project included developing a physical working model, essential for advancing the H-Frame aerial manipulator. It enabled hands-on testing of structural strength, endurance, and cleaning performance in real conditions, validating solutions and revealing issues like wind disturbances, limited flight time, and the need for full automation.

Future Scope:

Future improvements to the H-Frame aerial manipulator focus on enhancing performance and efficiency in real-world conditions. Field testing will validate stability, cleaning effectiveness, and adaptability across various weather scenarios, refining system behavior before large-scale deployment.

AI integration with stereo and thermal cameras will enable autonomous inspection, real-time decision-making, and adaptive cleaning based on surface type and wind conditions. Full autonomy will allow a single operator to manage drone swarms, enabling large-scale cleaning with minimal labor and training.

To extend operational time, research will target tethered power systems and hybrid energy models, minimizing downtime from battery changes.