WEEK 3

Article: Shen *et.al.*, Sunlight-powered sustained flight of an ultralight micro aerial vehicle, *Nature*, 2024.

QUESTIONS 3b

1. Figure 4a shows that the ratio of wingspan/body mass of the presented vehicle is much higher than the one of the other sunlight-powered UAVs. Would it be possible to upscale the design to match the size of the conventional UAVs but with higher efficiency? What challenges would such scaling pose?

2. The vehicle test was conducted at a sunlight inclination angle of approximately 48 degrees and a natural light intensity of 920 W m^{-2}. Was the angle of 48 degrees found to be the optimal or most efficient angle, or was this selected due to experimental constraints? How is the performance of the CoulombFly (particularly lift force and potential flight duration) affected by variations in inclination angle and solar irradiance? What would be the critical light intensity threshold below which sustained flight would no longer be possible? The article explains that solar cells are placed underneath the vehicle for mass stability. Why is there only two cells at the front? Why not placing cells all around the MAV for a better center of gravity?

3. How accurately does the mathematical formula for electrostatic torque (Me) predict the actual performance of the propulsion system? What is the optimum number of electrodes with respect to the number of rotor blades? In which way does the number of electrodes influences the dynamic behavior of the robot? The motor is comprised of 64 blades on the rotor and 8 pairs of electrodes on the stator. How would behave the motor if the number of blades and electrodes was doubled? How do the number and width of electrode plates affect the efficiency of the electrostatic motor? Is there an optimal combination of electrode plate width and rotor blade count that maximizes torque and rotational speed without excessive energy loss?

4. Can you explain the working principle of the 12-stage Cockcroft-Walton voltage multiplier used in the HVPC, and how does it enable the conversion of low DC voltage from solar cells to the high DC voltage required by the electrostatic motor? Are there alternative voltage multiplier designs or power conversion technologies that could be considered to further enhance efficiency or reduce component size and weight? The HVPC's efficiency peaks at 58% with 100 MΩ loads but operates at 24.1% efficiency under flight conditions (330 MΩ). Why not optimize for lower resistance to maximize efficiency? Is this a trade-off for voltage stability, material limits, or motor compatibility? Could adaptive load-matching circuits dynamically adjust resistance mid-flight to improve efficiency? The authors say the maximum power conversion efficiency of the HVPC increases up to 58% for a load resistance of 100 MΩ, while it was 15% for a load resistance of 1 GΩ. What is the theoretical basis for this behavior?

5. In the design of dynamical systems like flying robots, trade-offs are inevitable. The authors primarily focus on performance metrics that showcase the strengths of their design (vertical flight, endurance, power efficiency, etc.). How would you rate this electrostatic motor-driven design in terms of horizontal acceleration, angular acceleration, agility, and overall controllability. Do you think this robot is realistically viable for the practical applications stated in the paper (rescue, monitoring, etc.)?

6. In Figure 3c, the output voltage reaches a minimum at a particular frequency and then increases again as the frequency decreases. What causes this behavior in output voltage? Similarly, why does the power conversion efficiency (Figure 3d) drop beyond certain frequency values despite a constant duty cycle?