M2
SPEC-DRONE

SOLAR PANEL ELECTRODE CLEANING DRONE

Kabato Burka, Justin Soto, Nicholas Tarallo, Luke Morrison, Rithvik Katikaneni, Patrick Rose

Advisor: Prof. Masoud Salehi

Problem

Accumulation of dust on solar panels can reduce output significantly.

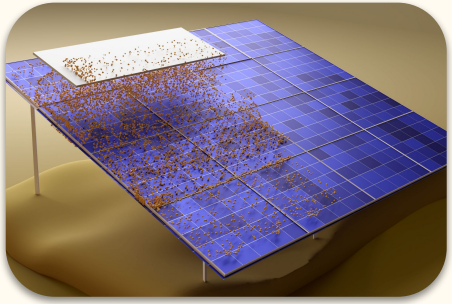
Widely used Solutions*:

- Washing with water - cleaning solar panels currently is estimated to use about 10 billion gallons of water per year — enough to supply drinking water for up to 2 million people.
- Waterless cleaning/ Scrubbing - tend to cause irreversible scratching of the surfaces, which also reduces efficiency.

Added problem: Cleaning is a labor intensive task

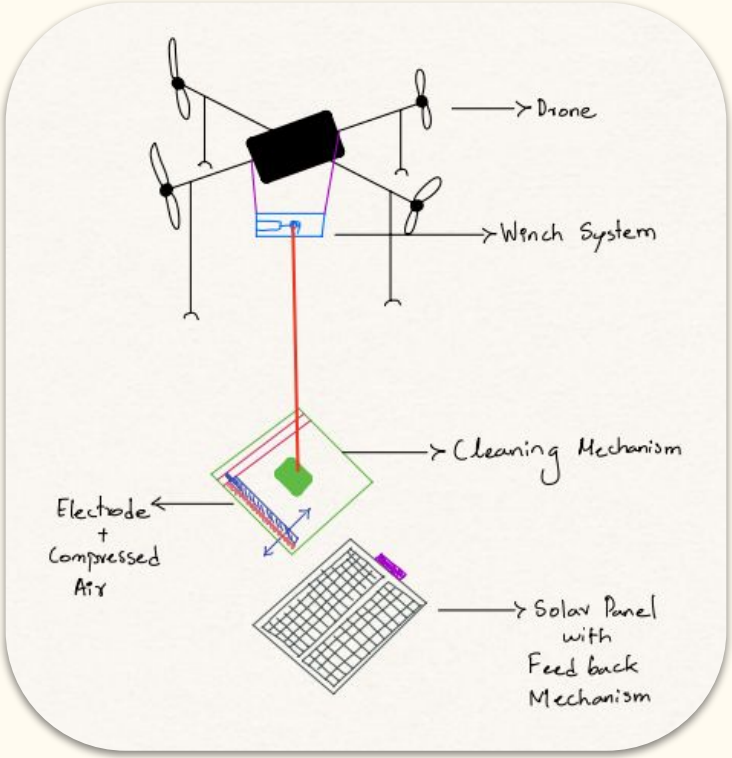
*https://news.mit.edu/2022/solar-panels-dust-magnets-0311

Idea - Drone Deployed Electrode and Air Based Solar Panel Cleaning Mechanism



https://www.science.org/doi/10.1126/sciadv.abm0078

- Electrode based electrostatic repulsion to disrupt dust particles
- Inspired by research at MIT
- Still an experimental system



- 2 available drone based panel cleaning systems in market
- Water based
- Rover based

Solar Industry

Country	2023 Total capacity (MW)	By 2028 Total capacity Medium Scenario (MW)	2024-2028 New capacity (MW)	2024-2028 Compound annual growth rate (%)	Political support prospects
China	656,045	2,422,149	1,766,104	30%	
United States	173,185	462,443	289,258	22%	
India	90,069	241,738	151,669	22%	
Germany	82,979	186,498	103,519	18%	
Brazil	39,443	118,356	78,913	25%	
Spain	36,273	82,251	45,978	18%	
Australia	36,109	79,043	42,934	17%	
Japan	90,357	131,889	41,532	8%	
Italy	29,844	64,388	34,544	17%	
Türkiye	12,239	42,553	30,314	28%	
France	18,912	47,401	28,489	20%	
Poland	16,832	39,442	22,610	19%	
Netherlands	22,916	44,061	21,145	14%	
South Africa	9,291	28,634	19,343	25%	
Taiwan	12,443	30,591	18,148	20%	
Greece	7,149	23,436	16,287	27%	
United Kingdom	17,697	33,419	15,722	14%	
Saudi Arabia	3,181	18,649	15,468	42%	
Romania	3,350	18,130	14,780	40%	
South Korea	27,252	41,100	13,848	9%	

https://api.solarpowereurope.org/uploads/Global_Market_Outlook_for_Solar_Power_2024_a083b6dcd5.pdf?updated_at=2024-06-14T14:43:37.929Z

Global Solar Energy Market size was valued at USD 180.78 billion in 2022 and is poised to grow from USD 193.62 billion in 2023 to USD 335.16 billion by 2031, at a CAGR of 7.1% during the forecast period (2024-2031).

https://www.skyquestt.com/report/solar-energy-market

Drone

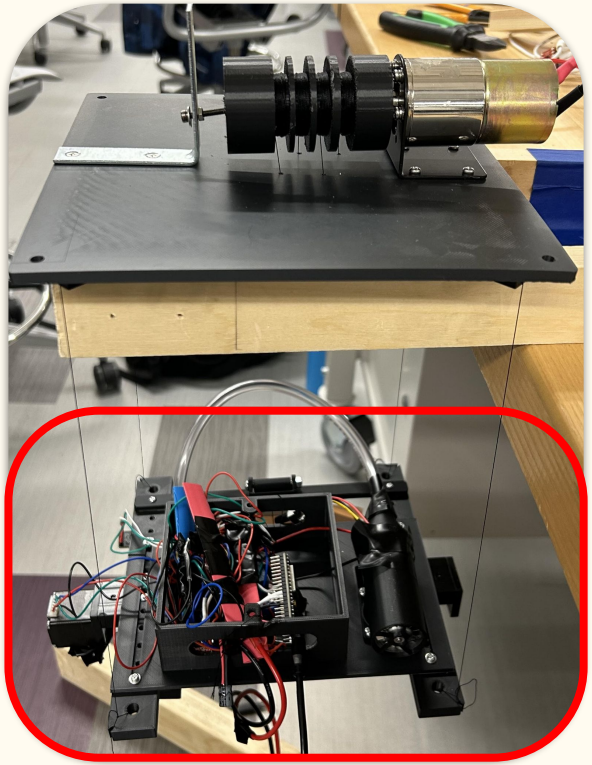
Hardware

- AeroNU - NUAV Frog
- Custom Landing Gear
- GPS Positioning
- Pixhawk
- NVIDIA Jetson

Software

- ArduPilot
- Python (DroneKit)

Winch

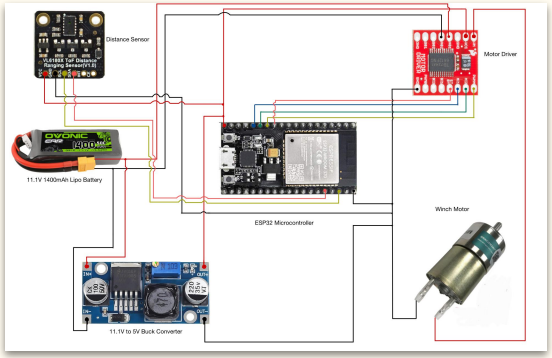


Hardware:

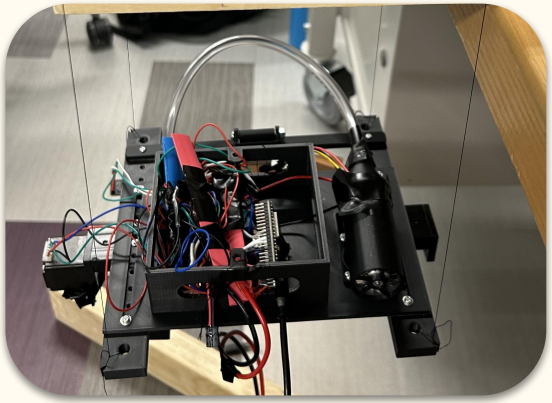
- Purpose: To lower and raise the cleaning mechanism
- An ESP32 provides the motor with ±12V
- A distance sensor is used to tell when to stop the motor from retracting the cleaning mechanism
- Nylon thread used to suspend cleaning mechanism

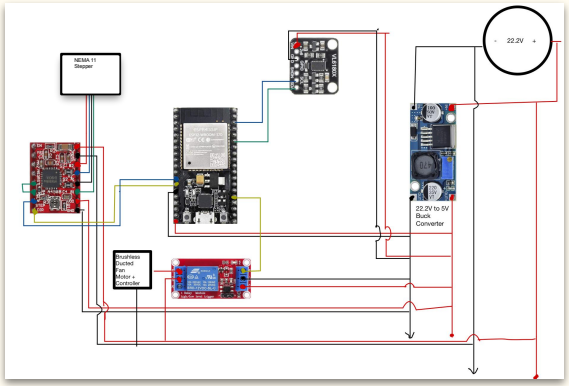
Software

- Arduino IDE was used to program the ESP32
- ESP32 on the winch will lower, raise, or stop the winch depending on signals received from the mechanism.



Cleaning Mechanism





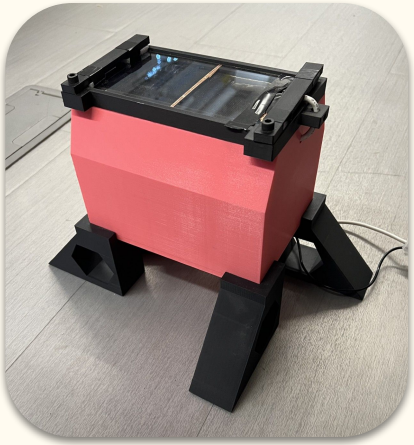
Hardware

- NEMA11 stepper motor with linear actuator driven by A4988 motor driver
- Brushless ducted fan motor pushes large particles and small particles that were pulled off with electrode.
- Air channeled through vinyl tube and 3D printed mechanism with holes
- Nylon string holds frame vertically from winch
- Electronics placed atop the linear actuators frame

Software

- ESP32 used to control all aspects of the mechanism
- Stepper motor accelerates and decelerates
- Relay is utilized to turn channeled air on and off
- VL6180X laser distance sensor connected via I2C determines distance between mechanism and solar panel.
- Height control messages to winch over WiFi (ESP-NOW protocol). Message is also sent at end of cycle.

Solar Panel Housing

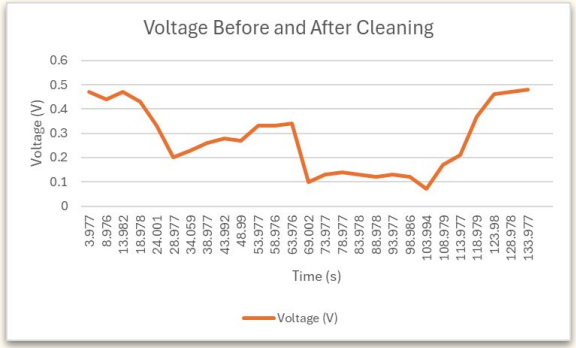


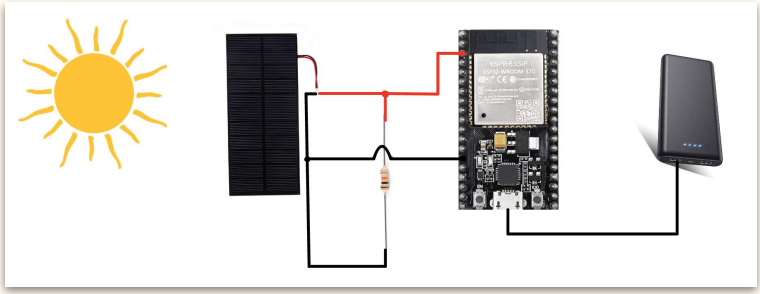
Hardware

- Purpose: To house the solar panel circuit, and to monitor the output voltage
- The solar panel is equipped with an ESP32 to keep voltage data over time
- The average voltage over time will drop once covered by various particles/dust

Software

- Keeps track of the current and average voltage produced by the solar panel.
- Sends this data using the ESP32 to control center.

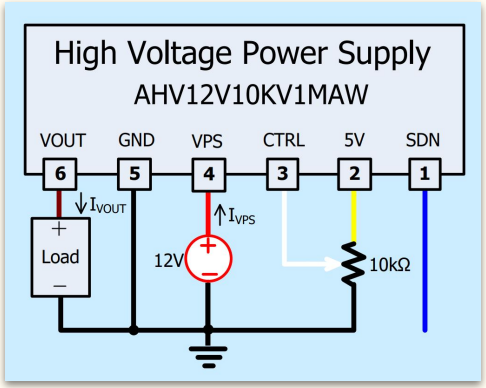


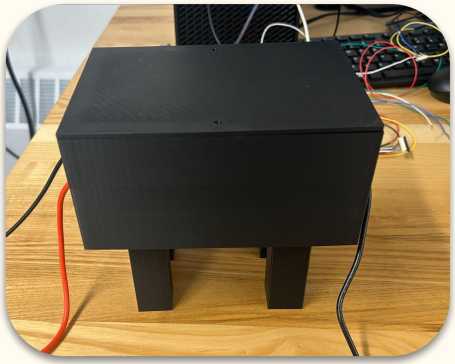


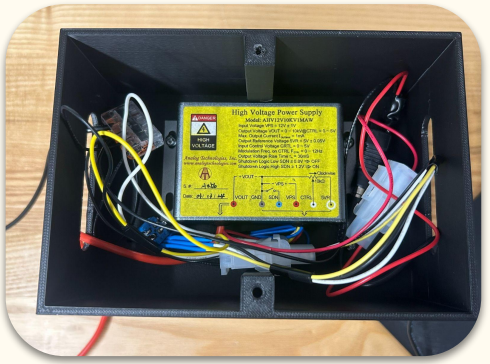
High Voltage Supply

Hardware:

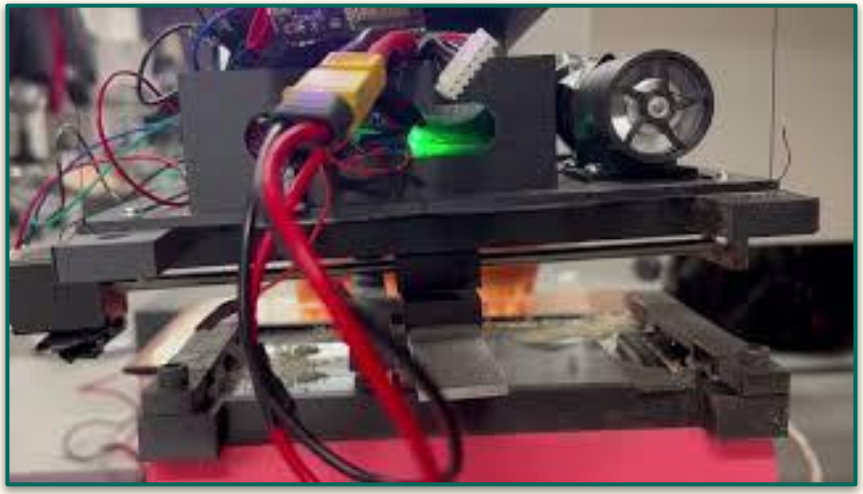
- Purpose: To apply high-voltage demand to produce the required electrostatic induction to displace dust
- Analog Technologies Inc. 1-10 kV DC-DC Power Supply (AHV12V10KV1MAW) generates high voltage
  - Given 12V/1A input
  - Regulated output by 10k-ohm potentiometer
- Wired and housed in box that sits beside and directly connects to solar panel housing/bottom electrode







DEMO



Changes if the solution was to be scaled

Angle Cleaning Mechanism

Larger Drone and Cleaning Mechanism

High Voltage on the Drone

Price if produced at volume:

Drone: $25,000 (Avg. Commercial Drone Price $10-50K)

HV Supply + Power System: $600

Mechanism + Batteries: $2000

Total= $27,600 x 2 Drones = 55,200 (For a 1 MW Farm)

(+ Cost of glass layer and contact)

Context:

1 MW (6-8 Acre) Solar Farm - $ 1 M **

1MW farm produces about 1,825MWh of electricity per year ***

Avg. Project Size - 69 MW ****

** https://coldwellsolar.com/commercial-solar-blog/how-much-investment-do-you-need-for-a-solar-farm/#:~:text=How%20Much%20Does%20it%20Cost,SEIA's%20average%20national%20cost%20numbers.

*** https://solarmentors.com/how-much-energy-does-a-solar-farm-produce/#:~:text=Key%20Takeaways,weather%20conditions%2C%20and%20technological%20efficiency

**** https://pv-magazine-usa.com/2023/02/17/over-25-gw-of-solar-is-actively-being-constructed-in-the-u-s/#:~:text=There%20are%20currently%20366%20utility,adding%2010.2%20GW%20of%20capacity.

Challenges

- Producing a High Voltage
- Procuring AZO Glass
- Channeling compressed air
- Managing overall drone payload weight
- Stability of drone during cleaning cycle

Budgeting

Cost for Drone: $18.38

Cost for Winch System: $60.48

Cost for Cleaning Mechanism: $494.77

Cost for Solar Panel: $175.38

Other: $12.63

Total Cost: $761.64

Exceeded Budget by $61.64

	A	B	C	D	E	F	G
1	Linear Actuator	1	Amazon	Stepper motor and linear actuator for electrode	62.99	4.92	67.91
2	)M-32-Developm	3	Amazon	r for Cleaning me	9.99		29.97
3	epper Motor Driv	1	Amazon		5.69		5.69
4	Blower Motor	1	Ali Express	Blower motor	7.84		7.84
5	Aluminum	1	Home Depot	Electrode	9.93	0.62	10.55
6	Winch motor	1	Amazon	tor for winch syst	19.22	1.2	20.42
7	Shunt	1	Digikey	= current throug	3.2	12.54	15.74
8	Distance sensor	2	Digikey	:e sensor for sola	6.9		13.8
9	Solar Panel	1	Digikey	Panel (180mm * 8	24.76		24.76
10	Diode	1	Amazon	C-DC Rectify Circ	9.29	1.76	11.05
11	Transformer	1	Amazon	Transformer	6.89		6.89
12	Iron Powder	1	Amazon	Dust Particles	16.45	14	30.45
13	Selric Thread	1	Amazon	Holding Winch	6.99	0.44	7.43
14	NST Transformer or Ebay NST Transformer	1	FMS Neon	to 12 kV AC Tra	50	12.13	62.18
15	ITO Glass Slides	1	Amazon	lectrode: ITO Gla	78	4.88	82.88
16	centrifugal fan	1	Amazon		13.99	0.87	14.86
17	0.12 in Copper Tape	1	Amazon	2 x 100mm bottor	5.09	0.32	5.41
18	Copper Sheet	1	Amazon	Electrodes wher	25.69	1.61	27.30
19	10 kV Power Supply	1	Analog Technologies Inc.	ment to have ele	189.00	24.00	213.00
20	10k Rotary Potentiometer	2	Amazon	e voltage of powe	5.90	5.85	11.75
21	FrSky XM Plus Receiver	1	Amazon	ne's receiver mo	17.30	1.08	18.38
22	Vinyl Tube	1	True Value		3.00		3.00
23	Poster Board	1	Target	poster	11.89	0.74	12.63
24	22.2 V Battery	1	Amazon		27.89		27.89
25	11.1 V Battery	1	Amazon		15.29		15.29
26	XT60 Connector	1	Amazon		7.99		7.99
27	DC Adapter	1	Amazon	HV Supply Input			6.58
28	Total						761.64

Special Thanks to:

Prof. Masoud Salehi, Prof. Bradley Lehman, Prof. Mahshid Amirabadi, Jackson and Matt from NUAV

Bibliography:

- https://news.mit.edu/2022/solar-panels-dust-magnets-0311
- https://www.science.org/doi/10.1126/sciadv.abm0078
- P. T. Krein, Elements of Power Electronics. 2008.
- https://www.science.org/doi/10.1126/sciadv.abm0078
- https://api.solarpowereurope.org/uploads/Global_Market_Outlook_for_Solar_Power_2024_a083b6dcd5.pdf?updated_at=2024-06-14T14:43:37.929Z
- https://www.skyquestt.com/report/solar-energy-market
- https://coldwellsolar.com/commercial-solar-blog/how-much-investment-do-you-need-for-a-solar-farm/#:~:text=How%20Much%20Does%20it%20Cost,SEIA's%20average%20national%20cost%20numbers.
- https://solarmentors.com/how-much-energy-does-a-solar-farm-produce/#:~:text=Key%20Takeaways,weather%20conditions%2C%20and%20technological%20efficiency
- https://pv-magazine-usa.com/2023/02/17/over-25-gw-of-solar-is-actively-being-constructed-in-the-u-s/#:~:text=There%20are%20currently%20366%20utility,adding%2010.2%20GW%20of%20capacity.

QUESTIONS ?