High-Altitude Solar-Powered UAV for Climate Research

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TEAM UAV — Studio G ARROWHEAD CENTER

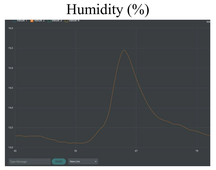
Mission

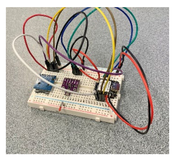
- Develop a solar-powered UAV capable of sustained high-altitude flight for climate research
- Integrate wing-mounted solar panels for flight operations
- Equipped with advanced sensors to monitor temperature, humidity, atmospheric pressure and CO2 concentrations
- Leverage renewable energy for UAV operations

Research

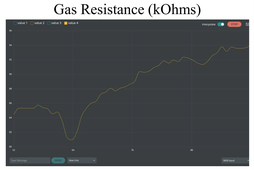
- **Clark-Y Airfoil:** Utilizing the UIUC Airfoil Data Site for the acquisition of precise airfoil coordinates and implementation in XFLR5
- **Ardupilot Mission Planner:** Flight control software for computer-controlled flights with preprogrammed waypoints, UAV tracking, and real-time monitoring of altitude, speed, and lift coefficients
- **Climate Data:** Integration and operation of sensors, and real-time processing
- **Solar Array:** Thorough experimentation aimed to verify the ability to produce sufficient voltage and current under varying environmental conditions
- **Hybrid Propulsion:** Combining battery power for high-demand phases like takeoff and rapid maneuvers with external solar power sources meant to extend flight duration

Humidity (%)

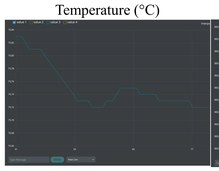




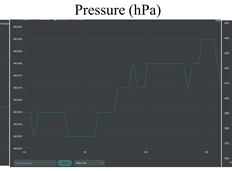
Gas Resistance (kOhms)



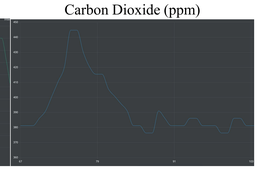
Temperature (°C)



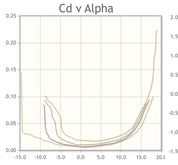
Pressure (hpa)



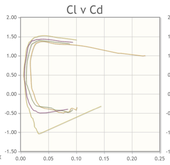
Carbon Dioxide (ppm)



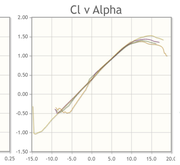
Cd v Alpha

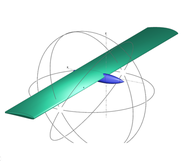


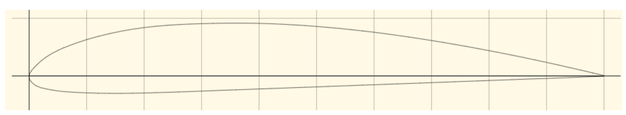
Cl v Cd



Cl v Alpha

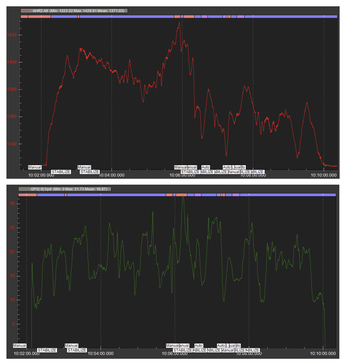


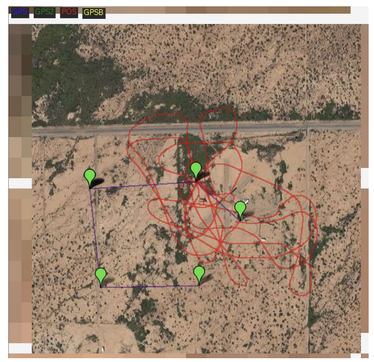


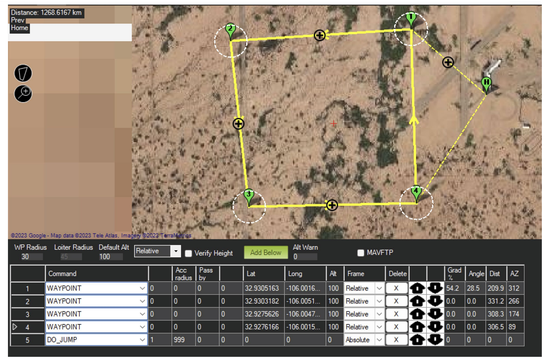


Final Design

- Software: Ardupilot Mission Planner
- UAV: RMRC Anaconda
- Telemetry: RFDesign RFD900x Telemetry Modem Bundle
- Pixhawk: Pixhawk Cube Orange+ Standard Set ADS-B (Cube and Carrier)
- PT40 Pitot Tube: Digital Air Speed Sensor - MS4525DO
- Receiver: R7008SB S. Bus2 FASSTest Receiver 14SG 18MZ 18SZ
- Transmitter: 16IZS 18-Channel Air Transmitter Only
- Compass: Cubepilot Here 3+ GPS Unit for Cube & Pixhawk with iStand
- Motor: SunnySky X4120-480 V3
- Propeller: APC Electric E 15x8E
- Electronic Speed Controller: Hobbywing Platinum Pro 80A LV
- Battery: Battery: LiPo 22000 mAh – 25/35C 4s
- 5x Servos



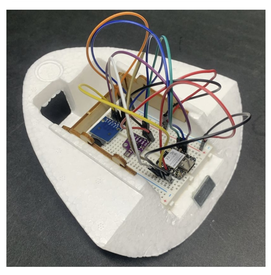


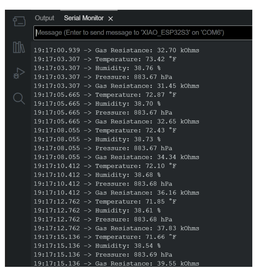


	Command	Acc. radius	Pass by	Lat	Long	Alt	Frame	Delete		Grad °	Angle °	Dist	AZ
1	WAYPOINT	0	0	0	32.9305163	-106.0016…	100	Relative	X	54.2	28.5	209.9	312
2	WAYPOINT	0	0	0	32.9303182	-106.0051…	100	Relative	X	0.0	0.0	331.2	266
3	WAYPOINT	0	0	0	32.9275626	-106.0047…	100	Relative	X	0.0	0.0	308.3	174
4	WAYPOINT	0	0	0	32.9276166	-106.0015…	100	Relative	X	0.0	0.0	306.5	89
5	DO_JUMP	1	999	0	0	0	0	Absolute	X	0	0	0	0

Sensors and Data Handling:

- BME680 sensor for measuring temperature (°C), humidity (%), pressure (hPa), and gas resistance (kOhms) with high accuracy
- MQ-135 sensor for monitoring CO2 levels (ppm)
- Both sensors are compact and meet aircraft size and weight constraints
- SEEED Studio XIAO ESP32S3 board manages multiple sensors and stores data on a 32GB SD card, ensuring ample capacity for climate data collection





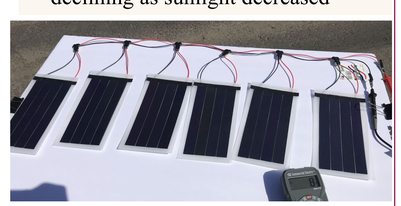
Solar Array Configuration and Testing:

Time	Voltage (V)	Amps (A)	Power (W)
12:00 PM	7.47	0.73	5.4531
12:37 PM	7.57	0.85	6.4345
1:03 PM	7.56	0.9	6.804
1:33 PM	7.69	0.81	6.2289
2:07 PM	7.25	0.81	5.8725
2:35 PM	7.23	0.73	5.2779
3:00 PM	6.83	0.68	4.6444
3:27 PM	7.3	0.59	4.307
4:10 PM	6.22	0.29	1.8038
4:19 PM	6.71	0.34	2.2814
5:59 PM	1.84	0.03	0.0552

Time	Volts (V)	Amps (A)	Power (W)	UV Index
11:09 AM	7.41	0.59	4.3719	3.5
11:58 AM	7.44	0.91	6.7704	5
12:00 PM	7.72	0.89	6.8708	5
12:29 PM	7.02	0.63	4.4226	5
12:32 PM	7.17	0.5	3.585	5
1:01 PM	7.12	0.37	2.6344	5.8
2:01 PM	6.07	0.26	1.5782	5.3
2:06 PM	6.8	0.43	2.924	5.3
2:30 PM	6.51	0.31	2.0181	5.3
3:04 PM	6.15	0.27	1.6605	3.9
3:41 PM	6.08	0.26	1.5808	2.2
4:09 PM	5.72	0.26	1.4872	2.2
4:36 PM	4.75	0.15	0.7125	1.9
4:41 PM	5.41	0.2	1.082	0.8

Time	Volts (V)	Amps (I)	Power (W)
12:45 PM	7.00	0.80	5.6
1:01 PM	7.29	0.90	6.561
1:03 PM	7.37	0.90	6.633
1:15 PM	7.14	0.90	6.426
13:40	7.27	0.90	6.543
2:00 PM	7.19	0.90	6.471
2:30 PM	7.14	0.80	5.712
3:00 PM	7.24	0.72	5.2128
3:30 PM	7.00	0.64	4.48
4:00 PM	6.95	0.57	3.9615
4:38 PM	6.54	0.34	2.2236
4:48 PM	6.42	0.30	1.926
5:38 PM	3.27	0.08	0.2616

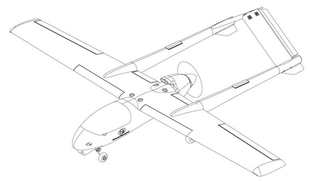
- Voltage and current readings were recorded over several days using a multimeter to monitor performance under varying conditions
- Testing process began with solar panels wired in parallel, generating 7-8V in direct sunlight
- A 5V solar charge inverter was incorporated to safely step down the voltage for battery charging
- The battery achieved a partial charge, verified by its indicator, demonstrating functionality
- Test confirmed the solar array's ability to charge a battery and support UAV operations
- Data analysis showed a bell-curve performance trend, with power output peaking at midday and declining as sunlight decreased



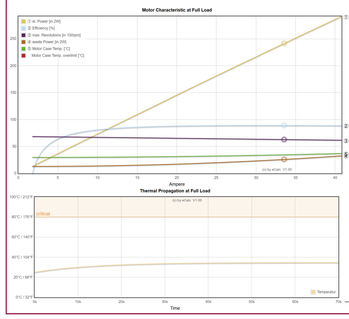
Proof of Concept - Simulation

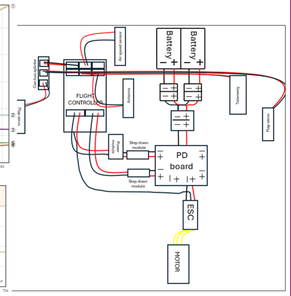
UAV Model Selection:

- Collaborated with the UAV lead at White Sands Missile Range to select a government-approved UAV model that aligns with project goals



- Wingspan: 2,060 mm
- Wing Area: 4900 cm^2
- Length: 1,410 mm
- Center of Gravity: 1/3 of wing from leading edge at the main spar
- Fuselage dimensions (Inside): L 66cm (26.5") x W 15cm (6") x H 8cm (3")





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