

Executive Summary

"Operation Touchdown" focuses on autonomous coordination between an aerial vehicle (UAV) and a ground vehicle (UGV). A multidisciplinary team of MAE, CSE, and EE students was tasked by Raytheon to develop this autonomous system. As the Electrical Engineering (EE) sub-team, our primary focus was the design, integration, and testing of the power distribution and electrical architecture. This poster focuses on the battery validity tests portion of our testing for the UAV.

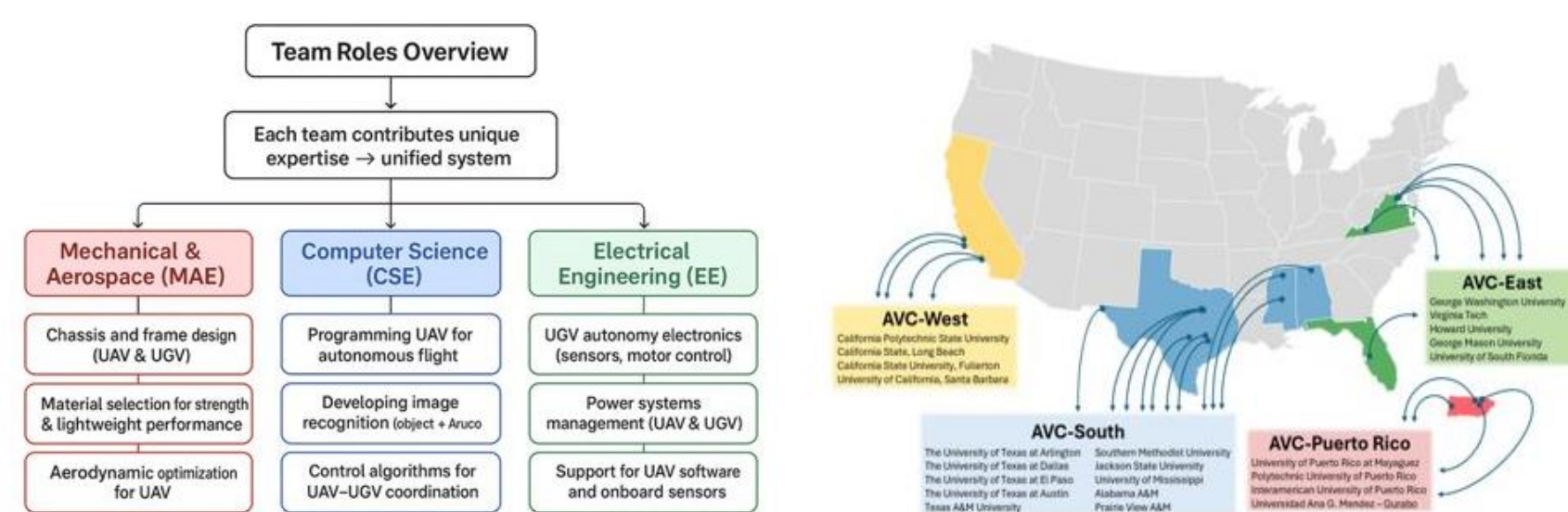


Figure 1. Sub-Team Responsibility Structure



Figure 2. Competition Regions (South Region)

Background

- **The Challenge:** Autonomous landing on a moving target requires high-speed data processing accomplished through the use of a PI 5 and a Brainchip Akida neural Processor.
- The challenge also requires a rapid motor response of the UAV, all while operating under strict battery life constraints and a GPS denied environment.
- **Motivation:** Inspired by complex engineering systems like the **Perseverance Mars Rover** and its helicopter, **Ingenuity**, this project explores localized, peer-to-peer communication and coordination for remote delivery and scouting.
- **Societal Impact:** Advancing autonomous landing technology is vital for future "last-mile" delivery services and search-and-rescue operations in GPS-denied environments.

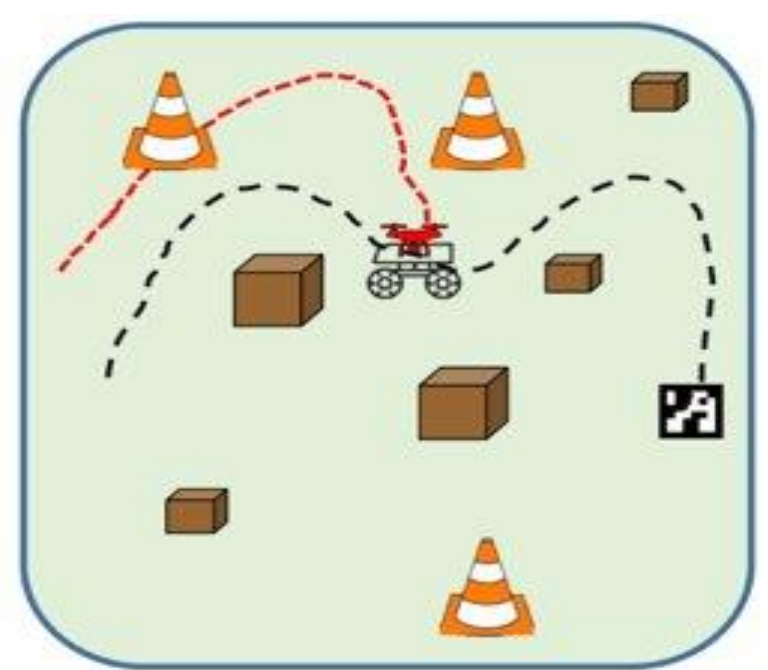


Figure 3. Challenge 3, image provided in 2526 Raytheon Autonomous Vehicle Competition Rules. Challenge 1 and 2 are compounded in this challenge.

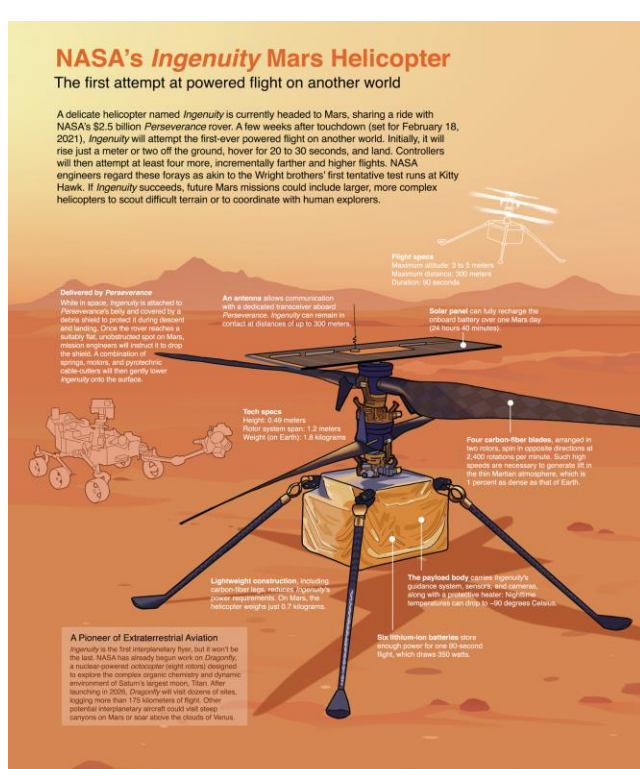


Figure 4. Ingenuity and perseverance rover

Experimental Setup

- **Design Constraints:** The system must operate without GPS or a ground station, requiring high-power onboard computing and a direct RF link between vehicles.
- **System Requirements:** The UAV must achieve an autonomous landing on a UGV moving at ≥ 0.2 mph within a 10-minute window. The team chose to complete the task in under 7 mins as that was one criteria for breaking a potential tie with another team.
- **Initial Analysis:** Motor tables were analyzed to map required Power against Thrust-to-Weight Ratios (TWR). A 4:1 TWR was chosen as the goal ratio for a perfect balance of maneuverability for landing and flight time endurance.
- **Conceptual Design:** To meet the high-current demands for this challenge, the team selected a 6S LiPo 8000 mAh battery. This insures adequate power for image processing via PI 5 and Akida, as well as adequate motor response during intensive maneuvers.
- **Down-Select Justification:** A 4S LiPo was initially considered but the 6S was chosen for its higher nominal voltages (22.2V). This higher voltage reduces current draw for the same output thereby minimizing heat and extending total mission time.

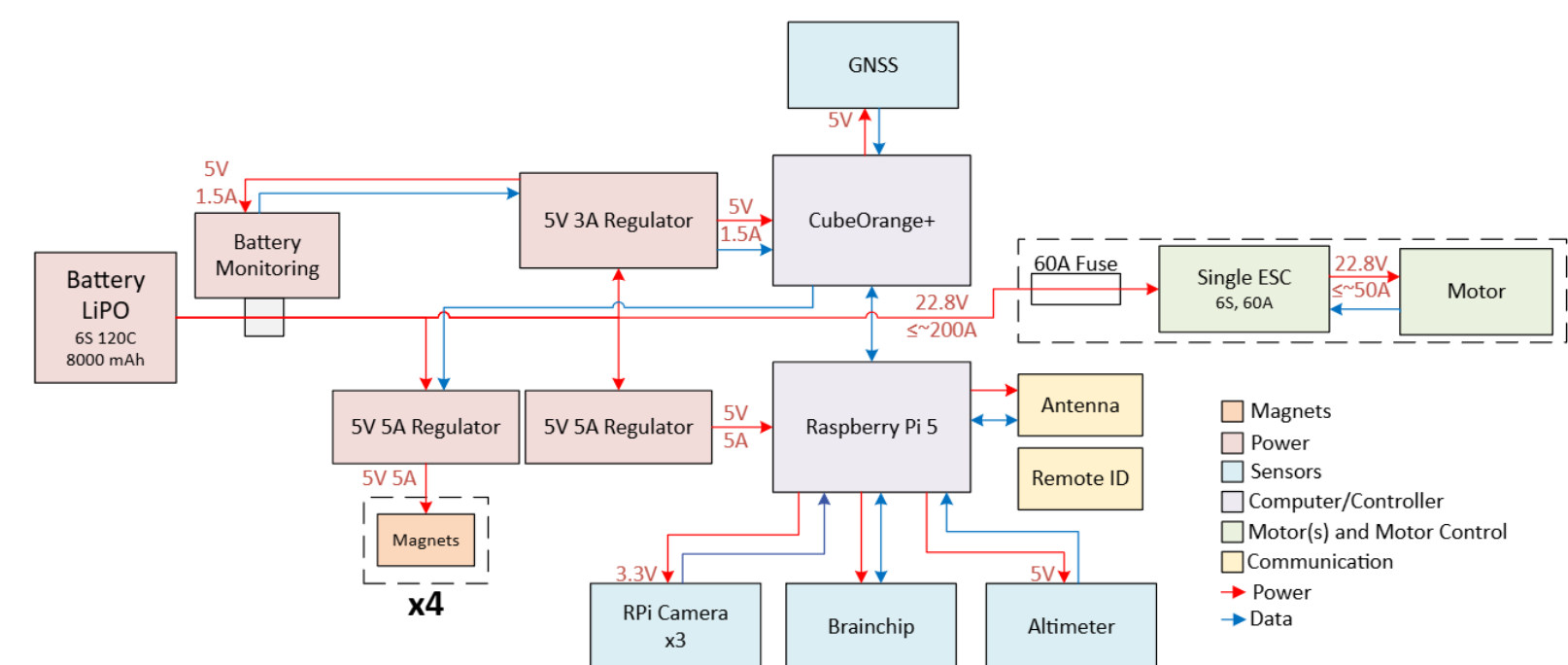


Figure 5. UAV Wiring Diagram

Experimental Test Plan

- **1C Discharge Protocol:** Establish a baseline for voltage drop by discharging the 6S LiPo at a constant (1C) rate to verify voltage safety limits.
- **Dynamic Load Profiling:** Program a test cycle featuring a constant "hover" (1.25 TWR) with 2-second "maneuver" bursts (2.0 and 3.0 TWR) every 20 seconds.
- **Safety Threshold Validation:** Define a hardware-protection cutoff at 19.8V (3.3V per cell) to determine the true mission window before critical power failure.
- **TWR vs. Wattage Mapping:** Use motor-provided thrust tables to calculate the exact wattage required for various flight intensities to use as a reference for variable discharge trials.

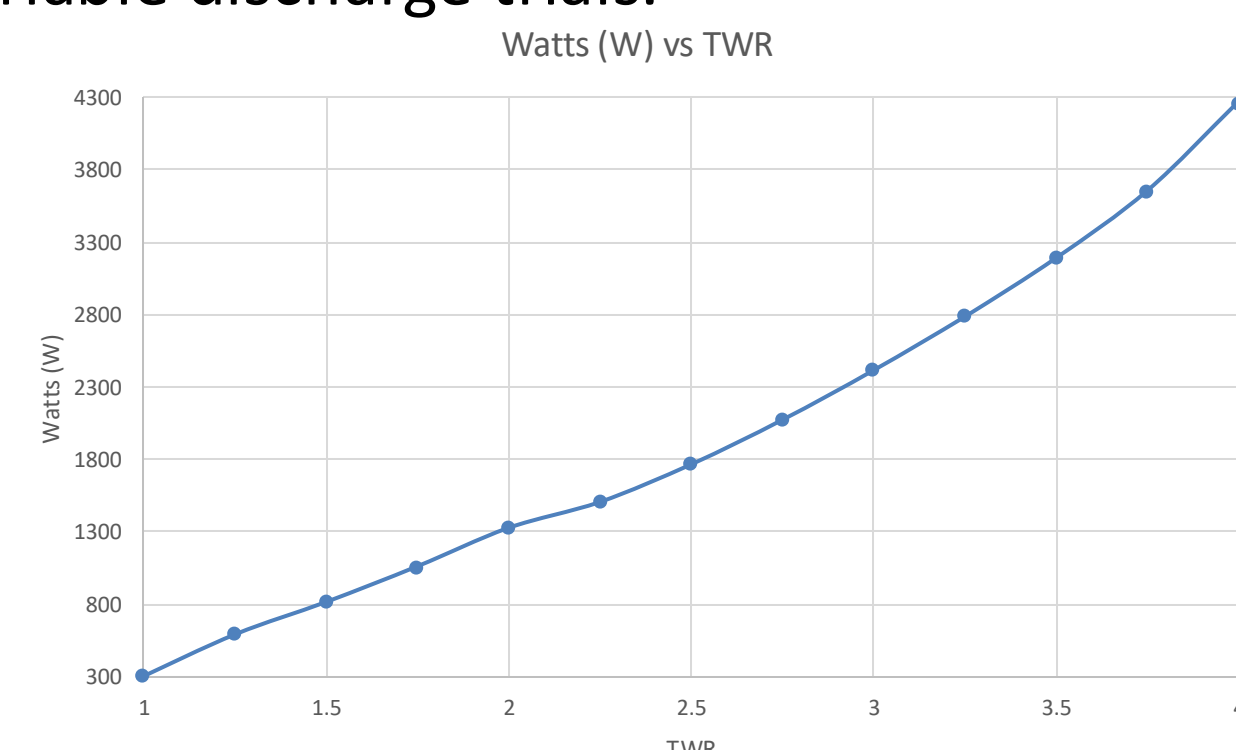


Figure 6. TWR wattages Mapped from Motor Specs

Weight of Drone (g): 2500g F100 1100kv with HQ8045-3 Propellers						
Throttle	Thrust (g)	Voltage (V)	Current (A)	RPM	Power (W)	Efficiency (g/W)
30.00%	517.08	25.09	3.05	6880	76.5245	6.757051663
35.00%	638.27	25.05	4.33	7607	108.4665	5.884489681
40.00%	766.38	25.02	5.74	8334	143.6148	5.336358091
45.00%	923.95	24.95	7.98	9140	199.101	4.64060954
50.00%	1093.76	24.89	10.65	9944	265.0785	4.126173945
55.00%	1248.08	24.83	13.34	10689	331.2322	3.767991155
60.00%	1435.92	24.77	15.61	11426	386.6597	3.713653117
65.00%	1605.01	24.69	18.7	12069	461.703	3.476282372
70.00%	1786.01	24.62	22.42	12737	551.9804	3.235640251
75.00%	1959.36	24.54	26.67	13244	654.4818	2.99375781
80.00%	2111.12	24.51	30.54	13722	748.5354	2.820334215
85.00%	2270.25	24.46	34.91	14216	853.8986	2.658688046
90.00%	2403.24	24.38	39.49	14510	962.7662	2.496182355
95.00%	2497.41	24.28	43.78	14844	1062.9784	2.349445671
100.00%	2597.38	24.22	48.59	15087	1176.8498	2.207061598

Figure 7. Motor Specs from Manufacturer



Figure 8. Experimental Devices. The battery connects to the programmable load which is the monitored with a National Instruments card

Experimental Results

- **Voltage Stability & "Fall-Off" Point:** 1C discharge testing revealed that the 6S battery maintains a remarkably linear output decrease until after the **22.2V nominal line** for the battery's lifetime.
- The critical "fall-off" point where voltage becomes unstable and drops rapidly occurs after the capacity falls below **8.75% (approx. 700 mAh)**. Well below our 20% safety limit.

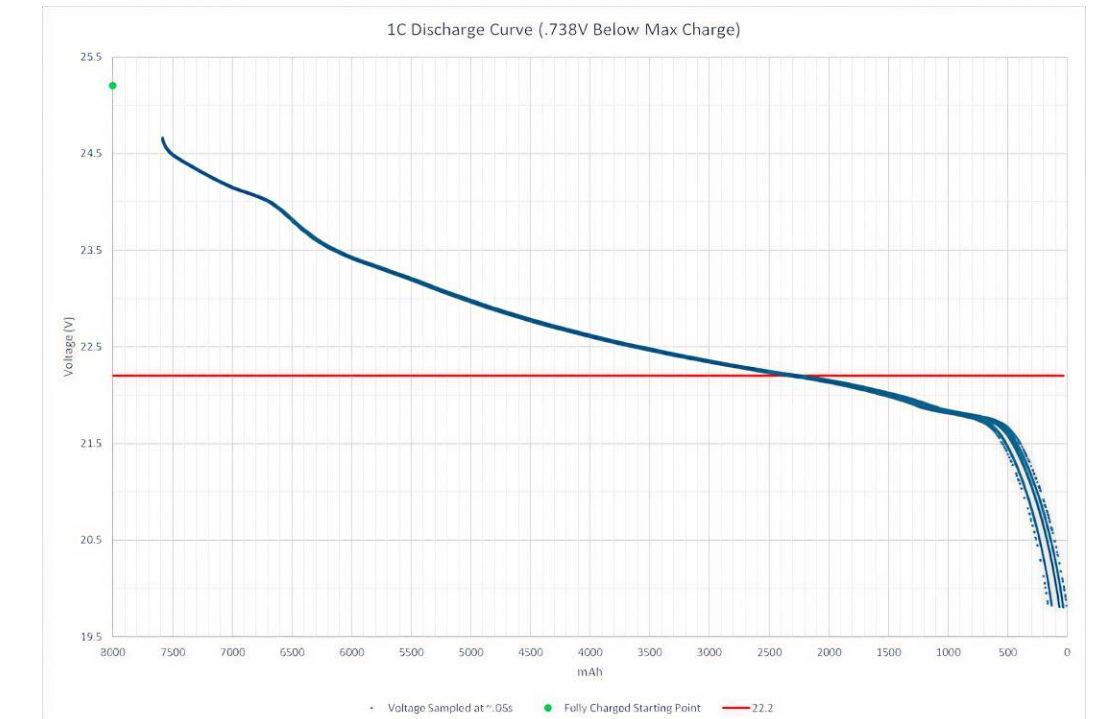


Figure 9. 1C Discharge

- **Constant High-Speed Trial (2.0 TWR):** A dedicated trial at a constant **2.0 TWR** resulted in a total flight life of **6 minutes and 50 seconds**.
- This defines the absolute minimum expected lifetime if the UAV operates at high speeds for the duration of the 7-minute mission window.

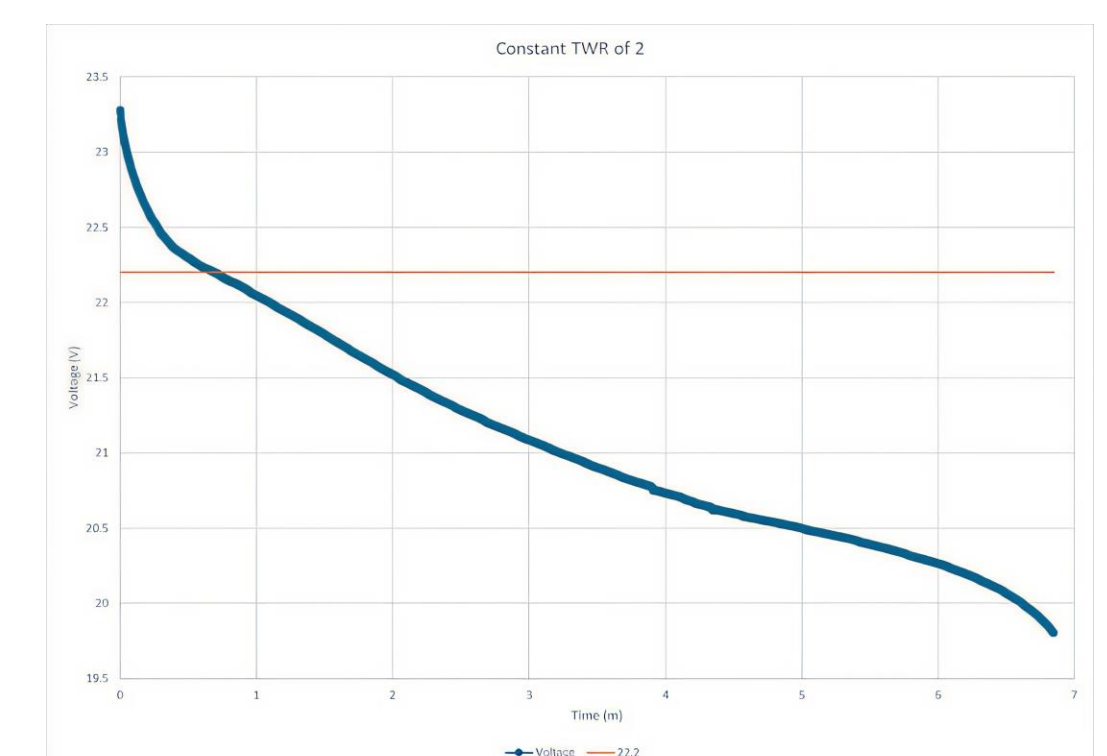


Figure 10. Constant TWR of 2 Discharge

- **Maneuvering Limitations:** In the variable trial, the system could no longer support the high-intensity **3.0 TWR bursts** after the **8-minute mark** as they began hitting the **19.8V safety cutoff**.
- However, the battery continued to support **2.0 TWR bursts** and the 1.25 TWR hover until the final cutoff at **~11 minutes**.

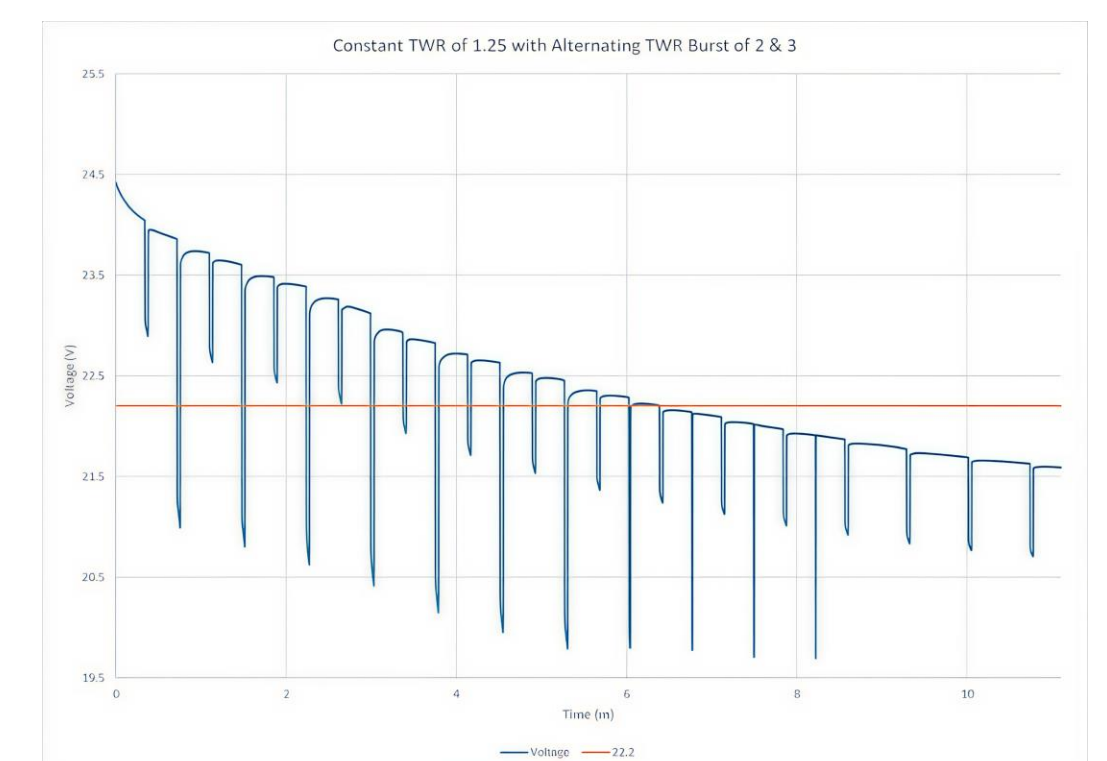


Figure 11. Constant TWR of 1.25 with Burst of 2 and 3 TWR Discharge

Conclusions

- Experimental data **validates** the 6S 8,000 mAh choice as the optimal solution for the "Operation Touchdown" platform. 6S topology minimizes thermal losses and ensures voltage stability during intense maneuvering.
- **Safety and Stability:** 1C discharge identified a critical "fall-off" point that validates the teams 19.8V cutoff to maintain reliability.
- **Capacity and Endurance:** Testing confirms the 6S battery meets the maximum allowed mission time of 10-minutes. TWR testing confirms we can complete the trial in 7 minutes under heavy load.
- This testing **proves** that the EE design is fully mission-ready for autonomous operations in a GPS-denied environment.



Figure 12. UAV & UGV

References

1. Raytheon Company, "2526 Raytheon Autonomous Vehicle Competition Rules"
2. J. Palmisano, "NASA's Ingenuity Mars Helicopter," *American Scientist*, Jul. 2021.