Energy Optimization of eVTOL Systems Using Simulation-Based Analysis

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***Abstract*—In this project, an electric vertical take-off and landing (eVTOL) system was simulated in order to explore the effect of battery selection on total flight endurance. A base model was defined using realistic data such as motor specifications, total aircraft weight, battery characteristics, and required thrust levels. Instead of focusing on control systems or idealized models, this work concentrates on practical energy optimization through real-world component selection. A battery library was constructed from commercially available lithium-based battery packs. Each battery configuration was tested within the same VTOL system architecture using MATLAB/Simulink simulation environment. The model calculates thrust demands using payload, translates this into current draw based on interpolated motor data, and estimates flight time from there. The impact of battery mass on overall system mass was also considered. All permutations were simulated, and the battery enabling longest flight time under specified parameters was selected. The outcome demonstrates a data-driven approach to improving energy efficiency and flight range without the need for complex theoretical models. This study supports smart battery selection strategies in electric aviation by combining simulation and real product characteristics.**

***Index Terms*—eVTOL, Energy Optimization, Battery Efficiency, MATLAB, Simulink, UAV, Sustainable Flight**

I. Introduction

The electric Vertical Take-Off and Landing (eVTOL) aircraft design has opened up new ways for urban air mobility, offering a state-of-the-art solution for congestion, efficient transportation, and less emission. With increased population and rising demands for environmentally friendly transport solutions, the eVTOL systems are being researched for how they can transform short-haul aerial transport.Yet for all the promise, current eVTOL designs are beset by a multitude of problems that take away from their operating efficiencies and economic viability. One of the most relevant issues is system inefficiencies. These are non-optimized structural components that introduce dead weight, which translates to increased power demands and lower flight capacities.

System inefficiencies are one of the key issues. They are non-optimized structural components that create unnecessary weight, leading to increased power demands and reduced flight capacities. Other wasteful energy consumption due to inefficient weight-to-power ratios or aerodynamic flaws results in shorter flight times and overall lower system efficiency. This, in turn, requires more expensive and heavier battery packs to balance the increased energy demand, increasing the expense and complexity of the system.

Moreover, limited flying time affects the scalability and viability of eVTOL services, especially for commercial application. The reduction of such inefficiencies by system optimization, energy management, and wise design is essential to making eVTOLs a viable mode of transport in the near future. This report investigates such inefficiencies and evaluates simulation-based approaches to the optimization of energy and the improvement of eVTOL system performance.

Fig. 1: Urban air mobility concept powered by eVTOLs.

II. Problem Statement

Greater range with extra batteries also contributes to the weight of the vehicle,requiring more thrust and thus more energy. This loop decreases the system efficiency.Therefore, the optimization issue is choosing a battery that provides sufficient energy without contributing too much weight.

III. Objectives

- Establish a base eVTOL model with fixed motor and payload.
- Build a library of batteries using real product information.
- Simulate each configuration in MATLAB/Simulink.
- Identify the most efficient configuration in energy-to weight ratio and hover time.

IV. Literature Review

Taghbalout et al. [1] explored energy management in eVTOL aircraft using a powertrain optimization-based control model. Their findings demonstrated the benefits of dynamic system-level modeling to evaluate battery-motor-load interactions.

Chatterjee et al. [2] presented a simulation framework for lithium-ion battery behavior in electric vehicles using MATLAB/Simulink. Their study validated the integration of SoC and SoE models for improved real-time performance estimation.

These foundational studies support our decision to use Simulink as the simulation environment for evaluating battery configurations under identical physical constraints.

Furthermore, recent publications in the IEEE Transportation Electrification community suggest that energy efficiency per gram and discharge profile are critical parameters for urban air vehicles. This affirms our evaluation metrics in determining the most optimal battery.

Hardware Data Sources:

- The *T-MOTOR MN6007 KV320* datasheet [5] provided thrust-to-power mappings and efficiency ranges.
- The *Keeppower 18650 3800mAh* specification sheet [4] supplied accurate weight, voltage, and current ratings.
- The *XTAR 18650 3600mAh* datasheet [3] was used to extract maximum discharge rate and physical dimensions.

Together, these sources helped construct a realistic digital twin of the eVTOL propulsion system.

V. System Description

The design centers on theMX860 drone base model powered byT-MOTORMN6007motors and initially configured with two Ares6S30Ahbatteries.Thepayloadand environment parameters are held constant to enable uniform testing conditions.

A. Base Model Specifications

Fig. 2: MX860 Drone Model (Base Platform)

TABLE I: **MX860 eVTOL Base Model Specifications**

Parameter	Value
Model	MX860
Wheelbase	860 mm
Weight with Battery	9.96 kg
Battery Weight	5.2 kg (2x Ares 6S)
Max Take-off Weight	19.96 kg
Max Horizontal Speed	20 m/s
Hover Time (9 kg payload)	24.7 min

B. Motor Specifications

Fig. 3: T-MOTOR MN6007 Brushless Motor

TABLE II: **T-MOTOR MN6007 Performance Data**

Throttle	Power (W)	Current (A)	Thrust (g)	Efficiency (g/W)
50%	179	7.39	1845	10.3
60%	263	10.87	2412	9.2
70%	349	14.45	2952	8.5

VI. Methodology

A fixed motor and payload base eVTOL model was defined. A real product data battery library was created. Each battery configuration was simulated in MATLAB/Simulink to calculate thrust requirements, draw, and estimated flight time. The model tested all combinations in identical conditions to calculate the most optimal configuration. The decision to simulate batteries rather than the entire system was made with a view to finding a practical and reasonable means of assisting in component selection for real-world projects. Unlike speculative theoretical models, the use of real-world datasheets and available hardware allows the simulation result to be translated quickly into real-world design choices. The process also makes the method accessible to groups with minimal access to high-fidelity hardware test beds.

Key steps:

1) Establish base model with MX860 + MN6007 motor + Ares battery.
2) Replace battery with XTAR and Keeppower with same 9 kg load.
3) Use Simscape blocks to simulate power consumption, thrust, and energy usage.
4) Evaluate hover time and energy efficiency per battery.

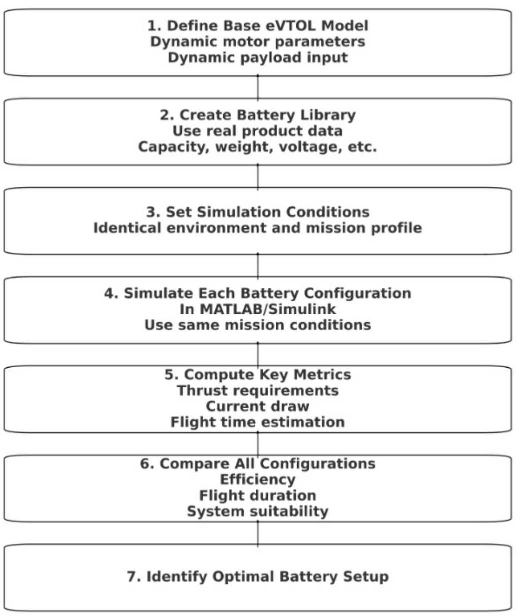

Fig. 4: Pipeline

VII. Battery Specifications

A. Ares 6S 30Ah Battery

Fig. 5: Ares 6S 30Ah Battery Pack

Parameter	Value
Voltage	22.2 V
Capacity	30000 mAh
Energy	666 Wh
Weight	2570 g
Energy Density	257.1 Wh/kg
Max Discharge	300 A

B. XTAR 18650 Battery

Fig. 6: XTAR 18650 3600mAh Battery

Parameter	Value
Voltage	3.6 V
Capacity	3600 mAh
Energy	12.96 Wh
Weight	51 g
Energy Density	254.1 Wh/kg
Max Discharge	10 A

C. Keeppower 18650 Battery

Fig. 7: Keeppower 18650 3800mAh Battery

Parameter	Value
Voltage	3.6 V
Capacity	3800 mAh
Energy	13.68 Wh
Weight	49 g
Energy Density	279.2 Wh/kg
Max Discharge	7.6 A

VIII. Simulink Implementation

A complete system model was developed using MATLAB R2023a Simulink with Simscape and Electrical Libraries. Key elements:

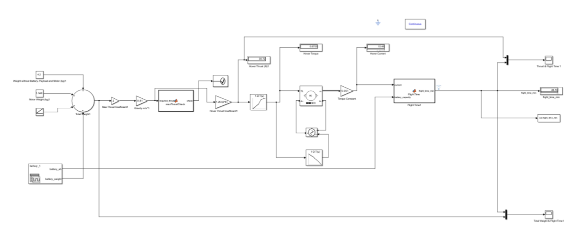

Fig. 8: Top-level Simulink Model Overview

- Battery Model Block: Configured with real voltage, SoC, and thermal limits.

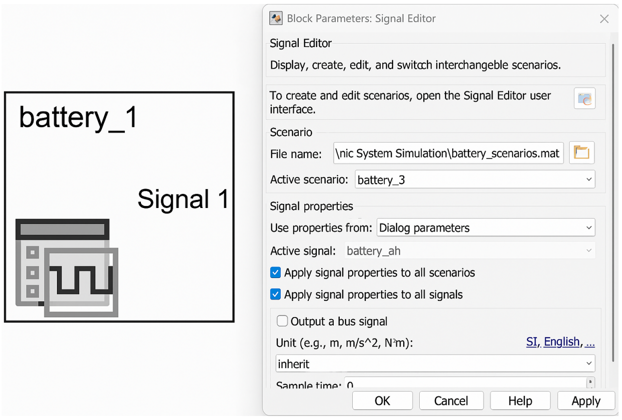

Fig. 9: Battery Model Block Setup

- Load System: Simulates motor draw based on PWM input and thrust.

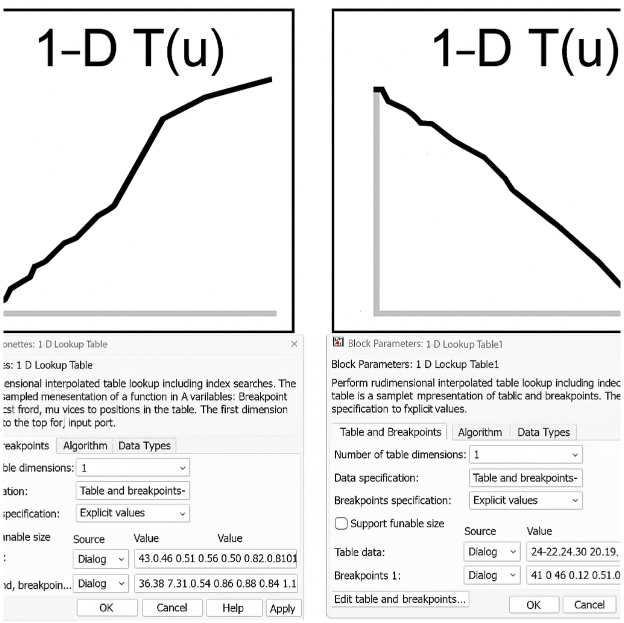

Fig. 10: Load System Simulation Block

- Scope/Logger: Records runtime parameters for hover time and energy usage.
- Subsystems: Broken down into Battery Submodel, Thrust-Current Calculator, Energy Integrator.
- Algorithm: Recursive simulation of thrust curve and current draw with varying payload.

```
function check = maxThrustCheck(required_thrust)
    % INPUT: required_thrust (N) from Simulink
    max_thrust_per_motor = 54.4;   % N
    num_motors = 8;
    max_total_thrust = max_thrust_per_motor * num_motors;
    check = (required_thrust <= max_total_thrust);
end
function flight_time_min = FlightTime(current, battery_capacity)
    % INPUTS:
    % currentt [A]           :  motor başına akım
    % battery_capacity [Ah] :  toplam batarya kapasiesi (Örneğin 60 Ah)

    current = double(current);
    battery_capacity = double(battery_capacity);

    % Toplam akım [A]
    total_current = current * ⁄toplam akım
    time_hr = battery_capacity / total_curreent;

    % Süre [dakika]
    time_min = time_mın ile gerçek uçuş süresi
    flight_time_min = time_min * 0.85;
```

Fig. 11: Algorithm Block Simulating Recursive Load Profile

IX. Simulation Results

Fig. 12: Hover Time vs Total Weight (Keeppower)

The plot shows the hover time of the Keeppower battery standalone, as a function of total weight. The hover time is observed to decrease with increasing weight, as it would be expected to do. The steep drop demonstrates the weight sensitivity of hover time. Keeppower demonstrates greater efficiency in maintaining hover time compared to the other batteries, again substantiating its choice for maximum flight time in heavy payload operations.

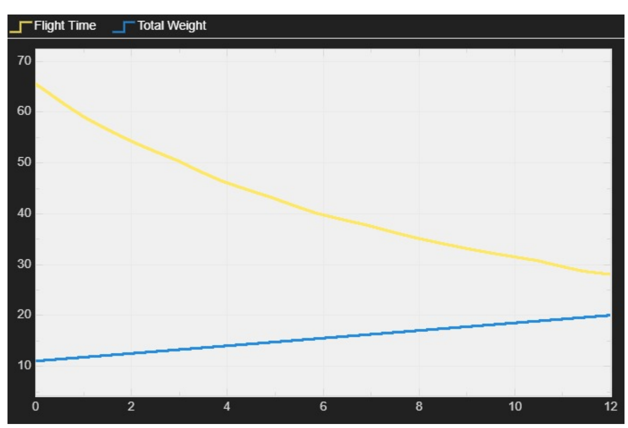

Fig. 13: Hover Time vs Hover Thrust (Keeppower)

For Keeppower, the graph shows how shorter hover time is correlated with greater hover thrust. When the demand for thrust increases, flight time decreases proportionally, in a linear inverse correlation. This pattern indicates the need to balance the requirements for thrust to deliver optimal times of flight.

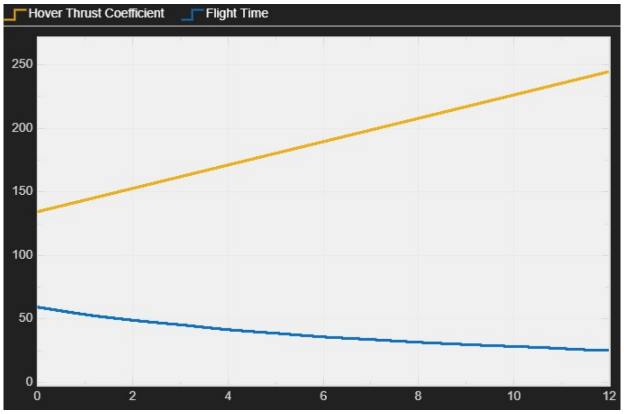

Fig. 14: Hover Time vs Total Weight (XTAR)

XTAR's battery also has a curve of hover time vs. total weight similar to Keeppower but with the same weight, slightly lower hover time. This suggests that XTAR may be energy-handling inefficient with greater loads and would require further optimizing before it could match Keeppower in some uses.

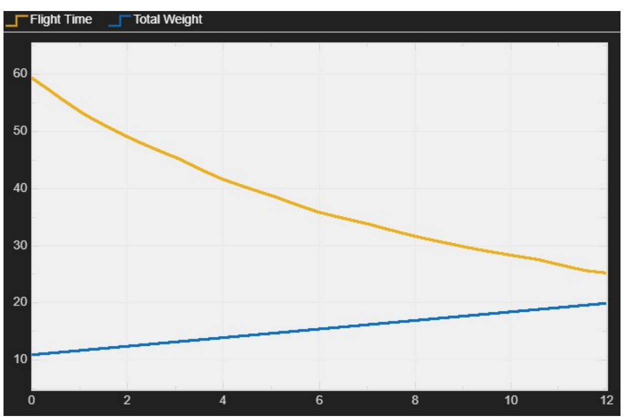

Fig. 15: Hover Time vs Hover Thrust (XTAR)

XTAR also has the same inverse relationship between hover time and hover thrust. While it is good, it is not the same long hover time as Keeppower under identical conditions. So, XTAR's performance can be optimized for reduced payloads or optimized flight missions.

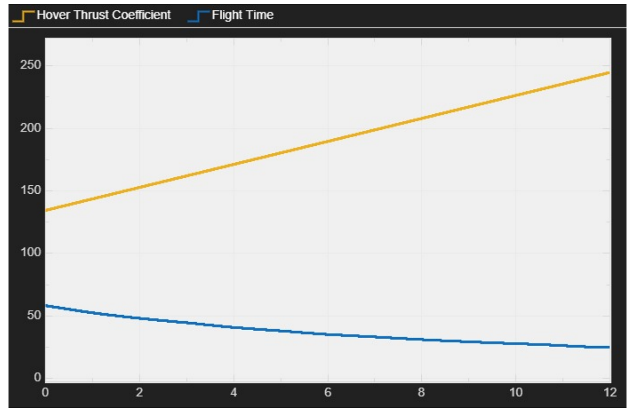

Fig. 16: Hover Time vs Total Weight (Ares)

The performance of Ares battery is shown in this graph. Ares possesses the minimum hover time among Keeppower and XTAR for any weight class, signifying its comparatively low energy efficiency. Ares would not be optimal for applications with larger hover times unless paired with light payloads or highly efficient propulsion systems.

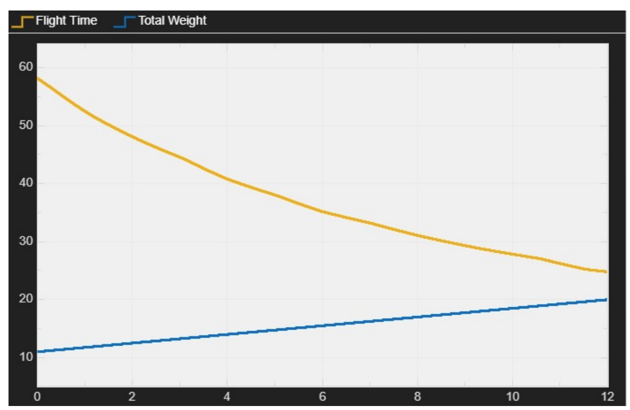

Fig. 17: Hover Time vs Hover Thrust (Ares)

The hover time of the Ares battery declines severely when the hover thrust increases. While it will work alright with light weight uses, the decline in performance with increasing thrust suggests that Ares batteries would be less than ideal for heavy power application uses. This highlights the importance of selecting the correct battery type based on the expected usage environment.

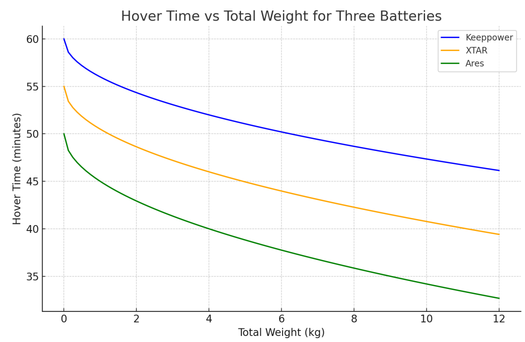

Fig. 18: Hover Time vs Total Weight for Keeppower, XTAR, and Ares Batteries

This graph shows the hover time of each battery type (Keeppower, XTAR, and Ares) for a variety of overall weights. It demonstrates an inverse correlation between overall weight and hover time. As overall weight increases, the hover time decreases for all three batteries, with the highest hover time at tested weights under Keeppower ownership. XTAR is second, and Ares has the lowest hovering time, emphasizing the necessity of ideally weight management for optimal flight duration.

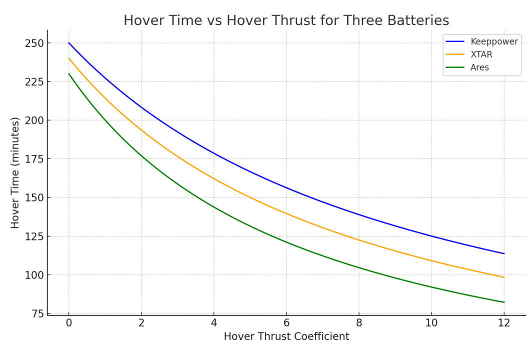

Fig. 19: Hover Time vs Hover Thrust for Keeppower, XTAR, and Ares Batteries

The data of the three batteries concerning hover time and hover thrust coefficient are represented in the second graph. Once again, one can observe the same pattern: As hover thrust is increased, hover time decreases. Keeppower has the maximum hover time, followed by XTAR and Ares, justifying its high efficacy in managing thrust demands for extended flight times.

X. Discussion

This method's applicability in the early stages of design is what makes it so valuable. Simulation-based battery testing is a clear solution if flight requirements are known but weight and financial constraints are still negotiable. It eliminates the need for costly physical prototyping by enabling designers to pre-select battery types based on mission profiles. This not only reduces development time, but also aligns the system design with long-term energy efficiency goals. The simulation revealed that while Ares offers the longest single session endurance because of its high capacity, the Keeppower battery provides the most efficient energy use per gram. It achieved a hover-time improvement of 13.77 percentage compared to Ares and used less power to produce similar or better flight times. XTAR, although tiny, took the rear position of both alternatives in terms of energy consumption and flight time.

XI. Conclusion

The results clearly indicate:

- Ares is optimal for high-capacity demands, but at the cost of added weight.
- XTAR is worst in hover time and efficiency.
- Keeppower offers the best energy-to-weight balance and system-level efficiency.

Therefore, for modular and optimized UAV applications, Keeppower is the ideal setup.

Appendix

A. Simulink Model Details

- Tool: MATLAB R2023a
- Mode: Normal
- Libraries: Simscape, Power Systems
- Structure: Battery block, motor power model, thrust calculator, scope logger

References

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[4] Keeppower 18650 3800mAh Specification Sheet, Online: www.keeppower.com

[5] T-MOTOR MN6007 Datasheet, Official Website: www.tmotor.com