Solar-Powered, Long-Endurance UAV for Real-Time Onboard Data Processing

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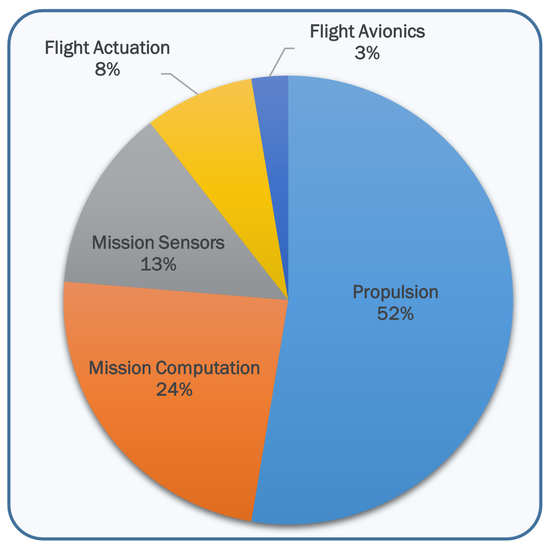
ABSTRACT

In recent years, we have seen an uptrend in the popularity of unmanned aerial vehicles (UAVs) applying them in countless scenarios, ranging from agricultural observation to mobile base stations. The key aspects of the progress of UAVs are endurance and safety. For endurance, a solar-powered, highly efficient aircraft managing the distribution of its power resources to the different subsystems holds the potential for continuous flight during daylight hours. A novel propulsion system optimization tool was developed that determines the optimal propeller and motor combination(s) for electric, fixed-wing unmanned aircraft, given desired mission requirements. The tool was experimentally validated by means of flight test as well as demonstrated in simulation, showing significant energy savings. Current work focuses on final development of the solar flight test aircraft, specifically focusing on miniaturization, performance, and efficiency improvement of the aircraft systems for flight test demonstration in the upcoming flight season.

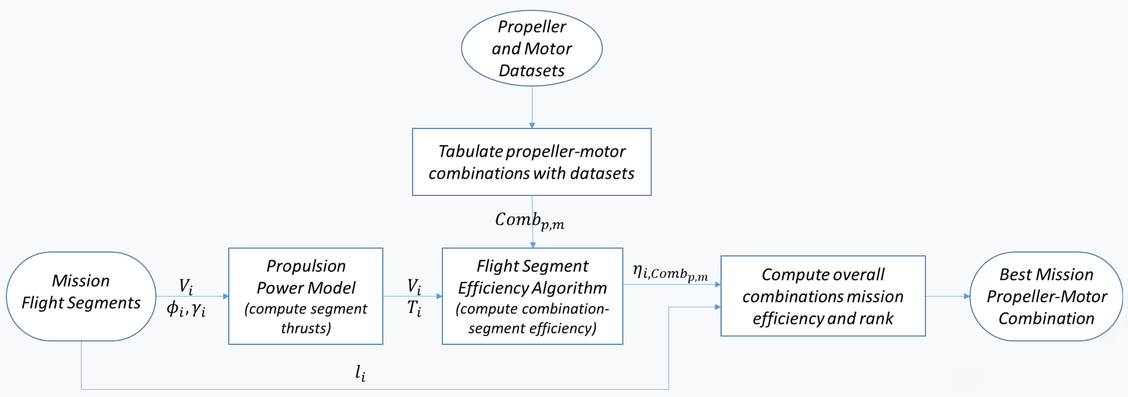
PROPULSION OPTIMIZATION

Limited on-board energy significantly limits flight time and usability of UAVs. The propulsion system plays a critical part in the overall energy consumption of the UAV; therefore, it is necessary to determine the most optimal combination of possible propulsion system components for a given mission profile, i.e. propellers, motors, and electronic speed controllers (ESC). Hundreds of options are available for each of the components without scientific advice for selecting proper combinations.



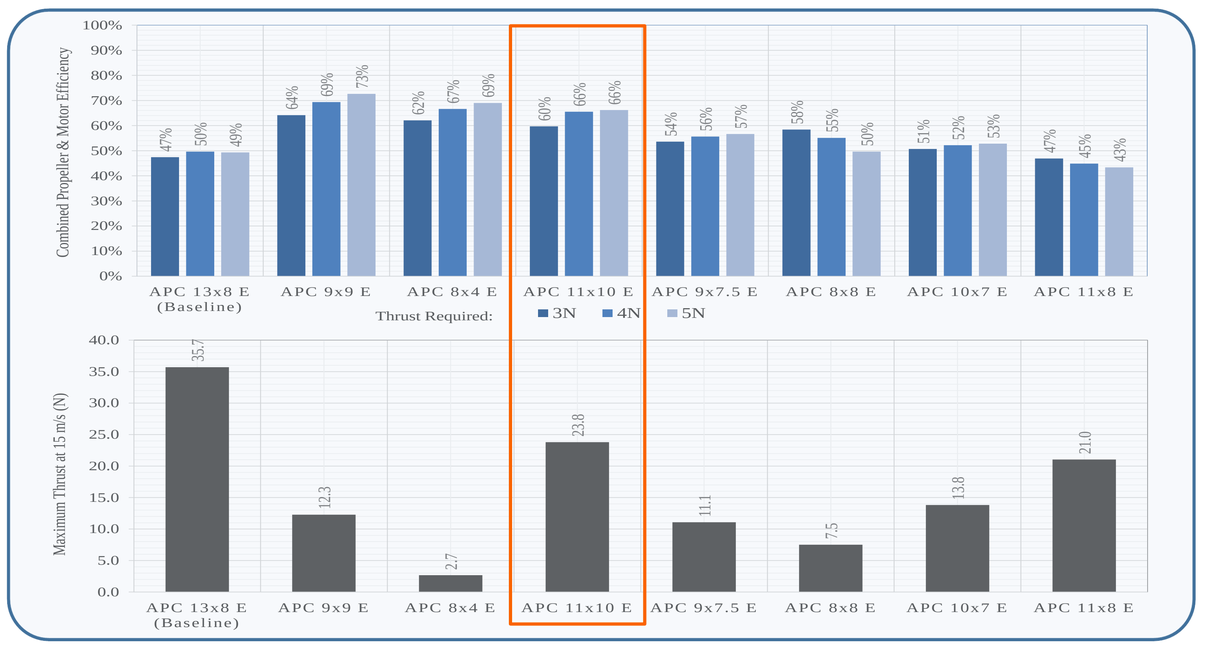
A propulsion system optimization tool was developed that determines the optimal propeller and motor combination(s) for electric, fixed-wing unmanned aircraft, given desired mission requirements. Specifically, missions are broken down into segments with velocity and thrust requirements, computed from flight path using a high-fidelity aircraft power model. The optimization tool then estimates the required propeller rotation rate, followed by the power consumption for each segment and propeller-motor combination. It then integrates segments into missions for each combination and tabulates the results, sorting by overall efficiency. Additionally, the tool considers aircraft safety by estimating the maximum thrust each combination can produce at stall and upset recovery conditions.

Propulsion System Optimization Tool Process Diagram



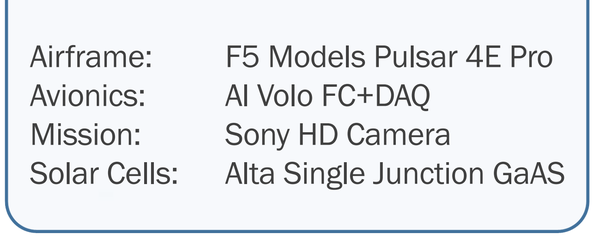
VALIDATION AND SIMULATION

Experimental validation testing was performed through flight testing of a fixed-wing UAV testbed. For practical considerations, the testing was constrained to level flight at 20 m/s, requiring between 3-5 N of thrust. Additionally, testing was bound to an existing motor, yet allowed any of hundreds of propellers. The top results were compared to the baseline in terms of total system efficiency and maximum thrust at stall speed (15 m/s). A propeller, with greater efficiency and sufficient stall thrust, was selected for flight testing against the baseline combination. The flight test demonstrated that the selected combination required 20% less power then the baseline, thereby validating the optimization tool.

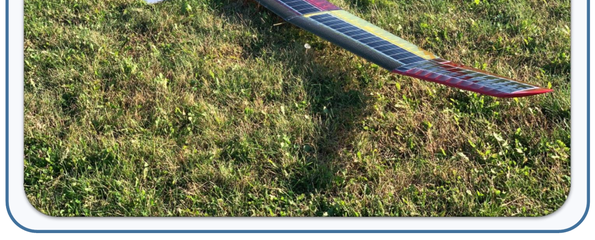


Simulations were then conducted for field coverage and long-distance, multi-site inspection missions with thousands of aircraft compatible motor-propeller combinations. The results showed power saving of 50-75% compared to the baseline combination.

Field Coverage



Multi-Site Inspection



SOLAR AIRCRAFT DEVELOPMENT

The solar flight test aircraft is currently in final development. Ongoing effort has been focused onto the airframe, avionics, mission, and solar-collection systems, especially miniaturization, performance, and efficiency improvement. Flight testing demonstration is expected in the upcoming 2020 flight season.

Specifications

Wingspan:	4.0 m (13.1 ft)
Mass:	3.1 kg (6.8 lbs)
Solar Power:	64 W
Battery Cap.:	302 W-hr
Airframe:	F5 Models Pulsar 4E Pro
Avionics:	AI Volo FC+DAQ
Mission:	Sony HD Camera
Solar Cells:	Alta Single Junction GaAS

REFERENCES

[1] O.D. Dantsker, S. Imtiaz, and M. Caccamo, “Electric Propulsion System Optimization for Long-Endurance and Solar-Powered Unmanned Aircraft,” Best Student Presentation at AIAA/IEEE Electric Aircraft Technologies Symposium, Aug. 2019.

[2] O.D. Dantsker, S. Yu, M. Theile, M. Vahora, and M. Caccamo, “Continued Development and Flight Testing of a Long-Endurance Solar-Powered Unmanned Aircraft: UIUC-TUM Solar Flyer,” Accepted to the AIAA SciTech Forum, Jan. 2020.

More information and publications available at:
http://rtsl-edge.cs.illinois.edu/UAV/

FUTURE WORK

- Optimize Mission Profiles and Aircraft Configuration
- Complete Aircraft Development
- Long Endurance Solar Powered Flight

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