Power-Aware Emulation Environment For Long-Endurance Solar UAVs

CPS: Breakthrough: Solar-powered, Long-endurance UAV for Real-time Onboard Data Processing. M. Caccamo (PI), CNS-1646383

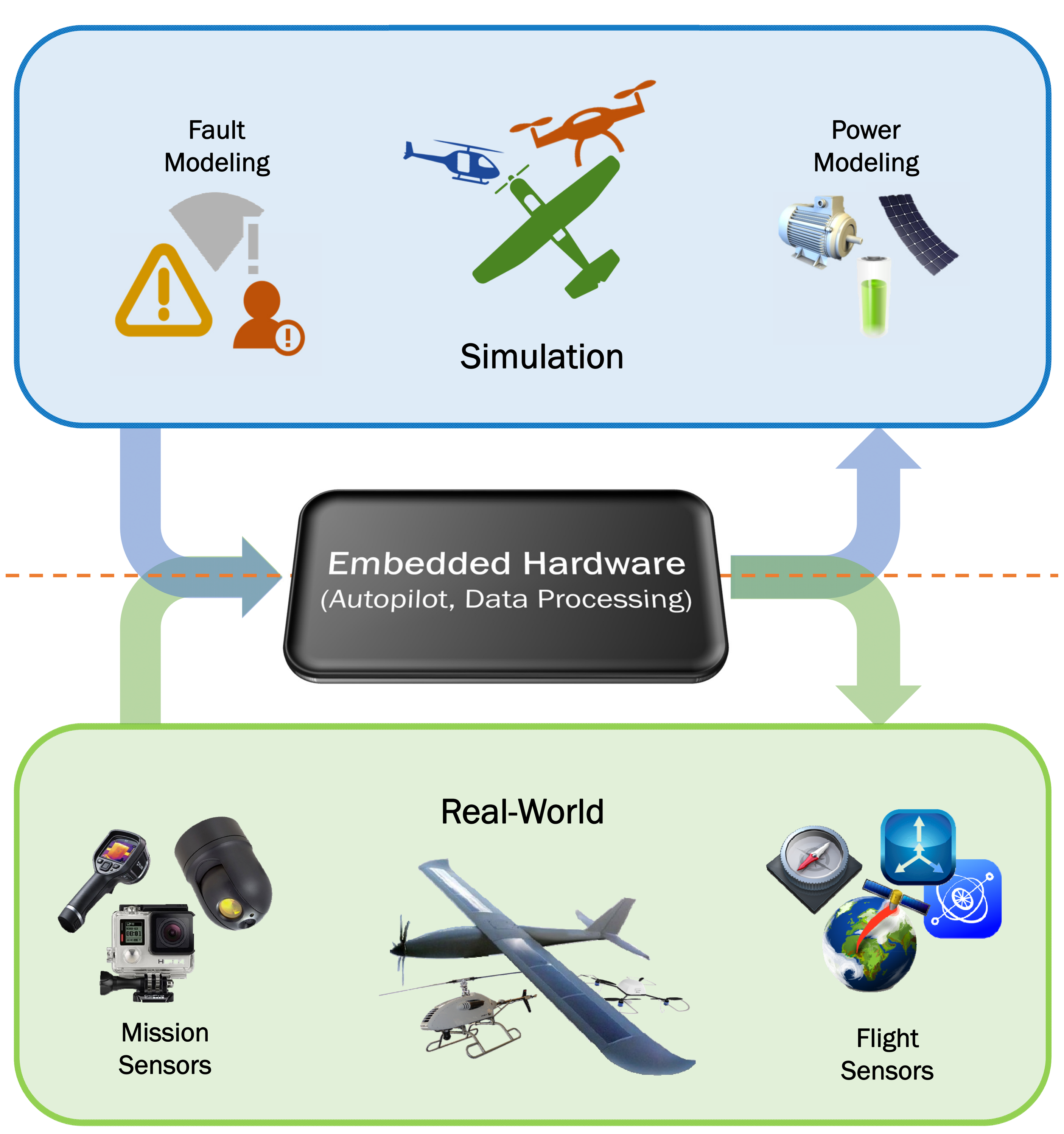
ABSTRACT

This project aims to expand the theoretical and practical foundations for the design and integration of UAVs capable of real-time sensing and processing from an array of visual, acoustic and other sensors. The traditional approach for small size UAVs is to capture data on the aircraft, stream it to the ground through a high power data-link, process it remotely, perform analysis, and then relay commands back to the aircraft as needed. Conversely, this research targets a solar-powered UAV with a zero-carbon footprint that carries a high performance embedded computer capable of budgeting at run-time the available power between the propulsion/actuation subsystems and the computing and communication subsystems. The ambitious plan is to develop a light weight and efficient aircraft capable of maneuver-aware power adaptation and real-time video/sensor acquisition and processing for up to 12 hours of continuous flight (this limit being set by daylight hours).

To achieve this goal a rapid-prototyping environment is needed to enable fast and inexpensive development and testing. Additionally parameterizable mathematical power models are a necessity for power-aware path-planning. The joint evaluation of both parts proves the concept and sets a baseline for further development of the long-endurance solar UAV.

EMULATION ENVIRONMENT

In order to rapidly develop an autopilot system as well as embedded data processing algorithms, it is invaluable to have a high fidelity simulation of the applicable scenario. The Emulation Environment (UAV-EE) is not only able to combine several different simulations (flight, power, failure, etc.) but further emulates the interface to the embedded hardware.

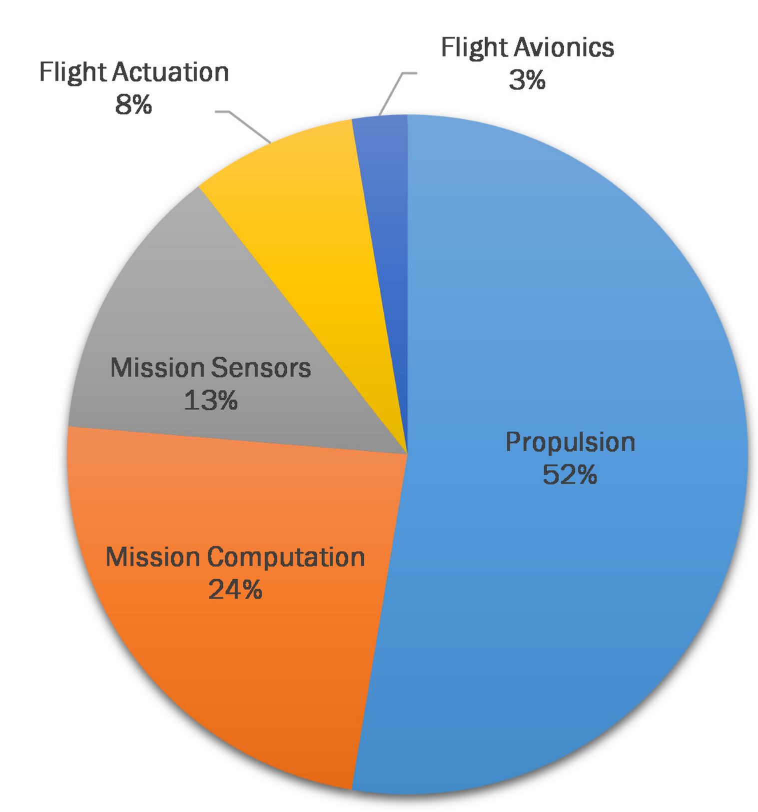


Advantages of the Emulation Environment

- Rapid and inexpensive prototyping of hardware and software
- Interface testing of the embedded hardware
- Evaluation of the embedded real-time computation
- Safe simulation of fault scenarios
- Variety of environments, vehicles, and sensors possible

POWER MODELING

The power consumption on a computationally intensive UAV breaks down into aircraft (propulsion, flight actuation, and flight avionics) and mission (computation and sensors) requirements. The presented power model focuses on the propulsion power (in a light-weight and small sailplane, it constitutes approximately 50% of the total power consumption).



Propulsion Power Modeling

$$P_{ss} = \frac{gm|\vec{v}|}{C_{LD}} \frac{\cos\gamma + C_{LD}\sin\gamma}{\cos\phi}$$

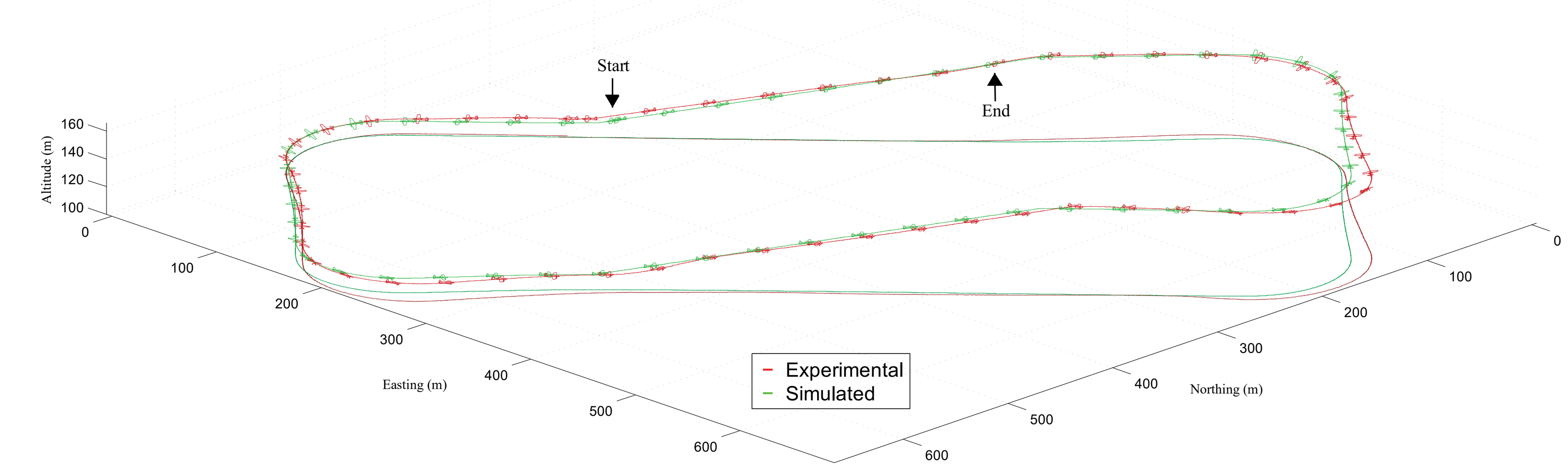
$$P_{dyn} = m(\vec{v} \cdot \vec{a})$$

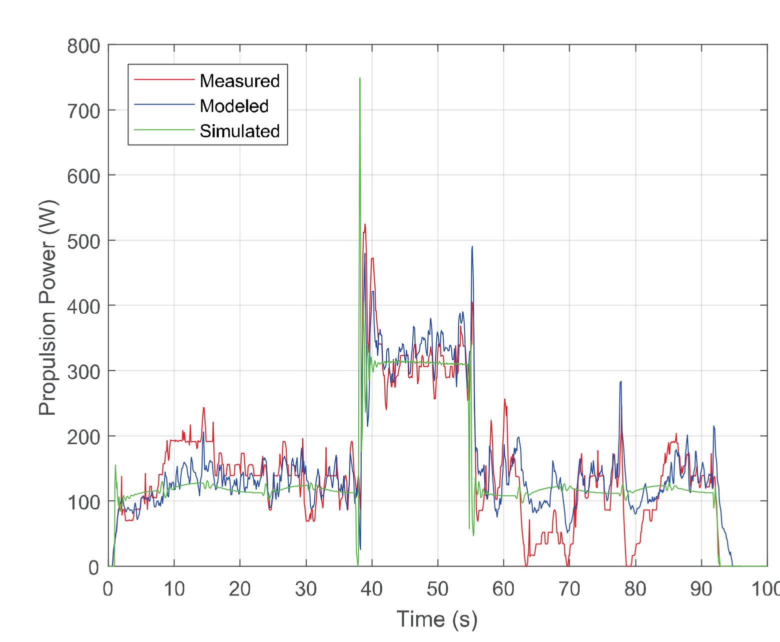
$$P_{propulsion} = \frac{P_{ss} + P_{dyn}}{\eta_m \eta_p}$$

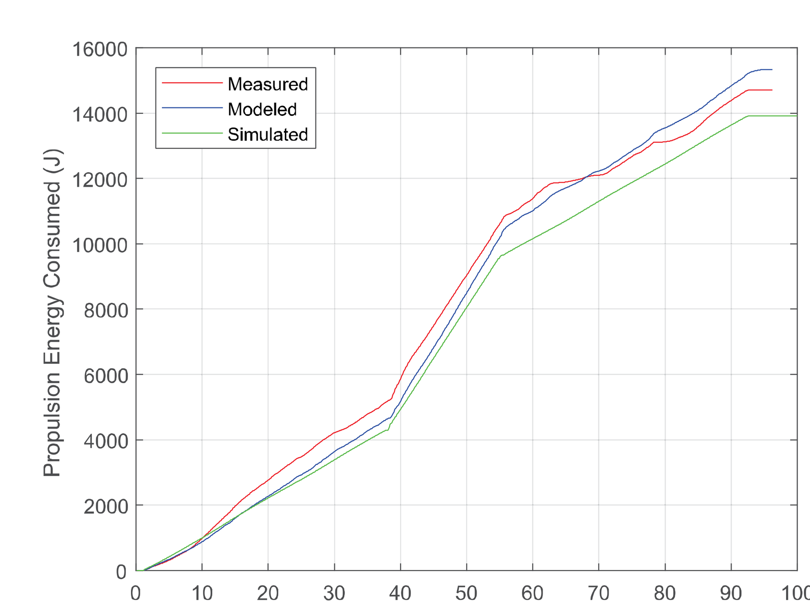
g, m, C_{LD}	gravity, mass, aerodyn. coefficient
$\vec{v}, \vec{a}$	velocity, acceleration
γ, ϕ	climb and roll angle
η_m, η_p	motor and propeller efficiency

EVALUATION

The integration of the proposed UAV power model into the emulation environment was experimentally validated using a fixed-wing UAV testbed. Below is a comparison between experimental (measured and modelled) and simulated flight paths, power, and energy consumed using the same autopilot configuration.







In the power curves, the blue curves correspond to the power model output using measured sensor data and the green curves correspond to the power model output using simulated sensor data. The red curves correspond to measured power values.

FUTURE WORK

Extend and Refine Power Models

Integrate Solar Model

Power-Aware Path Planning and Control

Long Endurance Solar Powered Flight

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