North Dakota Renewable Energy Council
Phase III Interim Report

Solar Soaring Power Manager

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Introduction

This document describes the accomplishments and current status of projects during phase III of the Solar Soaring Power Manager project. These activities took place at Packet Digital's facilities in Fargo, ND, as well as at the U.S. Naval Research Laboratory (NRL) facilities. Progress has been made on all phase III deliverables and the project is on track as per the original proposal. A status update of each deliverable is listed below.

Objective:

This research and development project will create a solar soaring power management system for Unmanned Aircraft Systems (UAS) to initially double fly times and ultimately provide unlimited endurance powered by solar energy. This will be achieved by harnessing solar energy with high-efficiency, flexible photovoltaics and auto-soaring technology to enable the UAS to autonomously gain lift from rising hot air along with advanced power management algorithms. Packet Digital will create an advanced solar power management and distribution system (PMAD) combining flexible, high-efficiency power conversion circuitry to dramatically extend flight times in unmanned aircraft.

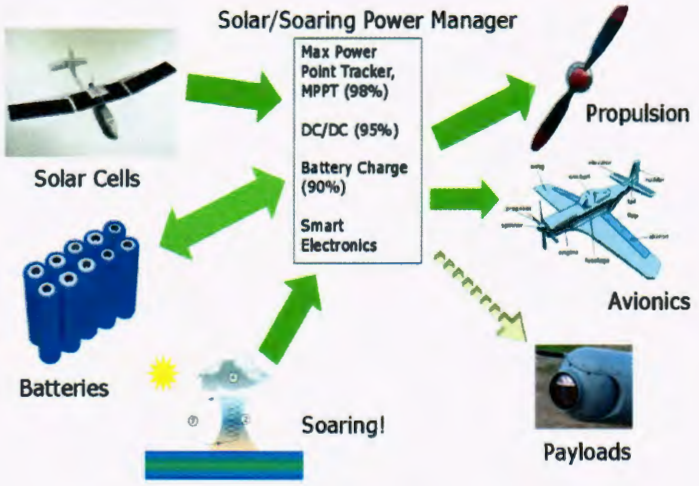

Figure 1: System Overview

This product will optimize the power conversion from the solar array to the batteries, from the batteries to the electronics, and from the batteries to the propulsion motor. The power conversion circuitry will provide state-of-the-art, high-efficiency power while the microprocessor will run advanced algorithms for Maximum Power Point Tracking (MPPT) and auto-soaring.

Schedule

This project is divided into three phases, of which phases I and II are 9-month duration and phase III is 12 months. This interim report covers the progress made during months 7-9 of phase III.

Deliverables

Phase III Deliverables:

- Produce a solar cell covering the desired spectrum with 30-35% efficiency, with a target of 40%
- Perform multiple flight tests utilizing a solar-enabled, extended-endurance UAS
- Achieve power management system with greater than 90% efficiency for typical loads, with a target of 95%, to extend battery life sufficiently to survive nighttime flight
- Innovate Maximum Power Point Tracker (MPPT) algorithm for extracting maximum charging capacity from the solar cells
- Develop a manufacturing plan for a commercial, extended-endurance, solar UAS

Status Updates

Objective 1: Solar Cell Development

See Appendix A.

Objective 2: Test Flights

See Appendix A.

Objective 3: Power Management Update

Electronic Speed Control

An updated hardware revision of the electronic speed control (ESC) was developed. The hardware update allows the end user the ability to program firmware updates. The software required to upload the firmware updates is currently under development. The size and weight of the updated ESC hardware was reduced to allow better integration into multirotor frames. The weight of the updated revision is 24 grams versus 43 grams for the previous revision. ESC board size was reduced to 27mm x 44mm from the previous 32mm x 49mm dimension. The maximum supported battery voltage remains at 6 cell maximum LiPo voltage and the continuous current rating has been reduced to 35 amps versus 55 amps of the previous revision.

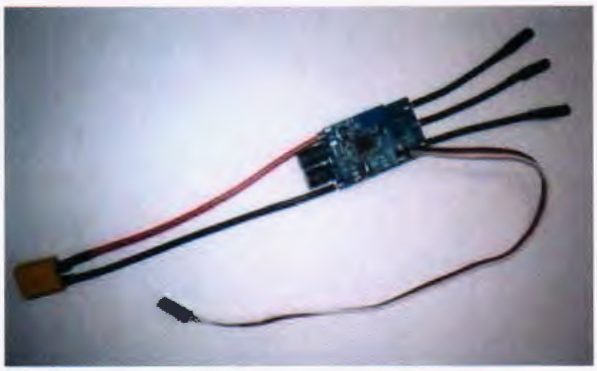

Figure 2: Commercial smart battery prototype

Smart Battery

Packet Digital has partnered with a quality Lithium Ion battery manufacturer, headquartered in the US, to bring a version of our smart battery to market for high-end and commercial drones.

See Appendix A.

Objective 4: Maximum Power Point Tracker Update

An update to the maximum power point tracker is ready for fabrication. Key improvements include:

- Support for higher voltage inputs
- More efficient and accurate current sensing
- Buck/boost capability

These improvements will enable the MPPT to work with a wider variety of solar array and battery configurations. Design reviews occurred at the end of May and the boards will be sent out for fabrication shortly.

Objective 5: Manufacturing Plan

A comparative structural analysis of the composite wing design is being performed with several types of core material, as well as the balsa-and-foam stock wing, to validate the design prior to flight testing. Test wings are currently being constructed at c2renew's facility in Fargo using a lower cost foam core for initial test purposes. They are expected to be ready for airframe fit up in June.

See Appendix A.

Budget

Total project cost for phase III is expected to be $1,125,000, of which $500,000 is provided by NDIC, and $625,000 is provided by the Naval Research Lab as matching funds. Table 2 lists the budget estimate for Phase III and Table 3 lists the budget status as of May 31, 2017.

Project Associated Expense	NDIC's Share	Naval Research Lab Share	Total
Total Personnel Costs	$390,000	$505,000	$895,000
Software Costs/Materials	$110,000	$120,000	$230,000
Total	$500,000	$625,000	$1,125,000

Table 2: Phase III Budget Estimate

Projected Associated Expense	NDIC Share	NRL Share	Packet Digital Share	Total
Total Personnel Costs	$425,903.05	$587,541.96	$65,517.97	$1,078,962.98
Software Costs/Materials	$74,096.95	$20,359.23	$0.00	$94,456.18

Total	$500,000.00	$607,901.19	$65,517.97	$1,173,419.16

Table 3: Interim Budget Status as of May 31, 2017

Summary

Phase III Deliverables:

- Solar cell development
  - The Naval Research Lab has fabricated wings with several sets of solar cells and evaluated their performance.
- Test flights
  - The Naval Research Lab performed ground testing with the Packet Digital electronics and battery to test performance. An endurance flight will be scheduled later in the year. Wings are being produced at c2renew and will be tested with an airframe in North Dakota this summer.
- Power Management System
  - The electronic speed control has been revised to target multi-rotor applications and a prototype has been produced and is currently being tested.
- Maximum Power Point Tracker
  - The MPPT is being adapted to reduce cost and operate over a wider input and output voltage range, making it compatible with a wider range of aircraft.
- Manufacturing Plan
  - c2renew continues to make progress on the wing manufacturing. Simulations are complete and the initial wings are being assembled now.

Significant progress has been made in phase III of this project and Packet Digital is on track to complete the objectives as per the original project timeline. The wing design is behind schedule, but it is anticipated that wings will still be complete by the end of the project. NRL is also on track in terms of the solar cell development.