

Contract No. R-028-038
“Solar Soaring Power Manager Phase III”
Submitted by Packet Digital LLC
Principal Investigator: Andrew Paulsen

PARTICIPANTS

Sponsor	Cost Share
Naval Research Lab	<u>\$625,000</u>
Subtotal Cost Share	\$ 625,000
North Dakota Industrial Commission	<u>\$500,000*</u>
Total Project Cost	\$1,125,000*

Project Schedule – 12 months	Project Deliverables:
Contract Date – September 16, 2016	Quarterly Report: November 30, 2016 ✓
Start Date – September 1, 2016	Quarterly Report: February 28, 2017 ✓
Completion Date – May 1, 2018	Quarterly Report: May 31, 2017 ✓
	Interim Report: August 31, 2017 ✓
	Final Report: No later than May 1, 2018 ✓

OBJECTIVE/STATEMENT OF WORK:

The overall goal of this project is to 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. In the first phases of the project the applicant accomplished the following:

- Produced a 37.6% efficient solar cell.
- Solar wings constructed and successfully flown, utilizing Packet Digital’s power system (MPPT, PMAD and Smart Battery.)
- Produced Maximum Power Plant Tracking (MPPT) hardware and algorithm tuned for high efficiency solar arrays and variable solar input environment. This technology has other solar applications and has seen interest from other companies.
- Produced a smart battery with approximately 440 watt hour capacity.
- Produced a power manager for all power components with greater than 95% efficiency.
- Produced an optimized torque motor control which improves propulsion system efficiency and reduced airframe vibration.

The third and final phase of the project will complete the following:

- Fabricate solar UAS wing using high efficiency solar cells
- Integrate power management and solar solutions into commercial UAS airframe.
- Flight testing, both at NRL and in ND.
- Develop a manufacturing plan for a commercial extended endurance solar UAS

The applicant will collaborate with c2renew, Chiptronics, Comdel Innovations and Zepher, Inc. to establish North Dakota molds, materials, and manufacturing process. Ultimately, this project could create manufacturing opportunities in North Dakota for a variety of products including solar arrays and UAS along with product development opportunities for North Dakota companies.

STATUS:

The contract has been drafted and forwarded to Packet Digital.

9/16/2016

Contract has been fully executed.

12/1/2016

First quarterly report has been received. The summary in the report states:

Phase III Deliverables:

- Solar cell development
 - NRL has continues to make progress on the multijunction cells, both type III-IV and GaAs cells.
 - Work has also been done on producing lightweight, robust, glass-free modules that can be integrated into the UAS with almost no increase to the system weight.
- Test flights
 - Initial solar test flights with the NRL at Aberdeen Proving Grounds were successful at proving the validity of the Packet Digital power system as well as the solar powered system. The flight was scheduled from sunup to sundown. The extended endurance aircraft flew the scheduled nearly 11 hours and landed with a charge on the battery.
- Power Management System
 - An updated and improved ESC has been designed and is demonstrating good functionality. Additional testing is ongoing.
- Maximum Power Point Tracker
 - An MPPT board with various design options was designed and characterized. This has provided data to optimize the MPPT in terms of size, weight, cost, and performance.
 - A new MPPT based on the best options from the test MPPT is currently being designed.
- Manufacturing Plan
 - Working with Chiptronics, LLC regarding the assembly of the power electronics
 - Custom solar wing mold design is complete and queued for fabrication through c2renew, Inc.
 - Solar cell lamination process is also being refined.

Significant progress has been made in phase III of this project and Packet Digital is on track to have a complete the objectives as per the original project timeline. NRL is also on track in terms of the solar cell development.

3/2017

Second quarterly report has been received. The summary in the report states:

Phase III Deliverables:

- Solar cell development
 - MJ solar array testing complete and ~26% efficiency was demonstrated.
 - First set of wings with integrated MJ solar arrays were built up and ready for flight testing.
- Test flights
 - No test flights were conducted during this period.
- Power Management System

- New, improved ESC has been designed and tested.
- Commercial smart battery prototypes built and currently being tested.
- Maximum Power Point Tracker
 - Designing buck/boost MPPT. Simulations show very high efficiency.
 - Commercial MPPTs built.
- Manufacturing Plan
 - Initial prototype wing was molded by C2renew. Several modifications to the process were made to improve the production of the second wing.

Significant progress has been made in phase III of this project and Packet Digital is on track to have a complete the objectives as per the original project timeline. NRL is also on track in terms of the solar cell development.

*On March 1, 2017 Packet Digital submitted a request for an additional \$125,000 as an amendment to the contract. The Renewable Energy Council heard the request on April 27, 2017 and recommended approval with contingency repayment requirements. The Industrial Commission accepted the Council's recommendation on May 1, 2017.

6/2017

Third quarterly report has been received. The summary in the report states:

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 completed 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.

11/2017

Fourth quarterly report has been received. The summary in the report states:

Solar cell development

- The Naval Research Lab has fabricated wings with several sets of solar cells that were commercially produced using technology they have developed. Performance has been evaluated both on the ground and in the air.

Test flights

- The Naval Research Lab has performed several all-day test flights with the solar wings and Packet Digital electronics and battery.

Power Management System

- The Smart Battery and Power Management and Distribution system have been successfully tested in both a lab setting and in test flights with the Naval Research Laboratory. A commercial version of the Smart Battery has been developed and displayed at AUVER and Interdrone. Packet Digital is currently working with a distributor to bring this to market along with a related charging system and management software.
- The electronic speed control has been revised to target multi-rotor applications and a prototype has been produced and tested.

Maximum Power Point Tracker

- The high performance MPPT has been successfully tested in a lab setting and in all-day test flights. It has been adapted to reduce cost and operate over a wider input and output voltage range, making it compatible with a wider range of aircraft.
- The maximum power point tracking technology developed under this program has been adapted for commercial use as well. Packet Digital is working with industry partners to include the MPPT in a Program of Record aircraft for the military.

Manufacturing Plan

- c2renew has completed a set of non-solar carbon fiber wings. The same molds and techniques will be used to integrate the solar arrays directly into the upper surface of the wings.
- Packet Digital is working with Johns Hopkins Applied Physics Lab and Solaero to supply the MPPT convert as part of a solar retrofit kit for the Puma UAS.

5/2018

Final report has been received. The summary in the report states:

Solar cells and arrays

- The Naval Research Lab fabricated wings with several sets of solar cells that were commercially produced using technology they have developed. Performance has been evaluated both on the ground and in the air.

Test flights

- The Naval Research Lab has performed several all-day test flights with the solar wings and Packet Digital electronics and battery demonstrating 14 plus hours of endurance.

Power Management System

- The Smart Battery and Power Management and Distribution system have been successfully tested in both a lab setting and in test flights with the Naval Research Laboratory. A commercial version of the Smart Battery has been developed and displayed at AUVER and Interdrone. Packet Digital is currently working with a distributor to bring this to market along with a related charging system and management software. The first order of 20 systems has been received and manufacturing is underway.

- The electronic speed control has been revised to target multi-rotor applications and a prototype has been produced and tested.

Maximum Power Point Tracker

- The high performance MPPT has been successfully tested in a lab setting and in all-day test flights. It has been adapted to reduce cost and operate over a wider input and output voltage range, making it compatible with a wider range of aircraft.
- The maximum power point tracking technology developed under this program has been adapted for commercial use as well. Packet Digital is working with industry partners to include the MPPT in a Program of Record aircraft for the military.

Manufacturing Plan

- c2renew has completed a set of non-solar carbon fiber wings. The same molds and techniques will be used to integrate the solar arrays directly into the upper surface of the wings.
- Packet Digital is working with Johns Hopkins Applied Physics Lab and SolAero to supply the MPPT convert as part of a solar retrofit kit for the Puma UAS.
- A manufacturing plan is in place utilizing Chiptronics in Dunseith, ND for electronics manufacturing, including the MPPT and Smart Battery electronics, as well as battery and smart charger assembly. The first batch order of batteries and chargers are being assembled by Packet Digital and manufacturing will be transitioned to Chiptronics for future builds.

This contract is now closed.

Updated 5/30/2018