

Contract No. R-025-034
“Solar Soaring Power Manager Phase II”
Submitted by Packet Digital LLC
Principal Investigator: Andrew Paulsen

PARTICIPANTS

Sponsor	Cost Share
Packet Digital	\$ 50,000
Naval Research Lab	<u>\$600,000</u>
Subtotal Cash Cost Share	\$ 650,000
North Dakota Industrial Commission	<u>\$350,000</u>
Total Project Cost	\$1,000,000

Project Schedule – 9 months	Project Deliverables:
Contract Date – December 9, 2015	Status Report: December 31, 2015 ✓
Start Date – October 1, 2015	Status Report: March 31, 2016 ✓
Completion Date – June 30, 2016	Final Report: June 30, 2016 ✓

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 phase of the project the applicant accomplished the following:

- Produced a 37.8% efficient solar cell.
- Initiated manufacturing of 22% silicon and 27% GaAs solar arrays.
- Produced wing molds for SBXC airframe to enable building of solar wings.
- Produced flight endurance model that predicts 21 hours of endurance with our system under development.
- Produced Maximum Power Plant Tracking (MPPT) hardware and algorithm tuned for high efficiency solar arrays and variable solar input environment.
- Produced a smart battery with approximately 440 watt hour capacity.
- Produced a power manager for all power components with greater than 95% efficiency.
- Produced laboratory bench hardware for testing of full electronic system.

In the second phase of the project the applicant will:

- Produce a solar cell covering the desired spectrum with 30-35% efficiency, with a target of 40%.
- Implement a solar soaring algorithms into a prototype of a commercially feasible product.
- Design MPPT and Power Management and Distribution (PMAD) system that is compatible to the commercial industry standards for unmanned aircraft that improves the performance of UAVs similar to the Altavian Unmanned Aircraft Systems (UAS) manufactured by ComDel. The industry compatible system will be integrated into a solar unmanned aircraft and tested at the Northern Plains Test Site.
- Develop a hybrid smart battery combining multiple storage technologies to be charged by solar in flight;

- Produce an optimized torque motor control prototype, with a target of improving propulsion system efficiency 5% and reducing airframe vibration;
- Test all prototyped solutions integrated in a labor environment.

STATUS:

The contract has been signed.

1/6/2016 - First status report received. A copy of the report is posted on the website. It states in its summary:

Phase II Deliverables:

- Solar cell development
NRL is currently developing inverted metamorphic solar cells with a third party with the potential to achieve between 30 and 33% efficiency. During this Phase these solar cells will be integrated into the UAS wings and included in the initial solar UAS flight testing.
- Update power system to support commercial UAS
Initial prototypes of the smaller, more flexible MPPT and PMAD have been received and are undergoing testing.
- Hybrid smart battery
Initial hybrid smart battery design is underway. Discussions have been initiated with commercial UAS fuel cell vendors. Feature and cost comparisons are in progress.
- Optimized torque motor control
A prototype design is underway and is currently being tested with the airframe motor. Performance measurements are in progress utilizing prototype hardware.
- Implement solar soaring algorithms
The platform hardware has been tested in flight and software development is in progress. NRL has performed flight tests in early November at Aberdeen Proving Grounds and logged more than 12 hours of flight time, including more than two hours of latched thermal soaring. Conversion of the MATLAB source code is the next step in the implementation process.

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

4/6/2016 - Second status report received. A copy of the report is posted on the website. It states in its summary:

Phase II Deliverables:

- Solar cell development
NRL has fabricated 5 junction solar cells capable of nearly 37% efficiency, 6 junction cells are in process.
The manufacturing process for flexible solar arrays which will incorporate solar cells into the wing skins has been defined and prototyped.
- Update power system to support commercial UAS
Initial prototypes of the smaller, more flexible MPPT and PMAD have been developed and are undergoing testing.

- Hybrid smart battery
Incorporating graphene LiPo batteries into the current smart battery to reduce impedance while minimizing impact to capacity.
Continuing to evaluate electrical and mechanical impact of adding a hydrogen fuel cell into our UAV.
- Optimized torque motor control
Optimized torque control motor controller is being characterized against industry standard motor controls. Firmware and tuning optimizations are ongoing.
- Implement solar soaring algorithms
Converting algorithms to Python code.
Targeting Xilinx Zynq devices are one possible implementation target.

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

7/20/2016 - Final report received. A copy of the report is posted on the website. It states in its summary:

Phase II Deliverables:

Solar cell development

- GaAs InP MJ cells have achieved 37.6% efficiency under 1 sun illumination.
- New Perovskite/Si solar cell identified and shows promise of offering 30% efficiency in a low cost manufacturing process.
- Solar wings constructed and successfully flown, utilizing Packet Digital's MPPT, PMAD, and Smart Battery.

Update power system to support commercial UAS.

- Smaller, lighter, GaN MPPT has been designed and tested. Efficiency is >95%.
- Smaller, lighter, PMAd-lite has been designed, tested and flown. It functions perfectly.
- The Botlink Extended Range and Data airframe was flown at the North Dakota Test Site as part of the NASA UTM project.

Hybrid smart battery

- Incorporated graphene LiPo batteries into the current smart battery to reduce impedance while minimizing impact to capacity.
- UAS-compatible hydrogen fuel cell systems were evaluated and initial design integration with a battery-based system was completed.

Optimized torque motor control

- Optimized torque control motor controller (ESC) was designed and tested. Final product is functioning and showing high efficiency.

Implement solar soaring algorithms

- Algorithms converted to python code to run on Zynq device.
- NRL has test flown on-board soaring algorithms successfully.

This contract is now closed.