PacketDigital® LLC

May 1, 2015

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

Dear Ms. Fine,

Packet Digital is submitting the enclosed grant application to request funding in support of the Renewable Energy Project, "Solar Soaring Power Manager" in the amount of $350,000. This funding will be used as a match for the nine month project which will run from September 1, 2015 to June 1, 2016 and has a total budget of $1 million. Other partners in this project include the Naval Research Lab, ComDel Innovation in Wahpeton, ND, the Northern Plains Unmanned Systems Test Site, NDSU and UND.

The development of a reliable Unmanned Aircraft System (UAS) powered by clean, renewable energy will have a very significant impact on North Dakota and the world over. The applications for this technology are nearly limitless, from agriculture to water management to pipeline monitoring.

If you have questions I can be reached at 701-365-4421 or terri.zimmerman@packetdigital.com.

This letter sets forth a binding commitment on behalf of Packet Digital to complete the project as described in the application. Thank you for our consideration.

Sincerely,

Terri Gunn Zimmerman
CEO
Packet Digital, LLC
201 N 5th St, Suite 1500
Fargo, ND 58102

enc

Renewable Energy Program

North Dakota Industrial Commission

Application

Project Title:

Solar Soaring Power Manager

Applicant:

Packet Digital, LLC

Principal Investigator:

Andrew Paulsen

Date of Application:

May 1, 2015

Amount of Request:

$350,000

Total Amount of Proposed Project:

$1,000,000

Duration of Project:

9 months - Sept 1, 2015 to June 1, 2016

Point of Contact (POC):

Terri Zimmerman

POC Telephone:

701-232-0661

POC Email:

terri.zimmerman@packetdigital.com

POC Address: 201 N 5th St. Ste 1500 Fargo ND

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ABSTRACT

Objective: 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.

Expected Results: This project will develop the most efficient solar cells, auto soaring, and power management algorithms to initially demonstrate doubled flight times and ultimately unlimited endurance in unmanned aircraft. Project expected results include:

- Develop the techniques for a UAS to autonomously seek, acquire, and exploit thermal updrafts
- Develop a 40% efficient solar cell in a flexible solar array, optimized for a UAS wing
- Develop a solar soaring power management and distribution system
- Demonstrate extended flight time on a UAS constituting the basis for an "eternal" aircraft

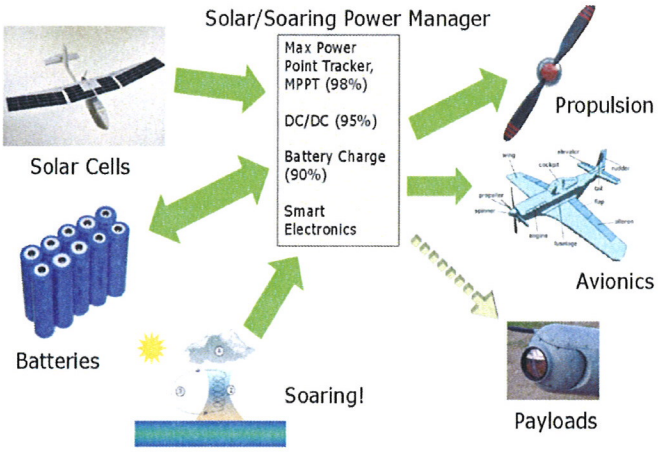
Duration: Three-phase project: Phase I of 9 months, Phase II of 9 months, and Phase III of 6 months.

Total Project Cost: $1,010,000 Phase I ($500k REC, $260k Naval Research Lab, $250k Private Investor), $1M Phase II ($350k REC, $600k NRL, $50k PI), and $1M Phase III ($375k REC, $375k NRL, $250k PI).

Participants: Packet Digital LLC, Naval Research Lab (NRL), ComDel Innovation in Wahpeton, ND, the Northern Plains Unmanned Systems Test Site, NDSU and UND.

PROJECT DESCRIPTION

Objective: This research and development project will create a solar soaring power management system for Unmanned Aerial Systems 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 and advanced power management algorithms.



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 runs advanced algorithms for maximum power point tracking, auto-soaring, and Packet Digital's patented On-Demand Power for optimizing power delivery.

Methodology: This project will incorporate classical systems engineering and rapid application development. Modeling of a UAS indicates that a 40% efficient solar cell combined with efficient soaring would enable continuous flight. This project will be divided into three main efforts: solar cell, soaring algorithms, and power management. The following summarizes the achievements for the Phase I effort:

Phase I Achievements - Solar Cell Development: NRL achieved 32.4% efficiency under one sun with a flexible, inverted metamorphic solar cell. To achieve higher efficiency, next generation of transfer-printed stacked multi-junction solar cells were designed, grown, and developed consisting of Aluminum Indium Gallium Phosphorus, Aluminum Gallium Arsenide, and Gallium-Arsenide layers. An initial triple-junction solar cell grown on Gallium Arsenide, stacked onto a single-junction InP grown cell resulted in an efficiency of 33.8% under one sun and the device achieved a near record setting efficiency of 44.75% under concentrated solar illumination of 837 suns. A flexible array design was developed of these solar cells for

mounting on the UAS wings. Geometries, mechanical, and electrical designs were completed and modifications to the SBXC airframe wings have been made to mount the solar cell arrays.

Soaring Algorithm Development Power budget models and the solar soaring algorithms were implemented for the SBXC airframe to extract the most solar energy during soaring maneuvers. Created solar soaring finite state machine to handle the mode switching between motor operations for various stages of flight. Test flights were conducted to measure solar insolation with an airframe outfitted with a solar intensity sensor. Modeling of the power budget shows the solar powered aircraft, SBXC, should be able to fly in North Dakota on the winter solstice for approximately 14.0 hrs and on the summer solstice for approximately 26.2 hrs using solar photovoltaic and autonomous soaring techniques. Saving 50% airframe weight and adding 50% additional photovoltaic array area makes eternal endurance feasible.

Power Management Development The fast-tracking, high efficiency Maximum Power Point Tracker (MPPT), smart battery capable of in-flight charging by solar and cell balancing, and Power Management and Distribution (PMAD) system have been designed, assembled, and tested. Characterization is ongoing and initial results are as expected. The initial architecture and feasibility analysis of a UAS-specific solar ASIC has also been completed during Phase I.

Phase II Objectives:

Objective 1: Solar Cell Development: The most efficient solar cells available that are applicable for UAS display efficiencies of 24-28% under one sun, terrestrial illumination. NRL has developed a design and manufacturing methodology to raise this efficiency. In collaboration with NRL, we propose to achieve the required 40% efficiency by creating a novel, stacked multi-junction (MJ) solar cell in which semiconductor materials with varying band-gaps are layered to efficiently convert the broad solar spectrum. The design is two MJ solar cells grown independently and stacked to produce a final device. This method enables achieving a broad range of bandgaps while maintaining lattice match to available growth substrates thereby ensuring the highest material quality. Optimum bandgaps will be determined using the NRL developed modeling tool, "NRL MultiBands™." Mechanical stacking will be achieved by "transfer-printing," a method naturally allowing for producing a thin, lightweight, flexible solar array, suited for the wings of a UAS.

Task 1 – Optimize the solar cell performance: Based on the results of Phase I, improved solar cell structures will be developed to achieve higher efficiency. The improved solar cells will be fabricated and tested. The resulting device will be characterized and methods will be determined for improvement in an iterative fashion. The optimized solar cells will be used in Task 2 to fabricate flexible arrays for integration onto the UAS wing.

Task 2 – Assemble MJ solar cells into a flexible array and integrate onto UAS. The MJ solar cells will be assembled into a solar array. The individual solar cells will be electrically interconnected and laminated into a continuous sheet. This sheet will then be used as the initial layer of the UAS wing skin. The UAS wing will be built up with the solar wing-skin to form the final flight product.

Objective 2: Update Power System to Support Altavian UAS

During Phase I, it was announced that Altavian would begin manufacturing UASs at ComDel Wahpeton. In order to support this manufacturing effort and build UAS expertise in the state of North Dakota, Packet Digital will modify the power system (MPPT, smart battery, and PMAD) to fit Altavian's UAS. Changes will accommodate differences in battery configuration and payload.

Task 1 - Obtain power distribution system specifications from Altavian, UAS. This will include specifications of the solar cells, energy storage, and power distribution system. Preliminary discussions have revealed that Altavian's system will require changes from the Phase I design.

Task 2 - Design the power management and distribution system to accommodate the design. The Phase I PMAD system will be leveraged. The MPPT, power conversion, and charging algorithms will be fine tuned for Altavian's aircraft with emphasis on efficiency, size, weight, and power.

Task 3 - Equip an Altavian UAS with the power distribution system. Conduct lab tests and test flights.

Objective 3: Hybrid Smart Battery

The Phase I smart battery utilized lithium ion batteries as the power source, which have high energy density, but low peak power density. A hybrid smart battery would offer high energy and peak power densities with the ability to be charged in flight by solar.

Task 1 - Complete a survey of available and emerging energy storage technologies. It is expected that lithium ion (high energy density) and lithium polymer (high peak power density) will be the energy storage

chemistries of choice. However, there are emerging alternative technologies such as lithium air batteries and fuel cells (hydrogen and direct ethanol) that need to be investigated.

Task 2 - Design the hybrid smart battery charging and delivery systems. Algorithms and circuits will be implemented to charge the smart battery safely and efficiently with solar. This logic will also determine under what circumstances power should be supplied from each battery technology.

Objective 4: Optimized Torque Motor Control

In a typical UAS, 98% of the system power is consumed by the propulsion system. Because the propulsion system dominates power consumption, increasing its efficiency is equivalent to increasing the solar array efficiency, but at a lower cost. Optimized torque motor control reduces wasted power and airframe vibration caused by harmonics in the motor drive waveforms.

Task 1 - Develop the optimized torque motor control algorithm for typical UAS motors and verify motor drive control functionality in simulation.

Task 2 - Design the motor control prototype. This includes FPGA implementation, identifying optimal gate drivers and FETs. The prototype will be tested and characterized with the motor selected by NRL.

Objective 5: Implement Solar Soaring Algorithms

Task 1 - Convert ALOFT solar soaring algorithms into C code that can run on low power embedded microcontrollers. This will include parameterizing the algorithms for various airframes.

Task 2 - Develop the prototype solar soaring module. This will include GPS, thermals sensors, and an embedded microprocessor that will communicate with the flight controller. The result will be a unit that can add flight-time-extending solar soaring capabilities to the broader UAS market, including Altavian UAS.

Phase II Completion: Once all of the above tasks are complete the separate solutions will be integrated into a prototype airframe and tested at the Northern Plains Unmanned Systems Test Site.

Anticipated Results: Phase II will result in flight testing of an aircraft with a Packet Digital solar power system and wing mounted high efficiency solar arrays. Enhancements over the Phase I system include higher efficiency solar cells, a hybrid smart battery for charging with solar energy and a prototype optimized torque motor control. It is expected that a flight time of several hours will be possible at the end of Phase II of this project using nothing more than clean renewable solar power and the innovative solutions developed

for solar cells, auto-soaring, and power management. A prototype solar soaring controller and a power system designed for an Altavian UAS will also be designed, built, and tested.

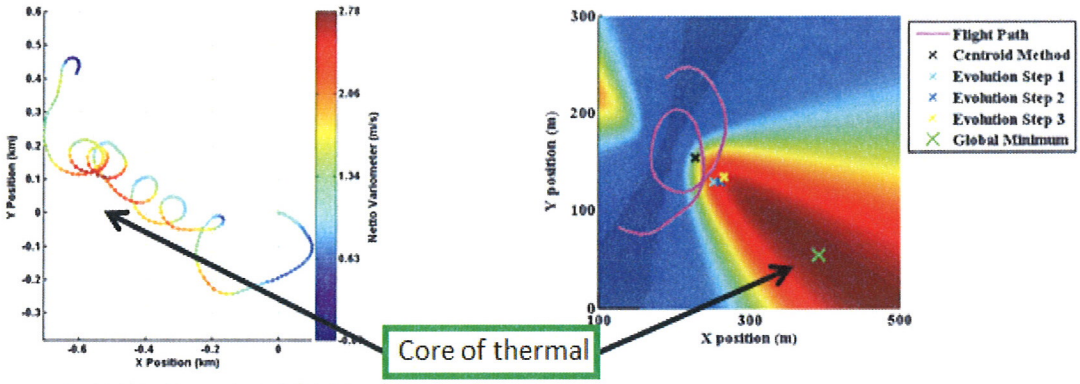
Phase II Deliverables:

- Produce a solar cell covering the desired spectrum with 30-35% efficiency, with a target of 40%
- Implement solar soaring algorithms into a prototype of a commercially feasible product
- Design an MPPT and PMAD that improves the performance of a ComDel manufactured Altavian UAS
- 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 lab environment

Facilities: Development activities will occur at Packet Digital's facility in Fargo, North Dakota. Packet Digital is fully equipped for the design and development of the prototype circuitry defined herein. A full tool suite of computer-aided design software and laboratory equipment is in place for conceptual design, debug, and integration. For photovoltaic research, NRL has expertise in optoelectronic device modeling, design, growth, fabrication, and characterization. NRL maintains a III-V semiconductor growth and processing facility with three Molecular Beam Epitaxy (MBE) reactors as well as a state-of-the-art solar cell material and device characterization laboratory including solar simulators providing high spectral fidelity. NRL also maintains an extensive capability in the design, fabrication, and flight testing of UAS. Additionally, facilities providing test equipment at North Dakota State University are available through a professional relationship. Manufacturing facilities are available through ComDel Innovations (CDI) in Wahpeton. The Northern Plains UAS Test Site is headquartered in Grand Forks, N.D., and uses several UAS Test Ranges.

Resources: Packet Digital, with power management expertise and mixed signal ASIC design experience, will develop the battery charging and high efficiency power management solutions. NRL, with extensive UAS expertise, will provide the soaring algorithms and high-efficiency solar array. ComDel Innovation in partnership with Altavian will manufacture and assemble the airframe. Packet Digital will partner with NDSU and UND on testing and analysis of the aircraft flight performance. The Northern Plains Unmanned Systems Test Site will be utilized for flight testing and evaluation.

Techniques to Be Used, Their Availability and Capability: The solar cell development will require new techniques to achieve the project goals. New materials will be used for the cell fabrication in order to achieve the 40% efficiency believed to be required for unlimited flight. These materials will also be fabricated using new techniques to insure the flexibility required. Although these aspects of the solar cell development will be new, NRL and Packet Digital engineering teams believe, based on their experience, that a solution is possible. The Packet Digital team will develop specialized power algorithms to optimize the solar energy. The techniques to be used for the power management portion of the project will be well understood and familiar to Packet Digital. The key techniques for soaring algorithm development will be nonlinear least squares to find center based on a specific mathematical model of the updraft cross-section.



Environmental and Economic Impacts while Project is Underway: This project is focused on using clean renewable solar energy providing a positive environmental impact as the aircraft will be flown for testing without using any fossil fuels. The economic impact will be significant with twenty to twenty-five persons being employed for the duration of the project.

Ultimate Technological and Economic Impacts: This project will expand the applicability of unmanned aircraft. Unlimited flight time and clean renewable power source will mean that these aircraft can be deployed to provide continuous surveillance for pipeline monitoring and environmentally sensitive areas. There is also great interest in utilizing UAS for precision agriculture for monitoring crop health and weed and moisture management. Also, unmanned aircraft can provide services such as Internet access to areas that lack the necessary infrastructure. This Internet access can be used for medical services, education, commerce and many other positive social and economic benefits.

NRL expects many benefits from this project including reduction in forces, increased troop safety, increased effectiveness of military operations, and others. These same benefits could help in the private sector as well, particularly where safety is a concern such as the oil and gas industry.

The solar cell and power management technology also has potential to improve any application that currently uses solar technology. The 40% efficient solar cell being developed is a great improvement over the most efficient solar cells today, which are around 33% efficient. The increased efficiency that is being proposed for this project could be used for homes, remote warning systems, traffic signals or any number of applications where a battery needs to be charged using solar energy.

Why the Project is Needed: Battery life on commercial UAS is extremely short, approximately 20 minutes, limiting applicability and uses. Significantly extending battery life and, ultimately, creating an eternal aircraft changes the entire industry, creating many new applications. A primary use for unmanned aircraft systems is surveillance; e.g. commercial monitoring of gas pipelines or agricultural crops or military surveillance over the ocean or remote areas, reducing risks for our soldiers. In any surveillance application, unlimited flight times are a huge benefit, realized in cost reductions and increased effectiveness. Time consumed returning for refueling is time taken away from doing assigned tasks. In many cases, where the task must not be interrupted, multiple aircraft are deployed in order to insure constant surveillance. Not only will this project reduce the number of unmanned aircraft needed for a particular task but the aircraft will use clean renewable energy rather than the fuels that are used today in extended flight applications.

STANDARDS OF SUCCESS

The project goal is to initially double fly times on a UAS and ultimately create unlimited flight endurance.

Project Deliverables:

- Deliver a 20% improvement in the efficiency of solar cell power, from 33% currently to 40% in order to provide enough solar battery power to enable unlimited flight
- Achieve power management with greater than 90% efficiency for typical loads, with a target of 95%, to extend battery life sufficiently to survive nighttime flight
- Innovative MPPT algorithm for extracting maximum charging capacity from the solar cells
- Soaring algorithms optimized for both daytime and nighttime flight to achieve unlimited endurance

The value to North Dakota: Current commercial fly times of UAS are approximately 20 minutes, making it impractical to utilize UAS for many applications. By developing this solar soaring power management to extend fly times and removing this limiting factor, UAS become more practical and applicable to many markets and users in North Dakota and globally including:

AGRICULTURE Crop monitoring (eg. disease, irrigation) Water absorption of soil Spraying to manage weeds and other pests	**ENVIRONMENTAL** Air quality management/control Wildlife monitoring and behavioral research Prairie and erosion monitoring
INDUSTRIAL Spill tracking Power line and infrastructure monitoring Runway inspection	**EMERGENCY RESPONSE, LAW** SWAT missions and narcotics sensors Law enforcement and border monitoring Monitoring surveillance of establishments
PIPELINE MANAGEMENT Leak detection Security	**COMMUNICATIONS** News and sports broadcasting Satellite augmentation systems
WATER MANAGEMENT Monitoring water levels, flood alerts	**CLIMATE MONITORING** Fire danger assessment

Packet Digital is already in discussion with a number of commercial partners including Google (Titan Aerospace), Singapore Aerospace, Microlink and Altavian. Packet Digital's management team brings over 40 years of experience in developing, incubating and commercializing new technologies. Packet Digital's CEO has extensive experience launching new products and services in global markets.

This research and development effort will bring the manufacture of solar soaring UAS with the longest flight time to ComDel Innovations in Wahpeton, North Dakota. The local universities will assist in fabrication design, testing and analysis. Testing of the Solar Soaring UAS at the Northern Plains Unmanned Aircraft Test Site will create more visibility for the test site and North Dakota and this cutting edge solar technology will attract collaborating companies to the test site. This effort will preserve jobs and create new jobs in the research and development with twenty to twenty-five persons being employed for the duration of the project, with more added for the manufacture of the UAS, testing and analysis at the universities and the North Plains Unmanned Aircraft Test Site.

This North Dakota project will enhance the research and education in the area of solar cells utilizing new techniques to develop the most efficient solar cells in the market. Achievement of persistent, solar powered light will require advanced power management and peak power tracking electronics. Within this

Renewable Energy Council project, the usage of a differential evolution or mutation methodology will be studied and researched. During the project, Packet Digital will work with both NDSU and UND.

BACKGROUND/QUALIFICATIONS

Packet Digital has developed power management integrated circuits and technology to extend battery life or reduce power consumption in a number of applications. Our patented On-Demand Power® technology addresses the shortcomings of software-based power management by moving the control out of the microprocessor and placing the intelligence inside the power management integrated circuits (PMICs). One of the key differentiators of our technology is that it offers *active* power savings, meaning the circuitry does not have to be put into a sleep mode to save power. This is critical in UAS applications because of the importance of maintaining full functionality while in flight. With our technology, we have extended battery life 400% in wireless sensors, 40% in a portable radio for the military, and reduced power consumption by 20% in data center servers. We will bring our expertise in building power-efficient systems and intelligent power management algorithms to develop the most power-efficient UAS.

Modeling of a UAS indicates that a 40%-efficient solar cell, combined with efficient soaring, would enable continuous flight. The NRL has developed the most advanced solar cells demonstrating 33% efficiency. We propose to achieve the required the 40% efficiency by layering semiconductor materials with varying band-gaps in an attempt to most efficiently convert the broad solar photon spectrum.

Achievement of persistent, solar-powered flight will require advanced power management and maximum power point tracking (MPPT) electronics. The role of an MPPT is to adjust the load voltage of the solar array to maximize the power that can be extracted. This is a dynamic process that must respond to changes in the environment such as changes in solar insolation and array temperature. Packet Digital has also developed novel methods for achieving MPPT.

This project will be completed in three phases. The first phase is nine months in duration and involves the architecture and prototype of the power management circuitry, fabrication of flexible solar cells, and development of the soaring algorithms. Power conversion, solar MPPT conversion, and battery charging algorithms will implemented using discrete parts. Phase I includes the integration of the discrete power management solution, solar cells and soaring algorithms into a test fixture to be tested.

Phase II of the project will be nine months in duration and will include increasing the efficiency of the UAS through use of a hybrid smart battery and more efficient motor control methods. Also in Phase II, the Phase I power system will be adapted to an Altavian aircraft manufactured at ComDel in North Dakota. Phase II will also include porting NRL's soaring algorithms to a generic microprocessing unit. The solar cell work will consist of improving the efficiency and flexibility of the cells by optimizing the materials and the substrate using the test results of Phase I. The soaring algorithm work will concentrate on nighttime flight. Phase II will conclude with the integration of the solar, soaring, and power solutions into a prototype UAS which will be used to demonstrate extended flight times.

Phase III will be six months in duration and will complete the project. All of the pieces of the project will come together to produce the complete unmanned aircraft system solution. The solar charging, soaring, and power management solutions will be integrated into the airframe. This completed UAS will undergo extensive testing at the test site in North Dakota. The test flights will be used to refine the design to achieve the stated goal of unlimited endurance flights. The solar cell and soaring algorithm work will continue for the NRL team as they work on further enhancements to the design.

Management Team: Andrew Paulsen, Director of Advanced Technology for Packet Digital, a key leader in the initial development of PowerSage® technology. He leads the Advanced Power Management Team, developing new products and technology. Paulsen has extensive research, testing, and product development expertise in the power field. He has significant experience in solar-powered vehicles, battery charging, and motor controls from many years leading the electrical group of the NDSU solar racing team.

Terri Zimmerman, Packet Digital CEO, has over 20 years of experience developing, incubating, and commercializing new technologies. She has raised over $500 million in capital to launch new products and services in global markets. She has grown companies to significant revenues resulting in successful exits. She has been appointed to a state economic development board by the Governor of North Dakota.

Naval Research Lab: Dr. Dan Edwards has been PI on two prior autonomous soaring efforts and wrote his Ph.D. thesis on the topic. He has participated as an autonomous soaring subject matter expert for the Office of Naval Research, Army Research Lab, and industry partners. He has extensive experience with long-duration UAS acting as a key player for the 48-hour Ion Tiger Liquid Hydrogen fuel cell program.

Dr. Rob Walters has over 20 years of photovoltaic experience and is currently managing three solar cell development efforts and has a recent patent on novel multi-junction solar cell design. He also has extensive experience and expertise in fielding solar cell experiments, including five space experiments and an underwater solar experiment. He is executing a flexible solar array development project under Department of Defense funding.

MANAGEMENT

Management Plan: Packet Digital will lead the effort with significant collaboration of NRL and support from ComDel Innovations, the universities, and the Test Site. Teams will work in parallel and interact directly as needed. Weekly status meetings will be held via teleconference, however, face-to-face meetings will be scheduled quarterly to ensure team cohesiveness. The development schedule and financial reports will be updated on a monthly basis. Major schedule items will include systems requirements definition, design and development activities, prototype development, integration and test, and final delivery.

Quality Assurance & Systems Engineering: Existing validated software and hardware will be leveraged as much as possible. A tailored systems engineering approach will be utilized for this development effort to efficiently execute the development while ensuring proper due-diligence is maintained. A risk management approach will be utilized including a matrix to track requirements that are deemed to have high risk.

TIMETABLE

The following table shows the project schedule for this phase. The timeline includes developing and testing discrete prototypes of the various systems as well as extensive lab testing and flight testing.

Task	September	October	November	December	January	February	March	April	May
Design Altavian Power System									
Prototype Altavian Power System									
Evaluate Energy Storage Tech									
Develop Hybrid Smart Battery									
Solar Cell Structure Improvement									
Solar Cell Fabrication									
Develop Motor Control Algorithm									
Design Motor Control Prototype									
Genericize Soaring Algorithms									
Design Soaring Unit									
Test and Documentation									
Interim/Final Reports									

BUDGET

Project Associated Expense	NDIC's Share	Private Sponsor Share	Naval Research Lab Share	Total
Total Personnel Cost	$299,000[1]		$486,000	$785,000
Software Costs	$35,000	$50,000		$85,000
Materials	$16,000		$114,000	$130,000
Total	$350,000	$50,000	$600,000	$1,000,000

1. Direct personnel costs plus indirect overhead and G&A (65%)

The $1,000,000 budget is based on estimates for the time, material and software for the tasks detailed above in the timeline. Above labor, material and software costs of $350,000 are estimated for the Renewable Energy Council Grant. Other partners have committed to fund 65% of the budgeted costs. NRL has committed matching funds of $600,000 for the nine month period.

Personnel Detail. The technical managers are budgeted 4 engineer-months for project oversight and will be involved with architectural design, reviews, documentation, and design verification. The software team is budgeted 4 engineer-months for algorithm and software design. The hardware team is budgeted 12 engineer-months for power conversion prototype boards, schematic design, layout, building and testing boards and airframe integration and testing. The ASIC design team is budgeted 5 engineer-months for energy storage research, circuit development, and FPGA prototyping. Project management and technology review time is also including in the budget.

PATENTS/RIGHTS TO TECHNICAL DATA

Packet Digital reserves the right to file patents related to the intellectual property generated from this proposal and will work with legal counsel to determine if additional patents could be filed. Our power management algorithms and methodology are protected by our patent portfolio. We also have copyrights and our registered trademarks include On-Demand Power®, PowerSage®, and Packet Digital®.

Altavian
Precisely different.

April 28, 2015

Terri Gunn Zimmerman
Chief Executive Officer
Packet Digital LLC
201 5th St N
Fargo ND 58102

Dear Ms. Zimmerman,

Altavian™, as a leading designer and manufacturer of precision Unmanned Aircraft Systems (UAS) is writing in support of Packet Digital's proposal for a solar soaring power management system for UAS and is keenly interested in the development you are doing to help increase energy efficiency and overall flight times. Altavian is interested in integrating Packet Digital's solar power delivery system into our aircraft that will be built in North Dakota at Comdel Innovations.

Altavian custom-engineers and manufactures unmanned aircraft solutions for the military, law enforcement and first responders, agriculture, natural resource monitoring, infrastructure and other industries with emphasis on high-resolution mapping and sensory payloads to help our customers collect precise and meaningful data for their operations. We continue to innovate and make advancements every day and our ability to assist our clients would be enhanced by improvements in power consumption and flight time. We are excited by the new opportunities Packet Digital is opening up for us and our industry by improving flight times with solar.

We have recently learned more about Packet Digital's On-Demand Power® technology and PowerSage® Power Management Integrated Circuits (PMICs). Our interest piqued when you began working with N.D. REC and the U.S. Navy to apply your power management expertise and initially double flight times in the Department of Defense's solar-powered UAS program.

We are extremely interested in the continuation of this project under Phase II which will extend the capabilities of unmanned aircraft and enable us to create solutions that were previously unimaginable. At Altavian, we believe in providing endless possibilities to our clients, and if we can continue to collaborate with Packet Digital, we can expand our clients' capabilities to grow food, develop land and infrastructure, manage resources and keep us safe and well. Please let us know how we can assist your efforts, and we look forward to working with you.

Sincerely,

Thomas Rambo
Founder and Chief Operating Officer
Altavian

2100 15th Street N
Wahpeton, ND 58075
701-671-6060

April 23, 2015

To: Packet Digital, LLC
201 N. 5th Street Suite 1500
Fargo ND

Attention: Terri Zimmerman

Subject: Letter of Support- Packet Digital, LLC - Unmanned Aircraft Systems (UAS) Development Initiative

This letter is written to express ComDel Innovation's support of Packet Digital in their efforts to secure funding for UAS technology advancement. ComDel Innovation is committed to assist this initiative by extending applicable product development, engineering and manufacturing services for UAS technology and product endeavors. We will look to Packet Digital to help us understand where we might apply our competencies of product design, precision machining, composite materials, injection molding, metal stamping or assembly operations to help fulfill their objectives. The recent UAS manufacturing activity at ComDel Innovation adds further motivation to help advance the technologies that Packet Digital is pursuing. Packet Digital is collaborating with our customer to assess the integration of future technologies into the airframe that ComDel Innovation is building.

There has been significant energy in our region gearing up for UAS technology and our region is uniquely positioned with a diverse set of capabilities and resources to move the UAS product platform forward. ComDel Innovation intends to work with Packet Digital team to strengthen the overall development team, helping enrich the environment to foster technology and new product development. As Packet Digital continues to map out future activities, please keep us informed and let us know where we might assist.

Sincerely,

Jim Albrecht
President
ComDel Innovation
Phone: 701-671-6134
E-mail: jim.albrecht@comdelinc.com

Sincerely,

Keith Mitterling
Business Development Manager
Precision Machining Technologies
ComDel Innovation
Phone: 701-671-61113
E-mail: keith.mitterling@comdelinc.com

NDSU NORTH DAKOTA STATE UNIVERSITY

Center for Nanoscale Science and Engineering
1805 NDSU Research Park Drive
Fargo, ND 58102

April 28, 2015

Ms. Terri Zimmerman
CEO
Packet Digital, LLC
201 5th St. N
Fargo ND, 58102

Subject: Letter of Support for Solar Soaring UAV Project

Dear Ms. Zimmerman:

North Dakota State University's (NDSU) Center for Nanoscale Science and Engineering (CNSE) is very interested in working with Packet Digital, LLC on various aspects of power management for unmanned aircraft systems for the proposed Phase II project. CNSE's experience and expertise in microelectronics design, rapid prototype fabrication, and testing make us a suitable, qualified partner in supporting Packet Digital on this project. We see significant opportunity for unmanned aircraft and are very excited to pursue research and development initiatives like this that will result in job growth and economic development.

CNSE was established in 2002 and conducts large-scale, multidisciplinary research for government and industry. The center is located in a state-of-the-art research facility in the NDSU Research & Technology Park. CNSE employs full-time research staff along with part-time students and faculty researchers. The facility includes cleanroom, laboratory and engineering spaces that host the design, synthesis, fabrication and characterization capabilities. The core competencies at CNSE include materials and processes for electronics and energy conversion, miniaturized electronics design and prototype fabrication, and research on polymeric and hard protective coatings. The installed equipment base at CNSE to support these research areas exceeds $25M.

The facilities, skilled staff, and capital equipment base comprising CNSE's core competencies are supporting a wide range of government and private-sector research and development projects including both DoD and DoE. The staff at CNSE, notably the microelectronics group, looks forward to the possibility of collaborating with Packet Digital on technology research and development for unmanned aircraft.

Sincerely,

Aaron Reinholz
Associate Director, Center for Nanoscale Science and Engineering
North Dakota State University

NDSU is an equal opportunity institution.

NORTHERN PLAINS UNMANNED AIRCRAFT SYSTEMS TEST SITE
Clifford Hall
4149 University Ave
Grand Forks, ND 58202

Robert Becklund
Director, Northern Plains Unmanned Aircraft Systems Test Site
4149 University Ave
Grand Forks, ND 58202

April 21, 2015

Terri Zimmerman
Packet Digital, LLC
201 5th Street North, Suite 1500
Fargo, ND 58102

Dear Terri,

I am writing this letter in support of Packet Digital and your Renewable Energy Council proposal "Solar Soaring Power Management for Unmanned Aircraft Systems." From meeting with you and your team of engineers and visiting your office and working labs, I am particularly interested in Packet Digital's innovative power saving approaches to extend battery life.

The Unmanned Aircraft Systems we are currently testing at the test site remain airborne for approximately 19 minutes. The collaboration and related work between Packet Digital, the Navy Research Lab and Comdel could change the paradigm for UASs and expand the applicability to additional markets and a broader group of users. Testing this innovative game changing technology for solar and UASs at the Northern Plains Unmanned Aircraft Test Site will create visibility for the test site and bring more interested companies to participate in the collaboration and create jobs.

The test sites will conduct crucial research to determine how to safely integrate UAS into the national airspace. The Northern Plains UAS Test Site was the first FAA test site to conduct flights, launching its first research flight in early May 2014. The Northern Plains UAS Test Site is headquartered in Grand Forks, ND, North Dakota plays a critical role in determining how to safely integrate UAS into the national airspace, and the Northern Plains UAS Test Site serves as an opportunity to enhance North Dakota's leadership position in the industry. Because of this, we are committed to working with companies of the highest caliber. We have found Packet Digital to be one of those companies and are excited to collaborate with them on this industry leading technology.

Respectfully,

Robert Becklund
rbecklund@nd.gov
(701) 777-6330

North Dakota

FARGO
JET CENTER INC

3802 20TH STREET NORTH, FARGO, ND 58102 USA
TEL: 1-800-7700-JET or 701-235-3600 FAX: 701-235-9717

April 28, 2015

Terri Gunn Zimmerman
Chief Executive Officer
Packet Digital, LLC
201 5th Street North, Suite 1500Fargo, ND 58102

Dear Ms. Zimmerman,

I have a lot of experience in my more than 36 years in aviation. I am a USA Navy Vietnam era veteran and a UND graduate where I studied aerospace science and electronics. Since graduation I have developed seven companies that are related to the aviation and aerospace industry .Today I still maintain a commercial instrument rating and multiengine rating and I'm enthusiastic about the work Packet Digital is doing in the unmanned aircraft space, which is why I am in full support of Packet Digital Phase II proposal, "A Solar Soaring Power Management System for Unmanned Aerial Systems (UAS)," presented to the North Dakota Renewable Energy Council.

Over the past five years, I've had the opportunity to learn more about Packet Digital's On-Demand Power® technology built into your PowerSage® integrated circuits, which save power in everything from military radios, to network servers, memory modules, notebooks and other consumer electronics. The potential applications for your products and services led me to invest over $4 million in Packet Digital to help fund your efforts to partner with leading manufacturers and military agencies.

My excitement escalated when we found an opportunity in aeronautics, specifically a collaboration between the N.D. REC and the U.S, Naval Research Laboratory to increase flight times in the Navy's solar-powered UAS. Phase I of the project has been an incredible success, with development of a smart battery and Maximum Power Point Tracking algorithms that have the potential to double flight times. The ultimate goal is unlimited flight time or endless endurance, and I believe we can get there.

As CEO of Fargo Jet Center and Weather Modification, Inc., I've been watching the UAS industry with a keen eye, but with the work Packet Digital is conducting under this proposal I see the opportunity for broader applications for unmanned aircraft that I have not seen before. Much of the atmospheric research, evaluation and cloud seeding we do has required manned aircraft, but as we increase flight times and capabilities of UAS, the opportunities increase for drones to collect weather data, predict or mitigate severe weather and increase precipitation on a world-wide basis.

I hope to see Packet Digital continue its work in power management for unmanned aircraft, and I will continue to offer my support, resources and connections to important industry leaders as you continue to develop and commercialize PowerSage applications for the UAS and aerospace markets. Packet Digital is helping us explore the skies in ways we never thought possible, and I'm excited to be part of your team.

Sincerely,

Patrick Sweeney
CEO
Fargo Jet Center and Weather Modification, Inc.

AVFUEL

MEMORANDUM
U.S. Naval Research Laboratory
Code 6810

DATE: May 1, 2015

REPLY TO
ATTN. OF: Dr. Robert J. Walters

SUBJECT: Letter of Support for Packet Digital

TO: Terri Zimmerman – CEO, Packet Digital

Dear Ms. Zimmerman,

I am writing this letter to express the continued commitment of my NRL team to our join effort with your company under the North Dakota Renewable Energy Council program. I feel that we have made excellent progress in Phase I, meeting all of our technical milestones and deliverables, and I feel we have an excellent chance to achieve equal success in Phase II. I am looking forward to our joint flight tests.

As with Phase I, the US Naval Research Laboratory (NRL) has funding to collaborate with Packet Digital on Phase II of this project for photovoltaic and autonomous soaring UAVs for eternal, low-altitude operation. My Branch at NRL currently has a four-year, $3 million program, from which we will be able to match Packet Digital funding. I understand that the Packet Digital proposal has three phases, and NRL will be able to match the Packet Digital funding at a level of $260,000, $600,000, and $600,000 for Phase I, Phase II and Phase III respectively.

We are excited about this Renewable Energy Council project to conduct innovative research and development in solar, auto soaring and power to bring longer fly times and extended mission life to UASs.

Robert Walters
Head, Optoelectronics and Radiation Effects Branch
NRL Code 6810