TECHNICAL REVIEWERS' RATING SUMMARY

R022-A

Solar Soaring Power Manager (Phase I)

Packet Digital
Principal Investigator: Andrew Paulsen
Request for $500,000; Total Project Costs $1,010,000

Rating Category	Weighting Factor	1B	1D	Average Weighted Score
1. Objectives	9	4	4	36.00
2. Achievability	9	3	2	22.50
3. Methodology	7	3	2	17.50
4. Contribution	7	4	2	21.00
5. Awareness	5	3	1	10.00
6. Background	5	4	3	17.50
7. Project Management	2	3	2	5.00
8. Equipment Purchase	2	4	5	9.00
9. Facilities	2	4	4	8.00
10. Budget	2	3	3	6.00
Average Weighted Score		175	130	**152.50**
Maximum Weighted Score				**250.00**

OVERALL RECOMMENDATION

FUND	x	
FUNDING MAY BE CONSIDERED		x
DO NOT FUND		

R022-A
Application of Solar Soaring Power Manager (Phase I)
Submitted by Packet Digital
Principal Investigator: Andrew Paulsen
Request for $500,000; Total Project Costs $1,010,000

1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Renewable Energy Council goals are: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear.

Reviewer 1B (Rating: 4)
I withheld the maximum points (didn't score "5" exceptionally clear) because I felt the proposal could have been more explicit to optimize that some of the modeling could be focused on North Dakota geography and uses. For example modeling the "optimum bandgap combination" for the solar "UAV environment" is vague. A solar UAV for agriculture in North Dakota may have different optimums as opposed to a solar UAV for winter wildlife monitoring in Alaska. Seasons, latitudes, etc… may provide differences in the physical optimums of the energy conversion device. (note: the top of page 5 references 'target ND UAS applications', but it wasn't clear to me it addresses ND climate, geography, and purposes). The project could better serve North Dakota if it was modeled to North Dakota optimums vs. general optimums. However there is no question that a solar powered UAV and dedicated/innovated electronics are consistent with the renewable energy project.

Reviewer 1D (Rating: 4)
- The primary goal of the project is to enable a doubling of UAS flight time through a combination of high efficiency, flexible solar cells and advanced power management systems with auto-soaring capabilities. This is expected to provide direct benefits to surveillance, particularly in agricultural and gas pipeline monitoring. The team states that the project will bring manufacturing of solar soaring UASs with the longest flight times to ComDel Innovations in North Dakota, directly supporting the competitiveness and manufacturing base of the region.
- The project is to partially involve both NDSU and UND, benefiting the research and education base of the state.
- The above are clearly listed and fall generally within the mission and goals of the REC.

2. With the approach suggested and time and budget available, the objectives are: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.

Reviewer 1B (Rating: 3)
The approach is methodical, leverages existing technology and experience, and includes tactical improvements in key areas that make it likely achievable.

Reviewer 1D (Rating: 2)
- The project has three primary elements that are to work collectively to enable a doubling of the flight time for a UAS: (1) a high efficiency, flexible solar cell, (2) an auto-soaring technology, and (3) an advanced power management system.
- The objectives for the auto-soaring technology and advanced power management algorithms are likely to be realized within the proposed timeline and associated budget.
- The targeted 40% efficient flexible solar cell will be very challenging and likely not achievable within the time and budget proposed. The team proposes a stacked triple junction (TJ) approach (six total junctions from two TJ cells). Current TJ and five-junction (non-concentrated) lab hero cells have demonstrated 31.1% and 38.8% efficiencies, respectively. While promising, these are non-flexible small area record cells that are far from manufacturing scale and not currently applicable to larger area conformal coverings at such efficiencies. There is no data provided in the proposal from NRL to demonstrate their current status compared to these records. Furthermore, modeling (with MultiBand software) is proposed in the tasks to identify the optimal six-junctions and associated materials the cell will need. This suggests the team has not yet begun work on integration of the proper materials, junctions, and flexible substrate – these are certainly very challenging and will require considerable time and resources to develop, making it unlikely to be realized within the project duration and budget.

3. The quality of the methodology displayed in the proposal is: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average.

Reviewer 1B (Rating: 3)
There are not a lot of specifics to adjudicate the quality of the methodology. Optimizing the power conversion, optimizing the power management, using existing phenomena like thermals to create lift are reasonable mechanisms. Systems engineering assumption appear to be made that may limit outcomes. For example, the assumption of a powered flight UAV vs. a lighter-than-air UAV, and that processor size needs to account for soaring rule-sets and charging rule-sets only (what about airspace management decisions, sensor management decisions, etc…) limits the outcome. A project that captures all the processor tasks, accounts for a 'budget', but goes on with the demonstration would provide a launching point for more outcomes.

Reviewer 1D (Rating: 2)
- There simply is not adequate technical description or reference to external work to substantiate many of the project expectations, particularly in the solar cell development component.
- While the algorithm and power management system development tasks follow a logical progression, there are significant shortcomings in the six-junction cell approach. The appendix provides a basic description of the approach and methods/tasks to be followed, but they fail to identify key risks and challenges that must be considered.

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Renewable Energy Council goals will likely be: 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Reviewer 1B (Rating: 4)
The project provides opportunity, not in a classic "how can solar power replace fossil fuel power plants" ways, but in new tools for agriculture and infrastructure optimization.

Reviewer 1D (Rating: 2)
- The project, if successful, would potentially provide new technology to agriculture producers in the state (a direct goal of the REC). Once concern, though, is the potential cost of the complete UAS, as this was not addressed in the proposal.
- The project would promote solar energy – a renewable energy – as an energy source for UAS's, though it is not within the listed priority areas of the REC (wind, biofuels, and biomass).
- The project is to retain/create 20-25 tech jobs, though it is not clear how many are for the duration of the project versus permanent to support future manufacturing and development of the system should the project be successful.

5. The principal investigator's awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 1B (Rating: 3)
Although there wasn't a lot of room to comment on existing research, data base searches on the topics discussed (dedicated power management circuitry, soaring algorithms without using sensors, etc…) showed consistent technology explanations. It should be noted that there are already claims of greater than 40% efficient solar, but the methods used to measure that 40% vary. The proposal did not make it clear how the 40% objective would be measured, but I think it is adequate to make sure the measurements and results are document after the testing is over.

Reviewer 1D (Rating: 1)
- No references were provided in the proposal.
- The team states that NRL has demonstrated "the most advanced solar cells demonstrating 33% efficiency," but there are no references or further detail provided. Furthermore, this "most advanced" cell is not present anywhere on the NREL record cell efficiency chart, making it very unclear what is being referenced.

6. The background of the investigator(s) as related to the proposed work is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 1B (Rating: 4)
In addition to the proposal's information, the participant's history and experience was referenced on websites. There was no derogatory information discovered, and a depth of experience.

Reviewer 1D (Rating: 3)
- The prime, Packet Digital, has prior experience and expertise in power management integrated circuits, demonstrating significant battery life extension in multiple applications (wireless sensors, radio, and data centers), though no references were provided.

- NRL has prior MJ solar cell expertise, though it is not clear if it has realized enough progress in 6-junction cells on flexible substrates to meet the timeline of the proposed project.

7. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very good; or 5 – exceptionally good.

Reviewer 1B (Rating: 3)
The test phase is a concern if the technology is optimized for one season and the project completion occurs in another. Current tests appear to occur in April/May 2015 (spring). If the power management is optimized for other seasons (winter, summer), the schedule may be a bit out of synch. Also, the project management plan (page 13) looks like it accounts for one design cycle for the power conversion circuitry. It would be interesting to have multiple design cycles if allowed to test the conversion circuitry.

Reviewer 1D (Rating: 2)
- A basic Gantt chart was provided to show the general timeline for the project tasks.
- Deliverables were listed, but no milestones (particularly interim milestones) were listed with target dates to allow for assessment of the project while active.
- The inclusion of an interim report is valuable and will certainly assist in enabling evaluation of the project progress.
- It is not clear why solar cell development/modeling is not to begin until one month into the project start given that this is a very challenging element of the project.
- The team states that actual battery selection is critical to allowing the development of the battery charging algorithm, but there is no milestone, task, or associated date listed in the program plan to indicate when this will happen.

8. The proposed purchase of equipment is: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

Reviewer 1B (Rating: 4)
Software purchase, although not named specifically, are reasonable.

Reviewer 1D (Rating: 5)
- No equipment is to be purchased based on the budget table provided on pg. 14.

9. The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.

Reviewer 1B (Rating: 4)
Having a UAV test area in North Dakota is an obvious benefit.

Reviewer 1D (Rating: 4)
- Packet Digital appears to have the necessary resources for the soaring algorithm and power management subsystems development, relying on discrete components in the Phase I effort.
- NRL has the necessary epitaxial equipment for the semiconductor materials growth required for the targeted cell, though specific semiconductor layers are not yet selected or specified for the 6-junction cell.
- Test flight demonstrations are possible through access to the Northern Plains Unmanned Systems Test Site.
- ComDel Innovation has the required resources for the airframe and mechanical sub-component assembly.

10. The proposed budget "value"[1] relative to the outlined work and the financial commitment from other sources is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value. (See below)

Reviewer 1B (Rating: 4)
This work would cost a lot more in laboratories I work in. The low overhead is consistent with a small business.

[1] *"Value" – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.*

[2]*Financial commitment from other sources – A minimum of 50% of the total project must come from other sources to meet the program guidelines. Higher priority is to be given if the application has private industry investment equal to or at least 50% or more of total cost.*

Reviewer 1D (Rating: 3)
- The project leverages ~$500k in private sponsor and NRL cost share to meet the *minimum* 50% requirement of the program.
- While one may question the likelihood of the team to meet the goals of the project in the timeframe proposed, the budget is perhaps low in comparison to what one would expect for such work. It is likely that the team has under-budgeted the work proposed (in both cost and time) given the extent of solar cell development required.

[1] *"Value" – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.*

[2]*Financial commitment from other sources – A minimum of 50% of the total project must come from other sources to meet the program guidelines. Higher priority is to be given if the application has private industry investment equal to or at least 50% or more of total cost.*

Section C. Overall Comments and Recommendations:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

Reviewer 1B ***(Fund)***
Some issues I already mentioned I'd like to re-emphasize:

- powered flight only one manifestation of UAS. Lighter than air (example helium blimps) are perfect for some missions (spot monitoring, communications relay, etc..), and could be enabled by efficient solar conversion, efficient power management, etc… but may need circuits and processors tuned to lighter than air flight vs powered flight.

- other aspects of UAS, especially managing/coexisting in airspace with other aircraft, will take processing power and rational decision making, and should be integrated into the systems engineering as soon as possible. Leaving a processor 'budget', or hooks in the soaring software architecture, would add momentum to the commercial transition opportunities in the future.

General Comments:

- Reliability was not mentioned in the proposal. If a UAS is going to exist 'perpetually' it is going to need very highly reliable components. If the power management circuitry breaks, the UAV will come down. Reliability should be included in the systems engineering approach from the onset.

- The state of North Dakota should get some modest intellectual property rights for granting the proposal. In the proposal, the company claims rights to all. People more familiar with the needs of North Dakota may be able to suggest possibilities in this area.

Reviewer 1D ***(Funding May Be Considered)***
A primary element of the proposed program is a 40% efficiency flexible solar cell that can be integrated into UAS applications. While the auto-soaring and power management concepts proposed seem rather feasible, one major shortcoming of the project was the lack of detail on the current status of the targeted flexible solar cell to be realized with six junctions. There was note of NRL achieving 33% efficiency in a prior cell, but the lack of external references and/or details in the proposal make it very difficult to believe that it will meet the timeline and capabilities proposed in the program. It is not clear what size this result was obtained at, how many junctions it contained, if it was on a flexible substrate, etc. The program targets are very challenging for the solar cell, and there was simply not enough information or reference to provide the requisite justification of the expected performance and timeline that have been targeted. Additionally, the cost is not discussed/addressed, leaving the market potential and cost feasibility unknown.