Idaho Incubation Fund Program

Progress Report Form

Proposal No.	**IF15-004**
Name:	**Dr. ~~Ryung Uh~~John Gardner**
Name of Institution:	**Boise State University**
Project Title:	**SAVE: Self-Organizing Air Vent System**
Reporting Period:	**July 1, 2014 to December 31, 2014**

Information to be reported in your progress report is as follows (attach additional information as needed):

1. Summary of project accomplishments for the period just completed and plans for the coming reporting period:

   Accomplishments

   The design of a 2nd generation SAVE board has been completed. While the priority of the 1st generation board design was to minimize cost, the goals of the 2nd generation board design was to incorporate a new energy harvesting technique to help reduce power consumption and enhance reliability. The new design architecture is based on a more powerful ARM based Atmel controller that allows for more robust control firmware and detailed user interfaces. We also upgraded our previous in-board PCB antenna and wireless radio with an all-in-one Atmel Zigbit module. The Atmel Zigbit module allows for us to use the Zigbee radio stack on a 433 MHz spectrum, giving us greater communication reliability from a firmware and hardware perspective. The board redesign also included a power conversion circuit to plug into 24V residential lines, and used a lower power switching regulator instead of a low dropout regulator for better power efficiency. Lastly, we included pin outs for a high precision Honeywell air pressure sensor for running experiments on air duct static pressure and overall system feedback.

   The other portion of the work done during this period was focused on researching energy harvesting techniques to incorporate into the board redesign. The intent of the energy harvesting was to help extend the battery life. We initially studied wireless RF energy harvesting, taking ambient wireless RF energy and converting it into battery storage. However, the power generated was negligible relative to our power budget. We then evaluated small wind turbines placed in the vent airflow to generate power. While these were better in terms of power generated when compared to wireless RF energy harvesting, they were still not sufficient to make a meaningful contribution to our power budget. In addition, the fans also would contribute to raising the load on the HVAC system and presented maintenance issues as well. The final approach we studied were indoor solar panels that could be mounted to the faceplate of the automated vent registers. The solar panels provided greater energy generation than the wind turbines, but still not sufficient to make a

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significant contribution to the power budget. In addition, the costs associated with the solar panels, as well as the necessary size made their use impractical as well.

Based on the poor results of the energy harvesting investigation, we directed our efforts to finding ways to reduce the power demands of the circuit. The two main circuits that comprised almost the entirety of the power budget are the radio (transmit and receive) and the motor that drives the louvers of the vent.

Lastly, we consulted with FAMCO, an HVAC parts manufacturer (Meridian, Idaho) for a design of this latest embodiment automated vent registers. They provided guidance and feedback on typical household HVAC voltage lines, pressure system load, and system indicators of the HVAC coils icing. FAMCO was very helpful in evaluating our board requirements and responsible for coming up with an optimal automated vent register tailored to our new board design that would minimize the HVAC system load. In addition, FAMCO evaluated the design to ensure it would be durable and fault tolerant.

Future Plans

Work is underway to address the outstanding issues on this project:

1) Avoiding coil icing (and related inefficiencies) and
2) monitoring overall system health through pressure measurements

To carry out these tasks, the test stand is being modified to accommodate a more realistic operating environment –including a variable speed air blower, an air distribution network and related instrumentation. This apparatus will allow a more thorough and convincing demonstration of the capabilities of the SAVE system.

~~*[John, please add your plans here…]*~~

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2. Summary of budget expenditures for the period just completed (include project burn rate):

PI Salary	$2,545
Student Salary	$3,580
Fringe	$ 642
Other Expense	$ 480
Travel	$ 0

Total Expense as of 12/31/14 = $7247

Burn Rate: $1,208 per month

3. Numbers of faculty and student participation resulting from the funding, including internships:

   Number of Faculty: 1 (Gang-Ryung Uh, PI)
   Number of Students Involved: 1 (Kyle Schwab, CS Graduate Student)

4. List patents, copyrights, plant variety protection certificates received or pending:

   A provisional patent application given Serial No. 61/835,276 was filed on June 14, 2013 for BSU 130. The provisional patent was not converted to a utility in June of 2014 due to concerns about damage to the cooling system as the invention was disclosed. The inventors were going to proceed on the project in the direction of finding solutions to warrant their system will not damage cooling systems in homes (ice in coils, compressor damage, etc.). We were then going to revisit patent filings when the additional research was done. As of this email, there is no patent protection on the SAVE system.

5. List technology licenses signed and start-up businesses created:

   There have been no licenses or options executed.

6. Status of private/industry partnerships (include enough information to judge level of engagement):

   There has been industry involvement on the front end (KEG and FAMCO), mainly consultations with the private sector on how to commercialize the technology and what customer difficulties might be encountered, but no spin-outs/start-ups or other industry involvement has occurred.

7. Any other pertinent information that will indicate to the council that the project is meeting satisfactory progress.

   The principal investigator, Dr. Uh, has left ~~the SAVE program~~Boise State University. Dr. John Gardner, Director of the CAES Energy Efficiency Research Institute and Professor in Boise State's Mechanical & Biomedical Engineering Department, will assume the PI role for the remainder of the program.

   Dr. Gardner has extensive experience in engineering research, product development and residential energy efficiency. His current research agenda which includes the use of self-organizing networks to improve smart grid operations is well aligned with the goals of this project.

   ~~7.~~
   ~~John is an excellent choice for this position, given his academic interest in autonomous networks using peer to peer communication for energy savings as well as his overarching understanding of commercial and residential energy needs, HVAC systems, energy infrastructure and energy policy.~~

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Key goals of the program under ~~John's~~ Dr. Gardner's leadership include:

- Complete the assembly of the modified test stand
- Determine the relationship between louvre setting and flow across cooling coils
- Determine the ability of pressure sensors to inform decisions regarding overall system health
- Investigating peer-to-peer communication among the SAVE modules to mimic robotic swarm behavior to achieve global outcomes (e.g. optimum system operation).

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~~*[John, please add content here].*~~

Below is a revised budget proposal to support these activities:

Remaining Budget	$	42,753
Reg Sal	$	24,845
Irr Sal	$	-
Sum Sal	$	-
Stu Sal	$	5,750
Fringe	$	7,973
OE	$	4,185
Travel	$	-
Capital	$	-
Subcontracts	$	-
Student Costs	$	-
Total Direct	$	42,753
F&A-0%		-
Totals	$	42,753

~~Remaining Budget~~	~~$ 42,753~~
~~Reg Sal~~	~~$ 24845~~
~~Irr Sal~~	~~$~~
~~Sum Sal~~	~~$0~~
~~Stu Sal~~	~~$5750~~
~~Fringe~~	~~$7973~~

OE	$4185
Travel	$
Capital	$
Subcontracts	$
Student Costs	$
Total Direct	$ 42753
F&A 0%	
Totals	$ 42,753

~~Dr. John Gardner Curriculum Vitae~~**John F. Gardner, Ph.D. , P.E.**

Preparation:

Institution	Field	Year	Degree
Cleveland State University	Mechanical Engineering	1981	B.S.
The Ohio State University	Mechanical Engineering	1983	M.S.
The Ohio State University	Mechanical Engineering	1987	Ph.D.

Registered Professional Engineer, State of Idaho, PE 9912
Fellow of the American Society of Mechanical Engineers

Appointments:

2010 – Present	Director, CAES Energy Efficiency Research Institute
2000 – Present	Professor; Dept. of Mechanical Engineering, Boise State University
2007– 2010	Associate Vice President for Energy Research, Policy and Campus Sustainability, Boise State University
2001 –2007	Chair of Mechanical Enrg Dept., Boise State University
2002 –2003	Acting Chair of Electrical and Computer Enrg, Boise State
1997– 2000	Professor-in-Charge of Undergraduate Programs, Department of Mechanical Engineering, Penn State, University Park, PA
1993-2000	Associate Professor of Mechanical Engineering, Penn State University, University Park, PA
1997	Visiting Professor, University of California, Davis
1987-1993	Assistant Professor of Mechanical Engineering, Penn State University, University Park, PA
1985-1987	System Administrator, Dept. of Mechanical and Aerospace Engineering, University of Delaware.
1983	Biomedical Engineering Educator Fellow, Project HOPE, University of Cairo, Egypt. (Taught short course in microprocessor applications in engineering college)

Selected Publications:

Textbooks:

1. Kulakowski, B.T., J.F. Gardner and L.J. Shearer, Dynamic Modeling and Control of Engineering Systems, 3rd ed., Cambridge University Press, 2007.
2. Gardner, J.F. Simulation of Machines Using MATLAB and SIMULINK, Brooks Cole Publishing. 2001.

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Journal Articles:

3. Kaiser, A.B., J.P. Cusumano and J.F. Gardner, 2002. Modeling and Dynamics of Friction Wedge Dampers in Railroad Freight Trucks, *Vehicle System Dynamics*, **Vol. 38**, No.1, pp. 55-82
4. Ebert-Uphoff, I., J.F. Gardner, W.R. Murray and R. Perez. Preparing for the Next Century: The State of the Mechatronics Education. *IEEE/ASME Transactions on Mechatronics*. **5:2**, June 2000, pp 226-227.
5. Edinger, B., Frecker, M., Gardner, J., 2001. "Dynamic Modeling of an Innovative Piezoelectric Actuator for Minimally Invasive Surgery," *International Journal of Intelligent Material Systems and Structures*, Vol II, No. 10, pp 765-770.
6. Gardner, J.F. and S.A. Velinsky. Kinematics of Mobile Manipulators and Implications for Design, *Journal of Robotic Systems*, **17**(6), June, 2000, pp 309-320.

Conference Proceedings:

7. Gardner, J.F., K. Heglund, K.V.D. Wymelenberg, C. Rieger, 2013, "Understanding Energy Flow in Commercial Building Using Modal Analysis", Proceedings of the 7th ASME Energy Sustainability Conference, July 14-19, Minneapolis, MN.
8. Shively, Dustin; Gardner, John; Haynes, Todd; Ferguson, James, "Carbon-Free, Site Independent- Energy Storage for Grid Integration," poster presented at the American Wind Energy Association Windpower 2009 Conference & Exhibition
9. Shively, Dustin; Gardner, John; Haynes, Todd; Ferguson, James, "*Energy Storage Methods for Renewable Energy Integration and Grid Support*," Proceedings of IEEE Energy 2030 Conference, 17-18 November 2008
10. Gardner, John; Pyke, Patricia; Schrader, Cheryl; Callahan, Janet; and Moll, Amy. "The Party's Over: Sustaining Support Programs When the Funding is Done." Proceedings of the 2008 Annual Conference of the American Society for Engineering Education, 2008-2786.

US Patents:

5,902,351: Apparatus and Method for Tracking a Vehicle. (with Don Streit and Aleks Brandt)

#7,847,421: System for Generating Electrical Energy from Ambient Motion (with L. Simmons, S. Jackson and S. Yano)

#8,030,786: System for Generating Electrical Energy from Ambient Motion (with R. Scott Jackson and David Harris)

Synergistic Activities:

- Program Director, Engineering Schools of the West Initiative at Boise State University. This 5-year program strives to improve access to engineering education through supplemental instruction in mathematics and integrated first and second year curricula.
- Member, City of Boise Climate Protection Committee
- Chair, Boise State Campus Sustainability Advisory Board
- Member, City of Boise Public Works Commission

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