COVER SHEET FOR GRANT PROPOSALS

State Board of Education

SBOE PROPOSAL NUMBER: (to be assigned by SBOE)	AMOUNT REQUESTED: **$50,000**
TITLE OF PROPOSED PROJECT: **A High Performance, Horizontal Plate Battery for Plug-in, Hybrid Electric Vehicles (PHEVs)**	
SPECIFIC PROJECT FOCUS: **To develop technology for high performance automotive battery to be used in hybrid electric vehicles and particularly plug-in electric vehicles**	
PROJECT START DATE: **July 1, 2011**	PROJECT END DATE: **June 30, 2012**
NAME OF INSTITUTION: **University of Idaho**	DEPARTMENT: **Department of Chemical Engineering**
ADDRESS: **P.O. Box 443020** **Moscow, ID 83844-3020**	
	E-MAIL ADDRESS: dedwards@uidaho.edu PI PHONE NUMBER: **(208)885-7229**

	NAME:	TITLE:	SIGNATURE:
PROJECT DIRECTOR	**Dr. Dean B. Edwards**	**Professor**	Dr. Dean B. Edwards
CO-PRINCIPAL INVESTIGATOR	**Dr. Frank Cheng**	**Professor**	Frank Cheng
CO-PRINCIPAL INVESTIGATOR			
CO-PRINCIPAL INVESTIGATOR			

	NAME:	SIGNATURE:
Authorized Organizational Representative		by Heather Nelson
	Polly J Knutson, Director **Office of Sponsored Programs** **University of Idaho**	5/27/11

SUMMARY PROPOSAL BUDGET

Name of Institution: University of Idaho

Name of Project Director: Dr. Dean B. Edwards

A. FACULTY AND STAFF

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested
% OF TOTAL BUDGET:				**SUBTOTAL:**	

B. VISITING PROFESSORS

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested

C. POST DOCTORAL ASSOCIATES / OTHER PROFESSIONALS

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested
R&D Engineer – 20% Effort	**$24.42/hour**	**2.4**			**$10,200**
Postdoctoral Fellow – 15% Effort	**$26.24/hour**	**1.8**			**$ 8,200**
% OF TOTAL BUDGET:	**36.8%**			**SUBTOTAL:**	**$18,400**

D. GRADUATE / UNDERGRADUATE STUDENTS

Name/ Title	Rate of Pay	No. of Months CAL	ACA	SUM	Dollar Amount Requested
½ Graduate Research Assistant – Academic Year	**$18.00/hour**				**$ 7,000**
One Undergraduate Research Assistant – Academic Year	**$12.00/hour**				**$ 3,000**
½ Graduate Research Assistant – Summer	**$18.00/hour**				**$ 2,300**
One Undergraduate Research Assistant – Summer	**$12.00/hour**				**$ 3,100**
% OF TOTAL BUDGET:	**30.80%**			**SUBTOTAL:**	**$15,400**

E. FRINGE BENEFITS Rate of Pay (%)	Salary Base	Dollar Amount Requested
R&D Engineer Fringe Rate = 37%	**$10,200**	**$ 3,800**
Postdoctoral Fellow Rate = 37%	**$ 8,200**	**$ 3,000**
Graduate and Undergraduate Students – AY = 1%	**$10,000**	**$ 100**
Graduate and Undergraduate Students – Smr = 9%	**$ 5,400**	**$ 500**
	SUBTOTAL:	**$ 7,400**

F. EQUIPMENT: (List each item with a cost in excess of $1000.00.) Item/Description	Dollar Amount Requested
Materials and Supplies	**$ 1,700**
SEM Usage	**$ 1,500**
Materials for Test Containers	**$ 1,500**
SUBTOTAL:	**$ 4,700**

G. TRAVEL: Dates of Travel (from/to)	No. of Persons	Total Days	Transportation	Lodging	Per Diem	Dollar Amount Requested
					SUBTOTAL:	

H. Participant Support Costs:	Dollar Amount Requested
1. Stipends	
2. Travel (other than listed in section G)	
3. Subsistence	
4. Other	
SUBTOTAL:	

I. Other Direct Costs:	Dollar Amount Requested
1. Materials and Supplies	
2. Publication Costs/Page Charges	
3. Consultant Services (Include Travel Expenses)	
4. Computer Services	
5. Subcontracts	
6. Other (specify nature & breakdown if over $1000) **Graduate Student Tuition AY**	**$ 4,100**
SUBTOTAL:	**$ 4,100**
J. Total Costs: (Add subtotals, sections A through I) **TOTAL:**	**$50,000**
K. Amount Requested: **TOTAL:**	**$50,000**
Project Director's Signature: Dr. Dennis Edwards	Date: 5/26/11

INSTITUTIONAL AND OTHER SECTOR SUPPORT

(add additional pages as necessary)

A. INSTITUTIONAL / OTHER SECTOR DOLLARS

Source / Description	Amount

B. FACULTY / STAFF POSITIONS

Description

C. CAPITAL EQUIPMENT

Description

D. FACILITIES & INSTRUMENTATION

Description

A High Performance, Horizontal Plate Battery for Plug-in, Hybrid Electric Vehicles (PHEVs)

Principal Investigator: Dr. Dean B. Edwards, Professor of Chemical and Material Engineering

Idaho Public Institution: University of Idaho **Total Amount Requested:** $50,000

Background: Plug-in hybrid electric vehicles (PHEVs) which have a 30-50 mile electric vehicle range are increasingly being manufactured and marketed. Projections for these and other HEV and EV batteries show a strong growth in demand, see Figure 1. Unfortunately, the present Li-ion batteries being used in most of these vehicles are expensive and are limiting the number of PHEVs and other HEVs being sold. Battery design and material innovations developed at the University of Idaho and with collaborators elsewhere can provide a high performance, cost effective battery for PHEVs and other HEVs.

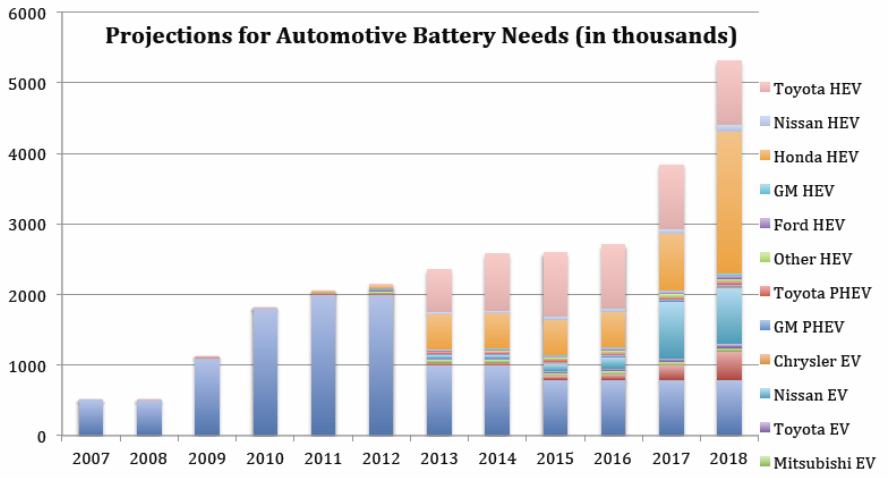


Figure 1 Projections for HEV Battery Demand (http://www.slideshare.net/CALSTART/calstart-webinar-batterychoicesapril2011)

The cost advantage that lead acid batteries have over other batteries, particularly Li-ion, is substantial, see Figure 2. Also, "wide spread usage of electric vehicles in Asia Pacific countries is related with the demand for lead acid batteries, as this chemistry is affordable for consumers at these regions" (Frost & Sullivan Report). The potential market for high

performance lead acid batteries is therefore in the range of $100M to $1B per year (Frost & Sullivan Report). Axion Power International, Inc. is a leader in making significant technical changes to conventional lead acid batteries (Frost & Sullivan Report). According to the Frost and Sullivan Report, the market for improved lead acid batteries is very large and Axion Power International is an innovative leader in this field. Axion Power International, Inc. is interested in our technology, see support letter. In addition, Exide Technologies, Inc., which is the largest battery company in the world, is sponsoring research on lead-acid battery additives at the University of Idaho (UI) and Savannah River National Laboratory (SRNL) and are also interested in this technology.

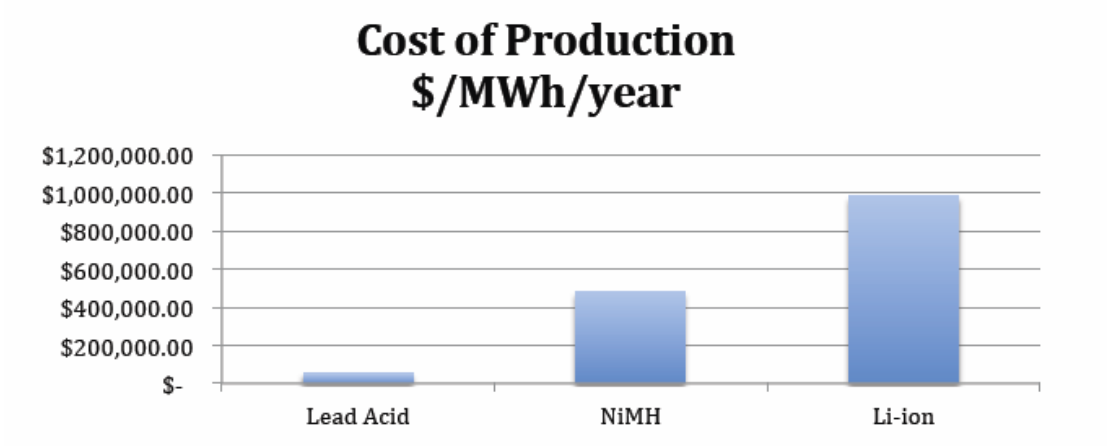


Figure 2 Estimated Yearly Cost of Running a Lead Acid, NiMH, and Li-ion Battery Production Facility (http://www.battcon.com/PapersFinal2011/ClarkeStephenPaperDONE2011_13.pdf)

The technology required to create this high performance, cost effective battery include the use of porous, hollow, glass microspheres (PHGMs), in a special horizontal plate, lead acid battery design. One example of a PHGM is shown in Figure 3. In addition, graphene coated PHGMs in both the positive and negative electrodes would provide additional benefits for this design including higher performance and longer life. The University of Idaho is developing intellectual property (IP) on using PHGMs in the horizontal plate battery design, have a patent

for use of conductive coatings on hollow glass microspheres (HGMs) or PHGMS, and have filed for a patent on the fabrication of graphene. Dr. Frank Cheng and his students at the University of Idaho in a serendipity moment discovered this graphene along with an inexpensive way of making it. This combination of intellectual property (IP) would provide the University of Idaho with a strong position when negotiating future licenses for this battery technology.

-

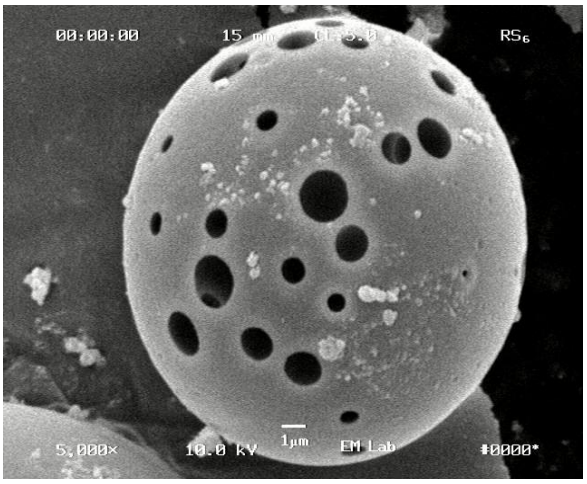


Figure 3 Porous hollow glass microsphere

"GAP" Project Objective and Requested Funds: The project objective is to demonstrate the improved performance of sealed, horizontal plate, lead acid cells using PHGMS, both with and without a graphene coating. We are requesting $50,000 for this work.

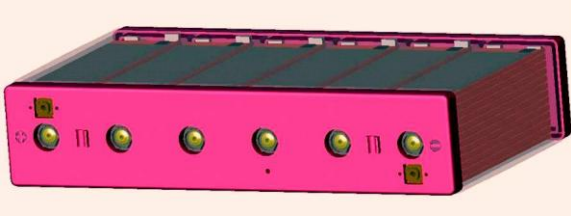


Figure 4 Horizontal Plate Battery Design

The University of Idaho developed a high power, lead acid battery for the Office of Naval Research (ONR) for use in military hybrid electric vehicles. The new sealed lead acid battery used a novel, low resistance topology consisting of horizontal plates having multiple inter-cell connections, see Figure 4. The figure shows six cells with each cell consisting of a horizontal stack of double-lugged plates separated

by glass-mat separators. This high power battery design results in a low profile module as shown in Figure 5. The novel design can provide both the specific power performance and life required for these applications.

The present horizontal plate battery, without the PHGM additives, can provide about 30 Whr/kg at the one hour rate and would be heavier than the Volt Li-ion battery for the same amount of stored energy but would cost significantly less. The Volt battery weighs about 400 lbs, costs over $8,000, and provides about 8 KWh of energy. An equivalent horizontal plate, lead-acid battery would require a 10 KWh capacity at the one hour rate (i.e. at 60 mph a 30-50 mile range would take less than an hour) so that 80% cycling of this battery would provide the required 8 KWh capacity and would weigh 730 lbs.

If the present horizontal plate battery is redesigned to use porous, hollow glass microspheres (PHGMs), the energy capacity at high rates (i.e. the one hour rate and higher) can be improved to 40 Wh/kg. The porous hollow glass microsphere provides structural integrity to electrodes while allowing them to store more electrolyte thereby improving their high rate capacity. This battery would weigh 550 lbs and cost approximately $1,000 to $1,500. In addition, our analysis shows that the 40 Wh/kg horizontal plate battery would have the same volume as the Volt battery. The proposed battery would therefore provide approximately the same energy as the GM Volt Li-ion battery and would have the same approximate volume. The Li-ion battery is of course lighter and weighs 400 lbs compared to the 550 lbs for the proposed battery. The use of graphene coated porous hollow glass microspheres (PHGMs) could further improve the specific energy performance and life of the battery with very little increase in cost.

University of Idaho's Priorities:

The University of Idaho places a very high priority on transferring technology developed by its researchers to the private sector. In addition, the UI is committed to helping create technology for a sustainable future both for our region and the country. The UI is also interested in licensing this technology and generating funds for the University of Idaho and the state.

Potential Impact on Idaho's Economy:

If this proposal is funded, the technology that we will be demonstrating could be a real "game changer" for the automotive market. This technology could be used in a wide range of vehicles from the low end electric scooters in the Far East to the high end PHEVs being developed and sold in the industrialized countries. Idaho companies could license and manufacture both the battery as well as the additives used in the battery. Other business opportunities for Idaho companies associated with this technology could also occur. For example, a high performance PHEV sports car, see Figure 8, could be manufactured in Idaho from designs developed at the University of Idaho that utilize the horizontal plate battery.

Project Work Plan and Budget:

The objective of the project and the work plan is to demonstrate the performance of sealed, horizontal plate, lead acid cells using PHGMS, both with and without a graphene coating. Although the performance improvement of having PHGMs in electrodes used in flooded cells has been shown, the use of PHGM electrodes in starved cells still needs to be investigated. The concern is that filling the PHGM with electrolyte in a starved configuration may be more difficult than in a flooded design. The proposed work and objective therefore addresses this concern.

In order to accomplish this objective, a number of tasks need to be completed. The first task is the fabrication of test containers where horizontal plates having the correct paste formulation can be cycled in a sealed, starved configuration. Task 1 is appropriately called "Fabrication of Horizontal Plate Test Containers (HPTC)." In the second task, paste having PHGMs would be formulated and used to fabricate plates. This task is called "PHGM Plate Fabrication." In addition, PHGMs would be coated with graphene in the third task which is called "Fabrication of Graphene Coated PHGMs." These graphene PHGMs would be used in paste to fabricate plates in Task 4, "Graphene Coated PHGM Plate Fabrication." In Task 5, "Cell Tests," the plates fabricated in Task 2 and 4 would be assembled into cells and tested. Task 6, "Project Management," would be responsible for managing the project and preparing all the required reports. These six tasks are discussed in more detail in the following sections:

Task 1) Fabrication of Horizontal Plate Test Containers (HPTC)

Previously, a proto-type Horizontal Plate Test Containers (HPTC), shown in Appendix A Figure 6, was assembled and pressure tested. The HPTC provides a sealed, horizontal configuration with compression on the plates being tested. The dual lugs are located so that a short strip of lead, spot welded to the plate, can easily be connected with the side of the chamber when the cover is removed. Spot welding the straps to the plates provides a quick, strong, and consistent method for completing the electrical hook-up in the HPTC.

Task 2) PHGM Plate Fabrication

In this task, we will fabricate paste both with and without PHGM additives. We will subsequently fabricate plates using the different pastes having varying amounts of additives. The plates will then be cured with procedures developed at the University of Idaho. In order to provide reproducible results, hand pasted plates not having PHGM additives fabricated by UI

personnel will be compared with production plates. All hand pasted plates having additives will then be compared to the hand pasted plates without additives, which are referred to as the "Baseline" plates. Once the individual plates are cured, they will be assembled and formed in a test cell as described in Task 5.

Task 3) Fabrication of Graphene Coated PHGMs

Enough PHGMs will be coated with graphene in this task to make batches of paste so plates and subsequently cells having these plates can be fabricated in Tasks 4 and 5. This coating process was developed at the University of Idaho and has been previously used to coat both diatoms and PHGMs.

Task 4) Graphene Coated PHGM Plate Fabrication

This task is the same as Task 2 except the PHGMs used to fabricate cells in this task will have a coat of graphene. The graphene coat will provide conductivity to the PHGM and will improve the energy performance of electrodes using these PHGMs.

Task 5) Cell Tests

After the plates have been cured, they will be assembled into cell stacks. The cell stacks will be placed in special horizontal plate test containers fabricated in Task 1. These cells will then be filled with electrolyte. The filling process of these cells will be done under a vacuum which will be varied from no vacuum to a maximum vacuum of negative 5-7 psi. Special fittings will be used on the test containers to facilitate transferring electrolyte into the cells at these different vacuums. This step is important in order to guarantee that the PHGMs are filled with electrolyte when used in a sealed, starved cell configuration. Porosity tests will be conducted to determine the amount of electrolyte stored in these plates.

The porosity of the plates after curing and formation will be established. These tests will investigate the amount of electrolyte stored in the plates and the performance of plates with and without the additives. The condition of the cured and formed plates will be recorded with pictures of the plates. The condition of the plates after cycling will also be noted and recorded.

Once a test cell is made, the first step is the formation process in which the active material of the plates is electrochemically transformed into lead dioxide (PbO_2) in the positive electrode and spongy metallic lead (Pb) in the negative electrode. After sulfuric acid is added, constant current or constant voltage charge may be used to charge the plates. After the formation charge, the test cell will be cycled, and the capacity of the cell tested at both high and low discharge rates.

Test cells typically have excess electrolyte added to ensure that the limiting factor is the plate being tested. During plate testing, cells consisting of only production plates are tested first to establish a comparison with hand-pasted plates without additives. In this manner, a control is established to verify that our hand-pasted plates provide results similar to production plates.

After the initial testing phase is completed where the performance of individual PHGM plates are evaluated, multi-plate cells having PHGM plates in both the positive and negative electrodes will be fabricated and tested. The results of these tests will demonstrate the performance of cells where both the positive and negative plates having PHGMs are used.

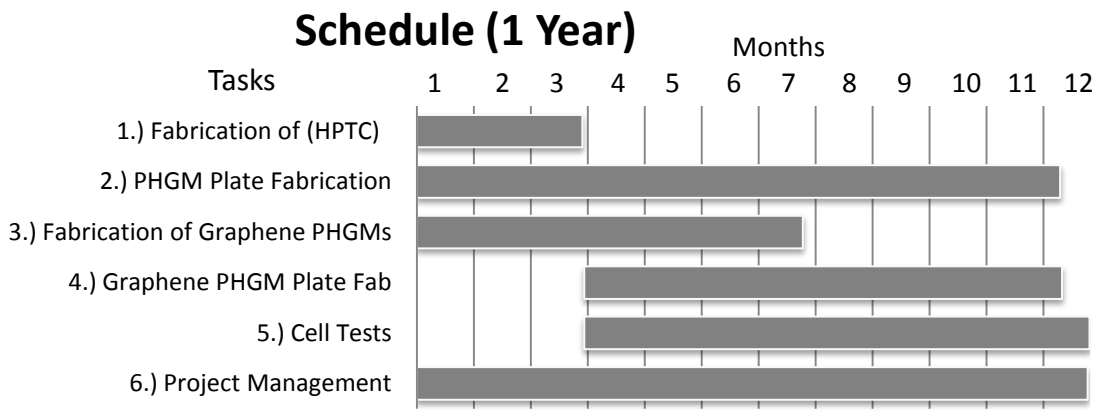
Task 6) Project Management

In this task, Professor Dean B. Edwards will be the principal investigator and provide overall project management. He will also be responsible for providing the State Board of Education (SBOE) with the project's quarterly and final reports.

Budget:

I. Salary Costs	
A. R&D Engineer & Postdoc Salaries w/Fringe	$25,200
B. Graduate & Undergraduate Student Research Assistants AY & Smr w/Fringe	$16,000
II. Expenses	$4,700
III. Indirect Costs – None Allowed	- 0 -
IV. Tuition Graduate Student RA	$4,100
Total Project Cost Year 1	$50,000

There will be no PI salaries on this project. However, University of Idaho faculty Dean B. Edwards and I.F. Cheng will provide minimal expertise over the duration of this project. A Research and Development Engineer will provide 20% effort to this project and a Postdoctoral Fellow will provide 15% effort to this project. One half graduate research assistant is to be employed 390 hours during the academic year at a rate of $18.00 per hour and one undergraduate research assistant is to be employed 250 hours at a rate of $12.00 per hour. A $1,700 allowance is projected for cell components including additives and miscellaneous research supplies. An allowance of $1,500 is projected for SEM usage to analyze cell plates and cell components including additives and $1,500 for materials to construct test containers.



Education and Outreach:

This project will partially support both a graduate and undergraduate student. The plug-in hybrid electric vehicle, shown in appendix A, was designed by a group of senior undergraduate engineering students. The horizontal plate battery developed for the Office of Naval Research presently powers the vehicle. In the future the horizontal plate battery being proposed for this work could power the vehicle and future undergraduate design projects will be used to further develop this vehicle. This provides educational opportunities for undergraduate students who also show their work to visiting high school students to support outreach.

Institutional and Other Sector Support:

The College of Engineering and Department of Chemical and Materials Engineering have agreed to support this project by allowing the use of the experiment station funds of up to 1 day a week to support professor Edwards. The use of the battery laboratory facilities will also be made available for this project. Axion Power International Inc. and Exide Technologies, Inc. are both interested in licensing this technology upon satisfactory completion of this project.

Appendices:

Appendix A: Facilities and Equipment:

The University of Idaho was founded in 1889 and is a comprehensive land-grant university with primary responsibility for research and Ph.D. programs in Idaho. The university's main campus is located in Moscow, Idaho and it maintains branch campuses throughout the state. The university is ranked in the highest Carnegie Foundation research classification as a Research Extensive University. The College of Engineering through its departments of Electrical and Computer Engineering, Mechanical Engineering, Civil Engineering, Chemical and Material Engineering, and Computer Science provides academic programs in a broad spectrum of engineering disciplines. Faculty and students in the college have access to a broad range of computational and experimental facilities.

The University of Idaho has a number of different laboratories that can be used to accomplish the proposed work. We have a 600 square foot Battery Lab that includes two vent hoods, an area with equipment for fabricating hand pasted plates, and test equipment for cycling cells and 12 volt modules. The horizontal plate test container that will be used in the project is shown in figure 6. The Battery Lab is equipped with two Arbin Instruments BT2000 Rechargeable Battery Testing System stations. The Arbin battery test stations are general-purpose testing equipment for battery testing, life cycling, and material research. Each channel is a fully functional potentiostat /galvanostat and covers very wide current, voltage and power ranges. The MITS Pro software is based on the MITS (multiple integrated testing system) concept with an emphasis on user-friendly interface.

The two stations are referred to as the "Little Arbin" and the "Big Arbin." The Little Arbin. in Figure 10, is configured for testing individual battery plates and cells and is configured with 16

channels each capable of 0-3 volts with up to 10 amps per channel. The Big Arbin is configured for testing complete battery modules and has a single channel capable of 0-18 volts with up 300 amps. Both of the Arbin test stations have their own dedicated temperature controlled test chambers. The Arbin test stations each have a dedicated desktop PC. A description of the data acquisition software, MITS Pro - Multiple Integrated Testing Software Suite can be found on the Arbin Instruments website (www.arbin.com).

The University of Idaho also has Scanning Electron Microscopes (SEMs) and other analytical instrumentation for analyzing plates. We have a 1700 square foot chemistry lab with two HP 5890A Gas Chromatographs, an HP 8453 Photodiode Array Spectrometer, a BAS CV50w Voltammograph, and a Gamry Corrosion/Battery Galvanostat/Potentiostat. Other analytical instrumentation is available at both the University of Idaho and Washington State University for use on this project.

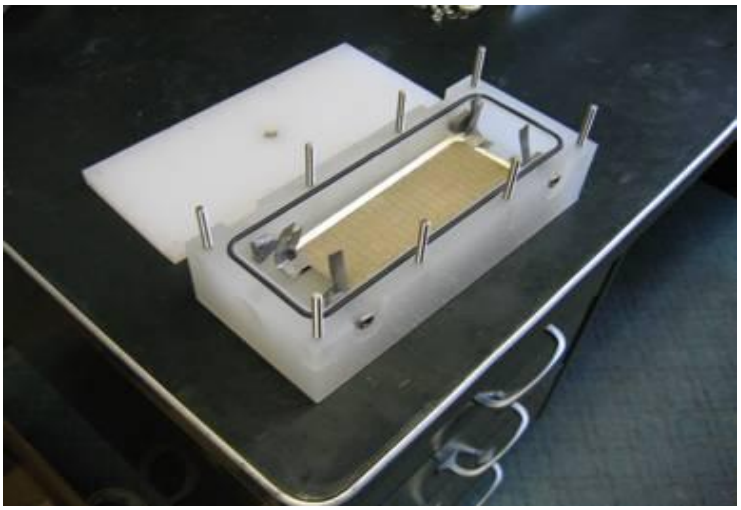


Figure 6 Horizontal Plate Test Chamber (HPTC)

Figure 7 Low Power Arbin Test Station

The plug-in hybrid electric vehicle shown in Figure 8 was designed by a group of senior undergraduate engineering students. The 30 horizontal plate W-hr/kg battery developed for the Office of Naval Research powers the vehicle. In the future, this vehicle could act as a test bed for the High Performance Horizontal Plate Battery being developed in this project.

Figure 8 University of Idaho Plug-in Hybrid Electric Vehicle with Horizontal Plate Batteries

Appendix B: Biographical Sketches and Individual Support:

Dean B. Edwards

University of Idaho
Moscow, Idaho 83844-0902

RANK OR TITLE: Professor of Chemical Engineering
DEPARTMENT: Chemical and Material Engineering
OFFICE PHONE: (208) 885-7229
EMAIL: dedwards@uidaho.edu

EDUCATION:

Ph.D., Mechanical Engineering, 1977, California Institute of Technology
Dissertation: "Time Domain Analysis of Switching Regulators"
M.S., Mechanical Engineering, 1973, California Institute of Technology
B.S., Mechanical Engineering, 1972, Illinois Institute of Technology

EXPERIENCE:

1996-present, Professor, University of Idaho
1986-96, Associate Professor, University of Idaho
1981-86, Technical Group Leader, Jet Propulsion Laboratory
1980-86, Member, Technical Staff, Jet Propulsion Laboratory
1977-80, Senior Engineer, Jet Propulsion Laboratory

PUBLICATIONS (last 4 years):

Patandar, S.N., McAllister, S. D., Cheng, I. F., Edwards, D.B., "Conductive Ceramic Coating on Poly Acrylonitrile-Vinyl Chloride (Modacrylic) Discontinuous Fibers via Electroless Deposition," *Journal of Power Sources*, 195 (2010) 362-366.

Zhang, S., Bean, T., Edwards, D.B., "Examination of different lattice structures in porous electrodes using a three-dimensional conductivity model," *Journal of Power Sources*, 195 (2009) 883-889.

McAllister, S. D., Patandar, S.N., Cheng, I. F., Edwards, D.B., "Lead Dioxide Coated Hollow Glass Microspheres As Conductive Additive for Lead Acid Battery," *Scripta Materialia*, 61 (2009), 375 – 378.

Ponraj, R., McAllister, S. D., Cheng, I. F., Edwards, D. B., "Investigation on electronically conductive additives to improve positive active material utilization in lead-acid batteries," *Journal of Power Sources*, 15 (2009) 1199-1203.

Newell, J.D., Patandar, S.N., Edwards, D.B., "Porous microspheres as additives in lead-acid batteries," *Journal of Power Sources*, 188 (2009) 292-295.

Edwards, D.B., and Zhang, S., "Three-Dimensional Conductivity Model for Porous Electrodes in Lead Acid Batteries," *Journal of Power Sources*, 172 (2007) 957-96.

McAllister, S., Ponraj, R., Cheng, I. F., Edwards, D. B., "Increase of positive active material utilization in lead-acid batteries using diatomaceous earth additives," *Journal of Power Sources*, 173 (2007) 882-886.

Redmond, J., Zhang, S., Edwards, D. B.,"Alternative Design for a Lead Acid Battery with Low Internal Resistance and High Power Density," Proceedings of the 10th European Lead Battery Conference, Athens, Greece, September 26-29, 2006.

Warner, J., Edwards, D. B., Kettelson, C., Manoranjan, V. S.,"Lead Acid Battery Grid Computer Aided Optimization," Proceedings of the 10th European Lead Battery Conference, Athens, Greece, September 26-29, 2006.

Current/Pending Support: Dean B. Edwards

NAME (List/PD #1 first)	SUPPORTING AGENCY AND AGENCY ACTIVE AWARD/PENDING PROPOSAL NUMBER	TOTAL $ AMOUNT	EFFECTIVE AND EXPIRATION DATES	% OF TIME COMMITTED	TITLE OF PROJECT
	Active:				
Dean B. Edwards, et.al.	Office of Naval Research N00014-10-1-0883	$1.388M	6/1/10-5/31/12	37.5% AY and 1 month summer '10	Magnetic Signature Assessment System using Multiple Autonomous Underwater Vehicles (AUVs), Phase III
Dean B. Edwards, et.al.	Exide Technologies, Inc. CR-09-002	$450k	7/1/09-6/30/11	4 wks in summer '09 and 1wk in summer '10	Developing Paste Additives for Advanced Lead-Acid Batteries
Dean B. Edwards, et.al.	Spark Technologies, LLC	$35k	8/15/09-6/30/11	1 wk in summer of '09	Developing Models for Evaluating Li-ion Additives

I. Francis Cheng
Tel. 208-885-6387

Cell: 208-301-3674

ifcheng@uidaho.edu

Department of Chemistry

University of Idaho

Moscow, Idaho 83844-2343

http://www.chem.uidaho.edu/faculty/ifcheng/default.htm

EDUCATION

Texas A&M University, College Station, TX Postdoctoral Fellow (1987-89)

Pennsylvania State University Analytical Chemistry Ph.D, 1988

University of Delaware Chemistry B.S., 1982

PROFESSIONAL APPOINTMENTS

University of Idaho Assistant, Associate and Full Professor of Chemistry (1997 -)

University of Arizona Scientist (1994-97)

Pima County Community College Tucson, AZ Adjunct Professor (1995-96)

Seton Hall University South Orange, NJ Assistant Professor of Chemistry (1989-93)

FIVE RELEVANT PUBLICATIONS (57 total since 1988)

"Increase of Positive Active Material Utilization in Lead-Acid Batteries Using Diatomaceous Earth Additives" Simon D. McAllister[a], Rubha Ponraj[a], I. Francis Cheng[a]*, and Dean B. Edwards *Journal of Power Sources*, **2007**, *173*, 882-886

"Investigation on electrically conductive additives to improve positive active material utilization in lead-acid batteries" Rubha Ponraj, Simon D. McAllister, I. Francis Cheng*, Dean B. Edwards, *Journal of Power Sources*, **2009**, 189, 1199-1203
http://dx.doi.org/10.1016/j.jpowsour.2008.12.077

"Selective and Rapid Detection of Triacetone Triperoxide by Double-Step Chronoamperometry" I. Francis Cheng and Yuqun Xie, *Microchemical Journal*, **2010**, 94, 166-170.
http://dx.doi.org/10.1016/j.microc.2009.10.016

"Conductive Ceramic Coating on Poly Acrylonitrile -Vinyl Chloride (Modacrylic) Discontinuous Fibers via Electroless Deposition" Sunil N Patankar, Simon D. McAllister, I. Francis Cheng, Dean B. Edwards, *Journal of Power Sources*, **2010** *195*, 362-366. doi:10.1016/j.jpowsour.2009.07.010

"Synthesis of graphene paper from pyrolyzed asphalt" I. Francis Cheng, R. Allen Gonzales, Yuqun Xie, Przemysław R. Brejna, Jency Pricilla Sundararajan, B. A. Fouetio Kengne, D. Eric Aston, David N. McIlroy, Jeremy D. Foutch and Peter R. Griffiths *Carbon*, **2011**, *49*, 2852-2861 doi:10.1016/j.carbon.2011.03.020

HONORS AND AWARDS

- Phi Kappa Phi (2001), Sigma Xi (1990), Phi Lambda Upsilon (1983)

CURRENT SUPPORT

- Akzo-Nobel Electroless Copper Deposition $14,894

PENDING SUPPORT

- Graphene Electrodes for Oxidations, Ultracapacitors, Batteries to AFOSR July 1, 2011 expected budget: $500,000 over three years

PATENT DISCLOSURES

- A Method for the Complete Combustion of Organics At Standard Temperature and Pressure and Aqueous Conditions, October, 2000
- A Method for Depositing Highly Active Pt Fuel Cell Catalysts on Carbon Nanotubes, October 2008
- A Method for the Rapid and Selective Detection of Triacetoneperoxide November 2008
- Bulk Synthesis of Graphene I July 2009.
- Bulk Synthesis of Multilayered Graphene II, October 2009
- Bulk Synthesis of Multilayered Graphene III, October 2009

CURRICULUM VITAE

University of Idaho
Moscow, Idaho 83844-1021

NAME: Edwards, Dean B. **DATE:** March 29, 2011

RANK OR TITLE: Professor of Chemical Engineering

DEPARTMENT: Chemical & Materials Engineering

OFFICE LOCATION: BEL 319 **OFFICE PHONE:** (208) 885-7229

EMAIL: dedwards@uidaho.edu

DATE OF FIRST EMPLOYMENT AT UI: August 1986

DATE OF TENURE: July 1, 1993

DATE OF PRESENT RANK OR TITLE: August 1996

EDUCATION BEYOND HIGH SCHOOL:

Ph.D., Mechanical Engineering, 1977, California Institute of Technology
Dissertation: "Time Domain Analysis of Switching Regulators"
M.S., Mechanical Engineering, 1973, California Institute of Technology
B.S., Mechanical Engineering, 1972, Illinois Institute of Technology

EXPERIENCE:

In Educational Institutions Since Receipt of Bachelor's Degree:

Teaching and Research:

Director of the Center for Intelligent Systems Research (CISR), 2000-present
Professor of Mechanical Engineering, University of Idaho, 1996-2008
Professor of Chemical & Materials Engineering, University of Idaho, 2008-present
Full Member of the Graduate Faculty
Teaching Assistant, California Institute of Technology

Courses Taught:

ME 220, Dynamics, 3 cr.

ME 313, Dynamic Modeling of Engineering Systems, 3 cr. (developed course)

ME 324, Dynamic Analysis in Machine Design, 3 cr.

ME 340, Strength of Materials, 3 cr.

ME 380, Modeling of Engineering Systems, 3 cr.

*ME 410, Production Engineering, 3 cr.

ME 426, Mechanical Design, 5 cr.

ME 476/576, Automation, Robotics, and Computer Integrated Manufacturing, 3 cr. (developed course)

*ME 481, Control Systems, 3 cr. (developed course)

ME 491, Seminar, 0 cr.

ME 492, Seminar, 0 cr.

ME 499, DS: Hybrid Electric Vehicle, 3 cr.

ME 501, Seminar, 1 cr.

*ME 548, Elasticity, 3 cr.

*ME 581, Fuzzy Logic Control Systems, 3 cr. (developed course)

*ME 582, Advanced Topics in Control Theory, 3 cr. (developed course)

*Video Courses

Teaching and Research (cont.):

Teaching Improvement:

Panelist on "Personal Reflections on Writing in the Classroom," Fall Teaching Forum, October 17-18, 1994.

Completed Faculty Development Workshop: "Using Writing to Improve Teaching and Learning," May 23-26, 1994.

Completed seminar entitled "Teaching Problem Solving and Decision Making," 1992.

Team-taught with Rick Gill to enhance teaching, Fall 1991.

Attended a forum on "Teaching Freshmen," 1991.

Completed a College of Engineering Teaching Seminar, 1990.

Completed course entitled "College Teaching," Ed/ 516, during the summer of 1989.

Previously Major Professor For:

Andy Rajala, "Enhancing Cooperative Behavior of Autonomous Underwater Vehicles with Language," Master of Science Thesis, University of Idaho, Spring 2006.

Doug Welling, "Fuzzy Logic Control for Autonomous Underwater Crawler Using Rotating Head Sonar," Master of Science Thesis, University of Idaho, December 2005.

Tom Bean, "Utilization of Surface Craft in Controller Design for Autonomous Underwater Vehicles," Master of Science Thesis, University of Idaho, December 2005.

Song Zhang, "Investigating Paste Additives to Improve the Specific Energy Performance of Lead-Acid Batteries," Doctor of Philosophy, University of Idaho, Summer 2005.

Charles E. Kinney, "A Fuzzy Logic Vision and Control System Trained with Human Knowledge for an Autonomous Vehicle," Master of Science Thesis, University of Idaho, May 2003.

Jonathan P. Stolte, "Acoustic Sensor Configurations for a Fuzzy Controlled Autonomous Vehicle," Master of Science Thesis, University of Idaho, April 2003.

James Richards, "Modeling a High Performance Auxiliary Power Unit for a Series Hybrid Electric Vehicle," Master of Science, University of Idaho, August 2001.

Ian Anderson, "A Fuzzy Logic Controller that Uses Quality Factors to Blend Behaviors for an Autonomous Forest Vehicle," Master of Science, University of Idaho, December 2000.

Alan Carlson, "Development of a Robust Hierarchical Fuzzy Logic Control System for an Autonomous Vehicle," Master of Science, University of Idaho, December 2000.

John R. Canning, "Development of a Fuzzy Logic Guidance System for Mobile Robots," Doctor of Philosophy, University of Idaho, May 1999.

William Beasley, "Design and Economic Feasibility of a Small Radio Controlled Log Skidder," Master of Science, University of Idaho, January 1998.

Jeff Luke, "Development of a Uniform Methodology for Designing Fuzzy Logic Control Systems," Master of Science, University of Idaho, December 1997.

Rick Cantrell, "Modeling and Designing a High Performance Lead-Acid Battery for Hybrid Electric Vehicles," Master of Science, University of Idaho, September 1996.

Pritpal S. Gill, "A Finite Difference Model for Simulating the Discharge Behavior of the Positive Electrode in Lead-Acid Cells," Master of Science, University of Idaho, August 1995.

Philip W. Appel, "Modeling and Verification of the Performance Limitations of Lead Acid Cells Utilizing Both Conductive and Nonconductive Paste Additives," Doctor of Philosophy, University of Idaho, May 1994.

Hong-Taek Choi, "Use of Fuzzy Logic to Calculate the Statistical Properties of Strange Attractors in Chaotic Systems," Doctor of Philosophy, University of Idaho, May 1994.

John Canning, "Development of a Radio Controlled Log Skidder with Fuzzy Logic Autonomous Control," Master of Science, University of Idaho, August 1994.

Philip W. Appel, "Investigation of the Capacity Limiting Mechanisms of the Lead Acid Battery During Low Rate Discharge," Master of Science, University of Idaho, May 1991.

Hong-Taek Choi, "The Dynamics of an Impact Printer Hammer and Print Quality," Master of Science, University of Idaho, May 1991.

Vellal Srikanth, "Evaluation of Positive Lead-Acid Battery Paste Containing Hollow Glass Microspheres," Master of Science, University of Idaho, May 1990.

Teaching and Research (cont.):

Walter Moden, III, "A Flexible Manufacturing System for Inserting Contacts into Flat Panel Keyboards," Master of Science, University of Idaho, May 1989.

Presently Major Professor For:

Jim Warner (ME)

Michael Santora (ECE)

Jason Redmond (ME)

Joel Albert (ECE)

Member of Past Committees (not major professor):

Akira Okamoto, M.S.E.E. completed Fall 2003

Aghogho Ekpruke, completed Summer 2003

Jonathan Dodge, M.S.E.E., completed Fall 2000

David B. Reiche, M.S.M.E., completed Fall 2000

Yafang Song, Ph.D., Mathematics (WSU), Fall 1998

William F. Danielson, III, M.S.C.S., completed Fall 1997.

Jianqiang Zhuo, Ph.D.C.S., completed Spring 1997.

Michael V. Spangler, Ph.D.Met.E., completed Spring 1997.

Troy Pearse, M.S.C.S., completed Spring 1996.

Roberta Fothergill, M.S.E.E., completed Spring 1996.

Xiulin Zhang, Ph.D.Ag.E., completed Fall 1996.

Chong S. Cho, Ph.D.Met.E, completed Fall 1995.

H.J. Kamath, Ph.D.E.E., completed Summer 1995.

Michael Abbott, M.E.M.E., completed Summer 1995.

Daryl Reece, M.S.M.E., completed Spring 1995.

Philip R. Martin, M.S.M.E., completed Spring 1995.

Linda Robertson Stuffle, Ph.D.E.E., completed Spring 1995.

Jianqiang Zhuo, M.S.C.S., completed Spring 1994.

Peter Sean Feeley, M.S.E.E., completed Summer 1993.

Berat Hakan Burocak, Ph.D.M.E. at WSU, completed Spring 1993.

George M. Niederaner, M.S.E.E., completed Fall 1992.

Daniel Seegmiller, Ph.D.M.E., completed August 1992.

Bin He, Ph.D.Ag.E., completed August 1992.

Jim Rose, M.S.E.E., completed May 1988.

H.J. Kamath, M.S.E.E., completed December 1989.

Cai Ying-Xia, M.S.C.E., completed July 1990.

Manjunath K. Shamanna, M.S.E.E, completed 1990.

James M. Prince, M.S.M.E., completed July 1991.

Deepak Upadhyaya, M.S.M.E., completed May 1991.

Mantena Prabhakar Raju, Ph.D.M.E., completed May 1989.

Joe Guarino, Ph.D.M.E., completed May 1990.

Ted William Barnes, Ph.D.E.E., completed December 1991.

Undergraduate Research Students:

Dan Niebauer, 1989.

Service:

Session Chairman for "Underwater Robot Control," proceedings of the 2005 IEEE International Conference on Systems, Man and Cybernetics, Waikoloa, Hawaii, October 9-13, 2005.

Session Chairman for "Fuzzy Systems" and Session Co-Chairman for "Uncertain Systems," proceedings of the 2005 ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Long Beach, California, September 24-28, 2005.

Hybrid Electric Vehicle (HEV) Competition Faculty Advisor (1991-present). Advised team leaders on organizing and designing HEV for national competition; participated in meetings, fund raising, and trip to competition.

Member of the Technical Committee for the Computers in Engineering Division of the American Society of Mechanical Engineers, 1994-97.

Session Chairman for "Applications of Fuzzy Logic and Genetic Algorithms in Engineering," at the 17th Computers in Engineering Conference, Sacramento, California, September 14-17, 1997.

Session Chairman for "Simulation and Fuzzy Logic," at the 16th Annual ASME Computers in Engineering Conference, University of California, Irvine, California, August 19-22, 1996.

Session Chairman for "Fuzzy Logic, Neural Networks, Genetic Algorithms, and Computer Simulations," at the 15th Annual ASME Computers in Engineering Conference, Boston, Massachusetts, September 17-21, 1995.

Session Chairman for "Fuzzy Logic Simulation and Robotics" at the 14th Annual ASME Computers in Engineering Conference, Minneapolis, Minnesota, September 11-14, 1994.

Session Co-Chairman for "Modelling of Fuzzy Systems" at the Ninth International Conference on Mathematical and Computer Modelling, Berkeley, California, July 26-29, 1993.

American Society of Mechanical Engineers (ASME) Student Advisor (1986-89). Advised club officers; helped organize and participated in meetings, field trips, and fund raisers; supervised design and paper competitions; and interacted with the ASME Regional Office and our Senior Section.

Review Papers for *Journal of Intelligent and Fuzzy Systems*, *Journal of Robotic Systems*, *Mechatronics*, *Journal of Computers and Mathematics*, and *Journal of Power Sources*.

Committee Assignments:

Hybrid Electric Vehicle Competition (Faculty Advisor)
NIATT Representative
Honors Student Advisor
Scholarship
Student Recruitment
Boise Manufacturing Program

Other Professional:

Employment:

1996-present, Professor, University of Idaho
1986-96, Associate Professor, University of Idaho
1981-86, Technical Group Leader, Jet Propulsion Laboratory
1980-86, Member, Technical Staff, Jet Propulsion Laboratory
1977-80, Senior Engineer, Jet Propulsion Laboratory
July 1976-April 1977, Engineering Consultant, Printronix, Inc.
June-October 1975, Engineer, Jet Propulsion Laboratory
1969-72, Co-op Student, Western Electric Company

Membership in Professional and Scholarly Organizations:

American Society of Mechanical Engineers (ASME)
Society of Automotive Engineers (SAE)
Pi Tau Sigma
Tau Beta Pi
Professional Engineer (Idaho, 1990)

PUBLICATIONS:

Books: (Refereed Chapter)

Edwards, D.B., "Powertrain Design for Electric Vehicles," *Automotive Engineering and Litigation*, Vol. V, John Wiley & Sons, New York, New York, 1993, pp. 231-259.

Refereed Journal Publications:

Patandar, S.N., McAllister, S. D., Cheng, I. F., Edwards, D.B., "Conductive Ceramic Coating on Poly Acrylonitrile-Vinyl Chloride (Modacrylic) Discontinuous Fibers via Electroless Deposition," *Journal of Power Sources*, 195 (2010) 362-366.

Zhang, S., Bean, T., Edwards, D.B., "Examination of different lattice structures in porous electrodes using a three-dimensional conductivity model," *Journal of Power Sources*, 195 (2009) 883-889.

McAllister, S. D., Patandar, S.N., Cheng, I. F., Edwards, D.B., "Lead Dioxide Coated Hollow Glass Microspheres As Conductive Additive for Lead Acid Battery," *Scripta Materialia*, 61 (2009), 375 – 378.

Ponraj, R., McAllister, S. D., Cheng, I. F., Edwards, D. B., "Investigation on electronically conductive additives to improve positive active material utilization in lead-acid batteries," *Journal of Power Sources*, 15 (2009) 1199-1203.

Newell, J.D., Patandar, S.N., Edwards, D.B., "Porous microspheres as additives in lead-acid batteries," *Journal of Power Sources*, 188 (2009) 292-295.

J. R. Canning, M. J. Anderson, D. B. Edwards, M. O'Rourke, T. A. Bean, D. L. Odell, "A Low Bandwidth Acoustic Communication Strategy For Supporting Collaborative Behaviors In a Fleet of Autonomous Underwater Vehicles, *Journal of Underwater Acoustics*, August 2009.

Bean, T., Beidler, G., Canning, J.R., Odell, D., Wall, R., O'Rourke, M., Anderson, M.J., Edwards D.B.,"Language and Logic to Enable Collaborative Behavior among Multiple Autonomous Underwater Vehicles", *International Journal of Intelligent Control and Systems*, Vol. 13, No. 1, March 2008, 67-80.

Edwards, D.B., and Zhang, S., "Three-Dimensional Conductivity Model for Porous Electrodes in Lead Acid Batteries," *Journal of Power Sources*, 172 (2007) 957-96.

McAllister, S., Ponraj, R., Cheng, I. F., Edwards, D. B., "Increase of positive active material utilization in lead-acid batteries using diatomaceous earth additives," *Journal of Power Sources*, 173 (2007) 882-886.

Edwards, D.B., and Zhang, S., "A Three-Dimensional Conductivity Model for electrodes in Lead Acid Batteries," *Journal of Power Sources*, 158 (2006) 927-931.

Anderson, I.P., Carlson, A.C., Edwards, D.B., Anderson, M.J., and Feeley, J.J., "An Autonomous Forest Robot That Uses a Hierarchical, Fuzzy Logic Controller," *Transactions of the American Society of Agricultural Engineers*, Vol. 48, No. 4, pp. 1603-1617, 2005.

Edwards, D.B., and Zhang, Song, "Influence of different aspect ratio additives on the performance of lead-acid batteries," *Journal of Power Sources*, 135 (2004), 297-303.

Song, V., Edwards, D.B., and Manoranjan, V.S., "Fuzzy Cell Mapping Applied to Autonomous Systems," submitted to the *Journal of Computing and Information Science in Engineering*.

Canning, J.R., Edwards, D.B., and Anderson, M.J. "Development of a Fuzzy Logic Controller forAutonomous Forest Path Navigation," *Transactions of the American Society of Agricultural Engineering.* Vol. 47, No. 1, pp. 301-310, 2004.

Edwards, D.B., and Schmitz, C., "Theoretical Calculations for Using Positive Electrode Compression to Increase Lead-Acid Battery Life," *Journal of Power Sources*, 85 (2000), 63-71.

Edwards, D.B., and Dayton, T.C., "Improving the Performance of a High Power, Lead Acid Battery with Paste Additives," *Journal of Power Sources,*85 (2000), 137-144.

Cantrell, R.L., Edwards, D.B., and Gill, P.S., "Predicting Lead-Acid Battery Electrode Performance Using Finite Difference Equations," *Journal of Power Sources*, Vol. 73/2, pp. 204-216, June 1998.

Edwards, D.B., and Choi, H.T., "Use of Fuzzy Logic to Calculate the Statistical Properties of Strange Attractors in Chaotic Systems," *Journal of Fuzzy Sets and Systems*, Vol. 88, No. 2, pp. 205-217, June 1, 1997.

Appel, P.W., and Edwards, D.B., "Understanding and Defeating the Physical Mechanisms Limiting the Capacity of Lead-Acid Batteries," *Advanced Performance Materials (APM)*, Issue 3.1, January 1996.

Edwards, D.B., and Canning, J.R., "Developing a Radio-Controlled Log Skidder with Fuzzy Logic Autonomous Control," *Transactions of the American Society of Agricultural Engineering*, Vol. 38, No. 1, pp. 243-248, 1995.

Appel, P.W., and Edwards, D.B., "Capacity Predictions for Lead Acid Battery Plates Having Conductive Additives," *Journal of Power Sources*, Vol. 55, No. 1, pp. 81-85, 1995.

Manoranjan, V.S., de Sam Lazaro, A., Edwards, D.B., and Athalye, A., "A Systematic Approach to Obtaining Fuzzy Sets for Control Systems," *Journal of Systems, Man, and Cybernetics*, Vol. 25, No. 1, pp. 1-9, January 1995.

Edwards, D.B., and Choi, H.T., "Impact Printer Hammer Dynamics and Print Quality," *Journal of Mathematical Modelling and Scientific Computing*, Vol. 3, No. 3, 1994.

de Sam Lazaro, A., Engquist, D.T., and Edwards, D.B., "Design for Manufacturability of Sheet Metal Parts with an Intelligent System," *International Journal of Concurrent Engineering: Research and Applications (CERA)*, Vol. 1, No. 2, pp. 117-123, 1993.

Edwards, D.B., and Appel, P.W., "Modeling Lead/Acid Batteries that have Positive Electrodes Containing Hollow, Glass Microspheres," *Journal of Power Sources*, Vol. 46, No. 1, pp. 39-48, 1993.

Appel, P.W., Edwards, D.B., and Stalick, T., "Modeling the Effects of Electrolyte Diffusion and Paste Conductivity on Lead/Acid Battery Performance," *Journal of Power Sources*, Vol. 46, No. 1, pp. 49-60, 1993.

Athalye, A., Edwards, D.B., Manoranjan, S., and de Sam Lazaro, A., "On Designing a Fuzzy Control System Using an Optimization Algorithm," *Journal of Fuzzy Sets and Systems*, Vol. 56, No. 3, pp. 281-290, 1993.

Edwards, D.B., Appel, P.W., and Hammond, B., "Evaluation of Hollow, Glass Microspheres Used as an Additive in Negative, Lead Acid Battery Paste," *Journal of Power Sources*, Vol. 38, pp. 287-294, 1992.

Edwards, D.B., and Appel, P.W., "Conductivity Model for Lead Acid Battery Electrodes Discharged at Low Rates," *Journal of Power Sources*, Vol. 38, pp. 281-286, 1992.

Edwards, D.B., and Srikanth, V., "Evaluation of Hollow, Glass Microspheres Used as an Additive in Positive, Lead Acid Battery Paste," *Journal of Power Sources*, Vol. 34, No. 3, pp. 217-232, 1991.

Edwards, D.B., and Carter, B., "A High Power, Sealed, Lead Acid Battery for Electric Vehicles," *ASME Journal of Engineering for Industry*, Vol. 112, pp. 293-298, August 1990.

Refereed Conference Proceedings:

Folk, A., Armstrong, B., Wolbrecht, E., Grip, H., Anderson, M.,and Edwards, D.,"Autonomous Underwater Vehicle Navigation using Moving Baseline on a Target Ship," *Proceedings of Oceans '10 MTS/IEEE* Seattle, Seattle, Washington, September 20-23, 2010.

Crosbie, B., M. Anderson, E. Wolbrecht, J. Canning, D. Edwards, "Synchronous Navigation of AUVs Using WHOI Micro-Modem 13-bit Communications," *Proceedings of Oceans '10 MTS/IEEE* Seattle, Seattle, Washington, September 20-23, 2010.

Morton, B., Soule, T., Kanago, A., Frenzel, J., Edwards, D., "Ordering Autonomous Underwater Vehicle Inspection Locations with a Genetic Algorithm," *Proceedings of Oceans '10 MTS/IEEE* Seattle, Seattle, Washington, September 20-23, 2010.

Pentzer, J., B. Armstrong, J. Canning, T. Bean, D. Odell, D. Edwards, M. Anderson, E. Wolbrecht, J. Frenzel, "Spatial Sampling of Magnetic Field Using Collaborating Autonomous

Underwater Vehicles," *Proceedings of MSS Battlespace Acoustic and Seismic Sensing, Magnetic & Electric Field Sensors (BAMS) Symposium, August 2010.*

Pentzer, J., B. Crosbie, T. Bean, J. Canning, J. Frenzel Michael Anderson, D. Edwards, "Measurement of Magnetic Field using Collaborative AUVs," *Proceedings of Oceans '10 IEEE* Sydney, Sydney, Australia, May 24-27, 2010.

Odell, D., Pentzer, J., Canning, J., Edwards, D.,"A Versatile Tracking System for Autonomous Underwater Vehicle Testing," *Proceedings of Oceans '10 IEEE* Sydney, Sydney, Australia, May 24-27, 2010.

B. Armstrong, E. Wolbrecht, D.B. Edwards,"Autonomous Underwater Vehicle Navigation in the Presence of a Magnetic Disturbance with an Extended Kalman Filter," *Proceedings of Oceans '10 IEEE* Sydney, Sydney, Australia, May 24-27, 2010.

J. Pentzer*, B. Armstrong*, D. Odell*, T. Bean, J. Canning, M. Anderson, D.B. Edwards, "On-the-Fly Measurement of Surface Ship Acoustic and Magnetic Signature Using Multiple AUVs", *Proceedings of MSS Battlespace Acoustic and Seismic Sensing, Magnetic & Electric Field Sensorw (BAMS) Symposium*, 2009.

B. Armstrong*, J. Pentzer*, D. Odell, T. Bean, J. Canning, D. Pugsley, J. Frenzel Michael Anderson, D.B. Edwards, "Field Measurement of Surface Ship Magnetic Signature Using Multiple AUVs", *Proceedings MTS/IEEE Oceans '09*, Biloxi, Mississippi, October 26-29, 2009.

J. Pentzer*, B. Armstrong*, T. Bean, M. Anderson, D.B. Edwards, N.V. Schmehl, "Preventing Extended Kalman Filter Instabilities During Two Transponder Long Baseline Navigation with Real Time Fuzzy Logic Parameter Adjustment", *Proceedings of IEEE Oceans '09*, Bremen, Germany, May 11-14, 2009.

Hallin, N., Johnson, B., O'Rourke, M., Edwards, D.B.,"A Fuzzy Logic Resource Optimizer for a Fleet of Autonomous Vehicles in Low-Bandwidth Conditions," *Proceedings of Oceans '09 IEEE*, Bremen, Germany, May 11-14, 2009.

Johnson, B., Hallin, N., Leidenfrost, H., O'Rourke, M., Edwards, D.B., "Collaborative Mapping with Autonomous Underwater Vehicles in Low-Bandwidth Conditions," *Proceedings of Oceans '09 IEEE*, Bremen, Germany, May 11-14, 2009.

Hallin, N., Johnson, B., Egbo, H., O'Rourke, M., Soule, T., Edwards, D.B., "Simulating Human Reasoning in Mine-Like Object Inspection Assignments for a Formation of Unmanned Underwater Vehicles," *Proceedings of the ECSIS Symposium on Learning and Adaptive Behavior in Robotic Systems*, Iasi, Romania, July 22-24, 2009.

Hallin, N.J., Johnson, B.L., Egbo, H.N., Ray, P.L., O'Rourke, M., Frenzel, J.F., Soule, T., Edwards, D.B., "Using Language-Centered Intelligence to Optimize Mine-Like Object Inspections for a Fleet of Autonomous Underwater Vehicles," *Proceedings of the 16th International Symposium on Unmanned Untethered Submersible Technology (UUST'09)*, Lee, New Hampshire, August 23-26, 2009.

Kanago, A., Frenzel, J., Edwards, D.B., "A MOOS Module for Monitoring Energy Usage of Autonomous Vehicles," *Proceedings of the 16th International Symposium on Unmanned Untethered Submersible Technology (UUST'09)*, Lee, New Hampshire, August 23-26, 2009.

Meyer, D., Frenzel, J., Edwards, D.B., "Sharing Clearance Data between Multiple Autonomous Platforms," *Proceedings of the 16th International Symposium on Unmanned Untethered Submersible Technology (UUST'09),* Lee, New Hampshire, August 23-26, 2009.

Egbo, H., Hallin, N., Ray, P., O'Rourke, M., Frenzel, J., Edwards, D.B., "Token Based Medium Access Control Solution for Underwater Acoustic Broadcast Communication," *Proceedings of Oceans '09 IEEE Biloxi,* Biloxi, Mississippi, October 26-29, 2009.

Hallin, J., Egbo, H., Ray, P., Soule, T., O'Rourke, M., Edwards, D.B., "Enabling Unmanned Underwater Vehicles to Reason Hypothetically," *Proceedings of Oceans '09 IEEE Biloxi,* Biloxi, Mississippi, October 26-29, 2009.

Tye, C., Kinney, M., Frenzel, J., O'Rourke, M., Edwards, D.B., "A MOOS Module for Autonomous AUV Fleet Control," *Proceedings of Oceans '09 IEEE Biloxi,* Biloxi, Mississippi, October 26-29, 2009.

Ray, P., O'Rourke, M., Edwards, D.B., "Using Collective Intentionality to Model Fleets of Autonomous Underwater Vehicles," *Proceedings of Oceans '09 IEEE Biloxi,* Biloxi, Mississippi, October 26-29, 2009.

Ray, P., O'Rourke, M., Edwards, D.B., "The Ontological Status of Autonomous Underwater Vehicle Fleets," *Proceedings of Oceans '09 IEEE Biloxi,* Biloxi, Mississippi, October 26-29, 2009.

Alberts, J., Edwards, D. B., Soule, T., Anderson, M., O'Rourke, M., "Autonomous Navigation of an Unmanned Ground Vehicle in Unstructured Forest Terrain," *Symposium on Learning and Adaptive Behaviors for Robotic Systems (LAB-RS),* Edinburgh, UK, August 6-8, 2008.

Zhang, S., Canning, J., Bean, T., Edwards, D. B., "Alternative Horizontal Plate Lead Acid Battery Design having High Power Density," *43rd Power Sources Conference,* Philadelphia, PA, July 7-10, 2008.

A. Crawford, D.B. Edwards, "Implementing Fuzzy Logic in the Control of a Biologically Inspired Robotic Cat Leg," *Proceedings of the 2008 ASME International Design Engineering Technical Conferences & Computers and Information in Engineering Conference,* New York City, New York, August 3-6, 2008.

Newell, J.D., Patandar, S.N., Edwards, D.B., "Using Porous Microspheres as Additives in Lead-acid Batteries," *American Ceramic Society (ACS) Conference on Materials Innovations in an Emerging Hydrogen Economy*, Cocoa Beach, FL, February 24-27, 2008.

Bean, T., Canning, J., Beidler, G., O'Rourke, M., Edwards, D., "Designing and Implementing Collaborative Behaviors for Autonomous Underwater Vehicles*," Proceedings of the International Symposium Of Unmanned Untethered Submersible Technology*, Durham, NH, August 19-22, 2007.

Beidler, G., Bean, T., Morrison, D., Merrill, K., O'Rourke, M., Edwards, D.,"From Language to Code: Implementing *AUVish," Proceedings of the International Symposium Of Unmanned Untethered Submersible Technology*, Durham, NH, August 19-22, 2007.

Merrill, K., Bean, T., O'Rourke, M., Edwards, D., "Toward a Neurocognitive Agent Architecture for AUVs," *Proceedings of Oceans '07 MTS IEEE,* Vancouver, B. C., October 1-4, 2007.

Redmond, J., Zhang, S., Edwards, D. B.,"Alternative Design for a Lead Acid Battery with Low Internal Resistance and High Power Density," *Proceedings of the 10th European Lead Battery Conference*, Athens, Greece, September 26-29, 2006.

Warner, J., Edwards, D. B., Kettelson, C., Manoranjan, V. S.,"Lead Acid Battery Grid Computer Aided Optimization," *Proceedings of the 10th European Lead Battery Conference*, Athens, Greece, September 26-29, 2006.

Rajala, A., O'Rourke, M., Edwards, D. B.,"AUVish: A Language for Cooperating AUVs," *Proceedings of Oceans '06 MTS IEEE,* Boston, September 18-21, 2006.

Santora, M., Alberts, J., Edwards, D. B.," Control Of Autonomous Underwater Vehicles Using Neural

Networks," *Proceedings of Oceans '06 MTS IEEE,* Boston, September 18-21, 2006.

K. Merrill, M. O'Rourke, D. Edwards. "An Intentional Framework for Communication Between Multiple AUVs." *Proceedings of Oceans '06 MTS IEEE,* Boston, September 18-21, 2006.

Merrill, K., O'Rourke, M., Edwards, D. B.," An Intentional Framework for Communication in Multi-Agent Systems," *Proceedings of the Formal Ontologies for Communicating Agents Workshop*, Malaga, Spain: ESSLLI, August 2006.

Coleman, J., O'Rourke, M., Edwards, D. B.," Natural Language Pragmatics in the ACL Literature," *Proceedings of the Formal Ontologies for Communicating Agents Workshop*, Malaga, Spain: ESSLLI, August 2006.

M. O'Rourke, A.G. Rajala, K. Merrill, J. Coleman, D.B. Edwards. "Identifying Error in AUV Communication." *Proceedings of Oceans '06 Asia Pacific IEEE*, Singapore, May 16-19, 2006.

Rajala, A., Edwards, D. B.," Multiple AUV Map Development," *Proceedings of Oceans '06 Asia Pacific IEEE*, Singapore, May 16-19, 2006.

A. Okamoto and D.B. Edwards, "Regulating a Formation of a Large Number of Vehicles," *Proceedings of the 2005 ASME International Mechanical Engineering Congress and Exposition*, Orlando, Florida, November 5-11, 2005.

A.G. Rajala, D.B. Edwards, and M. O'Rourke, "Collaborative Behavior for Vehicle Replacement in AUV formations," *Proceedings of the 2005 ASME International Mechanical Engineering Congress and Exposition*, Orlando, Florida, November 5-11, 2005.

D.M. Welling and D.B. Edwards, "Multiple Autonomous Underwater Crawler Control for Mine Reacquisition," *Proceedings of the 2005 ASME International Mechanical Engineering Congress and Exposition*, Orlando, Florida, November 5-11, 2005.

D.M. Welling and D.B. Edwards, "Training Methods of a Non-Linear Fuzzy Logic Controller for an Underwater Autonomous Crawler," *Proceedings of the 2005 IEEE International Conference on Systems, Man and Cybernetics*, October 9-13, Waikoloa, Hawaii, 2005.

T.A. Bean, A. Okamoto, J.R. Canning, and D.B. Edwards, "A Nonlinear Fuzzy Logic Controller Developed For an Autonomous Surface Boat," *Proceedings of the 2005 ASME International Design Engineering Technical Conferences & Computers and Information in Engineering Conference,* Long Beach, California, September 24-28, 2005.

B.N. Baker, M.J. Anderson, D.L. Odell, T.A. Bean, D.B. Edwards, "A New Procedure for Simultaneous Navigation of Multiple AUV's," Proceedings of the MTS/IEEE Oceans 2005 Conference.

B.N. Baker, M.J. Anderson, D.L. Odell, T.A. Bean, D.B. Edwards, "Performance of a Two-Hydrophone Heading Sensor and AUV Formation Flying Controller", *Proceedings of the 14th International Symposium Of Unmanned Untethered Submersible Technology*, August 21-24, 2005.

D.M. Welling, D.B. Edwards, "Crawler Control Strategies and Their Influence on Mine Finding Capabilities", *Proceedings of the 14th International Symposium Of Unmanned Untethered Submersible Technology*, August 21-24, 2005.

A. Rajala, D. Edwards, "Vehicle Replacement in AUV Formations", *Proceedings of the 14th International Symposium Of Unmanned Untethered Submersible Technology*, August 21-24, 2005.

Edwards, D.B., and Zhang, S., "A Three-Dimensional Conductivity Model for electrodes in Lead Acid Batteries," *International Conference on Lead Acid Batteries (LABAT '05)*, June 13-16, Varna, Bulgaria, 2005.

Reeder, C., Okamoto, A., Anderson, M. and Edwards, D., "Two-Hydrophone Heading and Range Sensor Applied to Formation-Flying for Underwater AUV's," *Oceans '04 Techno-Ocean'04 (OTO'04*) *Conference Proceedings*, pp. 517-523, 2004.

Okamoto, A., Feeley, J., Edwards, D., and Wall, R., "Robust Control of a Platoon of Underwater Autonomous Vehicles," *Oceans'04 Techno-Ocean'04 (OTO'04) Conference Proceedings*, pp. 505-510, 2004.

Welling, D., Edwards, D., and Anderson, M., "Fuzzy Logic Control for an Autonomous Underwater Crawler," *Proceedings of the ASME 2004 Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, DETC2004-57723, Salt Lake City, Utah USA, September 2004.

Edwards, D.B., Bean, T., Odell, D., and Anderson, M.J., "A Leader-Follower Algorithm for Multiple AUV Formations," *Proceedings of 2004 IEEE/OES Autonomous Underwater Vehicles*, Sebasco Estates, Maine, June 17-18, 2004.

Edwards, D.B., Feeley, J.J., and Okamo, A., "A Systematic Approach for Developing Nonlinear Control Systems with Fuzzy Logic," *ASME, 23rd Computers and Information in Engineering Conference (CIE),* Paper DETC2003/CIE-48288, Chicago, Illinois, September 2-6, 2003.

Kinney, C.E. and Edwards, D.B., "A Fuzzy Logic Vision and Control System Embedded with Human Knowledge for Autonomous Vehicle Navigation," *10th International Fuzzy Systems Association (IFSA) World Congres*s, Paper ID-002787 TF2, Istanbul, Turkey, June 29-July 2, 2003.

Kinney, C. and Edwards, D.B., "A Fuzzy Logic Trail Finding Algorithm Trained with Human Knowledge," *ASME, 22nd International Computers and Information in Engineering Conference (CIE),* Montreal, Quebec, Canada, September 29-October 2, 2002.

Edwards, D.B., and Zhang, S., "A Novel, Forty-two Volt, Horizontal Plate Battery Design," *17th Annual Battery Conference on Applications and Advances*, Long Beach, California, January 2002.

Song, Y., Edwards, D.B., and Manoranjan, V.S., "Fuzzy Cell Mapping Applied to Autonomous Systems," *ASME, 21st International Computers and Information in Engineering Conference (CIE),* Pittsburgh, Pennsylvania, September 9-12, 2001.

Howard, A., Tunstel, E., Edwards, D.B., and Carlson, A., "Enhancing Fuzzy Robot Navigation Systems by Mimicking Human Visual Perception of Natural Terrain Traversability," *Joint 9th IFSA World Congress and 20th NAFIPS International Conference*, Vancouver, B.C., Canada, July 25-28,2001.

Edwards, D.B., Bitterwolf, T.E., and Kincheloe, K., "Modeling Oxygen Evolution and Associated Failure Mechanisms in Lead Acid Batteries," *16th Annual Battery Conference on Applications and Advances,* Long Beach, California, January 2001.

Edwards, D.B., and Kinney, C.E., "Advanced Lead Acid Battery Designs for Hybrid Electric Vehicles," *16th Annual Battery Conference on Applications and Advances*, Long Beach, California, January 2001.

Carlson, A., Edwards, D.B., and Anderson, M.J., "Fuzzy Quality Measures for Use in a Hierarchical Fuzzy Controller," ASME, *20th International Computers and Information in Engineering Conference*, Baltimore, Maryland, September 10-13, 2000.

Edwards, D.B. and Dayton, T.C., "Evaluation of Two Paste Additives on Cell Performance," IEEE (OOTH 8490), *15th Annual Battery Conference on Applications and Advances*, Long Beach, California, January 2000.

Luke, J.H., Edwards, D.B., Anderson, M.J., and Canning, J.R., "Using Fuzzy Logic to Design a Trail Recognition Algorithm for an Outdoor Autonomous Guided Vehicle," ASME, *19th International Computers and Information in Engineering*, Las Vegas, Nevada, September, 1999.

Edwards, D.B., and Schmitz, C., "Theoretical Calculations for Using Positive Electrode Compression to Increase Lead-Acid Battery Life," *International Conference on Lead Acid Batteries* (LABAT '99), June 7-10, Sofia, Bulgaria, 1999.

Edwards, D.B., and Dayton, T.C., "Improving the Performance of a High Power, Lead Acid Battery with Paste Additives," *International Conference on Lead Acid Batteries* (LABAT '99), June 7-10, Sofia, Bulgaria, 1999.

Canning, J.R., Edwards, D.B., and Anderson, M.J., "Development of an Autonomous Log Skidder," American Nuclear Society, *8th International Topical Meeting on Robotics and Remote Sensing*, Pittsburgh, Pennsylvania, April 1999.

Anderson, M.J., Canning, J.R., Edwards, D.B., and Luke, J.H., "Ultrasonic Echoes Obtained in the Outdoor Environment," *16th International Congress on Acoustics and 135th Meeting of the Acoustical Society of America*, Seattle, Washington, June 20-26, 1998.

Edwards, D.B., and Canning, J.R., "An Algorithm for Designing Conventional and Fuzzy Logic Control Systems," ASME, *17th International Computers and Information in Engineering*, Sacramento, California, September 1997.

Edwards, D.B., Cantrell, R.L., and Dayton, T.C., "Predicting the Performance of Batteries Having Paste Additives," *The Twelfth Annual Battery Conference*, IEEE 97TH8226, Long Beach, California, January 1997.

Edwards, D.B., Choi, H.T., and Canning, J.R., "Fuzzy Logic and Cell to Cell Mapping," ASME, *16th International Computers and Information in Engineering Conference*, Irvine, California, August 1996.

Canning, J.R., and Edwards, D.B., "A Method for Embedding Human Expert Knowledge into a Fuzzy Logic Controller," ASME, *15th International Computers and Information in Engineering Conference*, Boston, Massachusetts, September 1995.

Edwards, D.B., et al., "Computer Simulations for Design and Optimization of a Fuzzy Control System," ASME, *14th International Computers and Information in Engineering Conference*, Minneapolis, Minnesota, September 1994.

Edwards, D.B., and Canning, J.R., "Fuzzy Control System for an Autonomous Vehicle," *Ninth International Conference on Mathematical and Computer Modelling*, Berkeley, California, July 26-29, 1993.

Edwards, D.B., "Improving the Performance of Lead-Acid Batteries," *Society of Automotive Engineering (SAE) TOPTEC*, Invited Speaker, Dearborn, Michigan, June 3-4, 1993.

Edwards, D.B., "Improved Active Materials Utilization in Lead Acid Batteries," Fifth International Lead Acid Battery Seminar, International Lead/Zinc Research Organization (ILZRO), Invited Speaker, Vienna, Virginia, April 17-19, 1991.

Edwards, D.B., "A High Performance, Sealed, Lead-Acid Battery for Electric Vehicle Applications," *The Electrochemical Society Extended Abstracts*, Vol. 85-2, October 13-18, 1985.

Edwards, D.B., "Global Analysis of a Buck Regulator," *IEEE Power Electronics Specialist Conference*, June 1978.

Other Presentations and Conference Proceedings:

Newell, J.D., Patandar, S.N., Edwards, D.B., "Using Porous Microspheres as Additives in Lead-acid Batteries," *American Ceramic Society (ACS) Conference on Materials Innovations in an Emerging Hydrogen Economy*, Cocoa Beach, FL, February 24-27, 2008.

Invited Speaker, "Decentralized Navigation and Control for Large Groups of Autonomous Underwater Vehicles," *UI Electrical and Computer Engineering (ECE) Colloquium*, December 3, 2005.

Edwards, D.B., "Communication and Control for Multiple AUV's," invited *presentation at ONR Mine Counter-Measure (MCM) Technology Review*, Panama City, Florida, January 31-February 4, 2005.

Edwards, D.B., and Feeley, J.J., "Communication and Control for a Platoon of AUV's," *ONR Mine Counter-Measure (MCM) Technology Review*, Panama City, Florida, February 17-20, 2004.

Edwards, D.B., "What's Behind Fuzzy Logic," *Eighteenth Annual Inland Empire Forest Engineering Conference,"* Moscow, Idaho, March 6-7, 2001.

Invited to Vice President Gore's Workshop: "Partnership for a New Generation of Vehicles," Washington, D.C., January 13, 1994.

Invited Speaker, "Manufacturing a Quality Hybrid Electric Vehicle," Idaho Quality Seminar, Idaho Transportation Department, November 1-2, 1994.

Invited Speaker, "Fuzzy Logic Control Systems for Autonomous Vehicles," University of Nevada, Las Vegas (UNLV), Las Vegas, Nevada, March 31, 1994.

Invited Speaker, "Batteries, Electric Vehicles, and Hybrid Electric Vehicles," American Institute of Chemical Engineers at Battelle, Richland, Washington, March 1, 1994.

Edwards, D.B., "An Electric Vehicle Design Based on a High-Power, Sealed, Lead Acid Battery," Proceedings of the Society of Automotive Engineers (SAE) Passenger Car Meeting, Dearborn, Michigan, October 31-November 3, 1988.

Edwards, D.B., "Evaluation of a Sealed, Lead-Acid Battery for Electric Vans," Proceedings of the 23rd Intersociety Energy Conversion Engineering Conference (IECEC), Denver, Colorado, July 31-August 5, 1988.

Edwards, D.B., "AC Power System," Proceedings of the Electric & Hybrid Vehicle Symposium, Gainesville, Florida, December 1983.

Edwards, D.B., "A New Gate Turn-Off Thyristor/Silicon Controlled Rectifier Inverter Topology Optimizes System Cost and Performance," *Power Conversion Conference 10*, March 1983.

Edwards, D.B., "A New Polyphase SCR Inverter Using FET Commutation," *Power Conversion Conference* 8, April 1981.

Edwards, D.B., "An Integrated Battery Charger and State-of-Charge Indicator," *Electric Vehicle Council Exposition '83*, Detroit, Michigan, October 1983.

Edwards, D.B., "On Board Battery Charger/State-of-Charge Indicator," *Proceedings of the Electric & Hybrid Vehicle Symposium*, California Institute of Technology, December 1980.

Other Publications (Not Technical):

Merrill, K., O'Rourke, M., and Edwards, D. (2007). Applying intentionality to AUV communication. *Sea Technology*, 48, 25-30.

Amy Klamper, "Higher IQ: Robotic Subs Demonstrate the Potential for tactical Collaboration," *Sea Power*, August, 2007.

Robotic Subs Demonstrate Potential for Tactical Collaboration, by Amy Klamper, *Seapower Magazine*, August 2007

Mini Subs Show Major Promise, by Amy Klamper, *Spokesman-Review*, April 24, 2007

Article in *Spokesman Review*, "Underwater Robots Interact," by Shaw Vestal, November 24, 2005. Copyrighted and released by the Associated Press, edited versions printed in: Daily Herald (Snohomish, WA); Deseret Morning News (Salt Lake City, UT); Idaho Examiner; Lewiston Morning Tribune; The Olympian (Olympia, WA); The Oregonian (Portland, OR); Seattle Post-Intelligencer; Times-News (Twin Falls, ID); Tri-City Herald (Kennewick, WA); various news websites. Also mentioned on KBCI-TV (Boise, ID), KLEW-TV (Lewiston, ID), and KGW-TV (Portland, OR)

Article in *UI News*, "Building a Better Spy: UI Researchers Teach Autonomous Underwater Vehicles to Communicate and Cooperate," by Donna Emert, November 3, 2005.

Article in *Timber West*, "On the Trail of the Wood Dog," September 2000.

Articles and Television News Reports on UI-WSU Hybrid Electric Vehicle, 1991-94.

Article on UI-WSU Hybrid Electric Vehicle in *Idaho Currents*, publication for Idaho Department of Water Resources.

Articles and Television News Reports on UI-WSU Hybrid Electric Vehicle, 1993.

Article on Radio Controlled Log Skidder in the *Daily News*, 1992.

Article on Lead Acid Battery Research in the College of Engineering Magazine, 1992.

Article on Robotics in *Idahonian*, 1988.

PATENTS:

"Electrode with Conductive Fillers," Patent No. 5,667,917, issued to the Idaho Research Foundation, September 16, l997.

"Positive Paste with Lead-Coated Glass Fibers," issued to California Institute of Technology, 1989.

"Woven-Grid, Sealed, Quasi-Bipolar Lead-Acid Battery Construction and Fabricating Method," issued to California Institute of Technology, 1989.

"Composite Battery Separator," issued to California Institute of Technology, 1987.

"Improved Lead-Acid Battery," issued to California Institute of Technology, 1986.

"GTO Commutated SCR Inverter," issued to California Institute of Technology, 1986.

"FET Commutated Current-Fed Inverter," issued to California Institute of Technology, 1983.

"Voltage Reapplication Rate Control for Commutation of Thyristors," issued to California Institute of Technology, 1982.

"Quasi-Bipolar Battery Construction and Method of Fabrication," issued to California Institute of Technology, 1982.

"Bipolar Battery Construction," issued to California Institute of Technology, 1981.

GRANTS AND CONTRACTS (Funded):

Principal Investigator:

"Magnetic Signature Assessment System Using Multiple Autonomous Underwater Vehicles (AUVs), Phase III," Office of Naval Research (ONR) $2,000k (2010-12)

"Electromagnetic Signature Assessment System Using Multiple Autonomous Underwater Vehicles (AUVs), Phase II," Office of Naval Research (ONR) $1,600k, (2009-10)

"Power System Analysis for Unmanned Undersea Vehicle Using a Continuous Active Sonar," Alion Science and Technology $360k, (2009-10)

"Developing Paste Additives for Advanced Lead-Acid Batteries," Exide Technologies, Inc. $480k, (2009-10)

"Developing Models for Evaluating Li-ion Battery Additives," Sparks Technologies, LLC $35k, (2009-10)

"Developing a Vision System for an Autonomous Forest Robot," Idaho State Board of Education (SBOE) $75k, (2009-2010)

”Magnetic Signature Assessment System Using Multiple Autonomous Underwater Vehicles (AUVs,” Office of Naval Research (ONR), $2.0M, (2008-09).

“Cooperative Autonomous Underwater Vehicles Used to Search Large Ocean Areas for Mines,” Office of Naval Research (ONR) 07-028 Undersea Cooperative Cueing and Intervention. $500K, (2008-09).

“Developing Fleets of Autonomous Underwater Vehicles,” Office of Naval Research, $1.8M, (2005-06).

“Communication and Control for Fleets of Autonomous Underwater Vehicles,” Office of Naval Research (ONR), $1.2 Million, (2004-05).

“Fabrication of a Fleet of Mini-AUV’s,” Office of Naval Research, $65K, (2004-05).

“Intelligent Control Algorithms for Multi-Sensor Systems,” INL, $5K (2004-05).

“Advanced Lead Acid Battery Development for Military Vehicles (year 3),” Office of Naval Research, $1,000,000 (2006-07).

“Advanced Lead Acid Battery Development for Military Vehicles (year 2),” Office of Naval Research, $1,000,000 (2005-06).

“Advanced Lead Acid Battery Development for Military Vehicles (year 1),” Office of Naval Research, $1,000,000 (2004-05).

“Decentralized Control of Multiple Autonomous Crawlers and Swimmers,” Office of Naval Research, $375K (2003-04).

“Development of a Small Autonomous Log Skidder,” USDA, $150,000 (2001-03).

“Developing Human Embedded Vision Systems with Fuzzy Logic,” NASA ISGC, $10,000 (2001-02).

“Advanced Lead Acid Battery Development,” National Institute for Advanced Transportation Technology (NIATT), $21,705 (1998-99), $31,191 (1999-2000).

“Investigating Additives in the Positive Paste of Pb-Acid Batteries,” Advanced Lead Acid Battery Consortium (ALABC), Trojan Battery Company, $29,987 (1997).

"Sensor Development for an Autonomous Vehicle," Idaho Space Grant Research Initiation Award, $5,000 (1996).

"Development of a Small, Radio Controlled Log Skidder," University of Idaho Seed Grant, $6,000 (1996).

"Computer Modeling of Battery Additives," Arias Research Associates, Inc., $25,000 (1995, continuation of 1994 work).

"Developing a High Power, Long Lived, Sealed, Lead Acid Battery for Hybrid Electric Vehicles," General Motors Research Laboratories, $62,300 (1994-95).

"Computer Modeling of Battery Additives," Arias Research Associates, Inc., $24,617 (1994).

"High Performance Composite Electrodes for Lead Acid Batteries," GNB Inc., $50,000 (1992-93).

"Improving Active Material Utilization in Deep Cycled, Lead Acid Batteries," International Lead/Zinc Research Organization (ILZRO), $51,000 (1991-94).

"Robotic Skidder Development Grant," Potlatch Inc., $2,500 (1991); Bennett Lumber Co., $2,500 (1991).

"Composite Electrode Development for Electric Vehicle Batteries," General Motors Research Laboratories, $10,000 (1989).

"Composite Electrodes for Lead-Acid Batteries," University of Idaho Seed Grant, $3,436 (1989).

"Composite Electrode Research," University of Idaho Seed Grant, $2,957 (1988).

"Cell Testing Equipment," Electric Power Research Institute (EPRI), $35,000 (1987).

"Battery Laboratory Initiation Grant," Concorde Battery Corporation, $1,500 (1987).

"Power Supplies for Cell Testing," Department of Energy Grant Program, $2,000 (1986).

Co-Investigator:

"Decentralized Control of Multiple Autonomous Underwater Vehicles," ONR, $1,000,000 (2003-04).

"Field Evaluation of a Radio Controlled Log Skidder with Winch," United States Forest Service, $33,714 (2001-02).

"Autonomous Reasoning for Safe Landing," Jet Propulsion Laboratory, $145,000 ($20,000 for UI), 2001.

"High Performance Auxiliary Power Unit (APU)," NIATT, $29,940 (1998-99), $44,408 (1999-2000), $47,355 (2000-01).

"Research Cluster for Intelligent Control of Nonlinear Dynamic Systems," NASA EPSCOR, $25,000, (1999-2000).

"Dynamics and Controls Laboratory," Hewlett-Packard University Equipment Grant Programs, $514,000 (accepted 1993).

"Hybrid Electric Vehicle Competition," Industrial Sponsors, $111,500 (1992-94).

"Biodiesel Powered Engine for Use in a Hybrid Electric Vehicle," NCATT Seed Grant Program, $5,000 (accepted 1992).

"Ultrasound Vision and Fuzzy Logic Control System for an Autonomous Vehicle," Idaho Space Seed Grant, $5,000 (1992).

"Hybrid Electric Vehicle Challenge Proposal," Ford Motor Co., $10,000 (1992).

"A Shock and Vibration Model for Disc Drives," Hewlett Packard Corporation, $1,437 (1989).

I am currently investigating the use of composite materials in electrodes for lead-acid batteries. Composite materials hold the promise of improving the energy performance of electrodes without the usual attendant loss in life. The results of this work could have great value for electric vehicle batteries and consequently has been supported by a number of industrial sponsors. I am also collaborating with other researchers to develop powertrains for hybrid electric vehicles through the Center for Intelligent Systems Research (CISR).

My other research focus has been on fuzzy logic control systems and language-centered intelligence (LCI). I have developed, with a group of other faculty members, a novel algorithm for optimizing "fuzzy" logic control systems and implementing a language based artificial intelligence system (i.e. LCI). LCI uses the language and the logic associated with that language to perform hypothetical reasoning. This collaboration has been very successful and we are now applying it to autonomous vehicles including multiple autonomous underwater vehicles that communicate and cooperate with each other.

HONORS AND AWARDS:

University of Idaho 2006 Research Excellence Award

College of Engineering Faculty of the Year Award, 2004-05

Best Paper Award for Theoretical Contributions in the 21st Computers and Information in Engineering Conference, Pittsburgh, Pennsylvania, September 9-12, 2001. The paper was entitled "Fuzzy Cell Mapping Applied to Autonomous Systems."

Best Paper Award in the "Simulation and Fuzzy Logic Program," at the 15th Annual Computers in Engineering Conference, Boston, Massachusetts, September 17-21, 1995. The paper was entitled "A Method for Embedding Human Expert Knowledge into a Fuzzy Logic Controller."

California Institute Fellowship, 1975-76

A.R.C.S. Fellowship, 1974-76

Western Electric Scholarship, 1968-72

Postdoctoral Associate Qualifications:

Dr. John R. Canning has worked at the University of Idaho as a Postdoctoral Fellow for seven years on various projects. His primary focus has been on autonomous underwater vehicle research but several projects have involved research and testing on both lithium ion and lead acid batteries. These projects include modeling and computer simulations of battery components, fabrication and testing of components and complete battery models. In addition, several of the projects required the design and construction of complete battery packs including electrical, thermal and safety systems on hybrid electric vehicles, autonomous underwater vehicles and battery test chambers. Dr. Canning has visited Axion Power's production facilities to assist in the casting of high-tin content lead acid battery grids. Other related work includes rebuilding a Hybrid Electric HMMWV to test a lead acid battery designed at the University of Idaho.

Dr. Canning is extensively involved in the lab work required for this project. This includes mixing the battery paste, pasting the grids, curing, test cell assembly, and operation of the Arbin test stations for both the individual test cells and full battery modules. He is currently assisting the students in constructing the current PHEV that will be used to demonstrate the advanced high power lead acid battery.

Appendix C: Letters of Support

AXION POWER™
INTERNATIONAL INC.

May 23, 2011

Dr. Dean B. Edwards
Dept. of Chemical and Material Engineering
University of Idaho
Moscow, ID 83844-1021

Dear Dean,

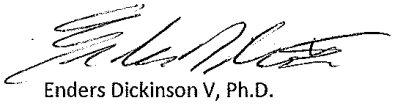
Axion is supportive and excited about the work you have proposed for application to the State Board of Education (SBOE) Incubation Fund Program entitled "A High Performance, Horizontal Plate Battery for Plug-in, Hybrid Electric Vehicles (PHEVs)."

We believe that advanced lead–acid battery technology has the potential to provide batteries suitable for hybrid electric vehicles (HEVs), including plug-in HEVs, as well as other demanding applications. We are very interested in the battery design and additive technology being evaluated and hopefully demonstrated in the SBOE proposal. The combined technologies have the potential to elevate lead–acid to a capability that would be competitive and more cost effective than the Li-ion battery presently being used in the GM Volt vehicle.

Axion is committed to developing and bringing to market advanced battery technologies. Large markets are evolving for high performance batteries that can be used in electric vehicles, HEVs, PHEVs, and energy storage. The technology being investigated in your proposed work could result in a very competitive battery for these emerging markets. As Axion has worked previously with you on the horizontal plate battery design and has successfully constructed working module prototypes, we are interested in seeing this technology advanced further.

We have enjoyed working with you in our previous collaborations and look forward to future collaborations with you and the University of Idaho.

Sincerely,



Enders Dickinson V, Ph.D.
Director of Research and Development
Axion Power International, Inc.
edickinson@axionpower.com

3601 Clover Lane • New Castle, Pa 16105 • Tel: 724.654.9300 • Fax: 724.654.3300 • Toll Free: 877.324.9300
www.axionpower.com