Refuelable Electric Car (IPRO 313) Spring 2010 Project Plan

Compiled by Galina Shpuntova for the Interprofessional Projects Office

Illinois Institute of Technology

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CZAR-CAR: REVOLUTIONIZING THE WAY YOU DRIVE!

Contents

TEAM CHARTER

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The team is advised by Dr. Francisco Ruiz of the department of Mechanical, Materials, and Aerospace Engineering at IIT and Dr. Ray DeBoth.

Team Purpose and Objectives

Team Vision:

To become and be recognized as a unified, efficient, and skilled team capable of confidently approaching, analyzing, and solving a multi-faceted technical problem with a global impact.

Team Mission:

To make significant strides toward creating a working prototype of a refuelable electric vehicle using a zinc air battery and to raise public awareness of the potential of this technology.

Team Objectives:

1. To construct and thoroughly test a single zinc-air fuel cell unit according to applicable standards and procedures.
2. To improve on the existing zinc-air fuel cell design based on the results of testing the first unit.
3. To check existing systems on board vehicles donated by Argonne National Labs next semester.
4. To replace systems that are out of order or unsuitable for use in a zinc-air powered system.
5. To spend idle periods in designing a system for refueling the prototype vehicle that is cost-effective, safe, and comparable in ease of use to current gasoline fueling systems.
6. To raise awareness and support of the project through publicity, directed toward potential corporate and non-profit sponsors, as well as the public.
7. Act ethically and legally, respect intellectual property rights, and verify the safety of the product throughout development and testing.

Team Values Statement

- Team members will show commitment to the project by demonstrating initiative for project tasks.
- Team members will treat one another with respect. They will attend meetings on-time and conduct discussions in a mature and focused manner. When running late or missing meetings, they will contact the team as soon as possible.
- Team members will respect themselves. They will seek help when it is needed and not overburden themselves.
- Team members will allocate project funds responsibly and with the consensus of the rest of the team and the advisor.
- Any problems regarding expenses or design flaws will be brought to the team immediately. Individuals and subteams will not be penalized or vilified for errors.
- Team members will establish and abide by detailed policies and procedures for data management, testing procedures, and safety.
- Team members will respect intellectual property rights.
- Design-related conflicts will be discussed and analyzed by all individuals whose work is affected by the design element. Pros and cons of each alternative will be discussed and each alternative evaluated before a decision is reached. Thus, decisions will be made in an objective and analytical manner.
- Personal conflicts between team members should be worked out in a mature manner between those teammates. Conflicts that cannot be resolved this way will be discussed at the next subteam meeting. Conflicts that still cannot be resolved will be discussed at the team meeting or with the advisor, whichever is more appropriate.

Project Background

Modern industrial society is highly dependent on the transportation of products and of people. The automobile is a preferred form of transportation for both individuals and businesses, as it can go virtually anywhere at any time. Private automobiles are valued by individuals for convenient, efficient transportation. Tons of goods are transported by trucks across the North American continent daily, making them indispensable to commerce. Buses relieve congestion in downtown areas of large cities, while providing city-dwellers with convenient transportation options.

All these vehicles are major consumers of gasoline fuels derived from crude oil. However, the global supply of crude oil is dwindling and is unlikely to support currently industrialized society, much less the industrialization of developing countries, for much longer. Furthermore, the internal combustion engines used by most vehicles spew hundreds of tons of pollutants into the atmosphere in the United States alone. Worldwide, this amounts to a staggering amount of carbon monoxide, nitrous oxides, volatile organic compounds (VOC's) and other pollutants exhausted into the atmosphere by the global fleet of vehicles. Even without touching on the controversial issue of global climate change, the impact on air quality and health is impossible to ignore. The United States must put considerable resources into regulating and monitoring air quality, to ensure the safety of its citizens. To further add to the detriment of internal combustion vehicles, the United States' national security is placed at risk due to a dependence on foreign oil because of an insufficient domestic supply.

Clearly, an alternative is desperately needed, which is why research into a number of alternative fuel options is currently being performed by every major automobile manufacturer. Biofuel-powered cars, hydrogen fuel-cell powered cars, and plug in hybrid-electric vehicles (PHEV), as well as fully-electric cars, are being considered as the successor for traditional internal combustion engine vehicles. However, each of these options has its own fatal flaw.

Biofuels must be eliminated first, chiefly because they do not solve the emissions problem, although they may reduce it temporarily or slow it down. Other concerns with biofuels include the amount of land needed to cultivate the biomass of which they are produced, and the possible impact of this on food production and on the environment if more land must be cleared to accommodate growing biomass for both fuel and food. There is also at this time a very limited infrastructure for processing, producing, and distributing biofuels, except as an addition to gasoline. Overall, this option does not solve all the problems, and still requires significant capital investment. It is not prudent to put that capital into a technology that offers such limited improvements on its predecessor when there are other options.

Hydrogen fuel cells can seem like an attractive option, at first. However, there are several concerns that disqualify them as a solution. Safety is a major concern: hydrogen is a highly volatile gas, and furthermore, it is difficult to contain due to its small molecular weight. The task of designing a hydrogen infrastructure that is safe and easy for the consumer to use is a daunting one. Another major concern is the production of hydrogen: the most energy- and cost-efficient way to produce hydrogen at this time is from hydrocarbon fuels, particularly natural gas, with a byproduct of many of the emissions that alternative fuel technology is attempting to eliminate. Although fuel cell technology is a definite improvement over internal combustion engines—fuel cells have a higher efficiency—they are still not a viable alternative energy source at this time.

Plug in hybrid vehicles are yet another popular solution—and a logical progression from hybrid vehicles of today. There are estimates that plug in hybrid vehicles could eliminate up to 90% of current fuel consumption. While this is clearly an improvement on current technology, plug in hybrid technology is still ultimately dependent on gasoline for trips longer than one battery charge. The technology is a step in the right direction—electric vehicles have been shown to be more efficient than internal combustion engines, even if they are ultimately charging from electricity produced from fossil fuels. Still, they are at most an intermediate step and an extension of the impending deadline enforced by the dwindling oil supply.

Fully electric vehicles (EV's) are the next step up from PHEV's. They run entirely off the electric grid, producing no emissions of their own. As mentioned above, running vehicles off the electric grid is more efficient than having each run off its own combustion reaction. Meridian International Research found in a 2007 report that electric vehicles were the only possible alternative to gasoline-powered vehicles.

The main question facing the electric vehicle market is, what kind of battery will it use? Lithium-ion (LiIon) batteries are a public favorite, but this could be due to familiarity—LiIon batteries power most portable consumer electronics devices. A LiIon battery to power an automobile must be one hundred times larger than a laptop computer battery. This, compared with global reserves of lithium, was shown in a Meridian report to be too scarce a resource to power cars around the world. Nickel-metal hydride batteries (NiMH) and sodium nickel chloride (NaNiCl) batteries are another alternative, but they are heavy, and the nickel supply is only a little less limited than the lithium supply. Both of these options also suffer from a recharge time unacceptable to the average consumer; a problem that has yet to be resolved.

Another alternative is the Zinc-air battery. It is an economical choice because there are no particularly rare or expensive components—zinc is one of the more abundant metals, and the fourth most abundantly mined. The product of the reaction, zinc oxide, is also readily recyclable back into zinc for reuse; this is actually cheaper than using new zinc!

There are several types of Zinc-air batteries—while the rechargeable battery is an option as it is with LiIon and NiMH batteries, the Zinc-air battery can also be used as a reconstructable or refuelable battery. The reconstructable option involves removing the battery and replacing parts consumed by the battery reaction. The refuelable option involves resupplying the battery with a slurry of zinc and electrolyte. Rechargeable zinc-air batteries have recently been significantly improved through the research efforts of ReVolt Technology, currently based in Switzerland; this has eliminated a prior barrier of low cycle life. The company endeavors to market them as a more energetic alternative to LiIon batteries for consumer electronics. Reconstructable batteries have been demonstrated by Electric Fuel, Ltd., based in Israel, which has worked with several organizations and government agencies, to create a zinc-air powered shuttle bus that used replaceable zinc-air cassettes. The technology was fully operational, but the cost involved in recycling the cassettes was prohibitive for most applications. The third option is the refuelable battery, invented and tested by John F. Cooper from Lawrence Livermore National Laboratory (LLNL) in Livermore, CA. A unique battery hardware design allows the zinc to be provided as <1mm sized pellets in a saturated solution of potassium hydroxide (KOH). The slurry of pellets in electrolyte can then be supplied without moving the battery hardware.

For automotive applications, this quality of the zinc-air refuelable battery is very important. Cooper showed that a battery can be refueled in less than 10 minutes, comparable to the amount of time spent by a consumer at a gas station today. The battery has sufficient energy density for the range per tank to be comparable to current values as well. The fact that the metal is recyclable means that after an initial investment, a minimum of new material would be required on a regular basis to sustain the transportation infrastructure.

The battery is also a good choice ethically. It is clean, safe, and environmentally friendly by virtue of having no toxic components and producing no emissions. It also contains no reactive materials—there is virtually no risk of fire or explosion, as there is with current gasoline usage and with hydrogen gas. There is one danger, and that is that potassium hydroxide is a corrosive substance. This will be an important consideration during design of refueling systems to avoid human contact with the chemical, which could cause chemical burns.

The battery is also an ethical choice on a social level—the abundance of the materials involved worldwide means this technology is accessible to developing countries as well as to industrialized countries. Intellectual property rights would of course need to be considered on an international level for this to occur legally and fairly, with due respect to the patent-holders.

The zinc-air technology is brimming with potential, but seems to have largely been overlooked in the public search for solutions to the gasoline problem. Consumer gasoline prices spiked to $4/gallon in some areas of the nation over the summer of 2008, as compared to around $1.30 in 1998. Prices of consumer goods have risen as well, sometimes as much as doubling, on products including food, toiletries, clothing, and school supplies; life's necessities. The public is paying the price for a continued reliance on oil. The public is also paying in healthcare costs and in lives due to poor air quality, particularly in cities. Ultimately, dependence on oil is costing in quality of life, and that is the most valuable thing.

The goal of the IPRO project is to demonstrate the potential of the zinc-air technology in a public way. The team will solicit the help of interested sponsors, including but not limited to, energy companies, automotive manufacturers, local electric car groups, government offices, transportation services (CTA, etc), and Power Air Corporation, the company that currently holds the rights to the ZARB technology. The team will also solicit help from interested individuals—John F. Cooper, the inventor and patent-holder of the ZARB technology, has expressed excitement for the project, as have several other individuals.

In the last semester, the first semester of this project, the team set the direction of the project and laid groundwork in the form of theoretical calculations, designs, and publicity. They consulted with electric car interest groups in the area, initiated and maintained contact with potential sponsors, performed research using books and internet sources, and reverse-engineered a ZARB cell when it became clear it could not be readily purchased externally. This team will make use of the support solicited by the previous team and the existing plans and designs to begin work on creating and testing prototypes. Several iterations may be necessary and the final prototype will not be ready this semester, but significant strides can be made. Simultaneously, the team will work on designing a safe, efficient, and easy-to-use refueling system that is as similar as possible to gas pumps. Lastly, the team will continue use every possible opportunity to publicize the project and its potential, including news media.

This project's scope prohibits having a single sponsor, but it is supported by donations from Exelon Corp., IIT's Wagner Institute for Sustainable Energy Research (WISER), and Argonne National Laboratories. It is also supported by expertise and time donated by Pioneer Conversions, the Fox Valley Electric Automobile Association, and many individuals on and off the IIT campus. The project is still actively looking for more sponsors and more support.

See Appendices A, B, C and D for more information.

Work Breakdown Structure

Team Structure

The team is organized into three teams, the Car Team, the Battery Team, and the Promotional Team. These teams were used at the advice of returning team members and due to a logical breakdown in tasks resulting from such a structure.

The teams have equal authority and there are no official leaders—decisions will be reached by consensus. This team structure was selected because no student at this point has significantly more familiarity with any part of the project to make educated decisions alone. Furthermore, electing a single leader would detract from the responsibility that rests with *every* team member.

Some team members felt their interests (at least for the time being) lay in more than one team; they were encouraged to take part in the activities of all the teams that interested them. Furthermore, it was recognized that a fluidity in the team structure was necessary to make best use of everyone's talents during all stages of the project.

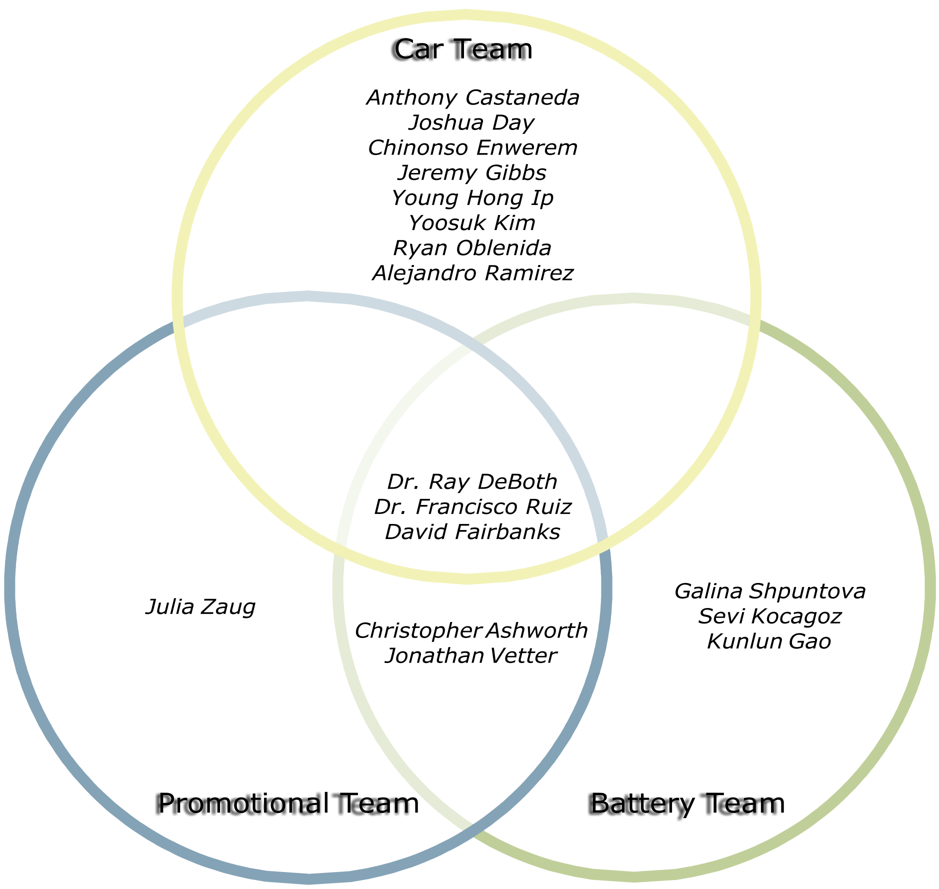

Figure 1: Team Organization

Major Tasks

Tasks are best organized with respect to the groups responsible for executing them.

Car Team

1. Examine and test all components in donated vehicles
2. Order any replacement parts as necessary
3. Remove broken components and install replacement parts

Battery Team

1. Finalize cell design from last semester
2. Manufacture single cell
3. Create and execute testing plan for single cell
4. Use conclusions to create alternative designs
5. Test alternative designs and select optimal design

Publicity Team

1. Identify funding opportunities with approaching deadlines
2. Publish articles in IIT media (TechNews, IIT magazine, etc.)
3. Contact IIT Media Relations Office and Chicago news media

Expected Results

The ultimate objective of the project is to have a complete drivable Zinc-Air Powered vehicle prototype that can be used to demonstrate the technology and the capabilities of the power system. However, there is no way this can be completed in one semester.

The expected state of the battery team at the end of the semester is having a fully tested and operational single fuel cell, with optimal performance parameters. This fuel cell should operate sufficiently well that stacks of these fuel cells can be made for testing. Once that is complete, and it should go smoothly if the single cell works smoothly, the stack(s) that will power a vehicle can be built.

The expected state of the car team at the end of the semester is having an electric vehicle that is operational using its secondary battery and requires only the zinc-air battery to be installed for completeness. While this is noticeably ahead of the expected state of the battery, there will be work to be done on auxiliary zinc-air battery systems (controllers, etc.) and the refueling systems that will be done as the batt ery is being completed.

The promotional team by the end of the semester will have submitted several more funding proposals, and had the project publicized through every means available. They are responsible for perpetually looking for events at which this project can be presented, networking opportunities, media releases, and other publicity and funding opportunities.

Work Breakdown

Task	Start	End	1/11	1/18	1/25	2/1	2/8	2/15	2/22	3/1	3/8	3/15	3/22	3/29	4/5	4/12	4/19
Car Team	1/11/2010	1/11/2010															
Test Controller	1/11/2010	2/4/2010															
Battery Source	2/4/2010	2/19/2010															
Order & Shipping	2/20/2010	2/26/2010															
Controller Selection	2/4/2010	2/26/2010															
Battery Removal	3/1/2010	3/5/2010															
Install Battery	3/15/2010	3/25/2010															
Testing Battery Charger	3/25/2010	4/12/2010															
Fabrication for Fuel Cell	4/13/2010	4/22/2010															
Battery Team	1/11/2010	1/11/2010															
Reading & Research	1/11/2010	1/19/2010															
Test Plan	1/19/2010	2/8/2010															
Finalize Design	1/11/2010	2/5/2010															
Manufacture & Assembly	2/5/2010	2/20/2010															
Testing 1	2/22/2010	3/17/2010															
Subsequent Designs	3/19/2010	4/2/2010															
Manufacture & Assembly 2	4/2/2010	4/16/2010															
Testing 2	4/17/2010	4/27/2010															
Promotion	1/11/2010	1/11/2010															
Identify Sources	2/4/2010	2/10/2010															
Prepare for CCST Talk at IIT 2/18	2/4/2010	2/18/2010															
Writing Proposals	2/11/2010	4/23/2010															
News & Media	2/4/2010	4/23/2010															
Legalities, Licensing	3/15/2010	4/23/2010															

Figure 2: Project Schedule

Designation of Roles

- ⇨ Minute Taker: Galina Shpuntova
- ⇨ Agenda Maker: Ryan Oblenida
- ⇨ Time Keeper: Christopher Ashworth
- ⇨ iGroups Moderator: Alejandro Ramirez

Project Budget

The budget for the entire project is listed in the table below. The only funds requested from the IPRO office are the expenses for promotional needs. The team plans on attending the conference on Storing Alternative Energy at IIT on the 18th of February. There is also a conference in March concerning the National Academy of Engineers in which the team will try and introduce the public to CZAR Car.

Table 1: Total project budget as of 1/19/10 (for reference only)

ITEM	UNIT PRICE	UNITS	ITEM TOTAL
Vehicle			
Vehicle Purchase[1]	$12,000.00	2	$12,000.00
Secondary Battery	$19.00	180	$3,420.00
Miscellaneous Parts	$1,580.00	1	$1,580.00
Electronics and Control System	$1,000.00	1	$1,000.00
Performance Testing	$1,000.00	5	$5,000.00
Group Total:			$23,000.00
Zinc-Air Battery			
Refueling System (Design & Build)	$8,600.00	1	$8,600.00
Current Collector	$100.75	26	$2,619.50
Air Cathode[2]	$500.12	26	$13,003.12
Plastic Frame	$368.13	26	$9,571.38
Zinc	$46.79	26	$1,216.54
KOH	$70.00	26	$1,820.00
Assembly Parts & Equipment	$295.00	1	$295.00
Group Total:			$ 37,125.54
Promotion			
Miscellaneous Promotional Expenses	$500.00	1	$500.00
Group Total:			$500.00
Total Projected Expenses:			**$ 61,625.54**

Note:

[1] The material for the air cathodes is a major portion of the battery cost. The material initially considered for this budget was based on platinum, but a substitute material, based on cobalt, was later found that was roughly five times less expensive while providing similar performance; this will decrease actual project costs. Furthermore, the focus of this semester is to build a single-cell battery, at a small fraction of the full battery cost.

The promotional team and the car team last semester had significant success in raising awareness and finding support for the project. The following table lists the donations so far received. Donations from other sources are currently being negotiated by the promotional team, which is also continuing to find new potential sources of funding.

Table 2: Donations Received to Date

DONATION	DONOR	VALUE
2 Electric Chevrolet S-10 Trucks	Argonne National Labs	$24,000
Funding matching outside donations	IIT WISER	$13,000

Team Members Background

Christopher Ashworth, 4th year, Aerospace Engineering

I have knowledge of Mechanical/Aerospace Engineering and AutoCAD/Inventor experience. I would like to gain a baseline of Chemical/Electrical engineering knowledge and further develop my communication skills.

Anthony Castaneda, 4th Year, Mechanical Engineering

I am interested in advancing automotive technology while learning about the chemistry and electronics required to do so. I have a strong foundation of current and past automotive technology that I hope will be an asset to the team as we develop solutions throughout the project. I also have a good deal of 3D modeling and 2D CAD experience along with moderate metal working and machining skills.

Joshua Day, 3rd Year, Electrical Engineering

I have an associate's degree in automotive technology, experience in diagnosing electrical car problems, and a willingness to learn about new technology. I look forward to learning how electric vehicles work and furthering my knowledge about them. I'm also excited to learn how to work with a team on a large project and how the zinc-air batteries work.

David Fairbanks, 5th Year, Mechanical Engineering.

I joined the IPRO because I was a part of the project over the summer of 2009 and last semester and enjoyed the project right from the beginning. I enjoy starting something from the ground up, and I like explaining problems as they come up. I also enjoy working with others. I have an aptitude for fluid mechanics, thermodynamics, and auto mechanics. I'm good at fundraising as well. I have dealt with sales in the past, so I know how to talk to people when trying to deal with selling a product, an idea, or philosophy. I'm also great at putting things together if that needs to be done.

Jeremy Gibbs, 4th Year, Mechanical Engineering

I have siginificant engineering knowledge, knowledge of automobiles, hands-on intuition and good organization. I'd like to learn about chemical issues when converting fuel into usable energy, and improve my time management skills.

Young Hong Ip, 3rd Year, Mechanical Engineering

I am very interested in renewable and alternative energy. I am very excited about the refuelable car because it would the automobile more self-sufficient and not pollute the environment as much. I can be helpful in the garage when it comes to taking parts out of the truck. I hope I will be able to help in documenting what we find (i.e. photos, reports, etc.) so that future semesters will be able to reference things easily. I am also versatile and would be able to help out any other group (Battery, Promotions) if needed. I am good at writing, creating flyers, and have many promotional ideas.

Yoosuk Kim, 4th Year, Electrical Engineering

I have knowledge of control systems and power electronics. I would like to develop practical skills with motor control devices and get some quality teamwork experience!

Ryan Oblenida, 4th Year, Electrical Engineering

I feel I have significant knowledge about rechargeable batteries, motors, and power electronics. I hope to develop my leadership and communication skills. I would also like to develop my skill with motor control devices and battery technology.

Alejandro Ramirez, 4th Year, Electrical Engineering

This project caught my attention, because I could incorporate both my car mechanics background and my electrical engineering skills. I have a working knowledge of circuits and connections. I am very familiar with Chevy cars and would be able to help in diagnosing and improving the design (tailored to Chevrolet ideally). I hope to improve my public speaking skills and contribute my knowledge to the team as much as possible.

Galina Shpuntova, 4th Year, Mechanical/Aerospace Engineering

I joined this IPRO because I was in it last semester and I loved the project. I think I still have a lot to give to it. Besides being the only continuing member of the battery group, I have an aptitude in fluid mechanics, thermodynamics, and heat transfer. I'm great at report writing and making presentations, and I have experience with CAD software. I hope this semester brings me great satisfaction from furthering a project I find very important and relevant. I also hope to develop skills in testing new technologies.

Julia Zaug, 3rd Year, Chemistry

IPRO 313 is a project that I feel is my duty to participate in, due to the situation our planet has found its self in. It is very important to explore all alternative energy options to reduce the rising pollution levels of our planet. I have a technical background that allows me to give input on the more engineering type components of the project. My biggest asset to the team is my communication skills and ability to communicate technical ideas to people not familiar with the subject. I hope to continue to meet new people during the process of the IPRO and continue to expand my knowledge of not only the technical, but social and business world. .