IPRO 313

Refuelable Electric Cars

Spring 2011 Final Report

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Introduction

The overall conflict that IPRO 313 is trying to resolve is the dependency on oil as a fuel source for automotive vehicles. Along with the global and financial concerns that go along with oil as a fuel source, there has been growing interest in electric vehicles.

Electric vehicles are the competitive issue that IPRO 313 has researched, investigated, and is working to resolve. Currently, most electric vehicles run on lithium batteries. The problems associated with these vehicles are the recharge time and service station compatibilities.

The most popular electric vehicle is the Testla Roadster, which has a driving distance of approximately 270 miles per full charge. Although this is an adequate driving distance, it takes six to eight hours for a full charge. This amount of charge time is a vital drawback for electric vehicles.

The vast majority of service stations are not electric vehicle friendly. Gas stations do not and have not set up areas for electric battery pack replacement, or vehicle charge. Without the public support of oil companies and service stations, electric vehicle are struggling to survive.

Team Objectives

1. To construct a budget.
2. To write an article for the IIT Alumni Magazine and contact prospective sponsors.
3. To contact NBC Channel 5 for a news segment on the team.
4. To design and machine a motor bracket.
5. To choose a secondary battery in order to conduct testing.
6. To design a portable service depot.
7. To determine how much zinc is required per distance traveled.
8. To continue discussion with Zinc Air, Inc.
9. To design an internal system for storing the zinc, distributing it to the fuel cells, and storing the resulting zinc oxide.
10. To thoroughly search for related patented information and perform competitive research.
11. To act as a team liaison.
12. To compile IPRO deliverables.

Organization and Approach

Team Structure

The group split up into five subteams: business & publicity, car, off- and on-car fueling systems, and intellectual property & intelligence.

Major Tasks

The business and publicity team was to be responsible for constructing a budget, writing an article for IIT Alumni Magazine, contacting prospective sponsors, and contact NBC Channel 5 news.

The car team was responsible for designing and machining a motor bracket and needed to determine specifications for a secondary battery in order to conduct testing.

The off-car fueling system team was to design the process of supplying the electric vehicle fuel tank with fresh zinc pellets while also serving as a location for the electric vehicle to empty its zinc-oxide tank. The main goal was to come up with a fuel pump similar to a fuel pump found at a local gas station which would supply the car with fresh zinc pellets while extracting the stored zinc oxide from the car.

The on-car fueling team was to design fuel distribution system inside the car. The objective of the system was to evenly distribute zinc-pellets to each battery cell in the zinc-air fuel cell battery. Once the zinc reacts inside the fuel cell, the by-product of reaction, zinc oxide, must then be removed from each cell, collected and stored for extraction.

The intellectual property and intelligence team responsible for researching current patents, competitive research, acting as a team liaison, and prepare IPRO deliverables.

Analysis and Findings

Business & Publicity

The business team worked to get the website and LinkedIn sites up, along with updating the Facebook page. They also sent in an article to the IIT alumni newsletter. There was some contact with the local NBC affiliate and that should be perused by the next team. They made a presentation at the MMAE Research Competition in order to gain additional funding

Car

The car team managed to finish a custom bracket for the engine of the car and got it ready for installation. Requirements for the secondary batteries to begin testing of the vehicle's systems have also been determined and appropriate batteries have been ordered.

Off- Car Fueling

The driving profile for this IPRO truck is 90kg of zinc pellets = 300 highway and city miles.

In the spring 2011 semester, we mainly focused our work on the process of filling the car with zinc and extracting the zinc oxide from the car. Our goal was to come up with a system which completes both processes simultaneously, through one exit port on the car, while having a system that could also easily be retrofitted to existing gas stations.

Filling the car:
In order to fill the car with zinc pellets we decided the best method would be to use a BSP (Bulk Solids Pump) feeder manufactured by K-Tron Process Group. A BSP feeder gives precise feeding of free flowing bulk materials such as Zinc. Therefore, this can be applied to our process while feeding the car with zinc Pellets. The following diagram shows how the feeder works. The main phases of this feeder are summarized. A more detailed explanation is in the following link:

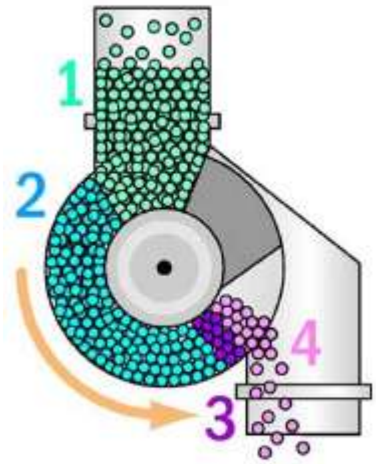
http://www.ktron.com/Products/feeders/BSP_Overview.cfm

Zone 1: CONSOLIDATION→ Inter-particle forces produce lock-up at the end of Zone 1

Zone 2: ROTATION→ Material is in lock-up condition throughout Zone 2 and rotates as a solid body

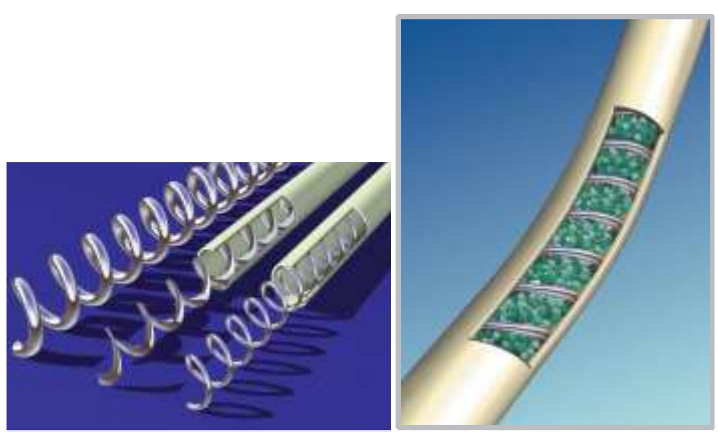
Zone 3: RELAXATION→Inter-particle forces fall below lock-up threshold

Zone 4: ACTIVE DISCHARGE→ Material discharge occurs



The BSP feeder also allows an easy way of monitoring how much zinc is being dispensed to the car by providing a uniform flow rate of particles.

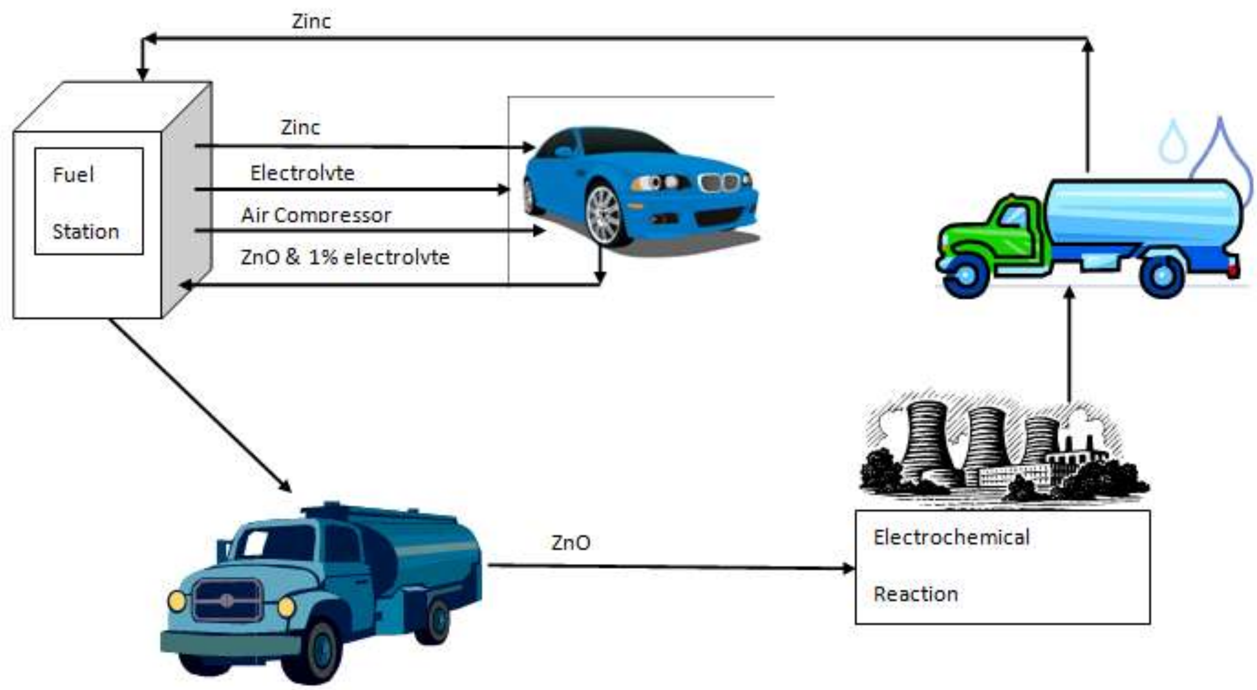
Extracting the ZnO:
In order to extract the zinc oxide from the car, a few alternatives were explored. The zinc oxide was expected to be in mainly powder form, however inefficient separation of zinc oxide and electrolyte would yield toothpaste like consistency of the stored zinc oxide which would be very difficult to extract. For our case, we expected approximately 1% of electrolyte to be present inside the zinc oxide when it is extracted. The possible alternatives for zinc oxide extraction that we explored in spring 2011 were using either a vacuum pump or using a flexible Archimedes Screw type conveyer to convey the zinc oxide out of the car. An example of a similar conveyor manufactured by Spiroflow is shown below. The conveyors manufactured by Spiroflow are too large for this application so alternative conveyors need to be designed if they are going to be a possible method of zinc oxide extraction. The extraction process still needs a lot of research and brainstorming.



Hose-Nozzle Apparatus:
In order to simplify the process for the consumer, both the filling and extraction process were to be

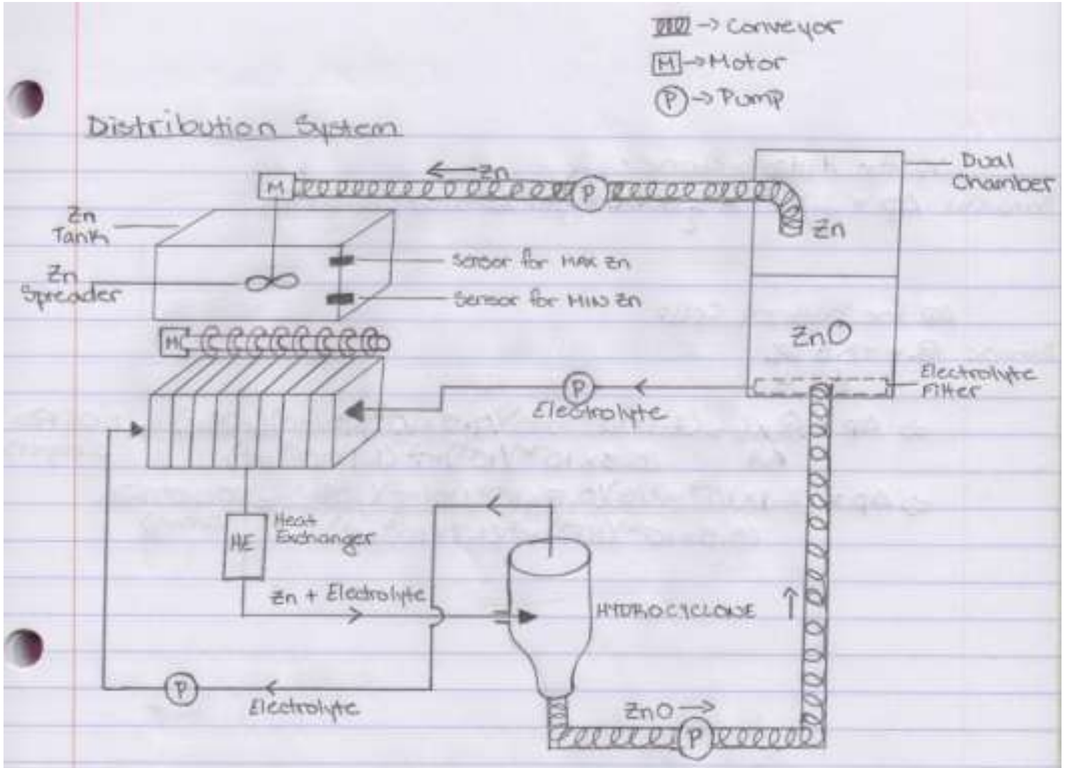
completed through one hose much like how gas is currently filled into a car via one hose. In order to accomplish this, we determined that the fuel pump hose should have three separated hoses inside of it. One of these hoses should dispense the zinc, one hose should extract zinc oxide and one hose should replenish any electrolyte that may have been extracted along with the zinc oxide. This hose would then attach to the car via a nozzle containing 3 male-end ports.

The diagram provided below outlines the entire off-car fueling system process.



In-Car Fueling

In the Spring 2011 semester, we came up with a preliminary design for a fueling system which supplies the zinc-air fuel cell battery with zinc pellets and collects the zinc oxide waste. A diagram of this system is shown below.



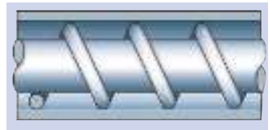
The system components are discussed below.

Dual Chambered Fuel/Spent Fuel Tank:
The dual chamber fuel tank consists of two compartments. One compartment contains the zinc pellets and the other contains the zinc oxide byproduct. A moving wall separates both compartments. As the zinc pellets are fed into the tank, the moving wall pushes the zinc oxide byproduct out to be collected by the off-car fuel system.

The tank is designed so that the upper chamber contains the zinc pellets and the lower chamber contains the zinc oxide. Compression springs located inside the lower chamber hold up the wall so that as zinc pellets are added to the car, the weight of the zinc compresses the springs causing the upper chamber volume to increase while the lower chamber volume decreases helping to force out the zinc oxide. As zinc is removed from the upper chamber and dispersed to the battery cells, the weight of the zinc pellets inside the upper chamber decreases causing the compression springs to expand which decreases the upper chamber volume. As this happens, the volume of the lower chamber increases which increases storage space for zinc oxide.

The lower chamber also has a percolation system built into the lower walls. This is used in order to drain out excess electrolyte from the zinc oxide. The electrolyte is collected and then pumped back to the battery system.

Conveyor:
In order to convey the zinc pellets from the Dual Chambered Tank to the battery distribution system, a flexible Archimedes screw is utilized.



The inner core prevents flooding/overfeeding of the solid material being conveyed. Within the flexible screw conveyor, the gap between the spiral and tube must be less than 1mm, so that the zinc pellets may pass with ease and agglomerations are reduced. A small motor will rotate the flexible screw conveyer.

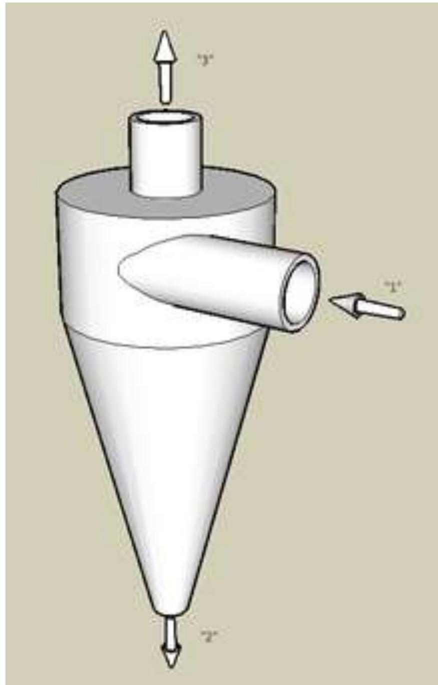
Battery Distribution System:
Zinc pellets must be distributed evenly within all cells of the battery. A zinc tank is placed above the battery cells which receive zinc via the conveyor, and with the use of a "zinc spreader" and a rotating shaft the zinc pellets will be distributed evenly to each cell.

The rotating shaft is composed of scaled down BSP feeders. Each feeding wheel is positioned above each battery cell. The wheel collects zinc from the zinc tank and dispenses it directly into the battery cell similar to the off car fueling system design.

The zinc tank will contain two sensors. One sensor will detect when the maximum amount of zinc pellets has been reached within the tank and will send a signal to the conveyor motor feeding in zinc pellets to slow down and/or stop. The other sensor will detect when the minimum amount of zinc pellets has been reached and will send a signal to the motor feeding in zinc pellets to speed up. This is done to maintain a minimum zinc level in the distribution tank which is essential for the BSP to function properly.

Heat Exchanger:
Once zinc reacts inside the battery fuel cells, electrolyte and zinc oxide byproduct mixture are collected and pumped out of the battery. Once the mixture is removed, it passes through a heat exchanger which cools the substance down allowing for zinc oxide precipitation.

Hydro-cyclone:
After the zinc oxide precipitates, it must be separated from the electrolyte. This is done using a hydro-cyclone. The hydro-cyclone spins the fluid around inside of it causing zinc oxide solid to fall out at the bottom of the hydro-cyclone and the electrolyte to flow out the top. The use of multiple hydro-cyclones in series allows for increased efficiency in separation. Once separated, the zinc oxide must be collected and conveyed back to the dual chambered tank.



Calculations:
The requirements for our system were to feed 120 kg of Zinc Pellets into the Car. Based on this value, we computed the necessary volume of the space that 120 kg of zinc pellets would occupy along with how much zinc oxide that would produce.

Zinc Properties

- Theoretical Zinc density =7140kg/m^3 = 445.73 lbs/ ft^3
- Experimental Zinc density (1mm diameter pellets) =4162kg/ m^3 = 259.82 lbs/ ft^3

Zinc Oxide properties

- Theoretical Zinc Oxide density = 5606kg/m^3 = 349.98lbs/ ft^3
- Experimental Zinc Oxide density (powder) =to be confirmed in future experiments

Balance equation
Zinc with the help of the catalyst (KOH) reacts with Oxygen and electrochemical produces electricity. As it can be seen, the byproduct of this reaction is zinc oxide.

$$2Zn + O_2 \longrightarrow 2ZnO$$

Zn has a molar mass of 65.39 g/mol and Zinc Oxide has a molar mass of 81.41g/mol

The following shows the calculation for volume of zinc oxide using stoichiometry.

Assume 120kg of Zinc This value corresponds to the amount of zinc required to make the car drive for 300 miles in just 1 fill. Also note that 120kg of Zinc occupy 28.8 liters of space.

$$120kg\ of\ Zinc\ x\frac{1kmol\ of\ zinc}{65.39\ kg\ of\ zinc}\ x\ \frac{2\ kmol\ of\ ZnO}{2kmol\ of\ zincc}\ x\ \frac{81.40kg\ of\ ZnO}{1\ kmol\ of\ ZnO} = 149.39\ kg\ of\ ZnO$$

In order to calculate the volume we use the density formula:

$$\rho = \frac{m}{V}$$

Therefore, for 120kg of Zinc reacting, the total volume of Zinc Oxide that will be produced is equivalent to 0.026 m^3 or 26.65 liters.

With these volume estimations, we can determine our tank dimensions. It can be seen that zinc oxide and zinc are quite dense; therefore space will not be an issue while designing the dual chambered tank.

We also attempted to compute the pressure loss of the electrolyte fluid as it passes through the battery cells. When packed with zinc, the cell becomes similar to a porous material. The pressure loss of flow through a porous material can be found using Darcy's equation.

The pressure drop for the battery cell can be calculated with the use of Darcy's Equation:

$$Q = \frac{-kA\Delta p}{\mu L}$$

where, ρ = Density of Water = 1000 kg/m^3

A = Area of Battery = (17cm)(1mm) = $1.7x10^{-4}m^2$

Q = Electrolyte flow = 2.1mL/s = $2.1x10^{-6}m^3/s$ (estimated by Cooper)

= $2.1x10^{-4}m^3/s$ (estimated by Denis)

Therefore,

Using Cooper's estimation for Q: Δp = 1.01kPa

Using Denis' estimation for Q: Δp = 101.07kPa

This calculation was necessary in order to determine the necessary pump properties for the electrolyte pump.

Intellectual Property & Intelligence

This team's purpose was to research, communicate, and prepare IPRO deliverables.

The research portion of this team was conduct on two areas, the patents and inventions associated with the refuelable electric car and the companies competing with the electric car. The majority of the IP team's research was patent based research. First, all of the old patents discovered by past semesters were categorized under car, fueling, or general. Organizing these patents took a considerable amount of time because a list of the patents' inventors was compiled in order to research the companies the inventors belonged to. After each patent was verified to be relevant, they were relayed to its corresponding team to be evaluated again for value. All of these patents can be found in iGroups within their respective team folders.

Due to all of the patent research and amount of new inventions this IPRO is designing, it was essential to understand how to file and acquire a patent. Closely working with Ray DeBoth and the invention notebook, the IP team became very familiar with the patent process and although none were obtained, the future IP teams simply need to work with the IPRO office to file a patent.

Another aspect of IP research was investigation into companies that could potentially compete with IPRO 313. These companies were located on past knowledge, general searches, conversations with Denis Vasilescu and Dr. Ruiz, and patent data. Once these companies had been researched, they were presented to the entire group for further evaluation. The two largest competitors were a research team at Ohio State University and a German based bus company. Ohio State University was trying to create an electric car prototype that ran on a lithium battery. The prototype is still under construction, but they are the closest academic competitors, and it was made clear by the class that IIT would be first.

The German based bus company was investigated because they were the only company that began manufacturing bus that used zinc as a fuel source. Their buses had replaceable zinc cartages, which had to be entirely replaced after every usage. The German company is currently in an intermediate state, but future IP teams should continue to research this group.

The companies working on similar concepts are Reveo, Inc. and a subgroup, eVionyx, Inc. Research was done on Power Air Corporation, which has generator prototypes.

http://www.poweraircorp.com/zafc/zafc3.php

Inventors researched includ Sadeg Faris of Reveo, Inc., and John Cooper, who has patents regarding production of zinc pellets.

There is a folder on iGroups with four of the most relevant patents found.

Communication was the most important function for the IP team. At the beginning of the semester, each of the four team members was assigned to one of the other teams to serve as a liaison between teams. This was valuable because it allowed for intermediate communication between groups that were not always able to meet in the same location as their work was performed outside of the classroom. This also allowed for the easy relay of patent ideas as well as research requests forthe IP team. The IP team basically played the role of the facilitator and archive for IPRO 313.

The final task of the IP team was to present the project during IPRO day. Although the members of the IP team would be presenting, this was the complete effort of everyone. Since the business team had previously presented a summary of the fueling systems for the MMAE poster competition earlier in the semester, a lot of the information from that presentation was incorporated.

Conclusions, Future Work, and Recommendations

Business & Publicity

The following semesters should plan to contact NBC Channel 5, as well as continue to update the LinkedIn and Facebook pages, as well as the website. Additional funding is also a goal.

Car

The batteries and mounting bracket need to be installed, then the car itself will be tested.

Fueling Systems

Possible Future Experiments and Calculations:
The zinc oxide byproduct, which contains some percentage of electrolytes, is said to have the consistency of toothpaste. The actual consistency is not known due to the fact that not enough experiments involving zinc oxide and electrolyte mixed have been performed.

Zinc oxide powder from Essential Depot: Bio Product Solutions as well as zinc pellets from Pellets LLC have been ordered in order to perform future experiments.

McMaster-Carr Crack-Resistant Polyethylene Tubing 1-1/2" ID, 1-3/4" OD was ordered as well in order to perform future flow rate experiments of the zinc oxide electrolyte mixture as well as zinc pellet flow rates.

Future plans for the off and on car fueling systems include prototypes of both fueling systems. In order to create prototypes, certain experiments and calculations must be performed. Calculations for all motors and pumps used in both systems must be done in order to attain the specifications of each motor and pump needed. All component designs need to be prototyped and finalized as well in future IPRO semesters.

Intellectual Property & Intelligence

Future work will include continuing research on companies and patents, aiding the fueling systems teams in applying for patents, and compiling IPRO deliverables.

Appendix

A – Budget

Budget		
items	$	
hoppers	1000	in car system
pipes	100	
tubes	100	
machine shop time	50/hr @ 20hrs	
car generator (2kW)	1000	car
machine shop time	50/hr @ 2hrs	
thermal plastic	200	
zinc pellets	100	off car system
pump	750	
container	100	
labor	250	
dispenser & piping	250	
	~7850	total

B – Team Members

Amanda Chatman

Victor Gasca

Yuri Henriquez

Ken Huang

Joshua Kanzelmeyer

Suro Kim

Mike Leresche

Samira Matezic

Dylan Maus

Alan Meier

Stanislav Micic

Raymond Nettles

Tuesday Njoagwuali

Neelkumar Patel

Cristina Perez

David Rojo Beitia

Jorge Romero

Steve Stanard

Omar Syed

Milton Terry

Mikel Urizarbarrena

Manuel Vazquez

Jonathan Vetter

Jerome Wisniewski

Aida Zhurgenbayeva

Charlie Ziman