The Tower

Undergraduate Research Journal at Georgia Institute of Technology

15th Anniversary Issue

The Tower

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Special thanks to the Student Media Board and all previous staff members of The Tower for their years of work.

Letter from the Director

Dear Reader,

What is the overall value of college-level research? Where does its results take us and what will it essentially contribute to our world? Will undergraduate research be taken as seriously as terminal degree projects by the larger academic community? These were but a few of the questions posed over fifteen years ago by a group of academically motivated Georgia Tech undergraduates as they completed their research projects for academic credit. In 2007, a group of those students approached the Office of Student Media and the Office of Undergraduate Research with a vision of spotlighting some of the original and unique research being conducted by undergraduate students at the Institute. While not a novel idea for a publication, it was the first collective vision for a non-terminal degree journal at Georgia Tech.

By 2008, multiple design formats and academic review structures had been suggested for a journal featuring the best and brightest Georgia Tech had to offer in underclassmen projects. Of course, many components were needed to collect, review, and publish a journal which met a national research institution's standard, but in Georgia Tech fashion, the first editorial board of *The Tower* successfully paved the way to what was become a journal of distinction in the world of higher education.

While creating a journal like *The Tower* has not always been an easy task, as academic schedules and outside forces like COVID challenged each edition, the gained value in publishing high-standard projects always prevailed. So, that brings us to this 15th Anniversary issue of *The Tower*, a collection of some of the best research manuscripts included in the first seven years of the journal's existence. Thank you to all the many researchers, editors, faculty, design staff and review teams who vetted and created just a few of valued moments in Georgia Tech undergraduate research history. To all of those who have conducted research before and all of those who are yet do so, just know that your undergraduate contributions are an invaluable point of pride and value to the Institute and the world at large. Keep up the great work and GO JACKETS!

Sincerely,

D. McCall Pitts

Mac Pitts
Director of Student Media and staff advisor to *The Tower*

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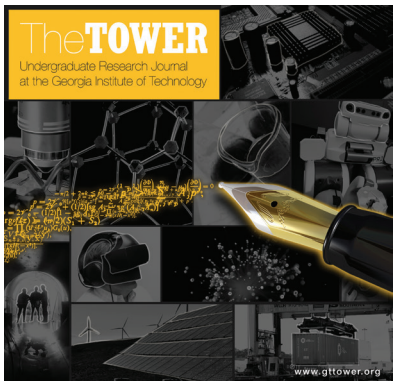

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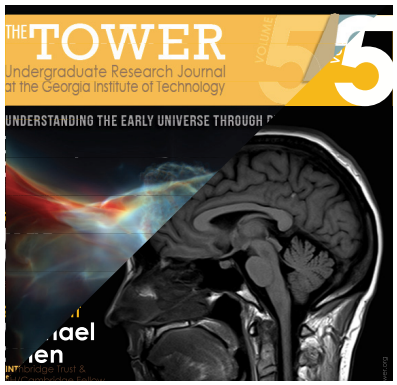

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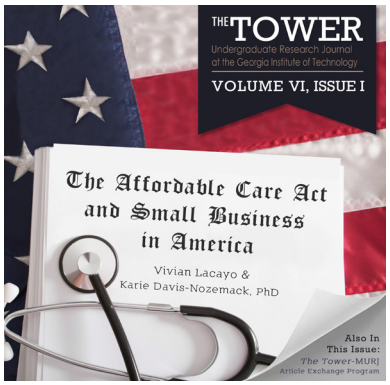

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Volume II - 2010

Synthetic Biology: Approaches and Applications of Engineered Biology

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Synthetic biology is expected to change how we understand and engineer biological systems. Lying at the intersection of molecular biology, physics, and engineering, the applications of this exploding field will both draw from and add to many existing disciplines. In this perspective, the recent advances in synthetic biology towards the design of complex, artificial biological systems are discussed.

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THE RISE OF SYNTHETIC BIOLOGY

Several remarkable hurdles in the life sciences have been cleared during the last half of the 20th century, from the discovery of the structure of DNA in 1959, to the deciphering of the genetic code, the development of recombinant DNA techniques, and the mapping of the human genome. Scientists have routinely tinkered with genes for the last 30 years, even inserting a cold-water fish gene into wheat to improve weather resistance; thus, synthetic biology is by no means a new science. Synthetic biology is a means to harness the biosynthetic machinery of organisms on the level of an entire genome to make organisms do things in ways nature has never done before.

Synthetic biology, despite its long history, is still in the early stages of development. The first international conference devoted to the field was held at M.I.T in June 2004. The leaders sought to bring together "researchers who are working to design and build biological parts, devices, and integrated biological systems; develop technologies that enable such work; and place this scientific and engineering research within its current and future social context" (Synthetic Biology 101, 2004). The field is growing quickly, as evidenced by the rapidly increasing number of genetic discoveries, the exploding number of research teams exploring the field, and the funding from government and industrial sources.

Akin to the descriptive-to-synthetic transformation of chemistry in the 1900s, biological synthesis forces scientists to pursue a "man-on-the-moon" goal that demands they discard erroneous theories and compels scientists to solve problems not encountered in observation. Data contradicting a theory can sometimes be excluded for the sake of argument, but doing the same while building a lunar shuttle would be disastrous. Synthetic biology comes at an important time; by creating analogous "man-on-the-moon" engineering goals in the form of synthetic bioorganisms, it is similarly driving scientists towards a deeper level of understanding of biology.

APPLICATIONS OF ENGINEERED ORGANISMS

It is expected that advances in synthetic biology will create important advances in applications too diverse and numerous to imagine. Applications of bioengineered microorganisms include detecting toxins in air and water, breaking down pollutants and dangerous chemicals, producing pharmaceuticals, repairing defective genes, targeting tumors, and more. In 2008, genomics pioneer Dr. Craig Venter secured a $600 billion grant from ExxonMobil to develop hydrocarbon-producing microorganisms as an alternative to crude oil (Borrell 2009).

Scientists are engineering microbes to perform complex multi-step syntheses of natural products. Jay Keasling, a professor at the University of California, Berkeley, recently demonstrated genetically engineered yeast cells (Saccharomyces cerevisiae) that manufacture the immediate precursor of artemisinin, a malarial drug widely used in developing countries (Ro et al, 2006). Before, this compound was chemically extracted from the sweet wormwood herb. Since the extraction is expensive and the wormwood herb is prone to drought, the availability of the drug is reduced in poorer countries. Once the engineered yeast cells were fine-tuned to produce high amounts of the artemisinin precursor, the compound was made quickly and cheaply. This same method could be applied to the mass-production of other drugs currently limited by natural sources, such as anti-HIV drug prostratin and anti-cancer drug taxol (Tucker & Zilinskas, 2006).

The most far-sighted effort in synthetic biology is the drive towards standardized biological parts and circuits. Just as other engineering disciplines rely on parts that are well-described and universally used — like transistors

and resistors — biology needs a tool box of standardized genetic parts with characterized performance. The Registry of Standard Biological Parts comprises many short pieces of DNA that encode multiple functional genetic elements called "BioBricks" (Registry ofStandard Biological Parts). In 2008, the Registry contained over 2000 basic parts comprised of sensors, input/output devices, regulatory operators, and composite parts of varying complexity (Greenwald, 2005). The M.I.T. group made the registry free and public (http://parts.mit.edu/) and has invited researchers to contribute to the growing library.

Some genetic parts code for a promoter gene that begins the transcription of DNA into mRNA, a repressor that codes a protein that blocks the transcription of another gene, a reporter gene that encodes a readout signal, a terminator sequence that halts RNA transcription, and a ribosome binding site that begins protein synthesis. The goal is to develop a discipline-wide standard and source for creating, testing, and combining BioBricks into increasingly complicated functions while reducing unintended interactions.

To date, BioBricks have been assembled into a few simple genetic circuits (McMillen & Collins, 2004). One creates a film of bacteria that is sensitive to light so it can capture images (Levskaya et al). Another operates as a type of battery, producing a weak electric current. BioBricks have been combined into logic gate devices that execute Boolean operations, such as AND, NOT, OR, NAND, and NOR. An AND operator creates an output signal when it gets a biochemical signal from both inputs; an OR operator generates an output if it gets a signal from either input; and a NOT operator changes a weak signal into a strong one, and vice versa. This would allow cells to be small programmable machines whose operations can be controlled through light or various chemical signals (Atkinson et al, 2003).

Despite the enormous progress seen in the last five years and some highly publicized and heavily funded feats, the systematic and widespread design of biological systems remains a formidable task.

CURRENT CHALLENGES

Standardization

Standards underlie engineering disciplines: measurements, gasoline formulation, machining parts, and so on. Certain biotechnology standards have taken hold in cases such as protein crystallography and enzyme nomenclature, but engineered biology lacks a universal standard for most classes of functions and system characterization. One research group's genetic toggle switch may work in a certain strain of *Escherichia coli* in a certain type of broth, while another's oscillatory function may work in a different strain when cells are grown in supplemented minimal media (Endy, 2005). It is unclear whether the two biological functions can be combined despite the different operating parameters. The Registry of Standard Biological Parts and new Biofab facilities have recently emerged to begin addressing this issue, and a growing consensus is emerging on the best way to reliably build and describe the function of new genetic components.

Abstraction

Drawing again from other engineering disciplines, and specifically from the semiconductor industry, synthetic biology must manage the enormous complexity of natural biological systems by abstraction hierarchies. After all, writing "code" with DNA letters is comparable to creating operating systems by inputing 1's and 0's. Levels could be defined as DNA (genetic material), Parts (basic functions, such as a terminating sequence for an action), Devices (combinations of parts), and Systems (combinations of devices). Scientists should be able to work independently at each hierarchy level, so that

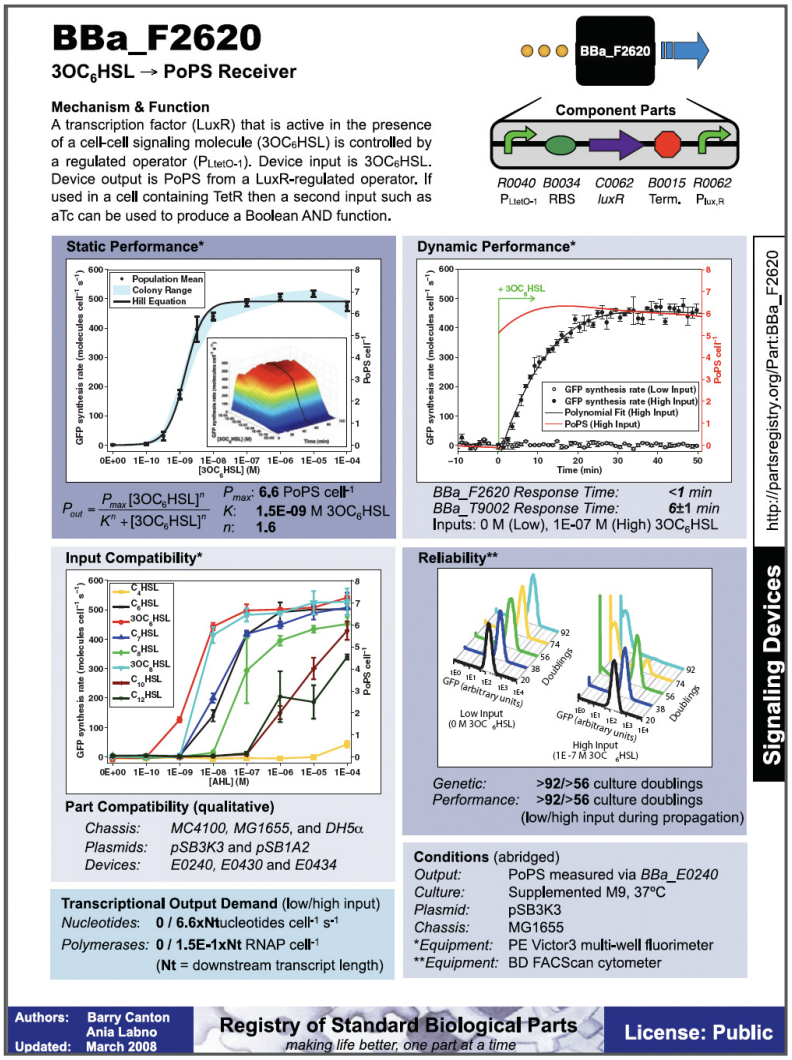

Figure 1. The Registry of Standard Biological Parts. This registry offers free access to basic biological functions that are used to create new biological systems. Pictured is a standard data sheet on a gene regulating transcription, with normal performance and compatibility measurements, plus an extra biological concern: system performance during evolution and cell reproduction. The registry is part of a conscious effort to standardize gene parts in the hopes of creating interchangeable components with well-characterized functions when implanted in cells. The project is open source; anybody can freely use and add information to the Registry.

device-level workers would not need to know anything about phosphoramidite chemistry, or genetic oscillators, etc. (Canton, 2005).

Engineered Simplicity and Evolution

The rapid progress made by mechanical engineering in this century was made possible by creating easily understandable machines. Engineered simplicity is helpful not only for repairs but for future upgrades and redesigns. While a modern automobile may seem complex, the level of complexity pales in comparison to a living cell, which has far more interconnected pathways and interactions. Cells evolved in response to a multitude of evolutionary pressures and mechanisms were developed to be efficient, not necessarily easy to understand (Alon, 2003). A related problem is that other engineered systems don't evolve. Organisms such as *E. coli* reproduce and have genetic mutations within hours. While this offers possibilities to the biological engineer (for instance, human-directed evolution for fine-tuning organism behavior), it also increases the complexity of designing and predicting the function of these new genetic systems (Hasteltine, 2007).

RISKS ASSOCIATED WITH BIOLOGICAL ENGINEERING

Accidental Release

Researchers first raised concerns at the Asilomar Conference in California during the summer of 1975 and concluded that current genetic experiments carried minimal risk. The past 30 years of experience in genetically-manipulated crops demonstrated that engineered organisms are less fit than their wild counterparts, and they either die or eject their new genes without constant assistance from humans. However, researchers concluded that the abilities to replicate and evolve required special precautions. It was recommended that all researchers work with bacterial strains that are specially designed to be metabolically deficient so they cannot survive in the wild. Still, some have suggested that an incomplete understanding and emergent properties arising from unforeseen interactions between new genes could be problematic. Such dangers have given rise to fears of a dystopian takeover by super-rugged plants that overwhelm local ecosystems.

Bioterrorism

Research in synthetic biology may generate "dual-use" findings that could enable bioterrorists to develop new biological warfare tools that are easier to obtain and far more lethal than today's military bioweapons. The most commonly cited example of this is the resurrection synthesis of the 1918 pandemic influenza strain by CDC researchers (Tumpey et al, 2005) and the possibility of recreating smallpox from easily-ordered DNA (Venter, 2005). There has been a growing consensus that not all sequences should be made publicly available, but the fact remains that such powerful recombinant DNA technologies could be used for harm.

Attempts to limit access to the DNA synthesis technology would be counterproductive, and a sensible approach might include some selective regulation while allowing research to continue. Now, as SARS, bird influenza, and other infectious disease emerge, these recombinant DNA techniques enhance our ability to manage this threat today compared to what was possible just 30 years ago. The revolution in synthetic biology is nothing less than a push in all fronts of biology, whether that impacts environmental cleanup, chemical synthesis using bacteria, or human health.

CONCLUSION

At present, synthetic biology's myriad implications can be glimpsed only dimly. The field clearly has the potential to bring about epochal changes in medicine, agri-

culture, industry, and politics. Some critics consider the idea of creating artificial organisms in the laboratory to be an example of scientific hubris, evocative of *Faust* or *Dr. Frankenstein*. However, the move from understanding biology to designing it for our requirements has always been a part of the biological enterprise and used to produce chemicals and biopharmaceuticals. Synthetic biology represents an ambitious new paradigm for building new biosystems with rapidly increasing complexity in versatility and applications. These tools for engineering biology are being developed and distributed, and a societal framework is needed to help not only create a global community that celebrates biology but also to lead the enormously constructive invention of biological technologies.

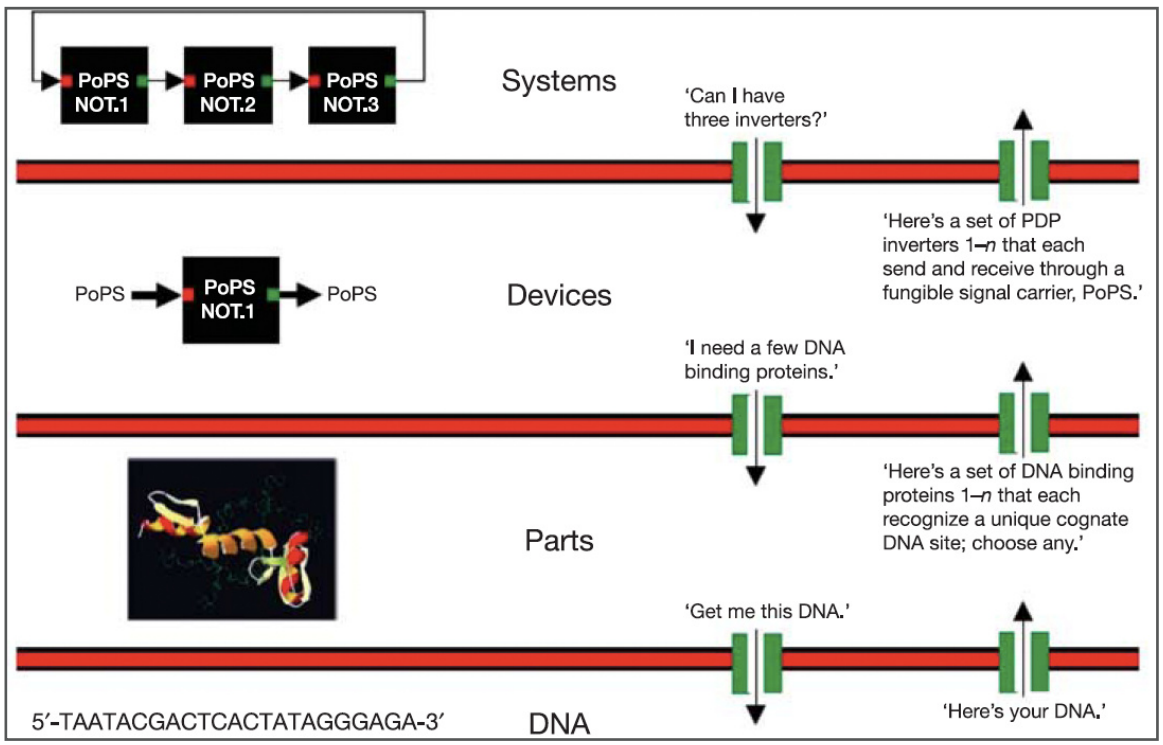

Figure 2. Abstraction Hierarchy. Abstraction levels are important for managing complexity and are used extensively in engineering disciplines. As biological parts and functions become increasingly complex, writing 'code' with individual nucleotides is rapidly becoming more difficult. Currently, researchers spend considerable time learning the intricacies of every step of the process, and stratification would allow for specialization and faster development. Ideally, individuals can work on individual levels, one can focus on part design without worrying about how genetic oscillators work, while others could string together parts to construct whole systems for possible biosensor applications. Image originally made by Drew Endy.

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Compact Car Regenerative Drive Systems: Electrical or Hydraulic

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The objective of the research is to address the power density issue of electric hybrids and energy density issue of hydraulic hybrids by designing a drive system. The drive system will utilize new enabling technologies such as the INNAS Floating Cup pump/pump motors and the Toshiba Super Charge Ion Batteries (SCiB). The proposed architecture initially included a hydraulic-electric system, where the high power braking power is absorbed by the hydraulic system while energy is slowly transferred from both the Internal Combustion Engine (ICE) drive train and the hydraulic drive train to the electric accumulator for storage. Simulations were performed to demonstrate the control method for the hydraulic system with in-hub pump motors. Upon preliminary analysis it is concluded that the electric system alone is sufficient. The final design is an electric system that consists of four in-hub motors. Analysis is performed on the system and MATLAB Simulink is used to simulate the full system. It is concluded that the electric system has no need for a frictional braking system if the Toshiba SCiBs were used. The regenerative braking system will be able to provide an energy saving from 25% to 30% under the simulated conditions.

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INTRODUCTION

With around 247 million on-road vehicles traveling around 3 trillion miles (Highway Statistics, 2009) every year, the efficiency of on-road vehicles are of major concern. As a result, hybrid drive trains which dramatically increase urban driving efficiency of vehicles have been developed and implemented in vehicles. Existing on-the-road hybrids have their secondary regenerative systems (Electric Motors and batteries) installed on their primary drive trains (ICE drive train) to provide the regenerative braking capability. Recently efforts have been put in designing drive train systems that have either hydraulic or electric components as integral parts of the systems. For example, in the Chevy Volt, a series electric hybrid system, the ICE is used to charge the electric accumulator, which in turn drives the electric motor (Introducing Chevrolet, 2009).

Electric hybrid drive trains have been implemented in passenger vehicles while hydraulic hybrids have been implemented in commercial vehicles. Since electric hybrid systems can operate quietly, enhancing passenger comfort, this system is implemented in passenger vehicles. However, current battery technologies in the market prevent high power charging and thus prevent the electric system from replacing frictional brakes. As a result a significant amount of braking energy is lost to the surroundings through heat. Hydraulic hybrids, in contrast, have the ability to capture most of the braking power. However, due to the characteristics of hydraulic components, the hydraulic systems suffer from the accumulator's low energy density; the Noise, Vibration and Harshness (NVH) also significantly affect the driving experience.

In an attempt to address the charging power density challenge faced by Electrical Hybrids and the energy density challenge faced by Hydraulic Hybrids, different drive systems were designed. Braking Power Analysis of the report presents simple braking power analysis as the foundation of further calculations in other parts. The initial approach to solve the problem was to incorporate an electrical system in an existing hydraulic hybrid system. Hydraulic Hybrid Drive System presents the Hydraulic Hybrid system engineering level analysis, and Hydraulic Accumulator Analysis investigates the hydraulic accumulator. It was confirmed that the hydraulic accumulator does not have a sufficient energy density for braking energy capture and therefore electrical accumulators were introduced to capture the access energy. Battery Analysis investigates the electrical accumulators. Upon the completion of Analysis, it was concluded that the electrical system alone is sufficient. As a result, an in-hub motor driven electric drive system (Figure 7) was chosen, and the analysis and simulations are presented in Electrical Systems of the paper.

BRAKING POWER ANALYSIS

Braking power analysis is performed to serve as a foundation for accumulator analysis in Hydraulic Accumulator Analisis and Battery Analysis. Analysis is conducted with an assumption of negligible rolling friction, air drag and other losses. The driving analysis is performed on a mid size passenger sedan, such as a Honda FCX Clarity. The Honda FCX Clarity fuel cell car was selected because the weight of the components in the car closely resembles the weight of the suggested drive system. The assumed vehicle mass is 1625 kg (Honda at the Geneva, 2009). The ECE-15 Driving Schedule is shown in Figure 1.

A 6 second 35 mph to 0 mph deceleration is assumed. The assumed braking slope resembles a rapid urban braking is more rapid than ECE-15 Urban Driving Schedule braking. A rapid 60 mph to 0 mph deceleration is also assumed. Under normal driving conditions, a passenger vehicle will take about 200 ft to decelerate (2009 Driver's Manual, 2009). The deceleration time involved can be obtained using Equation (1) and Equation (2)

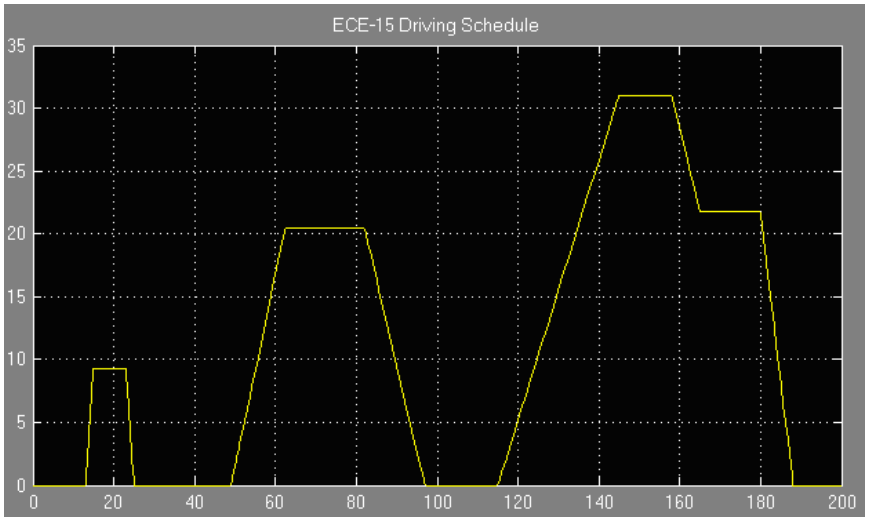

Figure 1. ECE-15 Driving Schedule; x-axis: time (s); y-axis: vehicle velocity (mph).

(1)

$$v_f^{\,2} = v_i^{\,2} + 2as$$

where is the final velocity of the vehicle, is the initial velocity of the vehicle, a is the acceleration of the vehicle, and s is the displacement involved in the acceleration. The time is obtained using Equation (2)

(2)

$$v_f = v_i + at$$

where t is the deceleration time. Using the provided equation, we obtained 11 seconds as the deceleration time. The energy dissipated can be obtained using Equation (3)

(3)

$$KE = \frac{1}{2}mv^2$$

where KE is the kinetic energy of the vehicle, m is the mass of the vehicle, and v is the velocity of the vehicle. The braking power can then be determined using Equation (4)

(4)

$$P = \frac{d(KE)}{dt} = mv\frac{dv}{dt} = mva$$

where P is the power involved with the braking. The deceleration details calculated are tabulated in Table 1.

HYDRAULIC HYBRID DRIVE SYSTEM

The initial approach to solve the problem was to incorporate an electrical system in an existing hydraulic hybrid system. The selected hydraulic system is the INNAS HyDrid. The architecture of the HyDrid system (Achten, 2007) is presented in Figure 2.

INNAS claimed that 77 Miles Per Gallon (MPG) is possible for the HyDrid system (HyDrid, 2009) because

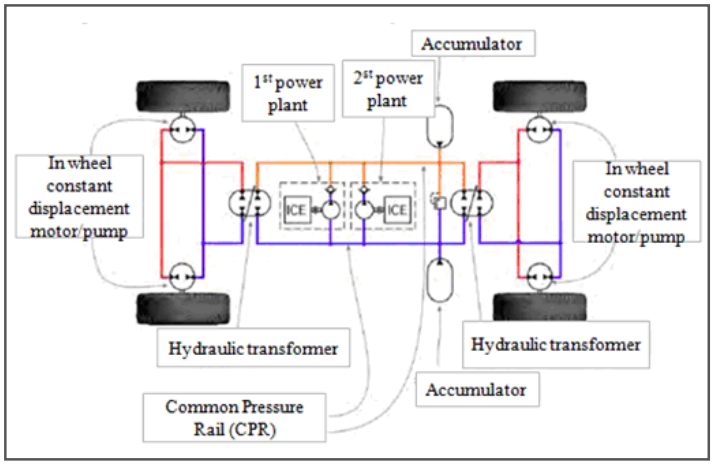

Figure 2. HyDrid Drive system adapted from Achten.

the secondary power plant allows engine off operation, and the Infinitely Variable Transmission (IVT) allows the engine to rotate at optimum RPM for efficiency. The INNAS HyDrid utilizes the INNAS Hydraulic Transformers (IHT) (Achten, 2002) in a Common Pressure Rail (CPR) (Vael & Acten, 2000). The IHT is claimed to have unmatched efficiency due to the Floating Cup Principle that it utilizes. The starting torque efficiency, according to Achten, is up to 90% (Achten, 2002) or above. The control method of the HyDrid is not published; therefore, a possible control method is presented to demonstrate how the IHT functions as an IVT and thus converting the varying pressure from the accumulator into the desired pressure for the in wheel constant displacement motor/pumps. When accelerating, either the pressure accumulator or the ICE will provide the required pressure in the CPR which will in turn be transmitted by the IHT to drive the in-wheel constant displacement motor/pump. The IHT is assumed to be a variable pump coupled with a variable pump/motor. A possible method of controlling the acceleration is to vary the stroke of the variable pump in the IHT while keeping the pump motor stroke and the ICE RPM constant. During braking, the pump (CPR side) stroke is kept constant while the pump motor stroke is varied to charge up the accumulator. The presented control method is presented in Figure 3.

A simulation is performed to demonstrate the control method. The system assumes that the vehicle has a 4 cylinder gasoline engine, a 0.85 volumetric efficiency for variable pump/motor, and a 0.92 volumetric efficiency for constant displacement pumps and inactive pressure accumulators. It is also assumed ideal pipe lines and no force is involved in the varying of the pump stroke. The simulation shows how by varying the IHT pump stroke the vehicle speed can closely follow a desired trajectory with minimal ICE rpm variation. The ICE rpm and the pump stroke variation are shown in Figure 4 and 5

v_i(m/s)	v_f(m/s)	t(s)	Braking Power (kW)
35	0	6	66.0
60	0	11	99.8

Table 1. Deceleration details for the assumed vehicle.

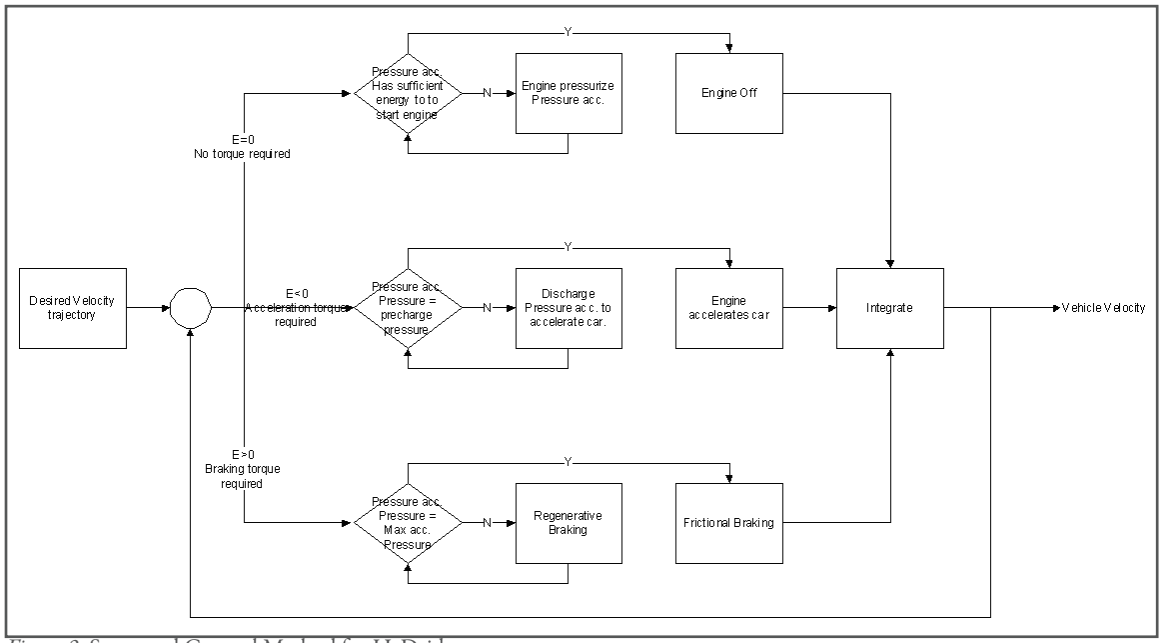

Figure 3. Suggested Control Method for HyDrid system.

respectively. The resulting vehicle velocity is shown in Figure 6.

The simulated vehicle velocity closely matches with the desired velocity trajectory, which is the ECE-15 driving schedule (Figure 1). The simulated velocity trajectory is idealized because of the idealized assumptions made in creating the simulation model. The pressure values provided from the simulation are also observed to be faulty. This simulation's values cannot be used for quantitative purposes. However, it is sufficient for the demonstration of the variation between the stroke of the pump in the IHT and the vehicle velocity.

HYDRAULIC ACCUMULATOR ANALYSIS

The hydraulic accumulator has sufficient power density but a low energy density. An attempt was made to quantify the energy storage capacity of a typical size hydraulic accumulator for a hydraulic hybrid vehicle so that the proposed additional battery pack can be correctly sized. A 38L EATON hydraulic accumulator (Product Literature, 2009) is assumed (Used in CCEFP Test Bed 3: Highway Vehicles). The parameters used for energy calculations are tabulated in Table 2.

Volume (m^3)	0.038
Precharge Pressure (MPa)	10.7
Precharge Nitrogen Volume (m^3)	0.038
Maximum Nitrogen Pressure (MPa)	20.6
Nitrogen Volume at Maximum Pressure (m^3)	0.0176

Table 2. EATON 38 L hydraulic accumulator.

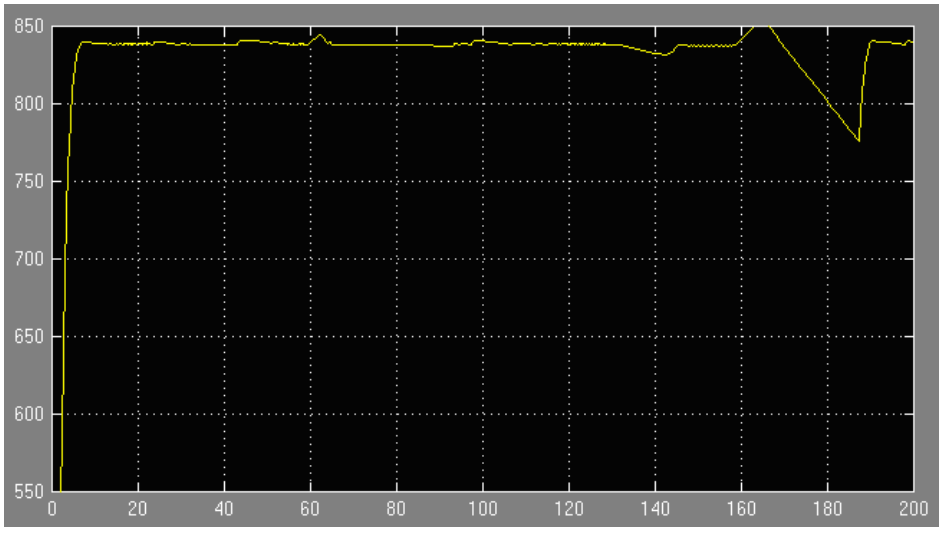

Figure 4. Engine RPM for HyDrid simulation; x-axis: time (s); y-axis: ICE rpm.

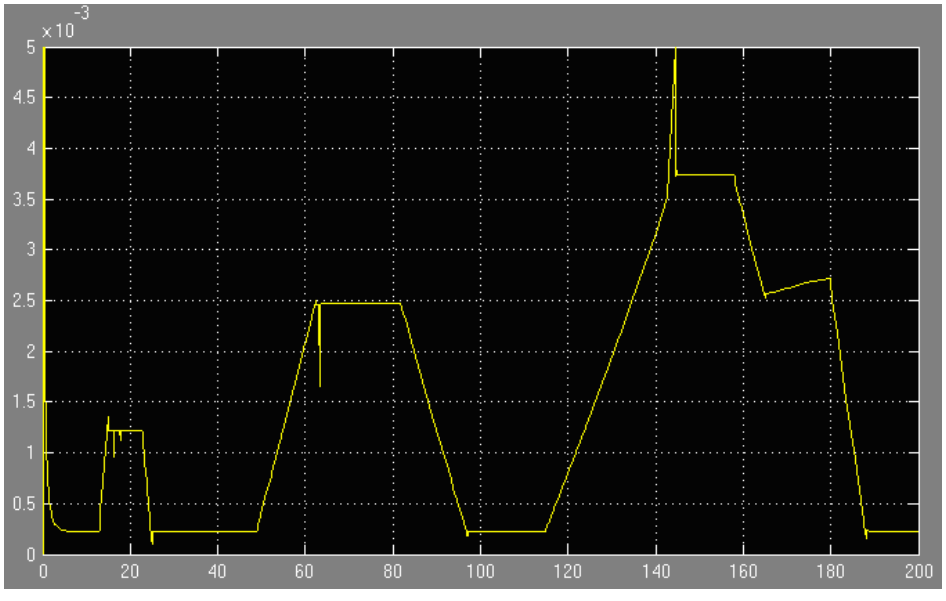

Figure 5. Pump stroke variation for HyDrid simulation; x-axis: time (s); y-axis stroke (m).

The assumed relationship between pressure and volume is shown in Equation (5)

$$pV^n = \text{constant} \tag{5}$$

where p is the pressure of the nitrogen in the accumulator, V is the volume of nitrogen in the accumulator, and n is an empirical constant. Using this relationship, the total energy involved in completely pressurizing or depressurizing the accumulator is shown in Equation (6)

$$W = \frac{p_f V_f - p_i V_i}{1 - n} \tag{6}$$

involved. Using Equation (5) and Equation (6) we can calculate the total energy storage of the EATON 38L pressure accumulator, which is 293.6 kJ. Using Equation (3) and assuming a vehicle with the weight of 1625 kg (from Braking Power Analysis), a 38L accumulator is sufficient for the acceleration from 0mph to 42.5mph. It is assumed that no energy is lost due to friction, drag, and inertia changes. As the main purpose of the hydraulic system in a Hydraulic Hybrid is to capture urban braking and to accelerate the car to a velocity where the ICE can be started, 293.6 kJ is sufficient. However, if the vehicle is braking from a speed higher than 42.5 mph, or the duration of braking is long, the hydraulic system will not be able to capture the braking energy.

Therefore an electrical system is introduced to capture the excess energy.

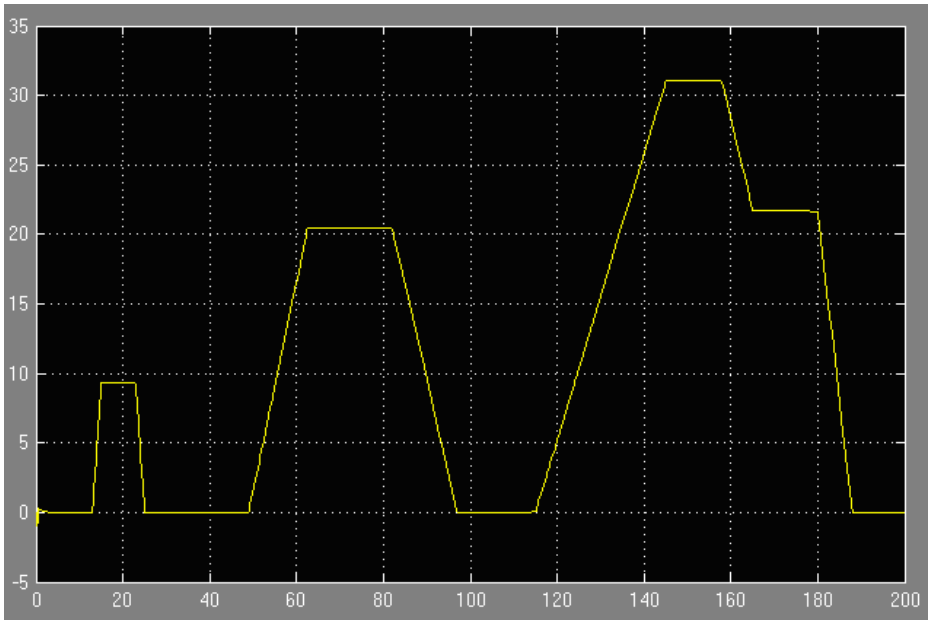

Figure 6. Vehicle velocity variation for HyDrid simulation; x-axis: time (s); y-axis: velocity (mph).

	SCiB Cell	LFP
Nominal Voltage (V)	2.4	3.2
Nominal Capacity (Ah)	4.2	1.1
Size (mm)	approx 62 x 95 x13	d=18, h=65
Weight (g)	approx 150	40
Charging time	90% in 5 min	99% in 30 min

Table 3. Sony LFP and Toshiba SCiB cell spec.

BATTERY ANALYSIS

The batteries are proposed to serve as secondary energy storage which will capture excess energy that cannot be captured by the hydraulic system. The two electric accumulators analyzed are the Sony Olivine-type Lithium Iron Phosphate (LFP) cells (Sony Launches High-Power, 2009) and the Toshiba SCiB cells (Toshiba to Build, 2009). Both cells exhibit impressive recharge cycles and high charging power density. Cell specifications are shown in Table 3.

The charging power density can be obtained using Equation (7).

$$\text{Charging power density} = \frac{(\%\text{Charge}) \cdot (\text{Energy Density})}{t_{\text{charging}}} \quad (7)$$

where is the charging time for one cell.(fix this sentence) Energy density can be described using Equation (8).

$$\text{Energy density} = \frac{C \cdot V \cdot 60 \text{ min} \cdot 60 \text{ sec}}{t_{\text{charging}}} \quad (8)$$

where C is the cell capacity in Ah, V is the nominal voltage, and m is the mass of one cell. The energy density and charging power density values obtained are tabulated in Table 4.

As shown in Table 4, the Sony LFP outperforms the Toshiba SCiB in terms of energy density by a factor of 1.3, while the SCiB outperforms the LFP in terms of power density by a factor of 3. As the major limitation in Electric Hybrid systems is the charging power density of batteries, the SCiB cell is used for further analysis.

As calculated in Braking Power Analysis, 66.0 kW is the maximum braking power occurred in a 6 second 35mph to 0 mph city braking. Assuming that all the SCiB cells used are arranged in such a way that the power density is equally shared among the cells and ideal electronic components, 90.8 kg of the SCiB cells are required. 90.8 kg of SCiB has a total capacity of 22,000 kJ. According to Braking Power Analysis calculations, each city braking involves 197.7 kJ braking energy, which is 0.9% of the battery pack's capacity. According to Toshiba, the capacity loss after 3,000 cycles of rapid charge and discharge is less than 10% (Toshiba to Build, 2009). Using the assumptions in Braking Power Analysis and assuming that the 10% of capacity loss after 3000 cycles is negligible, we can obtain 334 thousand cycles as an approximate

	SCiB Cell	LFP
Energy Density (kJ/kg)	242	316.8
Charging Power Density (W/kg)	726	198

Table 4. Sony LFP and Toshiba SCiB cell spec (charging power density and energy density).

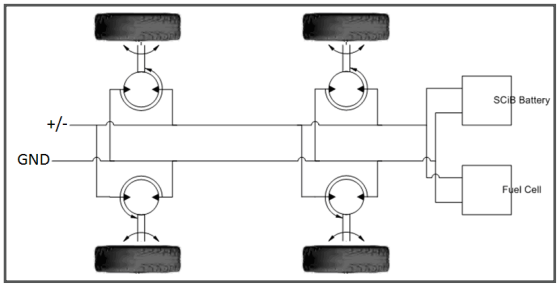

Figure 7. Selected Electric Car architecture.

for the regenerative braking and driving cycles allowed before the capacity of the SCiB drops below 90%. Using the same assumptions we can also find that 137.6 kg of SCiB is sufficient for the maximum charging power involved in the 11 second 60 mph to 0 mph highway accident braking. The weight of the battery pack required is slightly heavier than the 70kg battery pack in a Toyota Prius electric hybrid vehicle.

ELECTRICAL SYSTEMS

As shown in Battery Analysis calculations, the Toshiba SCiBs have a power density that is more than sufficient for regenerative braking. As a result neither the hydraulic system nor the frictional braking system is necessary in an electric vehicle equipped with the Toshiba SCiBs. A mechanical emergency brake should be installed to prevent accidents in case of regenerative braking system failure.

The possible simplest design is a plug in electric or a fuel cell vehicle that has 4 in-hub motors. The simplified system is shown in Figure 7. As shown in the Figure 7, the 4 in-hub wheel motors are directly connected to the wheel. With mechanical components such as the ICE, differentials, and the transmission removed, the vehicle weight can be reduced, and the efficiency of the whole driving train can be increased by at least a factor of 3 (Clean Urban Transport, 2009). Some efficiency values (Achten, 2009; Valøena & Shoesmith, 2009) are provided in Table 5 for comparison. The 4 in-hub motor design also allows the vehicle to enjoy a very small turning radius and other advantages of 4WD vehicles, such as increased traction performance and precision handling. To validate the design, a simulation is done for the system suggested. Because of the mechanical components removed, a lighter car is selected for simulation. The selected vehicle is a Honda Civic, with a vehicle mass of 1246 kg (Complete Specifications, 2009) and a CdA value of 0.682 m2. The air drag of the vehicle can be calculated using Equation (9) (Larminie & Lowry, 2003)

(9)

$$F_{ad} = \frac{1}{2}\rho C_d A v^2$$

The rolling friction of the vehicle can be obtained using Equation (10) (Larminie & Lowry, 2003).

(10)

$$F_{rr} = \mu_{rr} mg$$

	Approx. Efficiency
ICE	20%
Transmission (automatic)	85%
Transmission (manual)	92% to 97%
Differential	90%
Motor	90%
Battery recharge	80% to 90%

Table 5. Efficiency values of integral components of ICE drive train and electric drive train.

where F is the rolling friction force, μ is the rolling friction coefficient, which is assumed to be 0.015 (for radial ply tire) (Larminie & Lowry, 2003), m is the mass of the vehicle, and g is the acceleration due to gravity. As in-hub motor specifications are not readily available, the 4 in-hub motors are assumed to resemble the Tesla Roadster drive train system (2010 Tesla Roadster, 2009), which only involves a motor and a fix gear set with a gear train ratio of 8.28. The 375 V AC motor has a 215kW peak power and 400 Nm of torque. All the parameters, including Equation (9) and Equation (10), are included in the simulation.

The model simulates the vehicle attempting to follow the ECE Driving Schedule shown in Figure 1. The controller assumed is a PID controller with a Kp of 10.4, Ki of 0.546, and a Kd of -0.386 (MATLAB Simulink tuned for 2.06 second response time). The resultant velocity trajectory and the power variation are shown in Figure 8 and Figure 9 respectively.

As expected, the power stays below a value of 66kW, and there are negative values in the time versus power plot as deceleration is involved in the ECE 15 Driving Schedule. Because of the losses, the negative peaks that correspond to braking power have a magnitude that is relatively smaller than the positive peaks that correspond to accelerating power. From the simulation, the highest braking power observed is a little over 10 kW, which can easily be fully captured using the 70kg of SCiB battery packs (refer to Battery Analysis for calculations). Simulink scopes are added to the system to observe the energy change with and without regenerative braking systems. The results are shown in Figure 10 and Figure 11.

Comparing Figures 9 and 10, we can observe a 25% energy saving for the system with regenerative braking. Tuning the PID controller can increase the energy savings value up to 30%. Using a better controller has the potential to increase the energy savings value further.

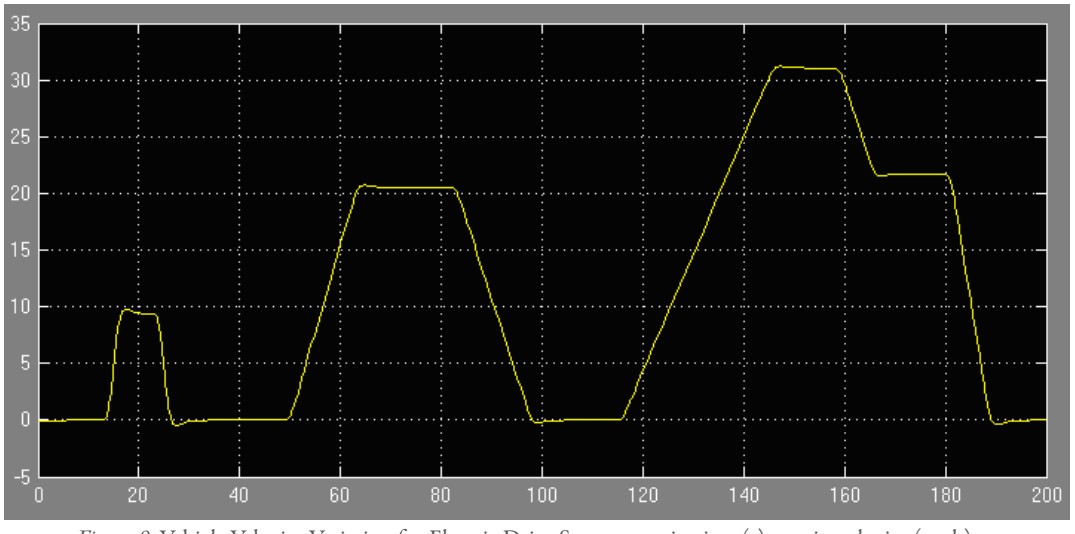

Figure 8. Vehicle Velocity Variation for Electric Drive System; x-axis: time (s); y-axis: velocity (mph).

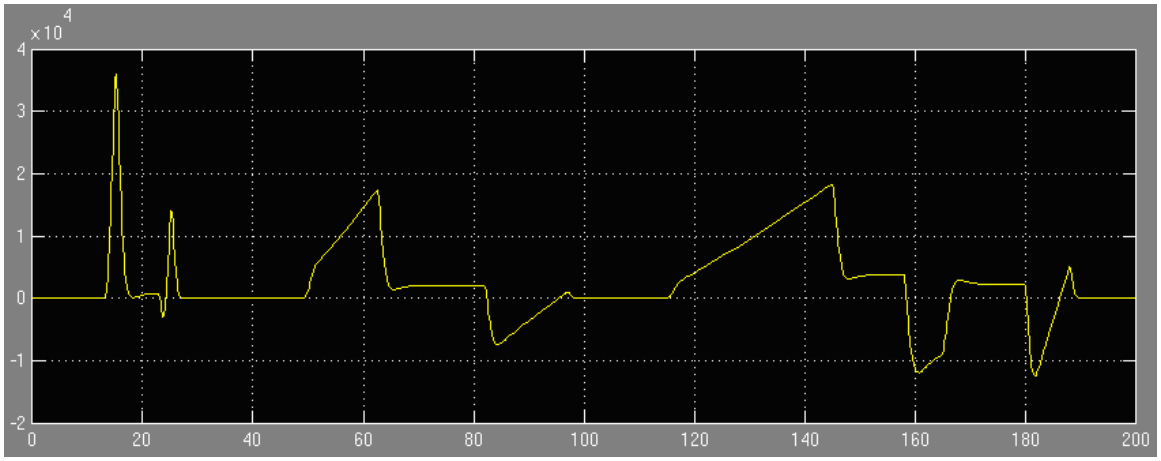

Figure 9. X-axis: time (s); y-axis: power(W) plot for Electric Drive System Simulation.

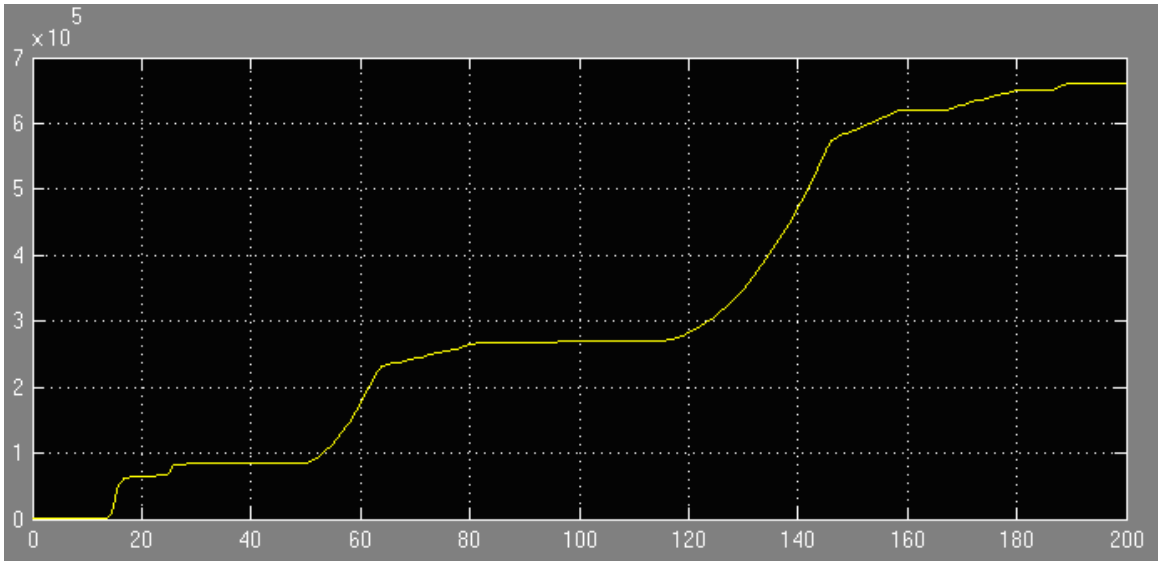

Figure 10. Energy required to complete the ECE 15 driving cycle without regenerative braking; x-axis: time(s); y-axis: energy(J).

RECOMMENDED FUTURE WORK

The hydraulic drive system may deserve a more in depth analysis. If the accumulator energy density can be improved, the hydraulic drive system may be a more environmentally friendly option than its electrical counterparts as the production and disposal of batteries leave detrimental effects to the environment. It is recommended that the simulation model be improved to better model the actual response of the HyDrid system. For the electrical system, efforts should be invested in the research of in-hub motors, which produce significantly less torque than a regular AC motor coupled with an 8.28 to 1 gear ratio gear train. Parameters within the Simulink model should be selected to better represent in-hub motors and the batteries should be modeled with greater detail, as different arrangements of the cells will result in different power density. Losses involved with the electrical components should also be investigated. One challenge that the electric drive system should overcome is the energy density issue of the batteries. The energy density of a battery is significantly lower than gasoline. Efforts should also be invested in technologies related with battery recycling.

CONCLUSION

An attempt was made to design a compact car drive system to address the charging power density challenge faced by electric hybrid vehicles and the charging energy density challenge faced by hydraulic hybrid vehicles. The initial approach to solve the problem was to incorporate an electrical system in an existing hydraulic hybrid system. The INNAS HyDrid was used as the foundation architecture for analysis. Simulations were performed to understand the control dynamics of the HyDrid. After performing quantitative analysis on hydraulic accumulators it was confirmed that hydraulic accumulators cannot provide a sufficient energy density for braking

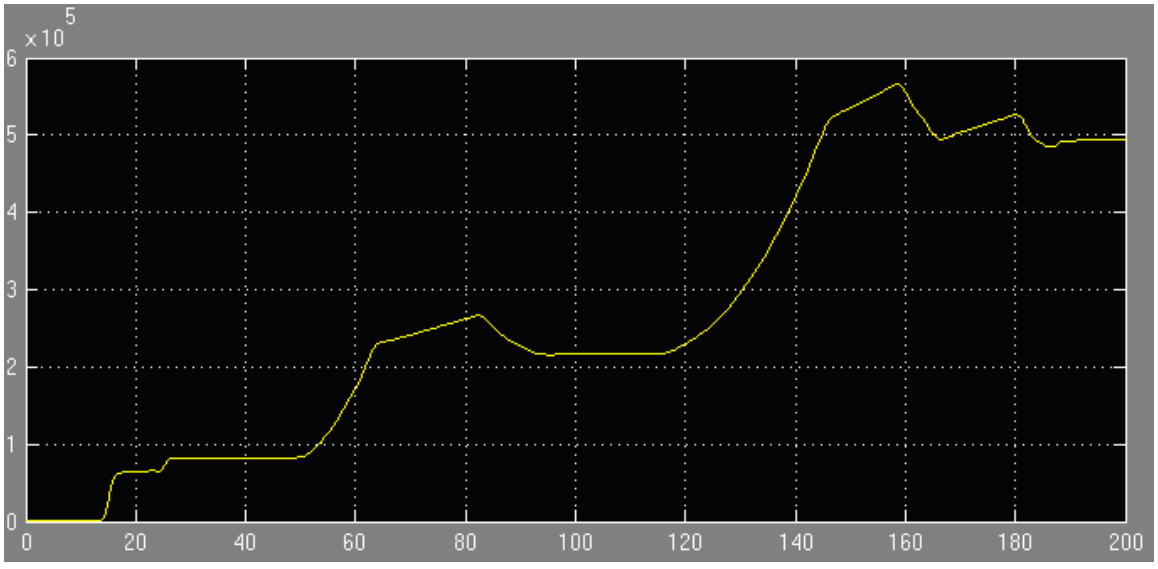

Figure 11. Energy required to complete the ECE driving cycle with regenerative braking; x-axis: time(s); y-axis: energy(J).

energy storage. In one of the intermediate designs, electrical accumulators were introduced into the system to capture excess energy that cannot be captured by the hydraulic system. The Sony LFP and the Toshiba SCiB were considered. The Toshiba SCiB was chosen as a result of its superior charging power density performance. Upon further analysis, it was concluded that the batteries have a sufficient charging power density to capture braking power. It was then suggested that the electric system can fully replace the hydraulic components, the ICE drive train, and the frictional braking system. With the convoluted hybrid system, which consists of a lot of inefficient components replaced by a simple electric only drive train, the vehicle drive train efficiency can be increased. An electrical system is simulated. The simulated models showed energy savings of around 25~30% with regenerative braking. The final drive system design consists of an electric/fuel cell vehicle with four in-hub motors.

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THE GMO CONTROVERSY AND ITS EFFECTS ON BRAZIL'S AGRICULTURAL SECTOR: FOCUSING ON SOYBEAN TRADE WITH THE EUROPEAN UNION

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"The investigation of genetically modified organisms (GMOs) is a recently popularized issue within the realm of international science and technology research. It has been a mere 18 years since the United States' FDA declared that genetically engineered foods are not inherently dangerous and do not require special regulation. In the midst of the publicized controversy surrounding the idea of genetically engineered food items, Brazil has been caught between two differing forces in the agricultural realm: commercial farmers, researchers, and agribusiness vs. environmentalists and consumer advocates. The history of GMO production in Brazil encompasses heated battles due to both internal and external disagreements. In addition to a general concern about the risks of growing and consuming bioengineered agriculture, the Brazilian government has struggled to integrate GMOs into the farming sector because Brazil's largest agricultural importer, the European Union, has remained hostile to GMOs, placing strict rules on the importation, labeling, and distribution of these foods within their markets."

I. INTRODUCTION

Because of this controversy, I have chosen to examine the implications of Brazil's decisions regarding GMO production and trade within the past twelve years, focusing on the Brazil-EU trade partnership and the effects of GMO suppression on the Brazilian agricultural community. In order to closely look at the changes that have occurred, I will focus on the soybean sector for two reasons: Brazil is the second largest producer of soybeans in the world and their first controversial GM legislation, proposed in 1998, concerns the use of Monsanto's Roundup Ready (RR®) Soybeans. Upon the introduction of this first piece of legislation, Brazil was hesitant to integrate biotechnology into its commercial farms, pressed by the European Union to remain GM-free because a large majority of European consumers were anti-GM, fearful of the unknown effects of bioengineering. But, as the GM conflict has persisted in Brazil, their federal government has repeatedly supported the dissemination of biotech crops and subsequent research and development in the field, while the EU continues to resist GM foods. So, why did Brazil make the change?

I will discuss the interactions between Brazil and the EU during Brazil's tense period of GM controversy, noting the nature of their relationship as trading partners and how trade patterns have changed since Brazil has stepped into the international GMO market between the years of 1998-2008. I suggest that Brazil's executive body and agricultural sector has been unable to resist the influence of large corporations, such as Monsanto, therefore they have seen an enormous increase in the percentage of GM soy crops produced and exported. But, rather than harming Brazil's economy, this has increased the EU's participation in trade with Brazilian soy growers. Since Brazilian regulations on GM crops are still in the process of being solidified, Brazil has the largest percentage of non-GMO soybean acreage in the world, with almost 30% of their soybean production classified as conventional. The EU has not shifted its trading focus away from Brazil, instead it has become even more interested in utilizing both the GM (on a limited scale) and the non-GM soy crops available, further distancing its market from the worlds' other important soy producers, including the United States and Argentina, who both have over 90% of their soy crop as GM.

II. THE DEVELOPMENT OF THE GMO CONTROVERSY IN BRAZIL

In September 1998, Brazil's National Biosafety Technical Commission (CTNBio) announced the Commercial Release of the Genetically Modified Soybean (Roundup Ready® Soybean), concluding that "there is no evidence of environmental risk or to the human or animal health from the use of the genetically modified soybean in question." This was the first attempt at GMO acceptance in Brazil, coming only two years after the manufacturer, Monsanto, introduced this herbicide tolerant bean on the international market. The resolution would allow Brazilian soybean farmers to purchase transgenic seeds from Monsanto as a five-year study was conducted to validate the new crops as harmless. Just weeks after this approval, backlash arose in the form a class-action lawsuit filed by environmentalists and consumer nongovernmental organizations (NGOs) within the 6th Civil Law Circuit of Brasilia. They claimed that CTNBio "didn't know enough about the safety of genetically modified crops when it cleared Monsanto." As a result, the lower court granted a preliminary order rescinding Monsanto's permission to distribute the RR® seeds. After this decision, Monsanto and the federal government appealed to the regional federal court.

The judges of this higher court denied the appeal in 2000, overruling CTNBio's decree, immediately placing an outright ban on GMOs in the region indefinitely, requiring that an environmental impact study (EIS) be conducted and labeling requirements be established before any other GMOs were taken into consideration. Quoted in the Wall Street Journal, Marilena Lazzarini, the executive coordinator of the Brazilian Institute for Consumer Defense (IDEC), one of the organizations that filed the suit against Monsanto, praised the court's decision: "We hope that now they [Monsanto] will stop their irresponsible goal of liberating bioengineered seeds in the country without the necessary evaluation of risks to the environment and human beings." In addition to IDEC's opposition to GMOs, the international conservationist organization Greenpeace vehemently opposed Brazil's new decree on soy planting. Mariana Paoli, the Campaign Coordinator of Greenpeace's Genetic Engineering Brazil depart-

ment stated: "We do not yet know the consequences of genetically modified organisms into the environment and public health. Therefore, we consider the application of the precautionary principle and the implementation of an EIS." Under the precautionary principle, the burden of proof that GMOs are NOT harmful falls on those who are supporting their use. So, therefore, in order for the genetically-modified foods to be considered acceptable, it would be the responsibility of an informed, ruling body to determine any risks and make that information available to the public.

After the GMO ban in 2000, some planters were stuck with Roundup Ready® seeds that they had already acquired from Monsanto, and some were anxious to use the product, so they began to smuggle the seeds from Argentina, who at the time was the world's second largest GMO producer. Argentina began using RR® seeds in 1996, and by 2003 almost 100% of their soy farms produced GM crops. The majority of these illegal crops were brought from Argentina into Brazil's state of Rio Grande do Sul, located right across the border in the southernmost part of the country. The federal government under President Fernando Henrique Cardoso did not support the court's ban on GM crops and, therefore, has been accused of "indirectly encouraging the growing of GM soya, [because] it lacked a clear policy on GM crops and failed to adequately monitor crops." Although Cardoso did not take a strong stance against Monsanto's seed, the state government took preventative measures, passing laws explicitly banning the cultivation of GMOs. They also tried to take advantage of the European Union's concern about GM foods, urging farmers to stick with the non-GM crops and protest the relentless push toward GMOs from companies like Monsanto. One pamphlet they published even said that science should be "under public control to benefit life, not under private control to [benefit] profit."

In the end, the state government was unable to implement these preventative measures, and it is estimated that around six million tons of transgenic soybeans (80% of the region total) were ready to be harvested after the 2003 season. This vast act of piracy had not gone unnoticed on the international soybean market; corporations and farmers across the globe who were legally growing the RR® soybeans spoke out against the ineffectiveness of Brazil's government to curb the theft of Monsanto's intellectual property. So, in March 2003, the federal government under newly elected President Luiz Inácio Lula da Silva, issued Provisional Measure (PM) 113, allowing the commercial use of the illegal crops that had already been grown using pirated seed. Following the publication of this measure in the United States, producers' concerns continued to escalate: Brazil's illegal exportation of GM soybeans gave them a distinct competitive advantage over the U.S., who had to pay both high taxes on their goods and royalties to the corporation. This emergency measure did not permit Monsanto to bring more RR® seeds in, but in an effort to save the Rio Grande do Sul farmers from losing millions of dollars of crop that would otherwise be destroyed, the Brazilian government deemed this a "conduct adjustment," only if the farmers would agree to not plant GMOs again. Monsanto tried to fight back against the Intellectual Property Rights violation by "requiring exporters in Brazil to sign license agreements" in order to export the RR® Soy that had been temporarily allowed in 2003 by issue of Presidential Decree, but since the crops were allegedly being placed back on the "ban list" the following year, such agreements were ignored and the illegal crops were distributed at the government's command.

At this point, PM 113 had set place very few, weak requirements such as the labeling of products in which GMOs consisted of 1% or more of the total volume. The labeling constraints were never adopted, and the Ministry of Agriculture even admitted that there "were not enough accredited laboratories available to certify GM and non-GM soybeans. President Lula, who passed this measure in 2003, was eager to make some changes regarding biotechnology, feeling pressure from GM corporations such as Monsanto, who were ready to see compensation for the harvesting of their RR® product. In an attempt to make sure the federal courts could not issue another moratorium on GMOs by disregarding all other entities who should be consulted on such an assessment, a new Brazilian Biosafety Law (No 11,105) was passed in March 2005. This law created the National Biosafety Council (CNBS), and re-established CTNBio as a group of 27 members from all facets of

agriculture, from a consumer rights specialist to a representative from the Ministry of Defense. Also, it provided safety norms and inspection mechanisms that all sectors of GM production and trade would be required to follow, including parameters within the construction, storage, research, and marketing sectors.

The most stirring portion of this law is that the responsibility of determining the safety GM products was completely handed to the newly formed CNBS. With this law in place, CTNBio was now allowed to provide the final word regarding the accepted technical opinion of GMOs. They were now in the position to implement much needed policies: monitoring research, authorizing new species of GM plants, and regulating the registration and farming of accepted crops. In Brazil, in order for a law to enter into effect, a regulatory decree must also be signed by the President, much like an Executive Order in the U.S. This decree cannot change the verbiage or provisions of the law, but it can create bureaucratic obstacles that could change the overall effectiveness of the law. Knowing that the Decree was needed, IDEC struck again, and the Federal Public Prosecutor filed a lawsuit in Brazil's Supreme Court called a Direct Action of Unconstitutionality (AIDN), claiming that the law was unconstitutional and, therefore, could be challenged in the highest court of law.

After eight months of rigorous debate among governmental officials, President Lula signed Decree No 5,591, implementing the provisions of Law No 11,105 and allowing CTNBio to finally get on track, regulating the GM trade in Brazil and expanding the use of GM crops throughout the nation. The law required that two-thirds vote was necessary within the CNBS to approve a new biotech agricultural product. Since the anti-GMO presence in Brazil was so fanatical and (even) militant, they were able to gain membership within CTNBio and block the passage of new GM regulations, inciting many scientists to ultimately leave the commission as no progress had been made and there were 500 pending new product requests. So, in 2007, President Lula signed Law No 11,460, changing the previous law, calling for a majority vote within the CNBS, rather than a two-thirds vote.

III. HOW HAS THE EUROPEAN UNION AGRICULTURAL SECTOR DEVELOPED WITHIN THE CONTEXT OF THIS GMO MOVEMENT?

In 1999, multiple countries in the EU started urging the European Commission (EC) to place a de facto moratorium on any new GMO approvals and in July 2000, EU ministers accepted the proposal, agreeing that no new GMOs would be accepted into the European market until further labeling and tracing methods were researched, tested, and implemented. Europeans have exhibited a growing concern about food health and safety since the late 1990s, prompted by the disturbing emergence of mad cow disease and instances of AIDS-contaminated HIV blood. Today, the EU still has very hard guidelines for GM crops, allowing very few GM foods into the country and almost no cultivation within the borders. The EU's opposition to the GM revolution has been intensified in recent years due to the steady growth of the anti-GMO movement across the continent, supported by the EC's regulatory approach and embedded in a general sense of apprehension. Europeans were susceptible to far-fetched information about GM effects, hearing stories about dangerous additives, unhealthy processing methods, and the risk of cross-contamination between GM crops and GM-free crops, because it was very difficult to contain the two varieties in their designated areas once seeds were cross-pollinated and multiple harvests had been conducted. In order to gain access to the EU soybean market, Monsanto was granted a reportedly vague patent two years before the GM controversy began in Brazil: 1996. This patent encompasses genetically modified plants that have been made resistant to glyphosate, Monsanto's own herbicide, also known as Roundup®. In agreement with the patent, the EC allowed Monsanto to introduce RR® soy into the EU market, but it was not (and to this day, is not) allowed to be cultivated on EU land.

The EC stresses the need to prevent "contamination" within the natural crop harvest, issuing a Commission Recommendation in July 2003 that outlines specific procedures to "ensure the co-existence of genetically modified crops with conventional and organic farming." Although the first point of this document states that no form of agriculture will be excluded from the EU, the reality

is that the guidelines that have been put in place in order for GM growers to gain access into the European market are so stringent that even the most experienced and preeminent corporations cannot break-through in a reasonable amount of time. As Brazil's government grapples with the idea of GMOs, some farmers have expressed their interest in remaining GM-free, seeing this as a way to remain competitive in the EU market is to produce the soybeans that they want to buy. Farmers believe that the price for natural soy will increase as the availability on the international market is contained primarily in Brazil, since it is the last major non-GE soy exporter in the world. As of 2006, the Federation of Rural Workers and Family Farmers in South Brazil (FETRAF-Sul/CUT) committed to selling more than 50,000 metric tons of GM-free soybeans to the European market with the help of the Dutch Soy Coalition. A report published by the EC's Directorate General for Agriculture and Rural Development published a study in 2007 urging the world's major soybean producers to consider the EU's harsh regulations and realize that even if the European Food and Safety Agency (the EU-wide regulatory agency for GM-related issues) gives clearance to a certain food or feed, that does not mean that all Member States have accepted the GMO, as well. In fact, there has never been a majority agreement among Member Nations concerning any GM product.

There have been many studies conducted investigating the EU's weariness of biotech foods, and many scholars have suggested that negative consumer perception lies in a widespread lack of knowledge about the effects of GM crops, causing fear and rejection that will continue to grow as long as the anti-GM movement advertises exaggerated defects in GM cultures and the EC implements different submission hurdles and labeling policies to which biotech companies must conform. In her paper, "Governing GMOs in the EU: A Deviant Case of Environmental Policy-Making?," G. Kristin Rosendal suggests the apparent lack of support is due to the ineffectiveness of "environmental policy in the face of influential corporate interests." She presents four theses to explain the EU's resistance to the biotech industry: a lack of internal unity, limited access to decision making, the strength of counterbalancing forces, and industry interests for protectionist reasons. The GM backlash, she says, has been fueled by counterbalancing forces within the internal sector, including the work of Environmental NGOs (ENGOs) such as Greenpeace/Friends of the Earth. An interesting element of the public opinion, she claims, is that "people [put] more trust in information from ENGOs compared to industry as well as regulatory authorities." Her conclusion looks to the future of GM policy in the EU, deeming the effect of external activities (such as WTO disputes) as a "dark horse" that will increase opposition to GM foods in the beginning, but in the long run these events will help strengthen the GM movement in countries surrounding and interacting with the EU, hopefully obstructing their harsh policies and facilitating a change in the EC's standards.

Another scholar, Sylvie Bonny, also discusses the influence of NGOs on the anti-GM movement, but rather than focusing on their work within the policy sector, she focuses on their ability to exploit the fear that many Europeans already possess concerning biotech foods by creating media hype and promoting non-GM products in all sectors. In her paper, "Why are most Europeans opposed to GMOs?", Bonny conducts a case study, comparing the anti-GM movement in France to that in the EU as a whole. She focuses on the development of this overwhelmingly negative response, linking the GM conflict to a strong distrust of firms and public authorities as food safety issues were widely publicized and the problems of industrial pollution came to the forefront around the same time that GM products were gaining ground in the international market. She also attributes the negativity to the strong influence of NGOs and other associations that focus only on the risks, representing a segment of the population that began as a small circle of environmentalists, but has evolved into an enormous movement including economic interest groups, human rights activists, and agribusiness firms. By incorporating many different media outlets into their publicity schemes, Bonny claims that this dynamic sector of the public has been able to provide inescapable sources of suspicious information to the public, criticizing the GM movement on all levels and encouraging public support.

In contrast to focusing on the transformation of public opinion with regards to policy support or media exploitation, Joyce Tait "analyzes

the risk-related problems that have arisen over the introduction of GM crops and food products in the context of the adoption of the Precautionary Principle (PP)" in her paper titled "More Faust than Frankenstein." This standard, established as a guideline at the 1992 United Nations Conference on Environment and Development (UNCED) through the Rio Declaration on Environment and Development, states that in order to protect the environment, each nation needs to interpret the safety of new technologies according to their ability, without disregarding potential damages due to a lack of certainty or scientific evidence. Ironically, in the EU's circumstance, a precautionary stance was originally taken as an attempt to draw support from the public, avoiding the problems that arose while under a preventive regulatory system. Tait proposes the idea that the PP should have helped to "smooth the path" for new products, acting as a mechanism for confidence as the community could rest assured that through this method, GM foods would go through a stringent admissions process with "effective oversight of the industry's activities." She describes the "overall trait trajectory," attributing the seamless rise of the anti-GM movement to a "perfect timing" sort of event, involving three important actors in the GM market; just as agri-business began arguing against regulation of the industry (in an attempt to gain further access into the market), GM promotional advertisements were attracting public attention and environmental NGOs (and others) were realizing the influence they had on public opinion due to the recent effects of the BSE Crisis (Mad Cow Disease). As Tait suggests, the Precautionary Principle was an important measure effecting the public impression of GM foods in the EU and the grade of confidence consumers had concerning the safety/reliability of testing procedures. In addition to the effect that the PP had on the EU's public view of GMOs, this strategy of acceptance played a large role in the creation of biosafety policy by the Brazilian government in the late 1990s, which will be illustrated in the following analysis of the EU-Brazil relationship during the GM controversy.

IV. WHAT ARE THE OUTCOMES OF BRAZIL-EU INTERACTIONS DURING THIS PERIOD?

After reviewing the evolution of GM agriculture and its social, economic, and political implications within both the EU and Brazil, the soybean-trade relationship between these two countries and how it has transformed since the introduction Monsanto's RR® Soybean in Brazil will now be considered. Due to a widespread feeling of dissent in the EU concerning the introduction of GM products into their economy, it seems natural for their trade relations with Brazil to go sour after their GM policy is broadened, allowing multiple new products by using their own process of admission and regulatio¬¬n. The EU is Brazil's largest agricultural export market, but even though it is assumed that Brazil is losing out because it has become a GM-soya producer and the EU is primarily interested in non-GM crops for human consumption, I suggest that Brazil has actually benefitted as an actor on the international market from the change. Since the other major soy producing countries (mainly Argentina and the US) have shifted towards primarily growing and exporting GM soy rather than non-GM soy, Brazil has taken a hold of the non-GM soy market as the only remaining producer. In the EU, therefore, they have a monopoly on the non-GM soy product market, which greatly improves the economic outlook of non-GM soy farmers in Brazil and fortifies their position in the international soy market.

Because of Brazil's historical background concerning the implementation of GM policy, including a distinctive transitional period, internal controversy, moratoriums, set-backs, and sometimes militant opposition, they saw stunted GM growth from the outset. Unlike the other two largest soybean producers in the world, Brazil's GM soya acreage as a percentage of their total soya acreage is hovering around 70% and conventional soy crops hold the other 30%. Neither Argentina (99% GM) nor the United States (90% GM) produce a significant non-GM soya crop that could be exported to the EU. Even though the United States is the world's largest international soybean exporter, when solely looking at the EU's soybean imports, we can see that they receive a much bigger portion of their soybean products from Brazil, and the difference between the quantity of crops imported has grown

every year since 2002, when United States' participation began to decline (see Figure 1). Another interesting indicator is the fact that even though the quantity of Brazil's exports have not experienced constant, progressive growth, the value of all soy brought into the EU has increased by 50% since 2006. Promoting this positive trade growth, the EU now allows the importation of hybrid-GM soybeans that contain a small percentage of Monsanto's RR® product.

This concession increases the amount of soybean product that Brazil exports across the Atlantic and strengthens the EU-Brazil trade partnership, which has become especially important in the face of recent events that have heightened skepticism over importing from countries that mostly produce GM crops. For example, in 2009, EC scientists discovered traces of RR maize® residue in several bulk shipments of soy being imported into the EU from the U.S, causing the EC to reject over 180,000 tons of GM soy. This incident could be duplicated in the near future; Argentina currently harvests multiple GM varieties that are not allowed in the EU and are not even in the assessment process. According to the EU's Zero-Tolerance Policy, "any shipment of food or feed must be completely free from even trace amounts of GM crops that have not been approved." Fortunately, Brazil does not currently allow any GM varieties that are not also allowed in the EU (at least in some portion). Because of this connection, the EU will focus their attention on Brazil's agricultural sector since a GM/non-GM mix-up is much less likely to occur. In that regard, Brazil will be poised to take over the EU's import market, boosting Brazil's soybean price and giving them a monopoly on the entire soy sector, both GM and non-GM.

In addition to the possibility of taking over the U.S's importation of soy to the EU because of legal restrictions and bans, Farm Chemicals International published an article in 2006 describing the changes in the EU soybean import market, claiming that U.S. imports had declined (previously confirmed in Figure 1) and the EU was shifting its focus to Brazil. This adjustment, they say, can be attributed to the fact that "Brazilian soybeans generally have a higher protein and oil content, and because European crushers prefer non-GM soybeans." Also, the article indicates that the Brazilian soybean shipping season lasts longer that in the United States, which they claim is generally competitive only between October-December.

Generally, the relationship between the EU and Brazil as trading partners has been very strong, faltering slightly during the GM controversy. After Brazil's decision to integrate GM soybeans, there was an uproar from the EU community as they struggled to convince Brazil's government to retain a precautionary stance on biotech foods. The EU sought to continue the importation of non-GM soybeans (and other vegetable products) as the European anti-GM faction grew to an overwhelming majority, including both retailers and consumers. In 2005, for example, the British Retail Consortium (BRC) called on Brazilian farmers to "resist further growth of GM planting because it will be enormously difficult to maintain trust in the food chain should Brazil's supply of non-GM soybeans dry up." The BRC implored UK food companies to "place firm orders for non-GM soya for animal feed because they "feared the availability of non-GM soya products would continue to decrease if they did not express their need for them. In addition to this fear of losing non-GM products in the EU, Brazilian food manufacturers feared that they would lose their partnerships with the European consumer market.

In 2006, the Brazilian Institute for Consumer Protection (IDEC, the same organization that filed a lawsuit against the 1998 Commercial Release of the GM Soybean) published an article titled, "Food Companies Have Adopted Policies Against GMOs." IDEC points out ten different food manufacturers in Brazil who have adopted policies against GM food products "as a way to meet the European consumer market." The article cites a 2005 Greenpeace study on consumer acceptance in the EU, claiming that 90% of all large retailers and 73% of all food and drink manufactures have a GM-free policy. An important aspect of the publication is a focus on environmental preservation, stating that with conventional soybean planting, a farmer can easily respect the environment around his crops. In the end, César Borges de Souza, the Vice President of Caramuru Alimentos (a grain processor and exporter in Brazil), said that the decision to adopt a non-transgenic policy was a "consequence of European

politics to trace the origin and processing of the product they consume." These two perspectives on the status of the non-GM soybean market between Brazil-EU are the two central positions of the non-transgenic movement, providing insight and analysis of each side's reactions.

After discussing the implications of the non-GM movement among separate economic entities in the market, the value of GM soybeans shall be shown in comparison to the average value of GM-free soybeans that are exported to Europe (see Figure 2). It is clear that the EU values non-GM crops much more than GM crops: in 2008, the value of 1,000 KG of non-GM soya was almost € 800; for GM soya it was barely € 400. This data provides a compelling argument for the proliferation of non-GM crops in Brazil. But, I am not suggesting that GM crops should be replaced – they should be supplemented with additional non-GM cropland.

Brazil has an enormous amount of arable land that has not been cultivated yet, and if non-GM producers utilize these resources to expand the non-GM market, the potential economic gains are astonishing. It is estimated that there are between 124-247 million acres of unused land that could be transformed into non-GM soy farms. By looking at Table 1 and Figure 3, we can see that between 1998 and 2009, the area of soybean crop harvested in Brazil climbed from about 30 million acres to almost 55 million acres, as production increased by 2/3. At 55 million acres, Brazil was producing almost 57 million metric tons of soy as a whole (GM and non-GM). Non-GM soy production is estimated to have equaled 14.34% of the total soybean production at that time, so about 8.17 million metric tons of non-GM soy were harvested in 2009. If the Brazilian agricultural sector develops unused arable land and the area of soybean cropland is increased to the conservative value of 100 million acres, then there is the potential for a harvest of 104 million metric tons of soybeans. If non-GM soy rises to just 30% of production, there could be 31+ million metric tons of non-GM soy harvested in Brazil. In this event, EU retailers and soy-processors would be able to provide many more non-GM food items to European consumers, who are still desperately seeking non-GM alternatives. The economic benefits of this non-GM market expansion would have an extensive impact on Brazil's lucrative soy sector: the country could potentially become the world-leader in exporting both GM-soy and non-GM soy products.

Through this analysis, I have concluded that non-GM production is still an essential part of the Brazilian economy. Brazil would face harmful economic repercussions if they, as the world's last large-scale provider of non-GM crops, stopped harvesting conventional (non-GM) soybeans. Brazil's current success as an international soybean exporter can be attributed to the influence of widespread GM-discontent in the EU on the expansion of the Brazilian agricultural sector. Brazil was in a unique position at the emergence of the GM movement in the late 1990s because they, unlike Argentina and the United States, did not latch on to the GM "bandwagon." Their current GM production level is nowhere near the levels of other world leaders in the international agricultural market. As Brazilian consumer defense organizations and environmentalists rallied against the harvesting of transgenic soybeans, the European Union urged Brazil's anti-GM movement to push harder, knowing that if Brazil's soy crops became 90%+ genetically modified, they would have no market for importing the non-GM soy products that their consumers were demanding. So, with the EU's support, Brazil has slowly transitioned to an international GM-soy producer while maintaining a large sector of conventional soy crop. Therefore, Brazil is able to trade soy products in two distinct markets, reaping the benefits of both GM and non-GM consumer bases, rather than solely profiting from GM-soy materials.

As a result of my analysis of the trading relationship between the EU and Brazil, I conclude that without the EU's support of their non-GM soy sector, Brazil would not have been able to reach its current level of soy production. Since GM-soy production in Brazil was stunted early-on, the soy-export market would have been quickly surpassed by other GM-soy providers; the proliferation of non-GM soy farming has secured Brazil's place in the international market and brought far-reaching economic prosperity.

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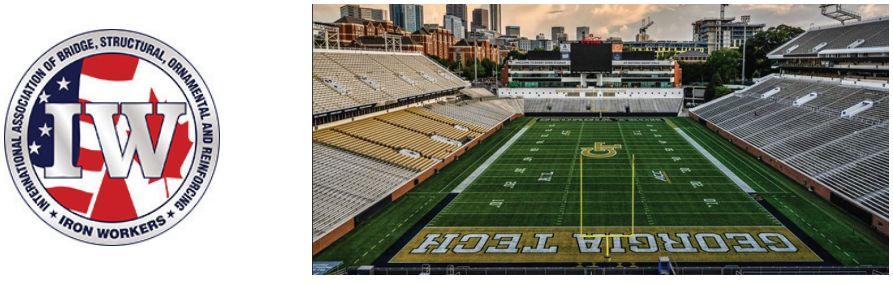

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Risk Informed Design of Offshore Wind Turbine Structures in the U.S. Outer Continental Shelf

Timothy Wade Cook

ABSTRACT

The United States has enormous potential offshore wind energy resources in the Atlantic, Pacific, Great Lakes and the Gulf of Mexico. However, progress in developing these resources has lagged behind that in Western Europe and no offshore wind farms have been built to date in the U.S. Continental Shelf. Uncertainties in U.S. siting and design criteria, specific regulations and standards, along with a lack of experience have challenged development by increasing both cost and the time to deployment. The reliability of offshore wind turbine farms is critical to industry success and should be secured efficiently with respect to cost. The ability to employ probabilistic risk management and decision theory in the design process of support structures would afford more transparent system reliabilities and more flexibility in design compared with prescriptive design standards. A general framework for risk informed design of offshore wind turbine structures is demonstrated on a typical monopole support structure. The structural parameters are manipulated to adjust the risk and to achieve the desired wind turbine performance at acceptable cost. In order to implement such a design procedure in practice, regulations must stipulate clear performance requirements in terms of system reliability for project approval.

INTRODUCTION

In order to meet future energy demands, the United States (U.S.) will have to not only test its ability to tap current known exhaustible energy sources but also expand and transition its energy portfolio to renewable energies.

Although the U.S. does not have any installed wind farms offshore to date, there are a number of proposed projects in various stages of approval, the most notable being the Cape Wind Project, a proposed 130-turbine offshore wind farm planned for Nantucket Sound off the coast of Massachusetts (Transportation Research Board (TRB), 2011). Developers of the project have been seeking approval for 10 years; in 2011, Cape Wind became the first offshore wind farm project approved in the U.S. by both state and federal governments. This landmark approval reflects both the determination of the project developers as well as recent legislative action favoring offshore wind development. To invigorate the development of renewable energy portfolios, the U.S. Department of Energy (DOE) recently published an ambitious initiative which aims for 20% of U.S. energy to be supplied by wind power (54 gigawatts from offshore) by 2030, with an interim goal of 10 GW offshore by 2020. In order to ensure successful deployment of the offshore wind industry the DOE identified two critical objectives: reducing the cost of energy and reducing the time to deployment (DOE, 2010).

There are many reasons why offshore wind farms are attractive when compared with onshore farms despite their higher initial capital cost, including favorable wind climatology, ability to upscale (increase utilization) and proximity to power demand.

Offshore, the wind is more consistent and the wind velocity is greater at lower elevations. Construction on the water allows larger structures that are not challenged by some onshore constraints (i.e. highway transportation). Moreover, the 28 Coastal and Great Lakes states account for 78% of the national energy demand. Also, the major cities located in these states generally pay higher costs of energy, further conducing the utility and cost competitiveness of strategically sited offshore wind farms (DOE, 2010).

The outer continental shelf (OCS) of the U.S. has the potential to provide 2,957 GW of gross (neglecting siting constraints) available offshore wind energy within 50 miles of shore, which translates to approximately 3 times the current capacity of the national grid (TRB, 2011). The U.S. is well positioned with the resources and the means currently available to become a leader in offshore wind technology and utilization.

The offshore wind industry is challenged by the uncertainties inherent in any nascent industry/technology. In order to compete against other energy sources (which may be subsidized and already benefiting from the economies of scale), offshore wind energy must be deliverable at a relatively attractive cost. To achieve cost goals, offshore wind facilities need to be highly reliable and durable (DOE, 2011). Offshore wind farm reliability is key in securing financing, insurance, social acceptance, market contracts and safety for both long-term and short-term perspectives.

Quantitative reliability assessments of an engineered system involve considering the probability that a system will successfully meet defined performance criteria for a defined period of time. Adopting a consistent probabilistic design framework, in which the uncertainties and the reliability of the design are transparent to the designer, allows the engineer to incorporate and optimize with respect to project-specific risks and produce comparable designs. While risk-informed design may require a higher level of competency by the engineer than traditional prescriptive methods, offshore wind turbine design is particularly well suited to benefit from a project-specific risk-informed design approach. For example, the design phase of an offshore wind turbine involves less than 4% of its lifecycle cost (DOE, 2010), and the presence of current uncertainties in the design process challenging the predictability of cost and reliability estimations may significantly influence total costs. Additionally, offshore wind turbines are designed in groups for a particular wind farm and have relatively little variability in structural configuration, thus facilitating even larger capacity for refining and updating reliability design and analysis methods compared with most civil engineering projects, which are typically unique.

STUDY OBJECTIVES

The objectives of this study project are two fold:

1) To introduce the concept of a risk-informed approach to performance assurance of offshore wind turbines located in the U.S. OCS, and
2) To demonstrate a general framework for risk-informed design of offshore wind turbine support structures with respect to a target level of reliability.

Basic reliability principles are introduced and a reliability analysis and design of a monopole support structure is performed based on an assumed acceptable level of risk to illustrate the concepts.

METHODS

Elements and Application of Risk-Informed Approach to Performance Assurance

The offshore wind industry is challenged by a lack of empirical observations or historical benchmarks from which to derive experience-based design criteria. Many agencies and countries, primarily European, have developed comprehensive yet largely prescriptive standards, and none are applicable, without significant modification, in the U.S. (TRB, 2011). In general, development of a risk informed basis for structural design requires:

- Definition of structural components and groups
- Identification of important failure modes or limit states for components and systems
- Stochastic models for uncertain parameters
- Quantified performance goals (i.e. acceptable reliability level)
- Standardized method and assumptions for reliability calculation
- Risk-consistent design criteria to achieve the performance objectives

Reliability-based Formulation of Design Criteria

In order to design for adequate performance, system requirements can be translated into so-called limit state conditions from which equations can be developed that separate the acceptable region of performance from what is considered the failure region. Defining the demand, S, and the capacity, R in a structural system, a safety margin, M, can be defined as:

$$M = R - S \quad (1)$$

A positive M in Eq. 1 represents adequate performance and a negative value represents failure. In the presence of uncertainty, R and S are random variables, and their uncertainties are modeled by their probability distributions. The failure condition, or limit state, is defined by the inequality of M

being less than zero because the demand exceeds the capacity (R) of the system. Given probabilistic descriptions of R and S, the probability of failure, Pf, can be determined as:

$$P_F = P[M < 0] = P[R - S < 0] \quad (2)$$

The probability of failure can be viewed as a risk metric, the complement of which is known as reliability. Thus, design for a stipulated value of Pf provides the basis of risk-based design. For example, the design parameters of the support structure or tower could be adjusted to achieve a target reliability allowing for economical and optimal design solutions by balancing decisions based on material consumption, performance requirements, failure consequences and probability of failure for each group/component (Sorensen & Toft, 2010). Note that Pf is a subjective measure, in the sense that it is dependent on the information available and the engineering models and assumptions used in performing the calculation. Thus consistent reliability analysis methods and assumptions are critical, and the reduction of uncertainties in engineering models allows for better reliability estimates.

Example Development: Reliability-Based Design of Monopole Turbine Support

To demonstrate the general concepts, we consider a typical monopole structure modeled to support a 5 MW turbine off the east coast of the U.S. (see Figure 1). The structural elements for the monopole include the pile and the tower. For simplicity, the wind turbine is assumed to be parked and the only limit state considered is the onset of yielding in the pile due to an overturning moment (OTM) from a combination of actions due to wind, wave and current. The wind turbine is modeled to represent the NREL 5 MW baseline turbine defined by Jonkman, et al (2009) with a yaw misalignment of about 8 degrees. The site and environmental conditions were extracted from MMI Engineering (2009), and the support structure was developed to be comparable to the monopole defined in that report. The environmental conditions reflect data consistent with siting south of Massachusetts and Rhode Island between Martha's Vineyard and Block Island, and the water depth is assumed to be 25 meters.

Thus, given:

1. Structural elements and configuration
2. Proposed site and stochastic description of hazards and environment
3. Definition of limit state
4. Assumed target level of reliability: Pf-target = 10-4 per year (DNV, 2007; TRB, 2011)

We seek the following goals:

1. More transparent structural system reliability
2. Ability to employ probabilistic risk assessment and managemen procedures when adjusting structural parameters

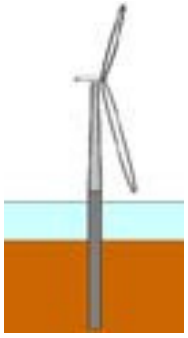

Figure 1. Typical Monopole Offshore Wind Turbine Structure.

PROCEDURE AND MODELS

Structural Reliability Analysis and Design Procedure

The primary engineering analysis tools used for this project included MATLAB, GTSTRUDL and GTSELOS. MATLAB's random number generation capabilities were utilized to simulate 100 random independent environmental conditions (i.e. wind-wave-current parameters) and to perform the reliability analysis using Monte-Carlo simulation methods. GTSTRUDL was used for structural analysis and evaluating structural response, while GTSELOS was used to calculate the structural demand from combinations of wind-wave-current. Figure 2 demonstrates the general procedure followed in a simple flow chart.

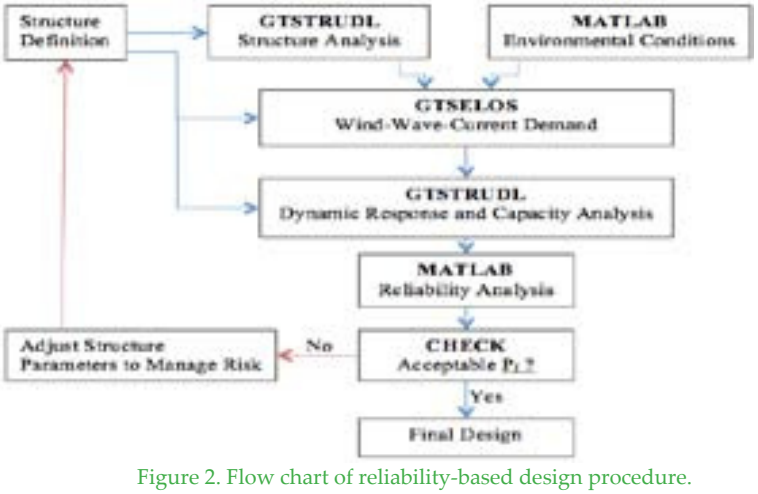

Figure 2. Flow chart of reliability-based design procedure.

Turbine Model

Only parked turbine conditions are considered. For simplicity, the NREL 5 MW baseline turbine is modeled as a point mass at the top of the support tower. An equivalent flat plate area of 292 m2 was estimated from loads data calculated for this turbine published by the American Bureau of Shipping (ABS, 2011) to model the viscous drag forces on the parked rotor nacelle assembly (RNA), assuming an overall drag coefficient Cd=1.28. This is assumed to represent roughly an 8 degree yaw misalignment. It is noted that the magnitude of the drag loads on the RNA are sensitive to the degree of yaw alignment (ABS, 2011).

Support Structure Model

The support structure defined in this report consists of two components: the pile and the tower. The pile is a single diameter extending from the penetration depth (60 m below mud line) to 10 m above the mean water level. To model a tapered tower, the tower defined in this report consists of 20 equal-length pipe segments with incrementally decreasing diameters and thicknesses from bottom to top. Consistent with common practice, the preliminary design of the support structure conforms to a target natural frequency range of 0.20 to 0.34 Hz to avoid resonance with the rotor and blade passing frequencies of the turbine in operating conditions (MMI, 2009). The initial structural model has a natural frequency of 0.241 Hz. Structural damping of all modes was assumed to be 1%. The tower and initial pile properties are defined in Table 1.

Table 1. Initial Pile and Tower Properties

Property	Pile	Tower
Base Diameter (m)	6. 5	6
Base Thickness (m)	0. 065	0. 03
Top Diameter (m)	6. 5	3. 78
Top Thickness (m)	0. 065	0. 019
Total Length (m)	95	77. 6
Density (kg/m3)	8500	8500
Damping Ratio	1%	1%
Young's Modulus, E (GPa)	210	210
Shear Modulus (GPa)	80. 8	80. 8

The specified steel density supplied by NREL (8500 kg/m3) is larger than typical steel values to account for paint, welds, and flanges (Jonkman et al., 2009). The pile is assumed to be an open tube driven to the target penetration depth with the interior filled to the mud line with soil. Pile-soil interaction is modeled using horizontal and vertical linear soil springs, estimated from soil spring data assumed by MMI (2009). The mass of the soil inside the pile is modeled as a uniform added inertia mass in the horizontal direction based on an assumed soil density of 18 kg/m^3. The structural model can be seen in Figure 3.

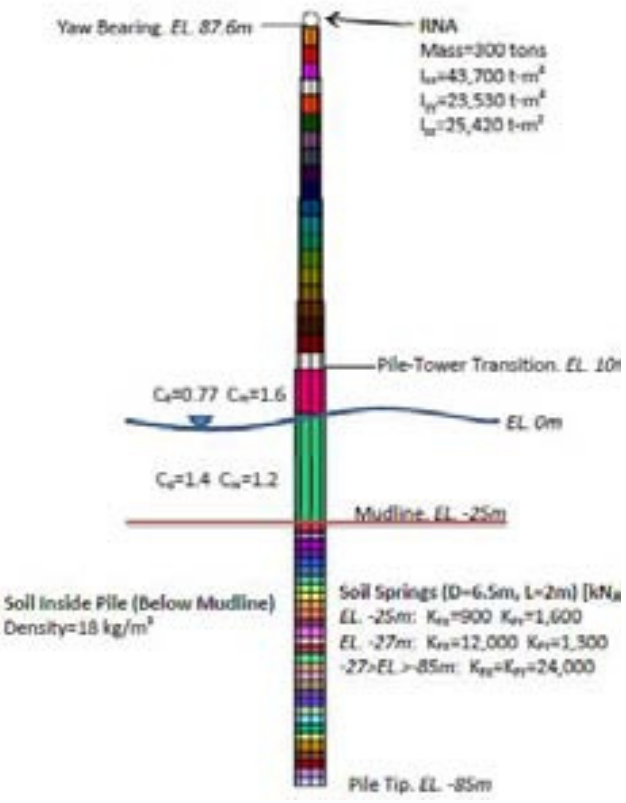

Figure 3. Support Structure Model

Environmental Load Data

The wind turbine structure is assumed to be set on a flat sea bed. The only environmental load conditions considered in this study are effects of wind, wave and current. Data supplied by MMI (2009) including scattergrams of:

- Wind speed (10m, 1hr mean), U10m,1hr vs. Significant wave height, HS
- Significant wave height, HS vs. Average zero-crossing wave period, TZ
- Maximum wave height, HMAX vs. HS

Along with 4 extreme storm conditions was used to estimate wind-wave-current condition parameters and statistical descriptions. A Gumbel (Type 1) distribution was used to model

U10m,1hr as shown in Figure 4 with location and scale parameters determined to be 15.28 and 7.95 respectively.

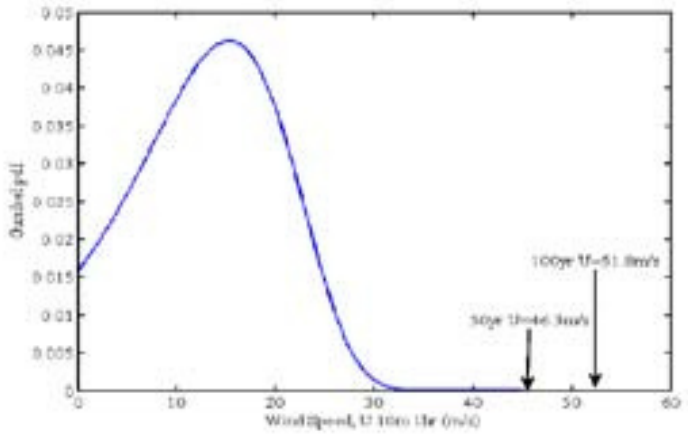

Figure 4. Defined Gumbel probability density function of annual maximum wind speed

The 50- and 100-year markers in Figure 4 indicate the annual maximum wind speeds with a 50-year and 100-year return period, respectively. The relation between U10m,1hr and the mean significant wave height, HS-mean, is shown by the best-fit power relation in Figure 5, which is based on selected average points from referenced scattergrams and extreme storm states.

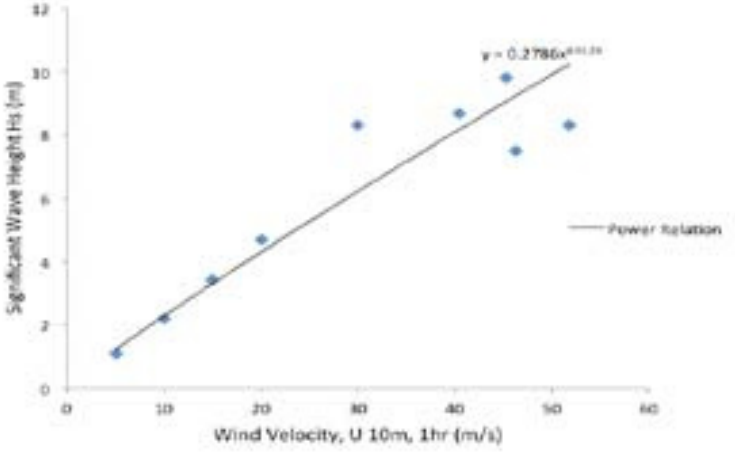

Figure 5. Relationship for HS-mean and U10m,1hr

From HS-mean, a random value for HS was generated with the assumption of a normal distribution about the mean and a modified standard deviation of 0.434 to account for an apparent 85% correlation between U10m,1hr, and HS observed in the referenced data. The 100 environmental events were simulated by generating random values of U10m,1hr and corresponding values of HS. The deterministic relationships for the remaining parameters are shown below.

$$H_{MAX} *= 2.144H_S^{0.8719} \quad (3)$$
$$T_2 *= 4.29H_S^{0.3512} \quad (4)$$
$$T *= 1.2T_2 \quad (5)$$
$$C_S = 0.0091U_{10m,\,1hr} \quad (6)$$

Note that the designation * indicates a relationship defined by MMI (2009).

Wind Demand

An empirical power law description of the wind speed profile shown in Eq. 7 was assumed with an exponent of 0.11 for extreme wind conditions, as suggested by IEC 61400-1 (2005).

$$U(z) = U_{10m,\,1hr}\left(\frac{z}{10m}\right)^{0.11} \quad (7)$$

in which z is the height above mean sea level. Wind viscous drag forces were calculated by Eq. 8:

$$F_D = \tfrac{1}{2}\varrho V^2 C_D A_{proj} \quad (8)$$

where

V is the wind velocity (m/s)
C_D = 0.5 (cylinder)
A_{proj} is the projected area of the surface (m)
ϱ = 1.225 (kg/m3)

Wave and Current Demand

Structural demands due to waves were calculated by GTSELOS using 5th Order Stokes Wave Theory. For simplicity, maximum breaking wave height and wave slam are not considered in this study. The values for the drag and inertia coefficients are consistent with MMI (2009). The current velocity at depth z, C(z), is defined as:

$$C_{(z)} = C_s\left(\frac{h_0 - z}{h_0}\right) \quad (9)$$

in which h0=50m is the reference depth for wind-generated current (DNV, 2007).

RELIABILITY ANALYSIS RESULTS AND DESIGN

Structural Demand, S

The 100 random environmental conditions were input as parameters for load calculation in GTSELOS and the maximum overturning moment (OTM) in the pile due to the applied loads was determined in GTSTRUDL. A Gumbel distribution was chosen to model the max OTM demand (see Fig. 6) because it is a common distribution type for modeling intensities due to maximum extreme environmental events (Ang & Tang, 2006). The distribution parameters (location and scale factor) were estimated by determining a best-fit line of the data assembled on a Gumbel probability plot.

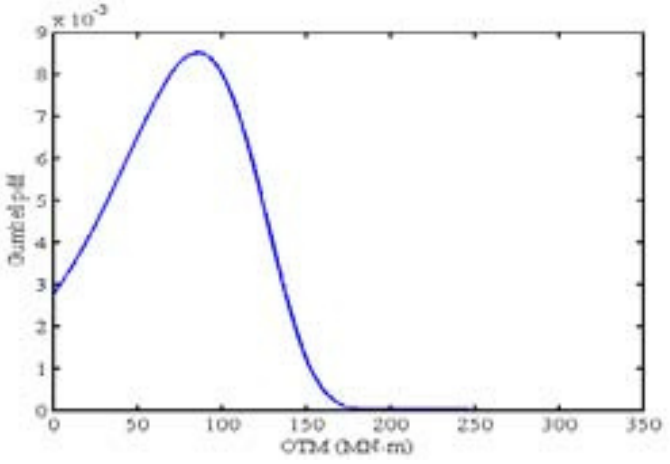

Figure 6. Gumbel probability density function of maximum annual OTM demand, S, for initial structure

Structural Capacity, R

The capacity, in terms of OTM, of the structural model was determined by incrementally increasing four extreme event storms and identifying the OTM values when the defined limit state was reached. The average was taken to be the nominal capacity, OTMnom, which was 587.7 MN-m. The mean value of yield strength of typical construction grades of steel is approximately 10% higher than the specified nominal yield strength, while the coefficient of variation of a fabricated shape would be approximately 12% (Ellingwood, 2000). Thus, the mean OTM capacity, OTMcap, was assumed to be 10% larger than OTMnom, or 646.5 MN-m. A lognormal distribution and a coefficient of variation equal to 12% was assumed to describe the OTM capacity as shown in Figure 7.

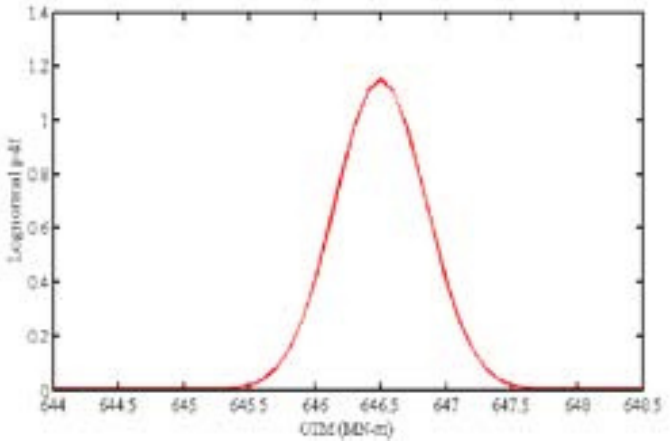

Figure 7. Lognormal probability density function of OTM resistance, R, for initial structure

Reliability Analysis and Check

A Monte Carlo simulation method was used for reliability calculations. With the estimated S and R distributions of the wind turbine support structure defined, 25 million random samples were taken from S and R, and the probability of failure was quantified by the ratio of the number of samples for which M was less than zero divided by the total number of samples. The probability of failure of the initial structure, Pf-1, was calculated to be 2.1x10-6 per year. Although Pf-1 is less than Pf-target, implying the risk is less than the level stipulated for design, an efficient design would have a Pf less than but near Pf-target¬ so the structure is not unnecessarily expensive in terms of cost and materials etc.

Design and Risk Modifications

Given the environmental conditions, structure configuration, and turbine, the design engineer can adjust the risk associated with failure induced by OTM, for example, by adjusting the OTM capacity (i.e. altering pile thickness, diameter, or selecting an alternate strength steel). To demonstrate the concept, it is assumed that decreasing the pile thickness is the most beneficial approach to increasing the risk to be nearer the target level. Thus, the pile thickness was reduced from 6.5 cm to 5 cm below the mud line. The natural frequency of the modified structure was 0.234 Hz, which remains within the target range. The analysis procedure was repeated with the same assumptions and the probability of failure of the modified structure, Pf-2, was calculated to be 3.1x10-4 per year, which is close to Pf-target and completes the risk-based design procedure.

CONCLUSIONS AND FUTURE DEVELOPMENT

Offshore wind turbine development, particularly in the U.S., would benefit from standardized risk informed design procedures. A general framework for risk informed design has been demonstrated on a typical monopole support structure sited on the U.S. OCS. Given consistent reliability analysis methods and assumptions, the Pf can be used as a risk metric for adjustment of design parameters with respect to cost to achieve an acceptable level of reliability. Examples of helpful methods and assumptions to be developed include region-specific statistical distributions for environmental parameters, recommended methods for determining distribution parameters, and consistent structural modeling assumptions. Additionally, in order to implement such a design procedure, regulations would need to define clear performance requirements (i.e. a P¬f-target) for project approval. As the industry is just being deployed in the U.S., regulators and standards organizations have the opportunity to endorse a risk informed design basis from the very beginning.

ACKNOWLEDGEMENTS

This report was developed as part of an undergraduate independent study project. The author is deeply honored to have had the opportunity to study and grow under the advisement of Dr. Bruce R. Ellingwood. His unsurpassed advice and expertise in structural reliability, risk assessment, and standards development proved invaluable and enlightened the author. Special thanks are also due to Dr. Emkin for providing software critical to the project, GTSTRUDL and GTSELOS.

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"Education is not preparation for life; education is life itself."

-John Dewey

Volume V - 2012

Measuring Firm Perception and Reaction to the Risks of Climate Change

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INTRODUCTION

The Carbon Disclosure Project (CDP) is a nonprofit organization based out of London, England, which partners with over 550 investors with assets of over $71 trillion to encourage major companies to voluntarily disclose greenhouse gas emissions in an annual survey. The CDP organizes the surveyed firms according to ten different industrial sectors ranging in diversity from the Energy to Financials sectors. Certain questions within the CDP's annual survey ask firms if they feel at risk of the physical or regulatory effects of climate change. A different set of questions asks firms if they have taken action during the surveyed year to reduce their carbon emissions. Through a comparison of the responses to these two sets of questions, we attempt to answer the larger question: Is a firm's concern for climate change necessarily an indicator of whether or not that same firm engages in methods to reduce their carbon emissions? This study provides insight into the kind of information that we may receive from the CDP and similar voluntary surveys pertaining to greenhouse gas emissions.

METHODS

We analyzed data from CDP surveys for the years of 2008, 2009, and 2010. In their surveys, the CDP targets a non-random sample of firms representing the largest and most successful firms across the world. The CDP groups firms according to ten industrial sectors: Consumer Discretionary, Consumer Staples, Energy, Financials, Health Care, Industrials, Information Technology, Materials, Telecommunications, and Utilities. The CDP divides risk into two categories, regulatory risk and physical risk. Regulatory risk is a perceived risk of penalties and other negative results stemming from regulations and legislation accompanying climate change. Physical risk is a perceived vulnerability to the tangible effects of climate change, such as flooding, natural disasters, crop devastation, or other negative effects. For our analysis, we averaged the two risk categories for each sector to produce the "Risk" category that is presented in our results. Firms that have implemented carbon reduction plans are labeled as "Action Taken". Individual firm responses to questions were aggregated according to industrial sector. This process was repeated for each sector and for the questions pertaining to whether or not firms had taken action to reduce their carbon emissions.

RESULTS

We found that, while some sectors exhibit a high percentage of concerned firms with a low percentage of firms participating in emissions reduction plans, some sectors were exactly the opposite (Figure 1A). While certain sectors, such as Consumer Discretionary and Materials have fairly consistent percentages for "Concern" and "Action Taken," other sectors, such as Energy and Health Care are much less consistent. Additionally, most sectors seem to indicate similar trends for all three years. That is, if they exhibit much more "Concern" than "Action Taken" (or vice-versa) in one year, they are likely to exhibit the same pattern in the other two years. We attribute this to differences across sectors in terms of feasibility and affordability of participating in an emissions reduction plan. Given that the CDP has a non-random sample of respondents, we did not test for statistical significance in these results.

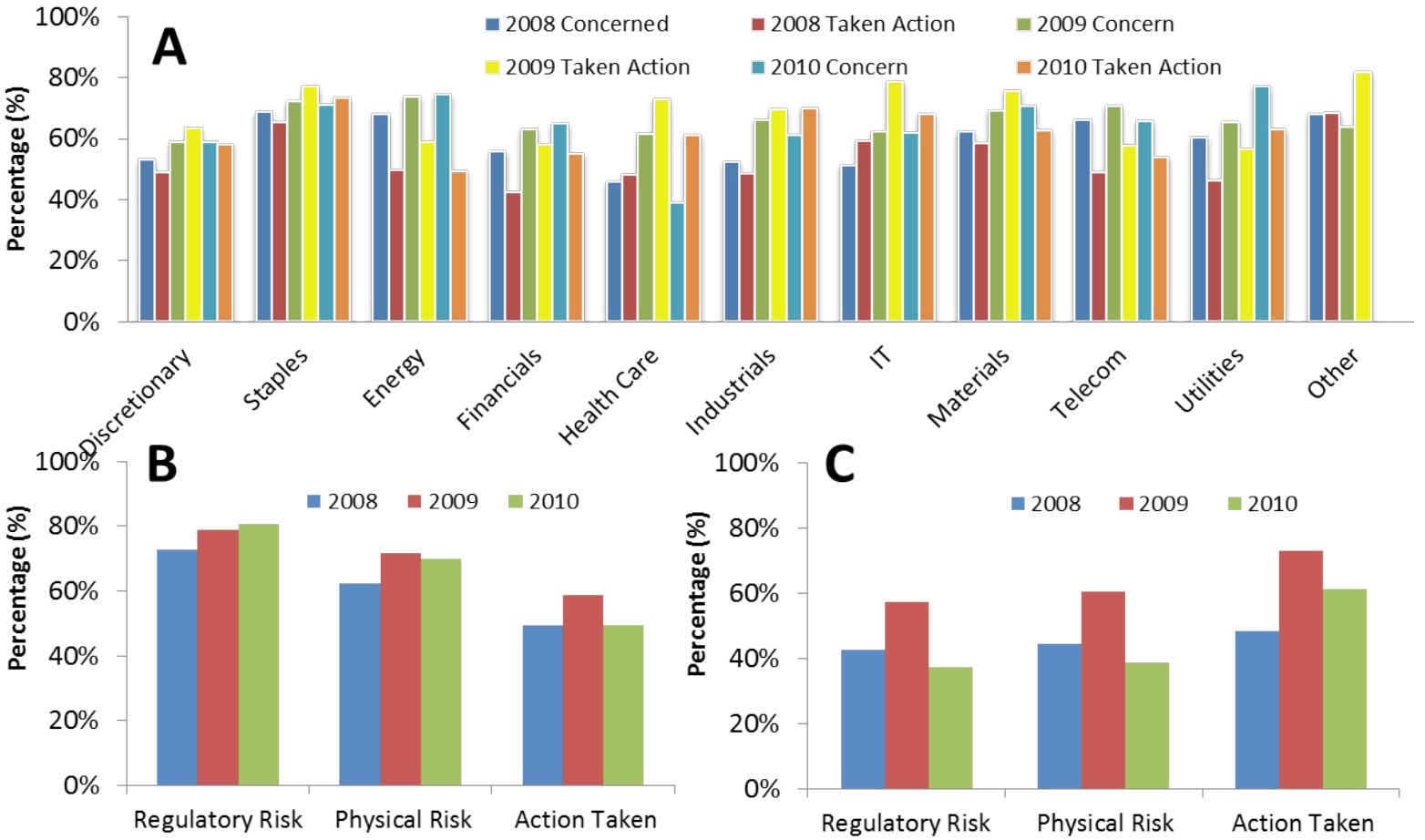

Figure 1. (A) Concern versus Action Taken, plotted as a percentage of firms responding to questions of interest. (B) Some Energy Sector firms that feel at risk do not take action against climate change. (C) Some Health Care Sector firms that do not feel at risk still take action against climate change.

Figure 1B and Figure 1C illustrate two cases of sectors behaving differently than would be expected given their perceived risk. In Figure 1B, the Energy sector perceives a degree of risk greater than the amount of action taken in all three years. Conversely, Figure 1C shows how the Health Care sector behaves oppositely – more firms take action than those who perceive risk. We attribute these behaviors to the differences in the cost of mitigating greenhouse gas emissions among the various sectors. For example, it is a much larger and more expensive endeavor to replace or update greenhouse gas emitting facilities associated with the Energy sector than it would be to take action in the Health Care sector.

CONCLUSIONS

Based on the results from these three years of the CDP, not all firms which exhibit concern for the risks of climate change also engage in measures to reduce their own carbon emissions. Likely, this is due to the relatively high cost of reducing carbon emissions in certain industrial sectors. In sectors where the costs are not as high, we examine some firms engaging in carbon reduction activity despite the fact that they do not perceive themselves to be at risk. Therefore, we conclude that firm concern for climate change is not necessarily an indicator of whether or not that same firm engages in methods to reduce their carbon emissions. This information sheds light on the larger question pertaining to what kinds of information we can gather from the CDP and similar voluntary greenhouse gas reporting initiatives. Future research initiatives may examine other questions in the CDP or other similar initiatives to further our understanding of what we can learn about participating firms and their reactions to carbon reduction and the threat of global climate change.

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Effect of Magneto-Hydrodynamics and Radiation Pressure on the Reionization of Dwarf Galaxies

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ABSTRACT

During the reionization period, from 100 million years to 1 billion years after the Big Bang, radiation pressure and magneto-hydrodynamics helped shape the primordial dwarf galaxies that ionized the neutral intergalactic medium. Dwarf galaxies are important to study because they help understand the formation and behavior of early galaxies in our universe. Through computational techniques, astrophysical simulations were created to model the formation of primordial galaxies, which were investigated to produce synthetic observations by numerical analysis. The brightness of dwarf galaxies was calculated and compared to observed data obtained from the Hubble Space Telescope. The star formation rate was found to be regulated by magneto-hydrodynamics, in accordance with increased ionization fraction and clumping factor. These parameters are thought to have contributed to the enhanced luminosities of the dwarf galaxies.

INTRODUCTION

Dwarf galaxies are born from gas clouds that coalesce in association with dark matter halos to form small galaxies that contain several billion stars. In comparison, the Milky Way galaxy contains approximately 300 billion stars. These galaxies are important for us to study because they can elucidate the physical laws that facilitated the creation of our universe and ultimately determine the fate of our universe. Dwarf galaxies, in particular, are useful tools for investigation because in depth study of a large galaxy would be too computationally expensive. Dwarf galaxies allow examination of the physical processes involved without the drawbacks of attempting to study it on the large scale.

One major physical process involved in the formation of dwarf galaxies is radiation pressure from stellar radiation during the reionization phase. Radiation pressure is the pressure exerted on a particular surface by forms of electromagnetic radiation. Reionization refers to the stage in the creation of the universe where the predominantly neutral intergalactic medium is reionized by various luminous sources, including primordial galaxies; the period of reionization spans roughly from 100 million years to approximately 1 billion years after the Big Bang ("Epoch of Reionization," MIT). Without radiation pressure, a galaxy would produce a dense, metallic, stellar region due to overcooling, which is characteristic of a flaw in simulation methodology (Wise et al., 2012).

Another important factor involved with radiation is magneto-hydrodynamics, defined as the study of dynamic electrically conducting fluids. Moving magnetic fields throughout fluid media can create electric currents that would directly affect the amount of radiation pressure and thus the reionization. The direct effects of magneto-hydrodynamics on galaxy formations are still not known. Therefore, the purpose of this investigation is to create a realistic model of dwarf galaxy formations, comparing a simulation including magneto-hydrodynamics against a control simulation involving radiation pressure. Particularly, two critical aspects of galaxy formation are magnitude of luminosity and star formation rate, which will serve to determine the overall effects of magneto-hydrodynamics on galaxy formation.

METHODS

The investigation was conducted entirely through computational astrophysical techniques, which included running a simulation with a defined set of physical laws involved. The di-

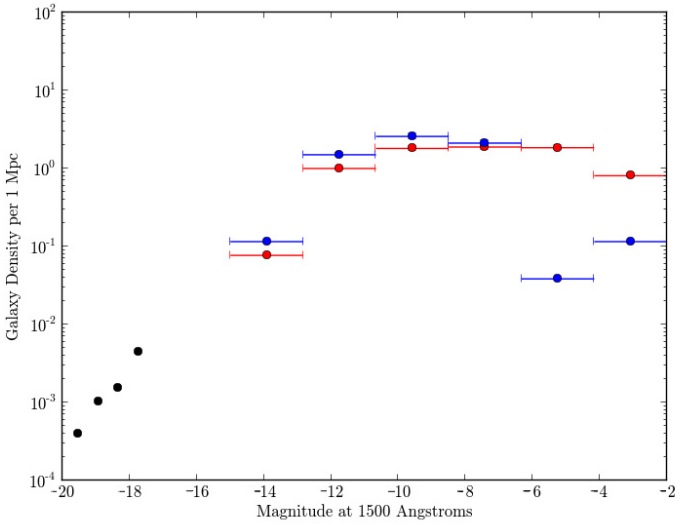

Figure 1. Histogram representing magnitude of luminosity measured at 1500 Angstroms (Å) for dwarf galaxies with redshift values less than nine. Hubble data obtained from telescopic observations was plotted in black (Oesch *et al.*, 2012). The galaxies were chosen at redshift less than nine because galaxies within this time region are comparable to the data obtained by the Hubble telescope. The data obtained from SG256-MHD are plotted in blue, and data from SG256-RP are plotted in red.

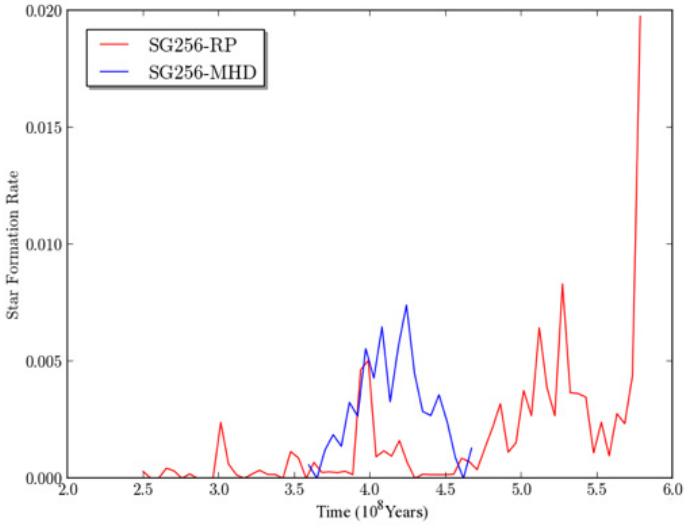

Figure 2. Plot of star formation rate plotted against time in years.

rect physical laws can be modified, including accepted ones like gravity and excluding controversial or theoretical laws. Specifically for this investigation, magneto-hydrodynamics was added to a simulation containing the accepted physical laws along with radiation pressure. Therefore, it can be observed how the simulation will run in different cases with different physics associated. The simulations were produced by the adaptive mesh refinement code, ENZO, which is designed for advanced multi-physics dynamic astrophysics calculations and simulations. The technique used by ENZO to produce the data implements an adaptive ray-tracing scheme, shooting electromagnetic rays throughout simulated particles and gases, which comprise the created galaxy (Wise *et al.*, 2010). A parameter file that included the necessary physics for the simulation was used to initiate the simulation. The simulations were run for a couple months each on NASA's supercomputing cluster, Pleiades. The first simulation run included radiation pressure, which we will refer to as SG256-RP. The second simulation run included magneto-hydrodynamics in addition to radiation pressure, which we will call SG256-MHD. The purpose was to investigate the effect of the inclusion of magneto-hydrodynamics on the formation of galaxies. Both simulations were 1 mega-parsec or 3.26 million light years co-moving in the expanding frame of the universe. SG256-RP was run for 750 million years, and SG256-MHD was run for 570 million years in the reference frame of the simulation. The length of the simulation was determined by the availability of computing time at NASA. The simulations each contained about 30 dwarf galaxies, which is approximately one thousand times smaller than the Milky Way galaxy.

The simulations were analyzed using the yt-project to produce synthetic visualizations of the data. Scripts were written using the yt module in Python to evaluate luminosity, star formation rate, and clumping factor and ionization fraction. Star formation rate was calculated by the number of stars that were created amongst all the galaxies within the respective simulation over time. Aggregate luminosity was determined by summing the brightness amongst all the galaxies within a simulation; the brightness of each galaxy was calculated within a sphere of a given radius depending on the size of the galaxy. Ionization fraction was calculated by dividing the ionized hydrogen by the

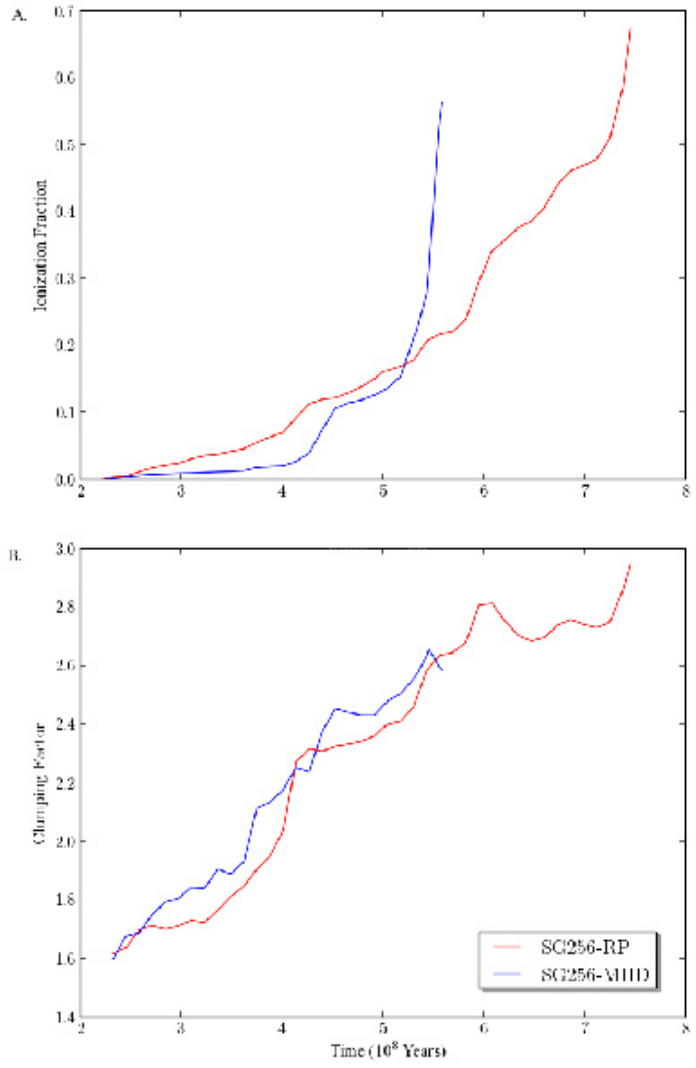

Figure 3. Ionization fraction (3A) and clumping factor (3B) are plotted against time with the same x-axis ranging from 200 million years to 800 million years.

total hydrogen. Clumping factor was calculated by the average density squared divided by the square of average density. Georgia Institute of Technology's computer cluster PACE was used to process the computer scripts.

RESULTS

Luminosity

It was previously thought that not many dwarf galaxies formed in the development of the universe, and that they do not contribute very much to the total luminosity of the universe. However, the data suggest that there are a large number of dwarf galaxies that tend to be instrumental in the visible luminosity. The data obtained from the Hubble Space Telescope is on the lower end of the intensity of luminosity, spanning from -17 to -19 (Oesch *et al.*, 2012). For comparison, the absolute magnitude of a Type 1A supernova is -19.3, which is approximately 5 billion times brighter than our sun (Hillebrandt *et al.*, 2000). This is due to the fact that the Hubble Space Telescope does not have the sensitivity to detect distant dwarf galaxies. However, the simulation can model the stellar radiation from galaxies within the simulation by radiation transport. The impact of the dwarf galaxies is shown to be very dramatic on the galaxy luminosity function (Figure 1). There appears to be a maximum in the luminosity function around -9, after which the function seems to plateau and begin decay. It was predicted that there would be a turnover point, and the magnitude of luminosity, $\phi(M)$, would decay according to a power law,

$$\phi(M)\, dM = (2/5)\, \phi^* \ln(10)[10^{(2/5)(M^* - M)}]^{\alpha+1} \exp[-10^{(2/5)(M^* - M)}]\, dM \qquad (1)$$

where M is magnitude and ϕ^*, α, and M^* are determined empirically (Simard, 1996). The luminosity data from SG256-MHD fit the prediction of the turnover point described by equation (1), and henceforth indicate that inclusion of magneto-hydrodynamics may be a better representation of the physics involved in galaxy formation compared to the simulation with all factors except magneto-hydrodynamics, SG256-RP.

Star Formation Rate

The star formation rate dictates the number of stars that are being formed per unit time. The simulation run with magneto-hydrodynamics (SG256-MHD) had a greater star formation rate at an earlier time compared to SG256-RP. Therefore, the data suggest that magneto-hydrodynamics stimulate star formation rate, because the largest star-forming time region occurs at 425 million years after creation in SG256-MHD compared to 525 million years in SG256-RP. It is known that in a galaxy below 40 K most energy is in the form of magnetic fields. These are the conditions at which these stars are forming, so it is reasonable that magnetic fields can differently affect star formation rates by increasing the amount of energy contained (Price *et al.*, 2010).

Clumping Factor / Ionization Fraction

The ionization fraction, defined as the ratio of ionized hydrogen to total hydrogen, greatly increases in SG256-MHD compared to SG256-RP (Figure 3A). The ionization fraction increases exponentially and maximizes in SG256-MHD at 550 million years, compared to SG256-RP, which does not reach this level until it gradually increases at 750 million years. The clumping factor, defined as the average of density squared over the square of average density, in SG256-MHD is similar to SG256-RP (Figure 3B). A higher resolution is necessary to clarify the implications of the lack of differentiation between clumping factors rates between SG256-RP and MHD. The recombination rate of hydrogen is directly proportional to the clumping factor. The increased ionization fraction is a direct consequence of the higher star formation rates seen in SG256-MHD.

DISCUSSION

The purpose of this investigation was to create a realistic model of dwarf galaxy formations, comparing a simulation including magneto-hydrodynamics against a control simulation involving radiation pressure. Using the magnitude of luminosity and star formation rate to determine the overall effects of magneto-hydrodynamics on galaxy formation, it was hypothesized that inclusion of magneto-hydrodynamics in simulation would produce more realistic results, fitting the data obtained from the Hubble Space Telescope. Recent literature suggests that radiation pressure must be included in astrophysical simulations to avoid creating a super-dense, highly metallic region, which is erroneous. These investigations reached this conclusion by constructing two simulations using radiation pressure as a dependent variable (Wise *et. al*, 2012). Using a comparable technique in this investigation, magneto-hydrodynamics was used a variable compared to a control to establish its presence in astrophysical phenomena. The stronghold of the data, the fit of the luminosity function, indicates that the simulations run with the inclusion of magneto-hydrodynamics correspond well with the intensity of brightness observed in our own night sky when compared to observed galaxies obtained by the Hubble Space Telescope (Oesch *et al*., 2012).

The results show that magneto-hydrodynamics increases the rate of star formation. The greatest star-forming time region occurs at 425 million in SG256-MHD compared to 525 million years in SG256-RP. There is a greater ionization of hydrogen due to the inclusion of magneto-hydrodynamics. The ionization fraction increases exponentially and maximizes in SG256-MHD at 550 million years, compared to SG256-RP, which maximizes at 750 million years. Ionization seems to increase star formation, which would explain the brighter luminosity observed that diminishes after the maximum. However, the results of the clumping factor appear to disagree with these findings. There is not a noticeable increase in clumping factor with the addition of magneto-hydrodynamics into the simulation. This seems to conflict with the increases in ionization fraction and star formation rate, but it may be possible that ionization fraction increases the star formation rate enough that an increase in clumping factor is not necessary for the appropriate luminosity function to be produced. All things considered, the inclusion of magneto-hydrodynamics appears to be consistent with the physical observations of known dwarf galaxies. As more computational research is conducted, a better picture of our universe is constructed, allowing us to further understand our cosmological origins and fate.

Subsequent research projects could be conducted by adding more resolution to the simulations, along with expanding the simulation timeframe, which would produce more thorough results. The time that the simulations are run depends on resources available. In Figure 1, it is possible that for the more luminous dwarf galaxies, one star or a small collection of stars could have contained the majority of the flux observed. Examination of the data obtained in the simulation indicates the presence of overdense highly luminous areas, which suggest that this might have occurred. Increasing resolution, which is similar to increasing resolution on a television, combats this because it allows for greater differentiation and definition. The predicted turnover point of the graph for the luminosity magnitude at 1500 Å could not be seen in the research conducted, but if the resolution were increased the turnover point could be accurately determined and this would eliminate the likelihood of a small group of stars over-representing the luminosity of a dwarf galaxy. The resolution available also depends on resources, as increasing will extend the time that the simulations are run by a couple months. Further experimentation into this subject is necessary to accurately discern the picture of our expanding universe. Using tools such as luminosity functions and star formation rates, we can determine that we have created accurate simulations of galaxies. This is essential to help us unravel the fate of the universe we live in and how galaxies behave over time.

Acknowledgements

I would like to thank my research advisor, Dr. John Wise, for his assistance in running the simulations and his aid in writing the code to analyze the data obtained. This project would not be possible without his guidance, and it is very much appreciated.

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The Entrance into the Stem Cell Era

An Opportunity for Theraputics, Diagnostics, and Drug Discovery

Mohamad Ali Najia

In recent years, stem cell research has emerged as one of the most exciting areas of scientific discovery and medical promise. Human embryonic stem cells capture the imagination because they are immortal and have an almost unlimited developmental potential. After many months of growth in culture dishes, these remarkable cells maintain the ability to form cells ranging from muscle to nerve to blood—potentially any cell type that makes up the human body. The proliferative and developmental potential of human embryonic stem cells promises an essentially unlimited supply of specific cell types for basic research and transplantation therapies for diseases, ranging from heart disease to Parkinson's disease to leukemia. Stem cells can also be used to study an individual's disease progression *in vitro*, opening up opportunities for personalized therapeutics and pharmaceuticals.

The early concept about how to harness stem cells was simplicity itself: harvest the unformed cells from embryos and inject them into needy recipients. The stem cells would then start rebuilding damaged hearts, pushing cancer to remission, or healing injured spinal cords. Heart disease, ALS, Parkinson's disease, and type I diabetes would all be swept away under the tidal wave of the stem cell cure. However, similar to a foreign kidney or heart transplant, injection of foreign cells would likely cause immunological rejection by the body. Destruction of human embryos for scientific research also poses numerous ethical challenges.

"Embryonic stem cells capture the imagination because they are immortal and have an almost unlimited developmental potential"

In 2006, researchers in Japan lead by Dr. Shinya Yamanaka from Kyoto University had an ingenious yet simple scientific breakthrough. Their discovery, which won the Nobel Prize in Physiology or Medicine, was predicated on reprogramming mature somatic cells, such as skin fibroblasts, into embryonic-like stem cells by using viruses to add only four genes into the fibroblast's nucleus. These reprogramed cells or "induced pluripotent stem cells," iPS cells, were shown to differentiate into nearly every cell type in the body and evade the perils of rejection since the cells were the patient's own. iPS cells essentially eliminate all ethical challenges surrounding the derivation of stem cells because no embryos are destroyed.

Numerous studies since have greatly advanced our understanding of the biology that regulates stem cell differentiation and the stem cell microenvironment. However, in order to realize the clinical promise of stem cells, our fundamental knowledge of stem cell biology must be translated into suitable applications. Dr. Todd McDevitt, Associate Professor in the Wallace H. Coulter Department of Biomedical Engineering and Director of the Stem Cell Engineering Center, argues that the nascent field of stem cell engineering will be increasingly necessary to realize the scientific community's envisioned goals of stem cell based therapeutics, diagnostics and drug discovery platforms.

Engineering conditions for iPS cells to differentiate homogeneously into a specific cell type is currently difficult. One study demonstrated that although global gene expression of iPS cells looks amazingly similar to embryonic stem cells, there are distinct regions in the genetic code of iPS cells that do not get reprogrammed properly. In those regions, iPS cells' genomes still resembled the tissues from which they came from, suggesting that the cells had not been fully set back to the embryonic stage. Consequently, iPS cell cultures can become contaminated with other cell types, which do not have the same coveted therapeutic potential.

"...development of reprogramming techniques represents a breakthrough that will open avenues of research and therapy"

Manually sorting these stem cells is time consuming and difficult; using chemical approaches can damage the DNA inside. To address the problem, post-doctoral fellow Dr. Ankur Singh and Dr. McDevitt, in collaboration with Professor Andres Garcia have demonstrated a tunable process that separates cells according to the degree to which they adhere to a substrate inside a tiny microfluidic device.

The adhesion properties of the human iPS cells differ significantly from those of the cells with which they are mixed, allowing the potentially-therapeutic cells to be separated to as much as 99 percent purity. The high-throughput separation process, which takes less than 10 minutes to perform, does not rely on labeling technologies such as antibodies. Because it allows separation of intact cell colonies, it avoids damaging the cells, allowing a cell survival rate greater than 80 percent. The resulting cells retain normal transcriptional profiles and differentiation potential. Using inexpensive, disposable "cassettes," the microfluidic system could be scaled up to filter increased volumes of cells and to allow the feasible possibility of commercialization and manufacture of stem cell therapies for humans.

The Georgia Tech researchers applied their new understanding of the adhesive properties of human iPS cells to develop a quick, efficient method for isolating these medically important cells. Their work, published in the journal *Nature Methods* [1], represents an innovative conversion of basic stem cell biology, biomaterials, and engineering into a strategy with therapeutic potential. During testing, iPS cell cultures were first allowed to attach to the microfluidic device before being subjected to the flow of buffer fluid. Cells with a lower adhesive strength detached from the substrate at lower flow rates. By varying the flow rate, the researchers were able to separate specific types of cells with high purity from mixtures in which those cells accounted for only a few percent of the total.

Since their discovery, iPS cells have captured the imagination of researchers and clinicians seeking to develop patient-specific therapies. Reprogramming adult tissues to embryonic-like states has countless prospective applications in regenerative medicine, drug development, and basic research on stem cells and developmental processes. To this point, more than 2100 research papers on iPS cells have been published since 2006, indicating a highly active and rapidly developing research field. Purification of iPS cells marks a significant achievement in realizing the promise of stem cells for therapies and scientific advancement. While much remains to be learned and significant challenges remain in iPS cell research, the development of reprogramming techniques represents a breakthrough that will ultimately open many new avenues of research and therapy.

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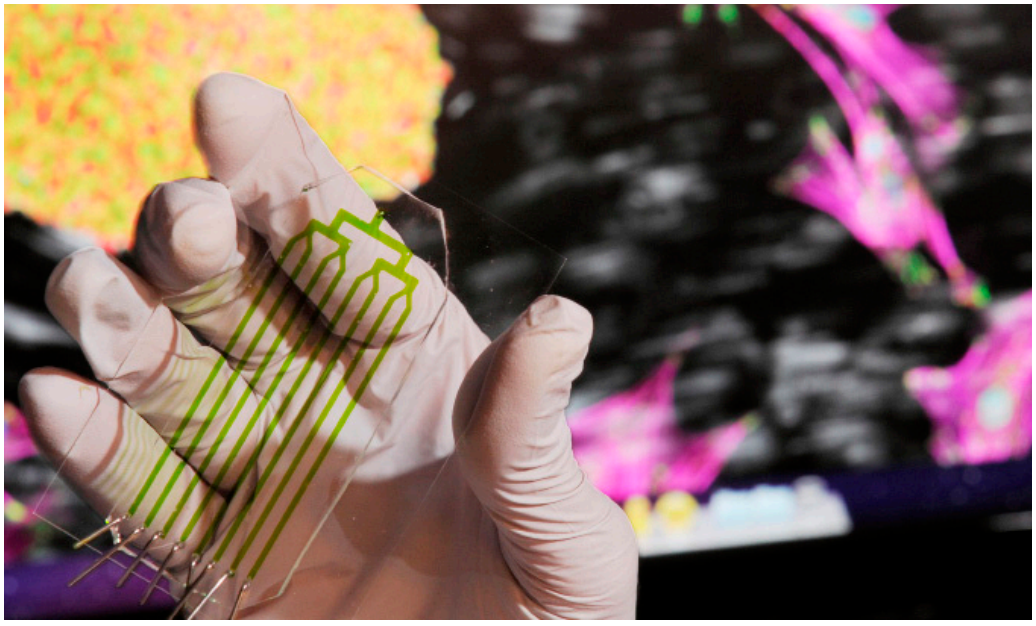

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Algorithms for Vehicle Routing in Warehouse Settings

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ABSTRACT

Vehicle routing algorithms can be used to route packages through large networks, analyze and help improve traffic patterns, and be used to improve the efficiency of shipping warehouses. Working with several shipping companies we have tailored our algorithms to achieve the best performance under the latter application. Topology of the warehouse, distribution of the jobs, ordering of the jobs, and the vehicle routes influence the efficiency of a warehouse. Our goals were to determine which aspects of the problem influenced performance the most. After running simulations changing one aspect of our solution strategy at a time we determined which parts of the problem were most important. The purpose of this is to lay a solid foundation of algorithms and determine which ones should be further explored and improved upon. The results of the simulations pointed toward the most important factors being the topology and method for routing vehicles. How the jobs were distributed among robots, and how they were ordered once distributed seemed to have little impact on the overall performance. Most of our initial efforts were not focused on the topology. These results could lead to more research focused solely on how to construct topologies that allow for rapid delivery of packages.

INTRODUCTION

Vehicle routing has been a challenging problem since the advent of self-driving vehicles and robots. This problem is interesting due to its wide range of applications. Vehicle routing algorithms can be used to route packages through large networks, analyze and help improve traffic patterns, and be used to improve the efficiency of shipping warehouses. Working with several shipping companies we have tailored our algorithms to achieve the best performance under the last application. Everything from topology of the warehouse, distribution of the jobs, ordering of the jobs, and the vehicle routes influence the efficiency a warehouse can achieve.

Given a topology and a list of packages, the objective is to move the packages from their source to destination while minimizing the total duration. A topology is a 2-D grid containing sources, destinations, and vehicles. Vehicles are not allowed to collide with other vehicles, sources or destinations. The list of packages is given in a specific order and describes the source each package is originally located at, and the destination it must travel to. Usually there is a partial ordering that must be maintained when delivering packages, the packages must arrive in the order given as input to each destination. The problem has been relaxed to ignore the ordering restriction as well as allowing the vehicles to have infinite acceleration. This means that vehicles can accelerate to their maximum (unit) velocity and decelerate to zero velocity instantaneously.

METHODS

All simulations were coded in Java making heavy use of the MASON Framework [3]. This framework has many built in

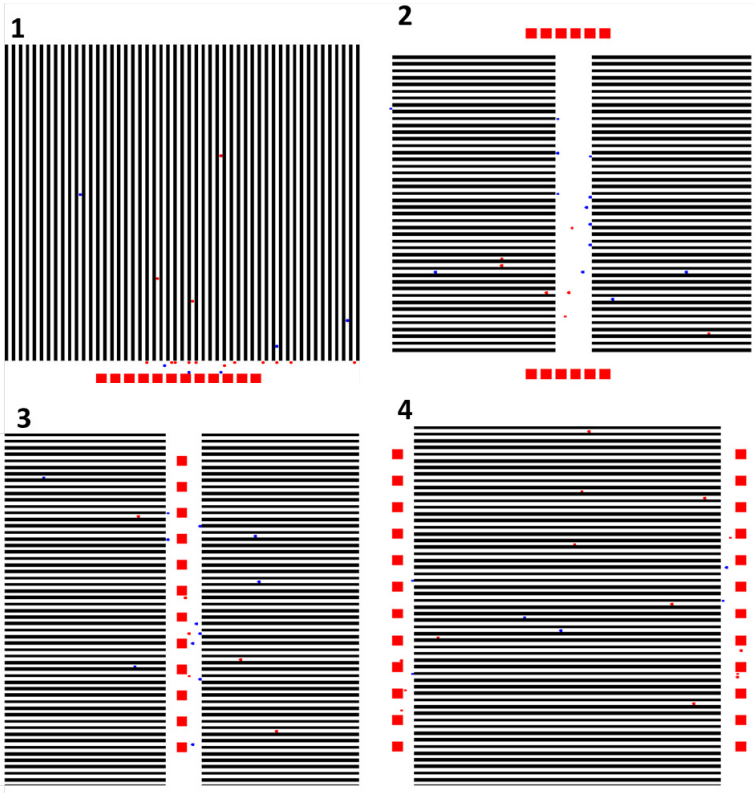

Figure 1. Proposed topologies where sources are black and destinations are red. Vehicles are blue circles, indicating it is currently carrying a package, or red circles, indicating that it is not carrying a package

tools for visualizing different types of simulations. We made use of built in tools to render the simulations in order to visualize the interactions of robots with the different topologies. Each topology was constructed by hand, and iterated on to improve the performance without changing the overall structure of the topology. The most difficult part of getting the simulations to work was coding it in such a way that it was possible to swap out algorithms easily and quickly. There was special care taken to keep the code general enough that we can develop and swap in more algorithms easily, but not so general that it would be impossible to code in a reasonable amount of time. A functional interface and factory pattern were used to accomplish this. The functional interfaces have no state and just serve mutate the problem based on the algorithm the interface represents. Then a factory is build that can return different implementations of these interfaces depending on which method you call. This allowed for a healthy amount of generality in our simulations.

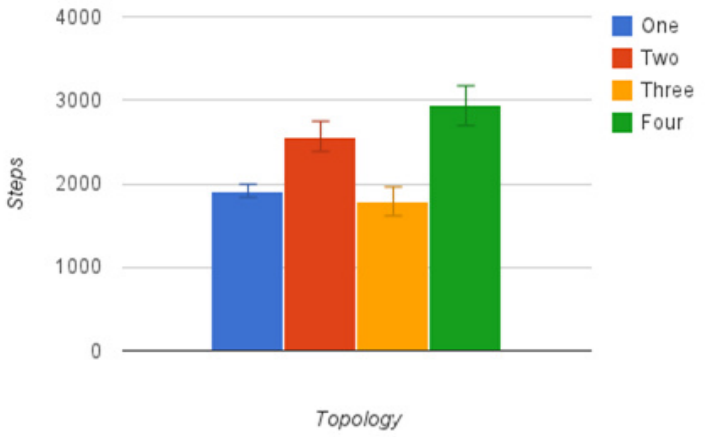

Figure 2. The performance of each topology, provided the number of robots and number of transportation commands were constant for each topological simulation

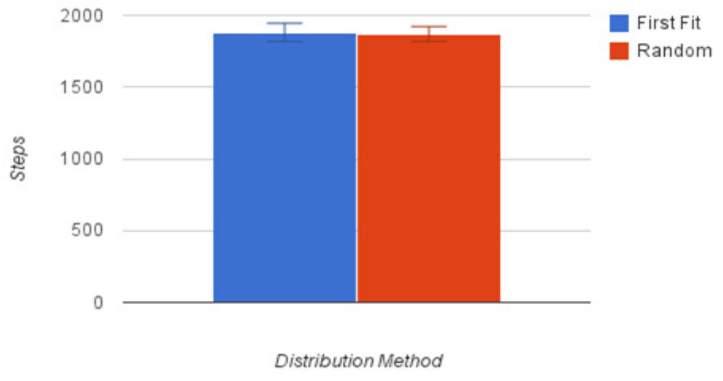

Figure 3. Performance of first-fit and random job allocation to robots

RESULTS

There were many aspects to this problem. Our initial research was focused on determining which parts of the problem had the greatest impact on overall efficiency. This will pave the way to more focused research related to the most important parts of vehicle routing, with the goal of implementing these solutions and improving the performance of warehouses.

Topology

When designing a topology there is a tradeoff between space and speed. With more space, vehicles have more room and avoiding collisions becomes easier, allowing for the faster transportation of packages; however, space is expensive and

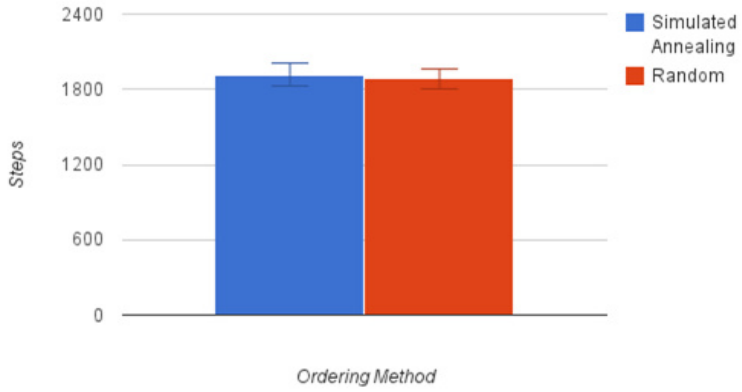

Figure 4. Performance of stimulated annealing and random job ordering approaches.

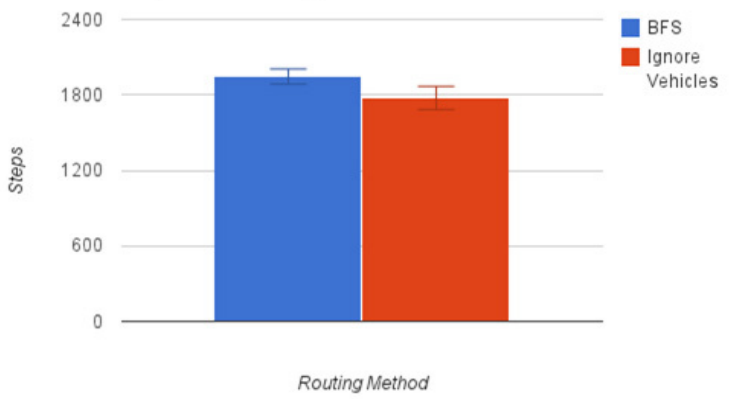

Figure 5. Performance of vehicle routing algorithms, using breadth first search and an optimal non-obstacle solution

cannot be sacrificed without significant increases in performance. We tested four different topologies that were built with approximately the same space efficiency but the sources and destinations rearranged. The number of vehicles was held constant throughout our testing. Figure 1 represents the different topologies with the vehicles in the process of running their respective routes.

When holding other aspects of the problem constant there was a wide variance in performance when changing topologies (Figure 2). Performance was measured by the duration of time (unit time step) the robot would take to reach its destination. Topology 3 (Figure 1.3) had the best performance due to its centrally located destination bins. Topology 4 (Figure 1.4) had the worst performance due to the polarity of the destination bins, causing robots to travel longer distances, on average.

Job Distribution

A job does not have a specific vehicle it must be assigned to. Distributing the jobs to the vehicles is another part of the problem that must be addressed. If each job's completion time can be estimated, then to minimize the total time, jobs should be evenly distributed among all robots. This minimizes any given robots total completion time. This can be modeled as a 1-D bin packing problem. Each robot is a bin with a maximum capacity. Pack the bins with jobs using their estimated completion time, adding more robots as necessary.

In order to conform to our original problem some additional work is required. A binary search is performed to find the minimum, maximum capacity that does not require more than the predetermined number of robots. The packing using this maximum capacity is then given as the job distribution. A simple first-fit solution was used as the bin packing algorithm. It was compared against randomly assigning jobs to robots without attempting to achieve an even distribution (Figure 3).

Job Ordering

Once the jobs are fixed to a robot, the order in which each robot completes its jobs can be altered. Intuitively having all of the robots work on an order in the same part of the warehouse at the same time will causes more congestion than if the robots' current jobs are spread out evenly through the warehouse for a given point in time. The algorithm we use to evenly distribute the jobs through the warehouse uses a simulated annealing approach (Tsitsiklis *et al.* 1998):

1. **Cache Paths**: The first step is to compute and store the paths between every source and destination, taking into account the stationary obstacles of the topology. Let $P_{i,j}(t)$ be the point on the path between source S_i and destination D_j at time t. We will be using these values as estimates since we cannot take into account robots colliding yet, estimates are fine for our purposes.

2. **Randomly pick a robot to optimize:** At random decide on a robot. For every pair of jobs assigned to the robot swap them, and if they increase the fitness function keep the change with a probability that increases to 1 over time.

3. **Compute interesting points**: We will define interesting points to be the 3 points location at the start of the time interval, the middle of the time interval, and the end of the time interval. These points in time must be recomputed each time the fitness function updates the arrangement.

4. **Fitness Function:** The fitness function can be computed by

going through every pair of jobs J_a, J_b with sources and destinations S_a, D_a, S_b, D_b, and summing over every interesting point in time relative to the start of the jobs, t.

$$\sum \text{distance}(P_{a,a}(t), P_{b,b}(t))^2$$

Maximizing this fitness function will evenly distribute the paths.

5. **Repeat and cool:** Repeat starting at step 2 and cool down the annealing until a maximum is found.

We compared this simulated annealing approach to randomly ordering the jobs within robots and the performance was nearly equivalent (Figure 4).

Vehicle Routes

To find vehicle routes a simple algorithm that performs a breadth first search (BFS) at every time step is used (Rivest *et al.* 1990). For each robot, determine where it needs to move towards next, perform a BFS using the robot as a starting point. Move along the path if one exists, otherwise do nothing. This very simple algorithm treats robots as stationary objects for each time step, so if a robot is in an aisle blocked off by two other robots it will not move until the other robots are out of the way. We compared this algorithm to an optimal solution where robots were not considered obstacles (Figure 5). Intuitively, the optimal solution where robots are not considered obstacles would be expected to perform better. Despite the BFS algorithm having slightly worse performance, it is still within the range of variability of the optimal solution. A BFS algorithm could still be a feasible routing vehicle routing mechanism.

CONCLUSIONS

After running many experiments two parts of the problem that were explored had a significant impact on the number of steps to deliver all packages. The most significant factor was the topology. Topologies 2 and 4 required many more steps than topologies 1 and 2. The construction of topologies 2 and 4 included two separate central delivery locations. This appeared to slow everything down compared to the topologies with one central delivery location.

The different strategies of routing vehicles also led to significant variance in the number of steps required. When collisions between vehicles were ignored the optimal routing was achieved for the fixed distribution and ordering of jobs. Using BFS and treating vehicles as obstacles resulted in an average number of steps that were more than 1 standard deviation away from the optimal. Future research can further investigate vehicle routing mechanisms to increase performance.

Distributing and ordering the jobs did not significantly impact the number of steps required. The solution strategies proposed for each part of the problem did not achieve results better than a randomized strategy. This could mean that our strategies are flawed, or these parts of the problem will not be a large contributing factor to the overall performance.

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The effects of the Patient Protection and Affordable Care Act on small and medium-sized American businesses

Vivian C. Lacayo[1] & Karie Davis-Nozemack, PhD[1]

The Patient Protection and Affordable Care Act (PPACA), also known as Obamacare, is the latest reform to the American health insurance system created in an effort to help solve the American healthcare crisis. The PPACA was designed to bring health insurance to 50 million Americans who cannot afford health insurance by expanding access to affordable policies and creating a system of incentives and penalties. The PPACA also shifts health insurance from a market-based system to a solidarity-based system where everyone will pay for the small number of people who are consuming most of the healthcare in the country, making it critical to have as many people participate in the program as possible. While the PPACA may pave the way to more insured Americans, the PPACA also has unintended consequences. Unfortunately, this law subjects small and medium-sized businesses to its education problems, perverse growth incentives and especially the lack of health care cost controls. It's evident that the creation of this law is a positive step for 50 million uninsured Americans, but it still has a long journey to become the perfect solution. This article discusses these issues and suggests solutions to these problems.

"Today, after almost a century of trying; today, after over a year of debate; today, after all the votes have been tallied – health insurance reform becomes law in the United States of America."
- President Barack Obama[1]

Introduction

On March 23, 2010, President Barack Obama signed the Patient Protection and Affordable Care Act (PPACA)[2], a law that brought much needed health insurance reform to Americans. It offers the possibility of health insurance to the 50 million people who currently cannot afford to pay for healthcare.[3] While the PPACA may pave the way to more insured Americans, the PPACA also has unintended consequences. This law is works in theory but is far from a perfect solution for all American healthcare ills. Insurance companies, hospitals, the American public, and small and medium sized businesses must deal with many unresolved issues now, even though the PPACA is still too new to know its full effects on the healthcare system and

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the economy.

Two major issues associated with the PPACA are its failure to address how the rising cost of healthcare will be controlled and a loophole in which the PPACA does not take into account companies with 26-49 employees, which get neither a subsidy nor a penalty relating to health insurance coverage. These two issues make it harder for companies to know what to do regarding the new regulations. This article will examine the PPACA's effects on small and medium-sized companies and propose solutions to the lack of education regarding it, growth limitations imposed by it, and limited cost control measures in the regulation.

Background

With such a high number of uninsured Americans and increasing healthcare costs, the United States needed a new approach to healthcare. A potential solution is contained in the PPACA, which was shaped by the complicated issues it was intended to solve. Its complex origin has led to a complex law.

Reforming the health insurance law

There are 50 million people in the United States that have no means of paying for their healthcare and are uninsured.[4] This healthcare crisis is a problem because these 50 million people seek treatment via charity or at the government's expense.[5] This cost-shifting passes the expense onto compensated care and/or to the government and the rest of the population.[6] The rising cost of healthcare exacerbates these transferred costs.

The primary purpose of the PPACA is to change the market based system of healthcare to a solidarity system, where the healthy will subsidize the cost of healthcare for the sick.[7] Everyone enrolled in the program shares the risk of unpredictable events; the healthy will not only subsidize the unpredictably sick, but also the predictably and chronically ill.[8] The law creates a solidarity system by preventing health insurance companies from banning preexisting conditions, a form of health status discrimination.[9]

Adoption of the PPACA

The problems of the American healthcare system have long been known but previous efforts to fix them had fallen short.[10] Healthcare reform was an important issue during the 2008 presidential elections, where both Hilary Clinton and President Barack Obama suggested different approaches to cover millions of uninsured Americans. After Barack Obama won the presidency, he started working with Congress on health care reform.[11]

The reform was officially named the Patient Protection and Affordable Care Act, but is commonly known as "Obamacare." Before it was signed into law by President Obama,[12] the bill went through several rounds of legislative revisions. It was first introduced to the House Committee on Ways and Means,[13] and the House passed the bill on October 8, 2009.[14] That same day, the bill was presented to the Senate. It was passed two months later on December 24, 2009.[15] The PPACA then went back to the House and was passed on March 21, 2010. The President signed the bill two days later,[16] enacting the most significant government expansion of the $2.6 trillion healthcare system since the 1960s.[17]

The PPACA is the beginning of a shift in the United States health insurance system from a market-based system to a solidarity-based system where the healthy subsidize the sick.[18] This presents an inherent challenge because, for the program to thrive, everyone has to be involved. Consequently, the more Americans who participate in the program, the more effective -it is. To achieve universal participation, the PPACA contains penalties, incentives, and other methods to encourage participation. These provisions make the law so complex that most people don't understand most of its rules or consequences. The law is a grand idea, but it has many flaws that need to be addressed before it becomes the ideal solution for the American people.

Requirements of the PPACA

Many policymakers and lawyers are still trying to understand this nearly thousand-page law. Similarly, company managers and CEOs are unaware of the way the law will affect them or how to deal with new regulations. For regular Americans it becomes even more challenging to understand their options, whether offered by their company or

through newly created market exchanges. The complexity of the law may ultimately discourage many people from participating.

The PPACA's success depends on getting as many people into the health insurance system as possible.[19] To prevent healthy people from dropping their health insurance if the price of coverage rises, an individual mandate was established to require a person/company to either buy health insurance or pay a fine. The PPACA also bans any annual and lifetime limits on coverage, and it extends the coverage to dependent children up to the age of 26.[20] This paper will primarily focus on the regulation of companies.[21] A small business (up to 25 employees) will have the opportunity to get a subsidy from the government,[22] in the form of a tax credit of up to 35% or up to 50%, after 2014, for their health insurance premiums.[23] Small companies also avoid any penalty if they forgo buying health insurance for their employees.[24] Mid-size companies get no subsidy and no penalties in regards to health insurance for their employees. Large companies, with 50 or more employees, don't get any type of subsidy from the government.[25] They do, however, face a penalty for not complying with the law. There are two types of penalties. Failing to offer coverage results in a fine of $2,000 for each full-time equivalent employee after the first 30 employees.[26] For large companies poor coverage will result in a $3,000 fine for any employee getting a government subsidy to help pay for their insurance and $2,000 fine for employees with no government subsidy.[27] Medium companies have neither penalty for nonexistent or insufficient coverage nor any subsidy to help cover their employees' health insurance premiums. The law defines a full time employee to be one who works 30 hours or more a week.[28] Previously, the Fair Labor Standards Act left the distinction between full-time and part-time employees to the discretion of the employer.[29] The subsidies and penalties created by the PPACA are enforced through the tax code.

Issues affecting small & medium-sized businesses

For small and medium-sized businesses, there are three primary problems with the PPACA. The first lies in the lack of nonbiased educational information available to the public. Second, the law's structure creates limits on growth for small and medium sized businesses. The third problem is the absence of cost control limitations for the rising costs associated with healthcare.

Education problems

There's a lack of easy-to-understand information available to the public. After the (2012 presidential/2010 midterm) election that caused this law to become infamous, there was a plethora of misinformation out for the public to read. Much of the politically-motivated misinformation describes the law in a very biased way that simply creates more confusion on what the new law actually entails and who will be affected. Through the lens of politicized information, the American public views the PPACA to be either the best possible solution to United States health care problems, or the worst possible solution, with people focusing only on the negative effects of the law.

Despite how much information is available on the PPACA, the fact that the law is so extensive and politically charged, makes it very hard for people who want to get educated on the subject to get access to reliable and impartial information. Many low income Americans, who are crucial to making the law function, are also largely unaware of the fact that they will be eligible for subsidies or what that entails.[30] The fact that people are uninformed about what is happening and don't know when the different provisions are coming into effect,[31] combined with the fact that the law is rolling out so fast may create low enrollment, which may mean higher premiums for those enrolled.

Many states have opposed certain provisions of the PPACA and have been reluctant to promote the new law in a nonbiased way to educate the people on their choices. Some states have opposed the PPACA's expansion of Medicaid because they believe it would be more costly for each state in the future.[32] To be eligible to receive funding from Congress, states have to contribute money towards the expansion.[33] More acceptance of and participation in the PPACA by the state governments is required to help persuade more people to enroll.

In addition to the fact that much of the available infor-

mation is full of political stigma, there is still a lack of general and understandable information available to regular Americans. Most information is intended to help insurance companies and small businesses (websites like sga.gov), but not the public. When information is available, it's often too complex or broad to understand. The little information available that is simplified is often from companies with hidden agendas.[34] Also, major regulation for companies was issued at the end of December 2012.[35] Unfortunately, the public was so focused on the holidays and the "fiscal cliff" debate that people didn't notice that this crucial regulation will affect all businesses because the number of employees that companies have during 2013 will affect their penalties for 2014.[36] Many businesses are unaware of this rule because they erroneously believe that the law will not take into account actions or decisions taken this year because the law comes into effect in 2014.[37] Many businesses are not worried because they incorrectly think that they have a year to plan for the PPACA's implementation, when the fact is that the time to act has already passed.[38] This may be happening because much of the information out there is targeted to the legal community, because the law will be enforced through the tax code.

Growth limitations

In addition to education issues, small and medium sized business also face perverse growth limitations under the law. Companies with 25 or less employees receive a government subsidy to help them pay for health insurance and will receive no penalty for failing to offer health insurance.[39] Companies with 26-49 employees receive no subsidy for their premiums and no penalty for lack of coverage or insufficient coverage.[40] Companies with 50 or more employees receive no subsidy for their insurance premiums, but are subject to a penalty for lack of coverage or insufficient coverage.[41]

The number of full-time workers that a company has can dramatically affect the cost of health insurance to the employer, thus it may significantly affect whether health insurance is offered to their employees. Small companies (25 or fewer employees) can receive a government subsidy up to 50% of the employer's premium contribution[42] but as soon as they hire the 26th employee, all the subsidy disappears. Companies will look for ways to maintain their subsidy since many will not be able to afford to pay for healthcare coverage without this subsidy, which could lead companies to artificially limit growth to avoid the loss of the subsidy. On the other hand, companies with 26 to 49 employees will have no incentive to start offering healthcare to its employees because medium-sized companies are not covered at all in the PPACA. They have no incentive or penalty to worry about. The problem is that as soon as they reach 50 employees, they must offer health insurance or they will be forced to pay the penalty. Many companies may not be ready to absorb the costs of either the penalty or the health insurance and may choose to stop hiring and growing.

The recent tax increases on personal income from 35% to 39.6% will make it even more difficult for small businesses to deal with the PPACA.[43] Because this law is enforced through the tax code, this change will affect any "small business owner who reports their company's profits as personal income".[44] Small business owners such as Tom Campanaro, president and CEO of Total Gym, have halted planned expansions due to the tax increase.[45] A company's business structure will also influence how it deals with the new law, since the income of many corporations are subject to double taxation at both the corporate and personal levels. Companies that have been scaling back how much they spend, such as Mr. Campanaro's Total Gym, will not have enough income to spend more on health care.[46]

Other businesses are also considering halting expansion until they can figure out their next move. Franchises, such as Visiting Angels, have held off expansion on any new deal that is near the 50-employee mark in order to avoid paying the hefty penalty.[47] The restaurant franchise Bennigan's has also slowed down expansion.[48] With so many companies scared to expand, the number of unemployed workers in the United States will not decrease. Unemployment may even increase if these companies decide to restructure their workforce toward more part-time workers instead of full time workers, another undesired and unintended consequence of the PPACA.

Unions are also worried that the new law require-

ments will drive up costs for their health-care plans and make unionized workers less competitive.[49] Some unions are considering shifting workers from their current plans to private coverage that will be subsidized by the government or dropping insurance altogether, but this would undermine a primary reason for having a union.[50] If unions don't receive the subsidies for their lower-paid members, companies with unionized workers can become less competitive. College professors are also being affected. Many colleges, such as Community College of Allegheny County in Pennsylvania, have decreased the number of classes that adjunct professors teach to avoid having to pay their health insurance.[51] For adjunct professors, teaching one or two less classes can make a significant difference in their salary and also the type of health insurance they will be able to afford.

The PPACA unintentionally incentivizes companies to restructure their workforce to keep the subsidy or avoid the penalty. Many are considering shifting from full-time to part-time workers and hiring more independent contractors instead of employees. Companies like Elizabeth Turley's Meesh & Mia Corp. have considered hiring independent contractors instead of increasing her staff to keep pace with her company's rapid growth.[52] Companies facing the PPACA are now considering hiring only part-time employees (which companies are not required to pay insurance for) or curbing their growth to avoid any penalties. Hiring independent contractors seems less expensive because companies do not pay employment taxes on wages or health insurance premiums. However, independent contractors come with other problems such as less control over the hours they work and the quality of work they produce, and also how much involvement they are allowed to have within the business.[53] Having independent contractors can be very complicated because tax laws that label workers as independent contractors are subject to interpretation, and improper classification may lead to large penalties.[54] In the end, hiring independent contractors to avoid the penalties will result in more uninsured Americans.

Some companies may also consider paying penalties instead of offering health insurance. On closer examination, however, they may realize even if they do take the penalty, it may still mean a large expense increase. Business owner Rick Levi currently offers health insurance to just 25 of his 102 full time employees.[55] If he were to offer health insurance to all of his employees the cost of his premiums would increase from $140,000 a year to $500,000 a year.[56] Because he has never made a profit that is greater than $500,000 a year, it makes sense for him to pay the penalty of $144,000 and drop insurance entirely.[57]

And last, since the PPACA is administered through the tax code, there is an incentive for tax evasion tactics in order to avoid having to pay penalties on health insurance, using artificial structures and legal loopholes to reduce tax implications. These maneuvers to avoid the penalties may result in an increase of tax planning and tax minimization. Increased tax evasion was certainly not an intended consequence of the PPACA.

Limited cost control regulations

All the problems mentioned above are significant for small and medium-sized business; however, the greatest and most unaddressed problem of the law is the lack of cost control regulations. Not only is health insurance very expensive for employers, but each year health insurance will most likely become more expensive due to increasing health care costs. Companies who offer health insurance now may not be able to afford higher premiums in the future. The law offers no way to control these rising costs. If the cost could be controlled, then many companies would more willing to provide health insurance for their employees, because they would know what to expect. Because this law is so extensive, rulemaking will take another 7-10 years to complete, making it even harder for companies to understand the impact of PPACA.[58]

Potential solutions

The problems of education, perverse growth incentives, and a lack of cost controls are significant issues for small and medium-sized business. However, they are not insurmountable. Additional government action and private sector solutions could limit the effects of the problems discussed above.

Solutions for education problems

A large part of the American public is unaware of the PPACA's implications for their lives. The public's lack of awareness is due to the law's complexity and the government's failure to educate the public on the PPACA. The government's education failure could be due to a lack of desire or incentive to educate the public, lack of resources for effective education, or unawareness of how best to educate the public. Regardless of the reasons for the lack of government-provided education, this education failure should be remedied. The government should have a multifaceted approach to educating the community on the PPACA and will need assistance from a variety of sources to reach as many people as possible. A federal agency office should be specifically tasked with coordinating all PPACA education efforts for the public. The PPACA is administered by at least three federal agencies: the Treasury, Labor, and Health and Human Services, which without a coordinated effort, will not be able to ensure that every aspect is covered or that the efforts are not duplicated.

This office could coordinate talks for parents at schools, universities, and town hall meetings to reach large portions of the public at once. Manuals and brochures should be created to explain in simple language about the law. There should be different versions for companies and for individuals, because different rules apply. Online and TV ads could also be used to inform people of the resources available to the public. All of these educational efforts, however, are unlikely to work effectively if opposing state governments do not support the federal government's work in their respective states. Other than the federal agency office, public interest groups can also be used to reach part of the community, which may not have access to aforementioned educational outlets. The office should also work with the private sector and non-governmental organizations to help accomplish this task.

Solutions for growth limitations

Under the PPACA, a full-time employee is defined as someone who is employed an average of 30 hours a week or 130 hours in a month, including seasonal workers.[59] The law uses the term full-time equivalent, which refers to employees who are not full-time employees.[60] This means that part-time or part-time seasonal workers can be lumped together to count as full-time employee. This definition makes it even harder for companies to escape the penalty. It also re-characterizes employees who may have previously been considered to be part-time.

For the PPACA to avoid limiting the growth of small and medium-sized companies as much, the law should redefine full time equivalent to be employees who work 40 hours per week, the more typically understood definition, reducing confusion for business and employees. The law should also eliminate the full-time equivalent employee definition. Because part-time employees are lumped together into a single full-time equivalent employee, companies may struggle to determine which employees are covered by the law. By clearly distinguishing between part-time and full-time employees, it will be easier to monitor compliance with the PPACA.

In addition, to help minimize growth limitations, it should be possible for small companies to add employees without the harsh effects of losing subsidies and gaining penalties. A transition could be introduced to ease the burden of having to provide insurance immediately. Companies that have between 26-49 employees are unsure of what to do. They have no subsidy to help pay for their employees' health insurance, but they also have no penalty if they don't provide health insurance. These companies should be offered a smaller subsidy to help incentivize them to offer health insurance. Having this smaller subsidy[61] will also ease the growing pains that companies with 25 or less employees would otherwise feel by suddenly losing the entire subsidies by adding a single full-time equivalent employee. Small companies could lose 1.4% of the subsidy for every employee over 25, so that by the time the company reaches 50 employees the subsidy will have been eliminated gradually.

This, however, is not a perfect solution. Offering more subsidies will radically increase the cost of the PPACA for the government. The government would have to provide money for the program that it currently does not have. It's possible that the greater funding could be offset by the fact that broader coverage will get more people involved

in the program and health care costs could be spread over more people. Of course, some people or political parties would oppose the fact that now the law would cover even more people, creating further challenges to implementing and regulating the law. The PPACA, however, will still take many years to be finalized and implemented so this change could occur later. It could come into effect in 2020, which would give the government time to decrease the current deficit and acquire the funds needed to implement it.

Companies may have to choose between the PPACA's incentives to constrain growth or offering lower cost health insurance. To surmount the growth constraints by lowering the cost of health insurance, some companies may choose to redesign their health insurance plans, allowing for different ways to distribute or absorb costs, which could lessen the growth effects. Companies may choose to offer Consumer Driven Health Plans (CDHP), self-funded plans, or use cost-shifting. CDHPs are appealing because they cost nearly 25% less than Preferred Provider Organization (PPO) plans.[62] Having self-funded plans can offer employers more flexibility when it comes to designing their insurance plans. Self-funded plans also offer more control over benefit design by better analysis to loss and trend data.[63] Reserves are set aside to pay claims out of current cash flows as they arise.[64] The last way that a company can redesign its plan is by shifting more costs onto employees. Cost-shifting can mean increasing co-pays, out-of-pocket maximums and deductibles. Using cost-shifting tactics may make companies less competitive because they will be less attractive to employees compared to other companies who offer more health coverage. Shifting costs to employees can also be tricky because if too much cost is placed on the employee, companies can become subject to insufficient coverage penalties, which are $2,000 per employee.

Small businesses can also choose to enter into a SHOP (Small Business Health Options) program.[66] Many small businesses pay up to 18% more for health insurance than larger businesses because of administrative costs.[67] By joining a SHOP program, a small company can increase its purchasing power by uniting with other small companies, offering better quality health insurance choices at lower costs and also pool their risk to decrease their costs.[68]

Solutions for limited cost control regulations

Ironically, the rising costs of healthcare helped create the PPACA, but the PPACA's failure to use genuine cost controls is also its greatest weakness. The fact that the PPACA has no way to control future healthcare costs makes it more challenging to accept. "National health spending is projected to continue to grow faster than the economy, increasing from 18% ($2.8 trillion) to about 25% of the GDP by 2037. Federal health spending is projected to increase from 25% to approximately 40% of total federal spending by 2037."[69] This high level of spending will affect how people deal with the PPACA but also how the government deals with all other government expenditures. Because of the rapidly increasing expenditures on healthcare, the government's resources available for other projects, such as education and infrastructure investments, will be decreased significantly. One way to prevent healthcare costs from crowding out other spending is to control growth in healthcare costs, for both public and private payers.[70]

Competitive bidding should be expanded to include more aspects of health care to drive down costs. Competitive bidding is a way to acquire bids "by openly advertising the scope, specifications and terms and conditions of the proposed contract as well as the criteria by which the bids will be evaluated."[71] The purpose is to obtain "goods and services at the lowest price by stimulating competition, and by preventing favoritism."[72] Competitive bidding has already been successful: Medicare was able to reduce its spending on wheelchairs by 42% using this technique.[73] The PPACA requires that Medicare expand competitive bidding for equipment, prosthetics, orthotics, and supplies to all regions by 2016.[74] Medicare should also extend competitive bidding to medical devices, laboratory tests, radiologic diagnostic services and all other commodities.[75] The competitive bidding process should be monitored by a panel of business and academic experts to ensure that it's used in a productive manner. The process should also require that insurance exchanges conduct competitive bid-

ding on behalf of private payers and state employee plans.[76] When creating a competitive bidding plan, the quality of the services should be closely monitored to ensure the process is done correctly because companies may drive down quality in order to offer cheaper services. Lower quality could cause people with more means to look elsewhere for their healthcare services, which could result in the system falling apart by having less people involved and resulting in high premiums.

"More than 75% of physicians face a malpractice claim over the course of their career."[77] The large number of malpractice claims results in the practice of defensive medicine, which increases the costs of healthcare but not necessarily the quality of care. In defensive medicine, doctors may be more worried about saving their careers than their patients. Defensive medicine is "the practice of diagnostic or therapeutic measures conducted primarily not to ensure the health of the patient, but as a safeguard against possible malpractice liability."[78] To decrease defensive medicine, a safe harbor could be created in which "physicians would be presumed to have no liability if they used qualified health-information-technology systems and adhered to evidence-based clinical practice guidelines."[79] A safe harbor system could be used to present evidence in the early stages of litigation and have a judge rule on malpractice cases instead of engaging in a courtroom battle.[80] A safe harbor could significantly lower doctors' malpractice insurance costs because malpractice cases would be resolved much faster and in a more efficient way. This would also imply that doctors wouldn't be as afraid of giving a wrong diagnosis (given it isn't life threatening) and may also reduce the number of unnecessary tests conducted on patients. An initiative called Choosing Wisely is developing these guidelines.[81] Choosing Wisely is a group of leading physician groups that have already released guidelines on 45 common tests that are overused or unnecessary.

Another way to limit healthcare costs is to have states, with the encouragement of federal grants, set an overall health-cost cap covering both public and private spending.[82] Massachusetts, the state plan on which the PPACA is modeled, has recently adopted such limits, and Maryland has capped hospital spending.[83] Health cost caps are essential because healthcare costs will not be decreased by simply shifting the cost from government onto health insurance companies, then onto business, and ultimately onto individuals. Panels of independent counsels composed of providers, payers, businesses, consumer and economists should be created to set the spending target.[84] An independent panel could minimize political agendas from inhibiting the creating of this cost controlling mechanism.

If health care costs aren't controlled and payers continue to shift costs onto individuals, healthcare will become even more costly. Extremely high healthcare costs will likely lead to people severely restricting their consumption of healthcare and they might forego necessary care. Failing to control healthcare costs can lead to bad outcomes for business, the government, and the public.

Conclusions

After analyzing many parts of the PPACA, it's evident that the creation of this law was a positive step for 50 million uninsured Americans; the PPACA is not, however, a perfect solution. The PPACA still has a long journey ahead to become a better solution. The PPACA has many problems regarding the lack of public education and awareness, perverse growth incentives for small and medium-sized companies, but most importantly its lack of cost control mechanisms. The most dangerous consequences could be avoided if the PPACA provided more effective controls for rising health care costs.

An unfortunate consequence of the PPACA is that companies are afraid to invest more in the healthcare of their employees. Companies fear that health insurance costs will keep rising each year with no way to slow them down or control them. Companies perceive that investments in health insurance would not just be for one year, but would increase each year. If companies could predict how much they would have to pay by controlling the cost of healthcare, it would be easier to predict the best approach to the PPACA.

As the PPACA shifts health insurance from a market-based system to a solidarity-based system, everyone will

pay for the small number of people who are consuming most of the healthcare in the country. Because there is no annual limit on the amount of annual healthcare coverage given to a person anymore, the only way to control the amount people will pay is by controlling the costs of healthcare. In the end, the PPACA has the potential to be a great solution for the United States. However, there are many aspects that remain to be addressed and many years of implementation to observe its actual effects on all businesses and on the public.

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Footnotes

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Robotic exoskeletons and the challenges facing the field

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Robotic exoskeletons have been built for augmenting human performance, assisting with disabilities, studying human physiology, and re-training motor deficiencies. The purpose of this paper is to review recent developments in robotic exoskeletons and challenges currently facing the field. We review the four broad categories of robotic exoskeletons: rehabilitative, assistive, augmenting, and haptic. Additionally, we comment on several challenges—including system weight, power supply, actuation, human machine interface/control, and device performance evaluation—which require further investigation in order to meet design goals.

Robotic exoskeletons are robots that can be worn by users to move with the body for various purposes such as rehabilitation or strength augmentation. Exoskeletons have been created to work in conjunction with multiple parts of the human body, but primarily focus on the legs, arms, and hands. Many exoskeletons have been produced in both academic and industrial settings to various levels of success. Only by examining previous approaches to exoskeleton design and the problems associated with these robots, can new effective designs be generated. By examining previous work in the field, past successes can be built upon and failures can be overcome to produce new robotic exoskeletons that are able to improve the lives of their users.

Robotic exoskeletons that have been designed in the past have differed vastly in their approaches to actuator technology, power supplies, mechanical design, control, and performance evaluation. Each of these design decisions provides challenges to the future design of exoskeletons. These challenges include the weight of the system, power supply, actuation, human machine interface/control, and device performance evaluation.

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Current robotic exoskeletons

There are multiple categories of robotic exoskeletons, each with different design requirements and target populations based on their functional goals. These categories include rehabilitative, assistive, augmenting, and haptic exoskeletons.

Rehabilitative robots

Rehabilitative robots are used to guide the user through a series of rehabilitative motions to aid in recovery from an injury or to regain motor skills. These robots can be used in temporary rehabilitative training programs to improve the motor function of a patient. These devices can be used in conjunction with virtual reality or video games to give the user feedback and to help the user to stay focused on his or her rehabilitation. Most of these exoskeletons are fixed to a stationary structure such as a wall or a chair (Van Asseldonk 2008; Gupta 2007). By anchoring the device to an immobile object, the issue of heavy system weight may be avoided by rehabilitative robots.

Assistive exoskeletons

Assistive exoskeletons work with physically impaired users to assist the users' movements. These devices are designed to work with paraplegics or those with functional weakness to provide the user the ability to move normally and could be used permanently or until the user has regained sufficient motor function (Kiguchi 2007; Neuhaus 2011; Perry 2007; Quintero 2011). These devices differ from rehabilitative robots in that they are intended to help users perform everyday movements instead of executing predetermined rehabilitative exercises/games.

Augmenting exoskeletons

Augmenting exoskeletons work with the user to enhance his or her strength; these devices have been typically used for heavy lifting applications such as factory floor lifting or military applications and are almost always portable or attached to a tether to provide power to the system (Kazerooni 2005; Pratt 2004; Walsh 2007; Liu 2004). The primary users of these devices are able-bodied individuals performing tasks that require extraordinary strength or stamina.

Haptic exoskeletons

Haptic exoskeletons have been used to interact with virtual environments or to control robotic manipulators with haptic (tactile) feedback (Dovat 2008; Letier 2008). These robotic devices exert forces on the body as the user interacts with a virtual environment. In this way, objects in the virtual environment can be "felt" and manipulated. These robots can also be used as part of a "master-slave" system in which the robotic exoskeleton "master" controls a robotic "slave" in another location (Letier 2008).

Challenges facing the field

Weight of the system

The weight of a robotic system's components often limits the capabilities of the device (Cenciarini 2011). Heavy components such as the actuators and power supply demand more power from the power source and limit the portability of the exoskeleton. To tackle this problem, some groups have chosen to anchor their device to an immobile object (Perry 2007; Cavallaro 2006). In this case, the user does not have to support the weight of the robot and the power source does not have to be carried by the robot. This strategy is more common in rehabilitative exoskeletons. Some groups have chosen to detach the heavy components of the exoskeleton such as the power supply and carry these heavy components along separately from the exoskeleton (Kong 2006; Kiguchi 2007). Others have reduced the weight of the exoskeleton by utilizing a more passive approach to actuation; these robots employ the use of springs and other energy-storing devices (Walsh 2006; Walsh 2007; Valiente 2005; Krut 2010; Rahman 2006). Additionally, the material choice for the exoskeleton plays a major role in determining the mass of the robotic system. Because of the excessive weight of some robots many groups have chosen to construct their systems from aluminum parts, making use of aluminum's high strength-to-weight ratio (Van der Kooij 2006; Gupta 2007).

Power supply

Current power supplies for robotic exoskeletons are often heavy and not very efficient. Additionally, power sources are not able to provide power to exoskeletons for very long periods of time. Power sources with short lifespans limit the utility of a device and add considerable mass to the system. The power source problem is one of the largest issues facing commercially available products because the devices cannot be used for long periods of time (Honda Stride Management Assist, Honda Bodyweight Support Assist, Rex Bionics, Strausser 2011, Tsukahara 2009).

Some groups have attempted to solve the problem of portable, efficient power sources by housing their devices within facilities (Colombo 2000). This approach allows the exoskeleton to connect to external power via a plug (immobile devices) or power tether (mobile devices). The most effective commercially available devices employ the use of rechargeable batteries to attempt to solve the power-source problem (Esquenazi 2012).

Actuation

Many different approaches have been attempted in terms of actuation, however, it is unclear which method is the most effective. There is a tremendous variation in the approaches that different groups have adopted for actuating their robotic systems. Most exoskeletons created in research settings use servo motors to actuate their robots, but the low strength-to-weight ratio of such actuators limit their efficacy in a portable system (Liu 2004; Kong 2006). Many commercially available augmentation exoskeletons use hydraulic actuators to power their systems, but systems that employ hydraulic actuators have many drawbacks such as noisy machinery, bulky actuators, and a low payload to system weight ratio (Walsh 2006). Many research groups have recently begun to design their exoskeletons with series elastic actuators (Van der Kooij 2006; Pratt 2004; Neuhaus 2011). These actuators may also facilitate human-machine interaction because they allow for impedance control (Hogan 1984).

Human-machine interfaces

The challenges posed by the human machine interface and the control of exoskeletons depend strongly on the exoskeleton's purpose. Additionally, the use of noisy biological signals poses significant problems for controller design. There is a great deal of variation in the scientific community with regards to how to best control a robotic exoskeleton interacting with a human user. User safety and determining user intent are of utmost importance when designing a controller for such a device. It is also important that a controller allow for minimal training by the user.

Some groups have implemented impedance controllers in their robots so that the robot can safely interact with the human user (Van der Kooij 2006; Gupta 2007). In this control setup, the impedance of the user is matched by the robot to provide coordinated motion of both the robot and user. Other exoskeletons have used position control of the robot in order to move the user's limbs through a predetermined trajectory. This type of control is most common with rehabilitative exoskeletons (Colombo 2000). Other devices have attempted to determine user intent by measuring biological signals such as muscle activity (Cavallaro 2006; Kiguchi 2007). Still, other leg exoskeletons attempt to determine user intent by monitoring trunk motion or forces exerted by the upper body (Strausser 2011; Quintero 2011; Tsukahara 2009).

Device performance evaluation

There is no standard method of analyzing exoskeleton performance currently, which causes a major problem in terms of determining the progress being made with successive exoskeleton designs. As new exoskeleton designs emerge, the groups producing the robots tend to state that there is improvement in patient mobility or that the device is successful. However, without a standard metric of comparison, the efficacy of many of these robots is unknown. One typical method of device validation that is used by some groups is the tracking of the user's joint kinematics and comparing these kinematics to a healthy control (Van Asseldonk 2008; Walsh 2006; Gupta 2007). Although this method is the most common, the quantifiable metrics that are calculated from the joint kinematics differ from robot to robot, making the comparison of exoskeleton performance

particularly difficult. Additionally, when evaluating the performance of a device it is important to understand the purpose of the robot. For example, rehabilitative robots may need to be evaluated differently from augmenting or haptic exoskeletons.

Looking forward

When looking to the future of robotic exoskeletons, it is important to note the hurdles that mark the path to a successful device. The design of a successful robotic exoskeleton depends largely on its intended purpose; augmenting exoskeletons have drastically different requirements from rehabilitative exoskeletons. With regard to future designs, the challenges of system weight, efficient power supplies, actuation, effective control, and performance evaluation all need to be tackled. These problems may be solved through the collaboration between researchers in different disciplines such as materials science, electrical engineering, rehabilitation, medicine, neuromechanics, controls, and others. Once these design hurdles have been overcome, effective exoskeletons may be realized for rehabilitative, augmentative, haptic, and assistive purposes.

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Open access for our generation

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Currently the research being paid for by US taxpayers is sitting behind a paywall. Despite that the majority of academic research in the US is performed by students and professors, publishing companies are earning huge profits. The open access movement seeks to transform the academic publishing ecosystem from profit-driven and exclusive to knowledge-driven and open. The vision, impact, challenges and future outlook of open accessing publishing is examined with respect to furthering scientific advancement and improving the academic publishing landscape.

Imagine attending a university where you were expected to teach full time while paying tens of thousands of dollars in tuition. Your fellow students graded your work, and less than 10% of the students in the school graduated. Then, if you were one of the lucky ones who did pass, your teaching would be recorded on video tapes and sold back to other students on a subscription basis, while the publisher pocketed the profits. Welcome to the current state of academic publishing.

A handful of publishing companies (most notably Elsevier, Wiley, and Springer, which accounted for 42% of the market in 2012) own a significant portion of academic journals. The research published in these journals is largely funded by taxpayer dollars through grants awarded by federal organizations, such as the National Institutes of Health (NIH) and the National Science Foundation (NSF). The articles are subjected to a rigorous peer review process, which professors do for free on their own time. Then this work, usually a product of years of federal funding and work by graduate students and professors, edited and reviewed by other professors for free, is handed over to the journals and put behind a paywall. Elsevier (by far the largest of the publishing companies) posted profits of over $720 million in 2011, with an astounding profit-margin of 36% ("Academic publishing," 2011).

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The peculiarities of the academic publishing system have long been known and reported, yet solutions have only been recently presented. The Open Access movement, starting in the year 2000 (Butler, 2003), as well as the many publications from the library world admonishing the rising costs of maintaining academic subscriptions (Bosch, Henderson, & Klusendorf, 2011) (Ivins, 2005), have sought to raise awareness of this issue and to create solutions. The Information Age and the new generation of scientists trained during this time are uniquely positioned to influence the course of academic publishing from profit-driven and exclusive to knowledge-driven and open.

A brief history of academic publishing

In the early 17th Century, the "scientific journal" as we know it did not exist. Scholars like Isaac Newton and Robert Hooke often published their discoveries in code, so that if anyone else made the same discovery, they could decode the message and prove that they had discovered it first (Hall, 2002). Scientists published infrequent, large volumes of their work. The first academic publication wholly devoted to science was the Philosophical Transactions of the Royal Society, (Oldenburg, 1665). This marked the beginning of a transition of publishing shorter, more frequent articles on current work rather than waiting for a whole book's worth of material before publishing. This trend continued as scientists became more professionalized and needed proof of productivity in order to stay in the good graces of their employers.

In the United States, by the turn of the 20th century, most research was published through non-profit university presses or scientific societies. It was not until the 1970s that there began a large trend for the more successful non-profit publications to be bought by for-profit institutions. (Elsevier, 2005) Throughout the decades, the average price of a journal subscription steadily grew at a rapid pace (Townsend, 2003). The primary consumers of these publications were the academic institutions themselves. In 2002, 65% of Elsevier's customers were academic institutions. (Gooden, Owen, & Simon, 2002). The rising costs of subscriptions came at the same time as the budgets of academic libraries were being cut. These two issues came to a head in the early 2000s in what is known as the "Serials Crisis" (Young, 2009; Panitch & Michalak, 2005). Most recently the issue was brought to national attention when Harvard University announced that it could not sustain its academic subscriptions, which was close to 3.75 million dollars a year (Faculty Advisory Council, 2012).

Peer review: What is it good for?

In today's publishing landscape, articles are subjected to rigorous peer review. This rigor is intended to filter bad papers out, and to give suggestions for mediocre papers to improve. This review is usually double-blind, meaning both the author's reviewer's names are unknown to the other party. However, as fields become more and more specialized, the list of peers a journal can call on for a given paper could be extremely small. This can lead to situations where either direct competitors are reviewing each other's work before publication, or the reviewer is not truly an expert in the field. There have been many articles and much discourse (Higgs 2007; Horton, 2000; Rennie D, Flanagin A, Smith R, & Smith J, 2003) on the efficacy of peer review in judging the merits of a paper. One article posits that the rigorous peer review process produces journals "exclusive in participation, innovation averse, few in number, outdated in content, restricted in scope, largely unread and increasingly specialized" (Whitworth & Friedman, 2009).

The open access movement

The Public Library of Science (PLoS) was founded in 2000. Founders Harold Varmus, the director of National Cancer Institute; Patrick Brown, a professor at Stanford University's Medical School and an investigator at Howard Hughes Medical Institute in California, and Michael Eisen, a professor at UC Berkeley wrote an open letter to the scientific community, urging researchers to only publish their work in journals that made the full free text of their articles available within six months of publication ("Early History | PLoS," n.d.). Over 34,000 scientists signed the letter, but changes were not evident in the years immediately following. So in 2003, PLoS launched its first open access journal, PLoS Biology.

Ten years later, the Directory of Open Access Journals

(DOAJ) lists 9,948 fully open journals, over half of which are searchable at the article level on its webpage ("DOAJ: Directory of Open Access Journals," n.d.). However, this rapid and impressive growth has not come without its share of criticism. In order to raise money for publishing and operating costs, most open access journals require a publication fee to be paid for by the author. Critics claim that the less prestigious of PLoS's offerings are extremely lenient in their review process in order to generate more revenue, in other words researchers are paying to be published when no other peer-reviewed journal would have let them in.

Whether or not these allegations are true, the effect that the open access movement has had on the industry is undeniable. In 2008, NIH released a statement requiring all research funded through it to be made open access within a year of its publication. At the time this was a huge step for the open access movement. This year in February the White House released a memorandum that all research funded through federal organizations with budgets of over 100 million dollars would be held to the same one year open access deadline (Holdren, 2013). Many members of the open access movement, including one of the founding members of PLoS Micheal Eisen, see this as a step backward, in effect codifying the 1 year embargo period that publishing companies enjoyed from NIH funded grants (Eisen, 2013). Others see it is a stepping stone to eventually requiring full open access.

Current issues with open access journals

Open access scientific journals have mushroomed into a global industry, driven by author publication fees rather than traditional subscriptions. This business model often promotes "predatory" publishing and an incentive to increase publication volume—rather than quality—in order to be profitable. Thus, concerns have arisen over the scrutiny of the peer-review process at many open access scientific journals. In a recent sting operation conducted by the prestigious, subscription-based journal, Science, several open access journals had little to no quality control of manuscripts submitted for publication (Bohannon 2013). Using an alias, a member of the Science Editorial Board submitted a bogus scientific paper with obvious experimental flaws to 304 open access journals around the globe. An astonishing 52% of the journals had ultimately accepted the paper for publication. Of the 255 papers that underwent the entire editing process to acceptance or rejection, about 60% of the final decisions occurred with no sign of peer review, likely without the papers being read by anyone. Of the 106 journals that discernibly performed any review, 70% ultimately accepted the paper. Most reviews focused exclusively on the paper's layout, formatting, and language. Nonetheless, reputable journals like PLoS had not only raised the issue of the paper's scientific quality, but also meticulously inquired about study's institutional review and documentation. The Science study reveals the need for more stringent oversight and publishing regulations for the emerging open access publishing enterprise. Ensuring that journals honor their obligation to peer-review is a challenge that the scientific community must rise to because journals without quality control are simply destructive for the advancement of science.

A vision for the future

It can be argued that the current peer-reviewed, publisher controlled system of sharing scientific discovery has served to standardize article writing. Nevertheless, this system has inherently unfair economic consequences. When public funds are used to generate research, then that research should be immediately available to the public. It is important for our generation of scientists to realize that the scholarly publishing industry as it is today has not always been in place. We have to come together and figure out solutions so that our libraries can afford to carry the work we ourselves are producing. We, more than ever before, have the power to choose where and how our research is published, and who has access to it. We need to change the culture that values the title of the journal in which a work is published and instead value the content of the work itself. We need to evaluate the peer-review process and make sure that it still makes sense in the face of having access to faster media with huge potential for collaboration and large-scale communication. A Morgan

Stanley research team in a report from 2002 urging the continued investment in Elsevier writes, "The nature of the scientific publishing industry will not change any time soon, in our view, despite the attempts [...] to encourage academics to publish their research directly on the internet and to encourage the 'boards' of individual journals (who peer review the scientific articles included in journals) to defect from commercial publishers to not-for-profit publishers" (Gooden, Owen, & Simon, 2002). I hope, more than ten years after this report was written, our generation of researchers can start to prove them wrong.

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