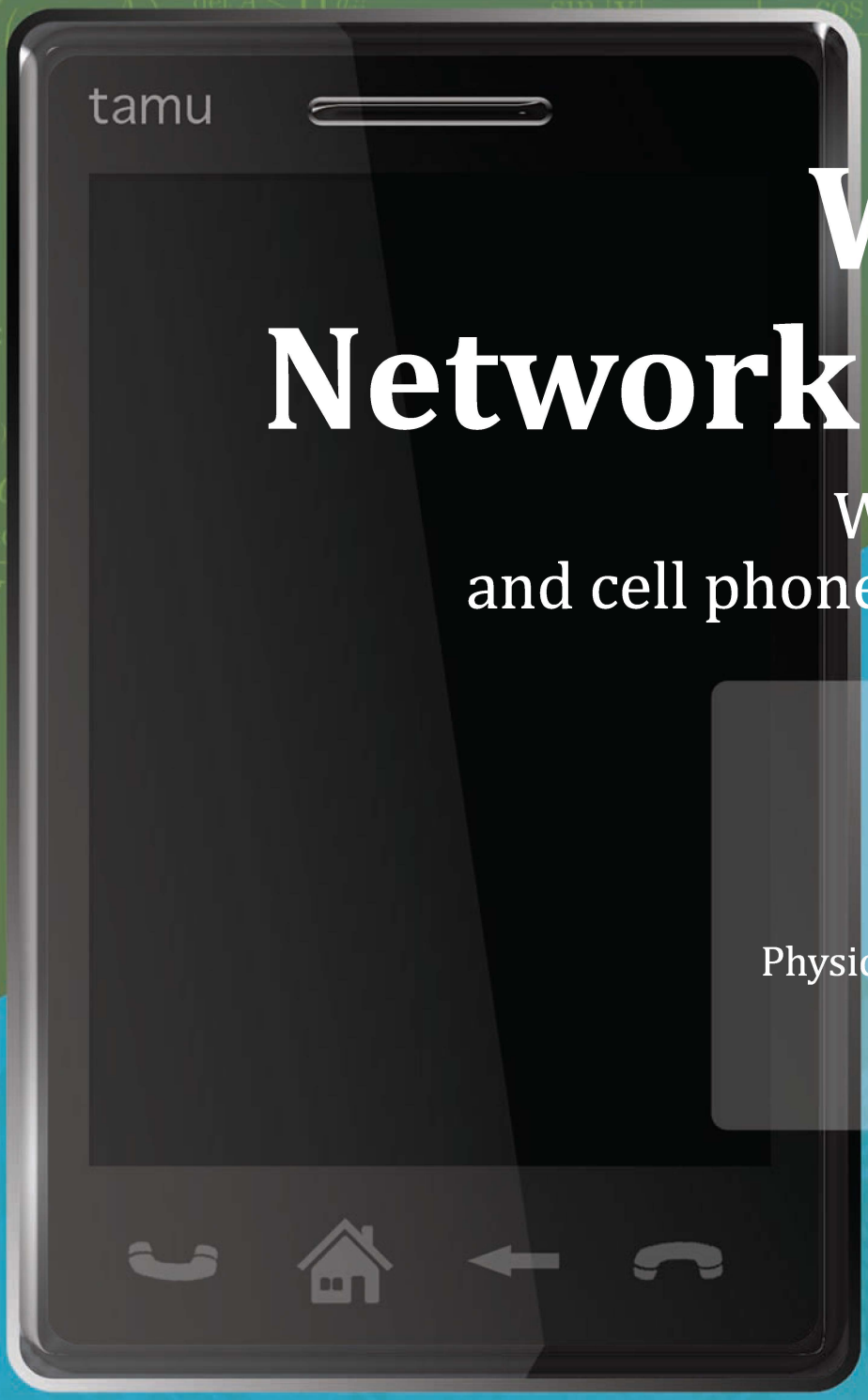
explorations
THE TEXAS A&M UNDERGRADUATE JOURNAL

FALL 2010 | VOLUME 2




# Wireless Network Coding:

## What linear algebra and cell phones have in common

**ALSO IN THIS ISSUE**

Atmospheric Science, Music, Mechanical Engineering, Forensic Biology, Astronomy, Physics, Cancer Biology, Education, Poetry, Computer Science, Marketing, Psychology

TEXAS A&M UNIVERSITY

# LETTERS FROM FACULTY

When I was a graduate student at Rice University, after earning my bachelor's degree at Texas A&M, I often pondered this quote from Demosthenes that was engraved on a cornerstone of Lovett Hall: "Rather would I discover the cause of one fact than to become king of the Persians."

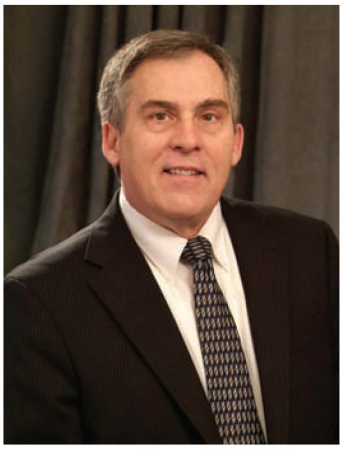
These words had a significant influence on me as a young person just starting out my career as a researcher. Now that I am much farther along in my career, I appreciate the truth behind them even more fully.

From the beginning, our land-grant mission at Texas A&M has been to improve the lives of people in Texas and beyond. We do this by preparing the next generation of leaders in the classroom and through extracurricular projects that underscore our core values, notably selfless service, integrity, and respect. But we also do this in our laboratories and through fieldwork, where generations of professors have added to the world's knowledge base and made discoveries that have improved our lives in fundamental ways—and where our students have experienced for themselves the profound satisfaction of discovering the cause of one fact while working alongside them.

Our mission of discovery is showcased in this second issue of *Explorations*, which contains research findings on issues that directly affect people across our state, nation, and world: food production, medicine, education, communication and so many others. As a scientist, I applaud our bright and talented undergraduate students for their work to date and for the great potential they will no doubt fulfill in years to come. As the president of Texas A&M, I am proud of our professors and students for the numerous and significant research contributions they continue to make on our behalf.

R. Bowen Loftin '71
President
Texas A&M University

Dear Readers,



One measure of an eminent university is the opportunities it offers to its students. Program diversity, study abroad, and especially the chance to participate in the discovery of new knowledge take the undergraduate experience from good to great.

I am currently in my second "tour of duty" within the Texas A&M System, having started my career as an assistant professor in the Department of Biology long before you, and alas some of your parents, were born. Throughout my research career I have had the privilege of mentoring scores of undergraduates in my laboratory. One characteristic they shared, and in my opinion the attribute that best defines our humanity, is curiosity. The simple need to know more has driven scholars to make remarkable discoveries throughout history.

The curiosity of those bright, talented undergraduates proved to be a powerful tool for challenging my graduate students, postdocs, and me to think more deeply about our experiments and to consider alternative explanations for our results. Their unique perspectives and enthusiasm more than paid for the occasional dropped beaker and added an infectious energy that made bench science fun.

Did all my undergraduate researchers become practicing scientists? No, several became physicians, some became veterinarians, a few are laboratory technicians, and a handful are secondary school teachers. I even lay claim to a patent lawyer. So no matter what path your interests lead you on, I am convinced that what you bring to the undergraduate research experience will enrich many lives—including your own.

Sincerely,

Craig L. Nessler
Director, Texas AgriLIFE Research
Texas A&M University

UNDERGRADUATE JOURNAL
**VOLUME 2, FALL 2010**



Web site: explorations.tamu.edu
Henderson Hall
4233 TAMU
College Station, TX
77843-4233, U.S.A.



TEXAS A&M
UNIVERSITY

# explorations

## THE TEXAS A&M UNDERGRADUATE JOURNAL

# International Astronomy Initiative: The Dark-Energy Camera

TYLER BEHM

*Something is making the universe expand too fast.[1] This mysterious phenomenon pushes away matter as though it had antigravity properties, and it distorts the fabric of space and time in a manner that Einstein's theories cannot predict. So far, no astronomy project has directly observed this substance, but several have confidently measured its consequences. We call this mysterious phenomenon "dark energy."*

**Background**

Dark energy is by no means a small correction. In fact, the most recent cosmological data[2] on the motion of matter through space indicated that dark energy and dark matter compose 96% of the universe. Yet ordinary matter, the building blocks for everything from this article to the stars in the sky, makes up only 4% of the universe. This stark difference and dark energy's antigravity properties have led cosmologists to hypothesize that the universe will continue to disperse until it is extraordinarily cold and lonely—the "Big Freeze."

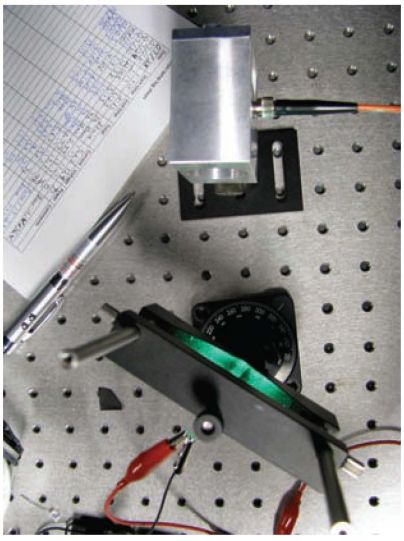
What is dark energy? Why can we not see it? How does it push away matter? These are deep questions that tug at the core of human curiosity. For now, astronomers don't have the answers. So scientists from around the world are uniting to develop a more powerful telescope, the Dark Energy Camera (DECam), in hope of answering these questions. This article will focus on the Texas A&M and University College London teams' endeavors to construct the DECam and what my research findings contributed to the Dark Energy Survey.

*The Dark Energy Survey*

The Dark Energy Survey is an international collaboration among 13 US, 5 UK, 4 Brazilian, and 3 Spanish research institutions. The survey will use DECam for 525 nights to view 15% of deep space. DECam will indirectly observe dark energy by observing dark energy's effects on surrounding ordinary matter. If we see galaxies that move faster than we expect, we know that dark energy is near the galaxies. The survey's goal is to improve measurements of the properties of dark energy.[3]

The primary telescope for the survey will be the Blanco Telescope at Cerro-Telolo International Observatory in Chile. The Texas A&M Astronomical Instrumentation Group will reequip Blanco Telescope's 14-foot-diameter mirror with a system of five large lenses that make up the DECam. These lenses must be properly aligned within DECam to avoid distorting the telescope's images.

Lens alignment studies are ongoing at the University College London, where I conducted half the research for this article. The London team will project a uniform circular laser into the lens. They will study the distortions in the cross-sections of the exiting laser and use that knowledge to create lens alignment procedures.[4]



This undertaking is massive, and proper calibration of our telescope is essential, lest our efforts go to waste. For this reason I have researched DECam calibration for my entire college career. At Texas A&M, I tested light-emitting diodes (LEDs) as a method for color calibrating our digital cameras. At the University College London, I ran computer simulations of calibrating lasers as they passed through the telescope's lenses. I will explain the approach and results of my two research experiences.

*Texas A&M: light source testing for color calibration*

The color calibration of our telescope is important because the images that we see of the stars are not their true images. Instead, Earth's atmosphere selectively absorbs certain colors of light and thus distorts pictures of the sky. Astronomers can compensate for

this effect by adjusting the sensitivity of a telescope's digital camera to certain colors. Furthermore, one can selectively observe certain colors by using a filter. The range of colors that a filter allows to pass is called a filter band. For example, light's wavelength (typically expressed in nanometers) determines its color; the visible filter band begins at violet (400 nm) and ends at red (700 nm).

My job with Texas A&M was to research light sources that could illuminate our desired filter bands because we wanted to use this light to calibrate the sensitivity of our digital camera.[5] LEDs were our first proposed light sources.

Practicing astronomy requires precision, which is why astronomers must know the wavelength of the LEDs' light to within a few nanometers. (This is an impressive scale; the head of a pin is 1,500,000 nm long.) Moreover, the temperature difference between night and day can affect the LEDs, so I created a temperature-controlled experiment to test LED performance. I needed to test two dependent variables: angle and temperature.

**Angle Experiment**

For my first experiment, I selected the light's exit angle from the LED's plastic coating as the dependent variable, whereas I kept all other variables unchanged. After collecting and plotting my data, I found that the LEDs' color did not depend on the angle, but their brightness did. This behavior met our expectations because it matches that of a standard flashlight (ergo the color is the same but brightness diminishes at the sides). Thus, my results were reassuring.

**Temperature Experiment**

LEDs have interesting properties that one can explain with basic circuitry. LEDs emit light by jumping current across a small electric potential gap. The light's color depends on how much energy jumping the gap required. Blue light is more energetic than red light, and thus blue light corresponds to a larger potential gap. By heating an LED, we can give the electrons in the current a greater average energy. The electrons would then need less additional energy to jump the gap, and their emitted light would be redder.

Proper temperature control was crucial for my test, so I custom built my experimental setup. I attached an LED to a computer-operated cooling device and enclosed the assembly in an insulated testing environment. Maintaining the same LED angle but adjusting the temperature shifted the LEDs' peak wavelengths further toward 700 nm (red) as temperature increased.

My data (1) showed that the LEDs had no angle dependency and (2) quantified by how much each LED became redder and less efficient with higher temperatures. My results suggest how LEDs, in general, respond to angle and temperature. My research could thus extend to improving the performance of LED devices such as flat-screen televisions.

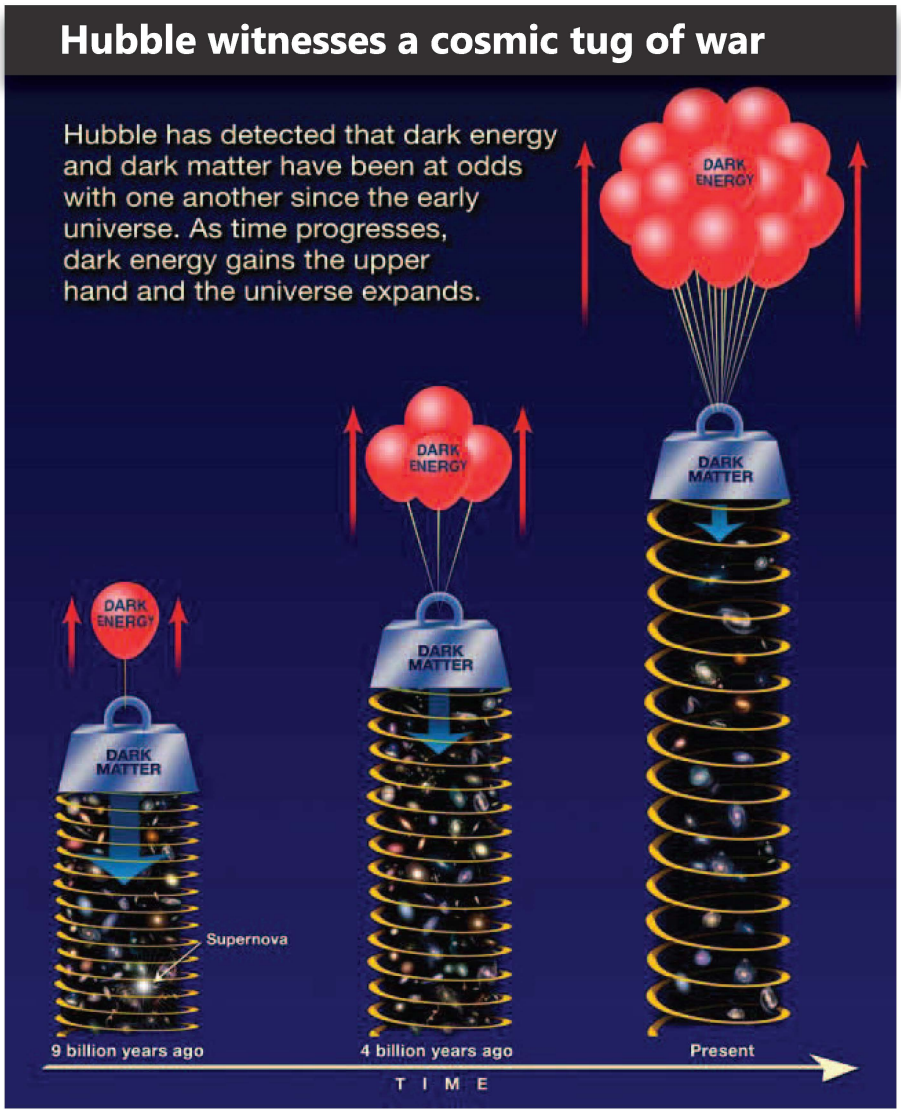
My results indicated that the LEDs had too much temperature variability to be suitable for DECam's Chilean climate. Instead, the Texas A&M Physics Observatory is using the LEDs to perform color calibrations. The Texas A&M Astrophysics Web site (astrophysics.tamu.edu) archives all LED data.

*London: Computer Simulations of Calibrating the Laser*

After concluding my summer research at Texas A&M, I studied at University College London. That year, the London Times ranked University College London—one of five UK collaborators on the DECam project—as the number-one research university in the United Kingdom. I looked forward to researching with the London DECam team.

*Experimental Setup*

The London Optical Science Laboratory was responsible for aligning the largest lens in DECam. Merely polishing the lens has taken 21 months. It is 3.2 feet across and weighs 380 pounds.[4] Aligning it properly within DECam requires a specially designed machine. The machine holds the lens on a revolving tabletop. As the table turns, a laser shoots through the lens and digital cameras capture changes in the laser. The laser's cross-section may lose its circular symmetry as the lens rotates. If so, either the lens has minute imperfections or the lens is misaligned.




*NASA, ESA, and A. Riess (Space Telescope Science Institute)*

The best method of researching our setup is with computer simulations. My task was to experiment with MATLAB (Matrix Laboratory Software) to gauge how much success I could achieve. A matrix is an array of numbers arranged in columns and rows. By assigning each element in the matrix to a pixel in a theoretical digital camera, I could study cross-sectional pictures of our calibrating laser.

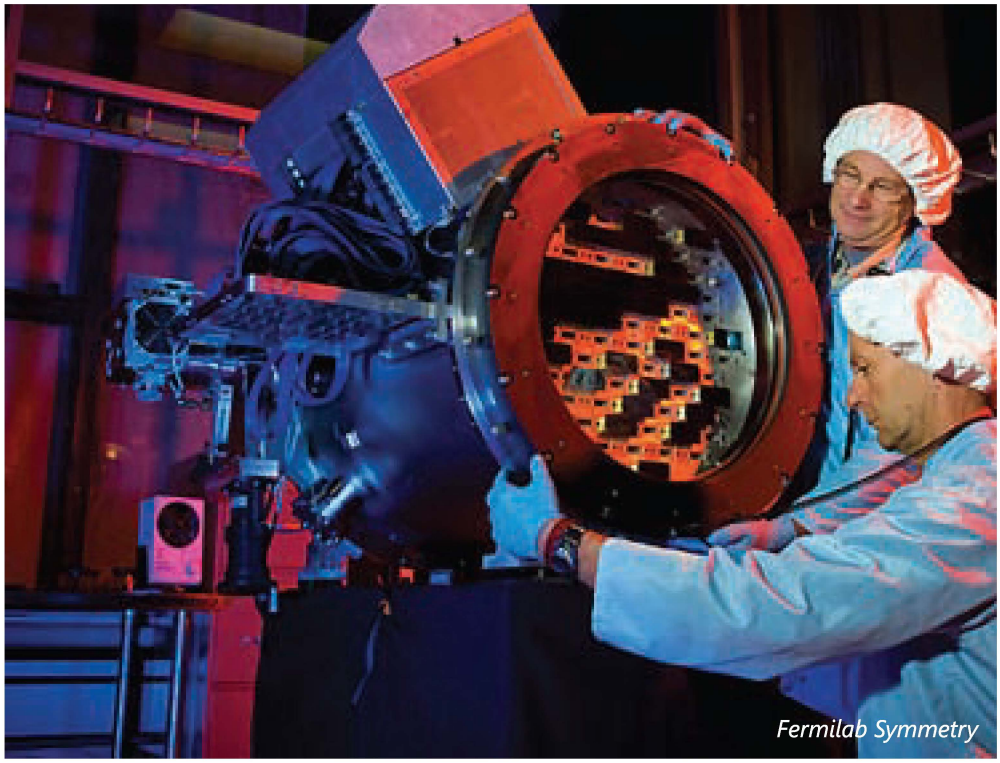
Our setup is like a three-part assembly line for laser light. First, our circular laser encounters a small circular stop. This stop cuts the laser into a doughnut shape known as an annulus. Second, the laser annulus travels through a small lens, which optically transforms the laser into a pattern that looks like circular

ripples in a pond, known as an Airy pattern. Finally, the Airy pattern is shot through the DECam lens. I used MATLAB to simulate all the laser's transformations.

*Computer Simulation*

MATLAB speaks in the language of mathematics, specifically geometry, and thus I had to as well. Think of an annulus as two concentric circles. Any pixel within the outer circle but outside the inner circle was declared part of the laser annulus. A special mathematical function models the optical transform. Then, I applied a special MATLAB function to the laser annulus and got the desired Airy pattern.

An Airy pattern is special among optical patterns: it is highly sensitive to changes in the laser annulus. We needed such sensitivity to detect errors. Thus, I needed to quantify how much changes in our lens would change our Airy pattern. To do so, I considered the image's astigmatization (deviation from a circle's perfect symmetry; for example, an ellipse is astigmatized, but a circle is not).


Fermilab Symmetry

**Results**

My attempts were successful; I measured the change in the Airy pattern with respect to changes in the laser annulus. By telling MATLAB to plot the astigmatization with respect to the laser annulus conditions, I found a trend indicating that the astigmatization of the Airy pattern rapidly increased to a maximum but then slowly fell off to zero. My results were also consistent with our knowledge that the Airy pattern is sensitive to changes in initial conditions.

This knowledge can empower future commercial research into using MATLAB for optical transformations. Further research could extend astigmatization programs to personal cameras. Camera manufacturers could use these computer simulations to derive perfect theoretical images, and then they could correct lens imperfections by comparing these perfect images to actual images that their cameras produce.

**Conclusion**

*Even the smallest error can be detrimental to our $18.4 million telescope.*[3]

My research focused on removing two potential sources of error: color calibration and lens alignment. I found that even LEDs were not stable enough to serve as light sources and that computers can model small misalignments. Although my results can apply to LED televisions or to personal photography, we are focused on the big picture: DECam. By constructing DECam, astronomers shine light on dark energy and, in doing so, learn more about the fate of the universe.

**Current Research**

Calibration of DECam is important, and I am pleased that I can devote my research to the cause. As of spring 2010, I am researching with the Texas A&M Astronomical Instrumentation Group. I am characterizing the performance of shutters that will go on DECam's auxiliary telescopes. I look forward to future work with my group and to the expected completion of DECam in 2011. ■

**Acknowledgments**

I thank my advisors, Dr. DePoy, Dr. Marshall, and J.P. Rheault of the Texas A&M Astronomical Instrumentation Group, whose support and instruction fostered my interest in astronomy research. I also thank Dr. Lanigan of the University College London Optical Science Laboratory for offering me a rare opportunity, as well as the mentorship to make it work.

**References**

1. Riess AG, et al. (Supernova Search Team). Observational evidence from supernovae for an accelerating universe and a cosmological constant. 1998. Available from http://arxiv.org/abs/astro-ph/9805201.

2. Spergel DN, et al. (WMAP Collaboration). Wilkinson Microwave Anisotropy Probe (WMAP) three-year results: implications for cosmology. March 2006. Available from http://arxiv.org/abs/astroph/0603449.

3. Fermilab, UIUC, UChicago, UC Berkeley, et al. (DES Collaboration). A proposal to NOAO for the Dark Energy Survey. July 2004. Available from https://des.fnal.gov/main_documents/A_Proposal_to_NOAO.pdf.

4. Doel P, et al. Design and status of the optical corrector for the DES survey instrument. 2008. Available from http://spie.org/x648.html?product_id=790049.

5. Marshall and DePoy (Texas A&M Instrumentation). Flattening scientific CCD imaging data with a dome flat field system. October 2005. Available from http://arxiv.org/abs/astro-ph/0510233.

# The Future of Shopping?
## The Evolution of the After-Retail Channel

CAMERON BROWN



*AREI channel research may show retailers how to improve their asset recovery and understand a new approach to the retail industry.*

**Introduction**

Although not all agree, most economists are earmarking December 2007 as the official beginning of a massive global retail recession, one in which the US economy shrank at a rate not seen since World War II. The retail industry began to see a decline in sales. Cutbacks, layoffs, closings, and bankruptcies became the hottest retail trends in 2008,[1] and contrary to the buzz of "stabilization" in 2009, retail sales continued to nosedive. The influx of Chapter 11 filings, store closings, and downsizing efforts further proved that the claims of stability were rooted more in hope and lacked any real substance to support them. However, a few bright spots were not only surviving but also thriving. At the end of the second quarter of 2009, TJ Maxx and Marshalls stores posted their highest numbers since they joined forces 14 years before and decided to aggressively open locations rather than close them. While analysts expected Sears and J.C. Penney's earning per share to drop as much as 20% and 30%, respectively, Ross stores were expected to see a growth of around 12% (O'Donnell 2008). Also, a new form of business was silently coming to fruition. Woot, one of the first to adopt this new method of retail, became the 25th fastest-growing company in the United States. They had seen a growth of almost 5,000% in only 4 years, and the economic hurdle that had tripped up so many others failed to impede their momentum. However, replacing the nearly 10 million jobs lost since 2007 will take years of strong recovery. Yet, these few winners in a sea of losers may have something in common and something to teach us. What was so special about these businesses that they could defy the economic tremors of the depression that shook so many others? Is this the future of shopping?

| Method | Example | Advantages | Disadvantages |
|---|---|---|---|
| Traditional and Brick Mortar | TJ Maxx<br>Ross | -Economies of Scale<br>-Physical displays | -Costs associated with physical storefront<br>-Must buy in large quantities |
| AREI e-Tailer | Overstock.com<br>Bluefly.com | -Huge product diversification[2]<br>-Open 24/7 | -Lack of physical store<br>-Most site traffic due to customer research |
| Liquidator/ Auction | Liquidator.com<br>eBay | -Achieve market understanding<br>-Ease of use | -Possibility competition acquires product<br>-Hard to estimate effect on brand integrity |
| OPAT | Woot!<br>SteapandCheap | -Niche marketing<br>-Strong psychological effect on consumer | -Revenue constrained by business model<br>-Typically backed by physical operation[8] |

*Figure 1. Features of AREI*

**Background: The AREI Channel**

These select retailers have one thing in common: they are all members of the After-Retail Excess Inventory (AREI) supply chain. The AREI channel serves the basic function of distributing and selling dead or dying products after they have been through the retail cycle. The most obvious benefit is that manufacturers and retailers in the traditional supply chain can recoup part of their investment by getting nonselling products off their shelves and into their revenue stream. This channel is gaining increased prominence and recognition as more and more executives in the retail world begin to understand the magnitude and breadth of its value. In fact, many businesses have created new positions and specialties for employees to maximize the AREI channel's utility, such as vice president of asset recovery and reverse logistics manager.

This channel, and the players within it, differs from the traditional retail supply chain in several ways. In the traditional supply chain, retailers will order products on the basis of perceived consumer demand, order lead time, and current inventory levels. The AREI channel, on the other hand, operates around the traditional retail channel's mistakes and making its money off the volatility in retail consumer demand. Whereas traditional retailers typically know when, what, and how much of a product they are getting, the AREI channel typically does not. They receive products at odd times and in varied quantities, sizes, and conditions.

**Types of Retailers**

The common misconception is that product makes its way into the inventory of an AREI retailer only if it fails to sell in the traditional retailer's store. Although true in a few instances, this view is overly simplistic. In reality, products reach this channel not only from traditional retailers' inventory but also from manufacturers and wholesalers/distributors. These products can reach the consumer through many different paths within the AREI channel, as well sometimes passing through as many as four additional parties before reaching the consumer's doorstep or shopping bag. Figure 1 briefly describes the main methods of AREI retail.

**Results**

My research data come from many diverse sources. I constructed an in-depth model of the AREI channel that was applicable to most industries. I then analyzed the trends and forces that affect-

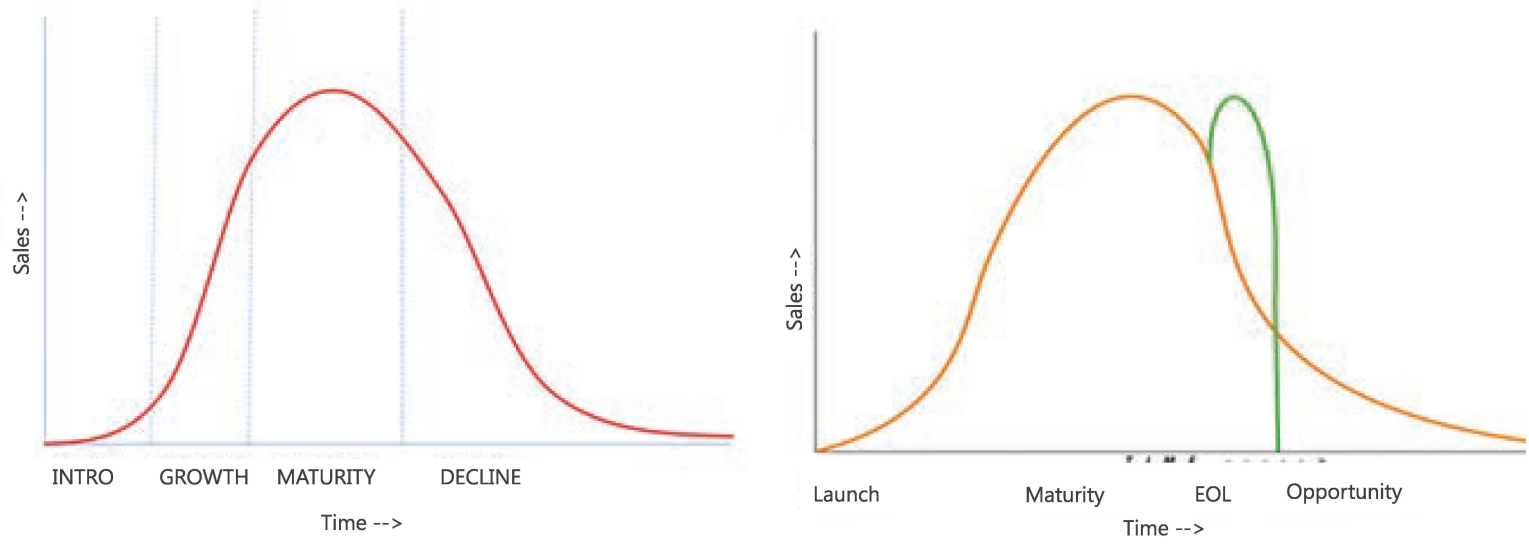



*Figure 2. The PLC curve on the left is the traditional curve with all four stages outlined. The figure on the right shows the effect that an OPAT has on the PLC. For an AREI retailer, the decline stage is seen as the opportunity stage.*

ed the AREI channel as a whole to understand what factors significantly affected the channels' success and operations. I then developed a set of metrics to evaluate the effectiveness of each AREI type previously identified. These metrics included the ability to shorten product life cycle (PLC), the effect on brand and price integrity, purchasing power, level of product diversification, inventory turnover ratio (which indicates how fast inventory is bought and sold), and the benefit to customer and manufacturer. Any supply-chain executive could use these data to choose an excess inventory strategy. Inventory is one of the largest costs associated with running a retail business, and there is much to gain from an understanding of the AREI channel. If a company can appropriately select its asset recovery, it could both save money and preserve its brand image. Following is part of the analysis of one AREI type that resulted in some of the more significant findings, the one-product-at-a-time (OPAT) retail model.

**The Future of Shopping?**

Since 2004, hundreds of OPATs began springing up on the Web. The explosion of Web-based retailers using the OPAT model itself is a testament to its profitability and effectiveness. One advantage of the OPAT model is the unrivaled ability to reduce the life cycle of a specific product, and it offers the highest level of security concerning brand integrity. Several factors work together to create a different type of shopping experience that makes this model successful. One such factor is the bounce rate. Woot.com experiences a bounce rate of 85%, meaning that 85% of the visitors to this site—more than 1 million a day—leave the site within 1 minute. This figure would spell disaster for other online retailers, but the employees at Woot are proud of this statistic. Because OPAT retailers offer only one product at a time, customers can typically decide whether they are interested in it within 60 seconds. OPAT Web sites receive such high volumes of traffic because everyone has at least 1 minute to spare in his or her day. This sales approach is the equivalent of putting a rack of highly discounted products in the middle of the busiest intersection in America. All people will see it as they drive by, and even if 90% have no interest in buying it, the 10% that do will easily clear out the inventory.

Because OPAT retailers focus heavily on selling one product at a time, the inventory turnover rate and their sales per square foot are significantly higher than those of traditional retailers. As a result, they are paying lower taxes on inventory, and their overhead expenses on inventory are greatly reduced. Manufacturers are typically hesitant to sell products for too low because they are worried that their brand may see a negative shift in consumer expectations.[3] If a consumer find the same product in different stores, it is safe to assume that he or she would purchase the product from the AREI retailer at the lower price. This is perfectly fine if it were to happen once, but if a customer were to find price discrepancies on the same products over and over, he or she would eventually begin expecting these low prices all the time and refuse to pay full retail price.

Yet consumer perceptions toward brands never drastically change under the OPAT model because the deal lasts only for a specified period and the product will not remain on shelves discounted at the same price for weeks. The result is similar to the marginal effects on consumer expectations seen on "Black Friday," the day after Thanksgiving where retailers typically offer deeply discounted prices for 1 day only. Consumers understand that the discount is temporary and limited. Certain OPAT retailers may also go as far as labeling the product as refurbished, even if it is brand new, to protect the manufacturer even further. In an interview with Woot executives,[8] the OPAT retailer admitted occasionally using this method to protect the brands that value their price integrity.

Also, as mentioned, the OPAT retailer can shorten or halt product life cycle faster than any other method of AREI retail. Figure 2 shows how an OPAT retailer can shorten the bell curve and add value to the supply chain. Although all AREI retailers reduce the life cycle of the product, OPAT provides the steepest and quickest decline and thus can reduce life cycle cost more dramatically.

Several other reasons explain the success of OPAT Web sites, including the cumulative psychological effect of time limits, limited stock, and lower prices that change consumer behavior to something that does not follow traditional consumer trends. Behavioral studies can partly explain this success. For example, a study from the University of Iowa found that the number of choices available to consumers affects their purchasing decisions.

*Contrary to logic, consumers were more likely to make a purchasing decision when they had fewer choices rather than having to decide among many.[6]*

The theory of cognitive dissonance also seems to explain some of this behavior. Cognitive dissonance is the uncomfortable feeling caused by holding two contradictory ideas simultaneously. The theory says that people have a motivational drive to reduce disso-

nance by changing their attitudes, beliefs, and behaviors or by justifying or rationalizing them. For example, when consumers see a product that they don't necessarily need but that is deeply discounted, they may have an urge to buy the product anyway, rationalizing the purchase as too good of a deal to pass up.[5] Overall, AREI retailers often change consumer behavior into something irrational and unpredictable, and this approach typically works in their favor.

**Discussion**

The information here reflects only a small part of the overall research. The final result extensively compared the types of retailers in the AREI channel as well as pinpointing the factors and trends that affect it. The purpose was to offer a means in which a retailer in the traditional supply chain could effectively select an appropriate AREI retailer that would deal with products in a manner most in line with the traditional retailer's business strategies and objectives. For the most part, retailers often neglect and seldom understand the AREI channel. Nearly all the literature and textbooks on retail management fail to even mention it. Yet, this market carries tremendous value, especially in a down economy, and can no longer be overlooked.

Implications for this research go beyond the specific uses of asset recovery and reverse logistics. The types of retail that this report outlines marks a fundamental shift in how retail sales will be approached from here on out.

*OPATs specifically have begun to completely change the game. It is safe to say that a change of this magnitude has not occurred, in terms of effect on consumer behavior, since eBay was created.*

The factors that make this model so significant are not product or genre specific. They can, should, and most likely soon will be used by any business to help sell any product and increase performance. It's the future of shopping and it's important to be ready. ■

**References**


1. Inc. 500: The fastest growing private companies in America. 2008. Available from http://www.inc.com/inc5000/2008/company-profile.html?id=200800250.

2. Bluefly Inc. (BLFY) Annual report 10k report, 2009.

3. Chen T, Erdem T, Kearne MP, Sun B. A dynamic model of brand choice when price and advertising signal product quality. *Marketing Science* 2008;27(6):1111–1125.

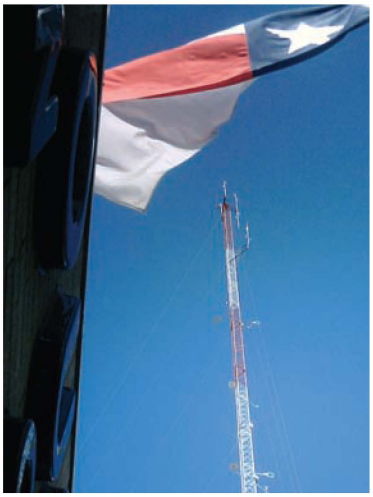
4. Farfan B. Retail industry information: overview of facts, research, data, and trivia. Available from http://retailindustry.about.com/od/statisticsresearch/p/retailindustry.htm.

5. Festinger L, Reicken HW, Schachter S. *When Prophecy Fails: A Social and Psychological Study of A Modern Group that Predicted the Destruction of the World*. New York: Harper-Torchbooks, 1956.

6. Cummings WH, Venkatesan M. Cognitive dissonance and consumer behavior: a review of evidence. *Journal of Marketing Research* 1976;13:303–308.

7. O'Donnell J. More shoppers head to discount stores. *USA Today*. 2008 February 7. Available from http://www.usatoday.com/money/industries/retail/2008-02-07-shopping-going-downscale_N.htm.

8. Rydl D. Woot! Company information. C. Brown. Carrolton, TX, 2009.



# The Low-Level Jet Over Houston, Texas

BRIAN HAINES

*The air quality of Houston has been a problem for some time now. What if we could reduce this pollution with a river of moving air? Through observational and analytical methods we can look for this river of air and determine when and how it occurs.*

## Introduction

For some time now Houston has had a problem with air pollution. Both federal and state agencies, as well as many university researchers, including Dr. Renyi Zhang and others at Texas A&M University, have found that a complicated mix of pollutants is responsible for Houston's continued violations of the National Ambient Air Quality Standard for ozone. High levels of ozone can worsen respiratory problems—for example, in people with asthma—and decrease lung function, especially in children.[1] High-ozone days often occur under stagnant conditions, when little air movement by winds keeps locally released air pollutants cooking in the sunshine, sometimes for days. So, a bit more wind may go a long way to help reduce Houston's air pollution. One of those winds that researchers have been interested in for many years is called a low-level jet (LLJ). The LLJ is a nighttime, moderate to strong wind that blows strongest just a few hundred meters above the surface. It can cause both transport and mixing of air at the surface, moving and diluting pollution downwind. Thus, the jet can assist in pollution reduction, which is one of many reasons that the jet bears examination.

Identifying particular LLJ cases requires examining a series of meteorological parameters that are not routinely monitored. It is necessary to relate identified jet cases to larger-scale atmospheric features, the weather. If a pattern emerges, a weather forecast can be used to predict the jet.

## Methods

First, we determined whether the presence of the LLJ is real over the city of Houston; nobody has ever described one over such a large urban area. All the needed meteorological data used for this project came from the Yellow Cab Company communications tower located 2 miles north of downtown Houston (Figure 1). The data spanned 2 years between summers of 2007 and 2009 and were analyzed using open-access R software.[2] A series of specialized meteorological, or micrometeorological, measurements were then examined to determine the presence of the jet: the exchange of radiation energy at the surface; the exchange of sensible heat energy (warm air transport); the change of wind speed with respect to height above the surface; the amount of air turnover per time, called turbulence; and the time rate of change of various pollutant concentrations during suspected jet nights.

The preceding parameters usually have distinct nighttime values or undergo certain changes during the night that indicate the possible presence of an LLJ. I surveyed the literature to find out what others had published about these values and changes and compiled a list of parameter values (Table 1) to guide me in finding periods with corresponding ranges during past jet events.[3–6]

The first parameter examined was net radiation to determine whether the day was clear or cloudy. On a clear day, solar radiation produces a snakelike shape, a *sinusoidal curve*. If the following night was clear as well, this can lead to strong nighttime cooling for lack of clouds intercepting infrared radiation from the surface, an effect we are all familiar with during clear winter nights. Such nights were then examined in the context of the sensible heat parameter. When the surface cools rapidly, sensible heat flux decreases during the night. Eventually sensible heat flux can turn negative, indicating that warm air from aloft is moving toward the surface. This process creates an *inversion*—temperature increasing with height instead of decreasing with height—which one can see from the tower data. Inversions commonly trap air pollutants near the surface and therefore lead to higher early morning pollution the next day, creating more ozone air pollution during the day. However, if the previous night is windy, that pollution can be dispersed. So, wind speed and turbulence at 60 m was examined next to help determine whether an LLJ was present. Because the jet is a fast-moving river of air, some higher wind speeds and increased turbulence should be expected if the jet was present. After exploring that, there was a new list of dates for further examination. Finally, the concentration of carbon dioxide and other pollutants were inspected to search for possible jet effects; cases were identified as short- or longer-term reductions of pollution by so-called downdrafts of cleaner air from aloft that the jet caused.

After the parameters were examined for each possible LLJ period, I picked two case studies for closer examination. In each case I gathered external surface meteorology data from the Texas Commission on Environmental Quality[7] station in Houston–Aldine to compare with our data from the tower.

| Parameter | Typical value at night |
|---|---|
| Wind speed | 7–12 m/s |
| Sensible heat flux | Negative (warm air transport toward the surface) and further decreasing |
| Turbulence (friction velocity) | Stronger, further increasing |
| $CO_2$ Concentration | Lower (approaching background) |

*Table 1. Typical parameters of the LLJ as observed at other field sites*

## Results

I focus on the two case studies here: 5–25 January 2009 (case I) and 7–9 April 2009 (case II). In both cases, the investigated parameters were indicative of a LLJ, as shown in Figure 1 for a few days during case I. Also, these two cases represented two different large-scale atmospheric conditions at different times of year.

*Case I*

In case I, a cold front had just passed through the area with a high-pressure mass moving in behind the front, leading to mostly clear conditions across Southeast Texas. In general, Southeast Texas was under the influence of a cold air mass with light northerly winds throughout the period. These meteorological conditions are important to understand when analyzing the various parameters of a jet. The first parameter analyzed was net radiation. Net radiation for this event showed a fairly sinusoidal curve, indicating a rather clear day. Sensible heat values were then analyzed and strong negative values were present each night, more negative than on average nights. This finding indicates that a strong inversion possibly formed over a larger region during those nights. For example, 7–8 January 2009 had negative values that were far less than typical values experienced during that time of season (Figure 1). Wind speed was then analyzed to determine whether the night was windier than usual. Values peaked at approximately 7 m/s and speeds decreased at 2 m/s down to the surface, which is windier than usual. All things considered, it seems likely that an LLJ was present during this period.

*Case II*

For case II, the large-scale meteorological picture was similar to case I in that a cold front had passed through the area a week ago, with high pressure located in the Gulf of Mexico west of Florida. Regionally, Southeast Texas experienced light southeast winds throughout the period, 7–9 April 2009. The net radiation data for this event indicated a rather clear day, associated with strong nighttime cooling. Sensible heat was analyzed next to see whether a strong inversion was present during any of the nights. On both nights, 7 and 8 April, strong negative sensible heat signatures occurred. I again looked at ozone concentrations to determine whether they indicated any possible mixing occurring (Figure 2) in the lower atmosphere.

When I first examined just the tower data I felt that there might be some error in the ozone data. After I analyzed the Houston–Aldine site data, things started to make sense. The tower takes measurements higher above the ground, whereas the Aldine site takes measurements closer to the ground. Cars emit nitrogen monoxide, which consumes ozone and explains the respective stronger dip in ozone concentration at Houston–Aldine (shown in Figure 2 with arrows). This finding was further corroborated when I analyzed nighttime wind speeds. The tower data illustrated moderately high wind speeds (Figure 2) occurring over the area during both nights, 5–9 m/s. There are spikes of weaker winds that are followed by dips in ozone concentrations. This finding makes sense in that when wind speed increases, more mixing occurs and vice versa. Higher winds speeds replenish ozone quickly by moving it downward from aloft. In summary, it seems likely that a jet was present on both nights.

## Conclusion

*From the research presented, one can reasonably assume that the LLJ does occur in urban Houston.*

The frequency of this event is difficult to determine without more analyses. Atmospheric conditions for the jet seemed to occur in all seasons. In the fall and winter it was typical to see a strong cold

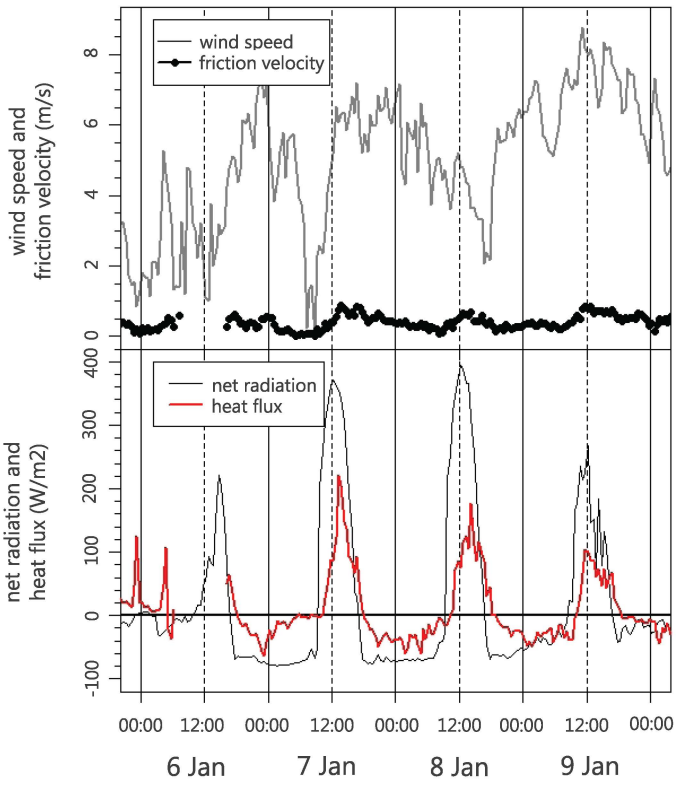



*Figure 1. Yellow Cab tower wind speed and friction velocity (at 60 m above ground) from 6–9 January 2009 (top panel) and respective net radiation and heat flux (bottom panel). Note lower heat fluxes during the clear nights, 7–8 January.*

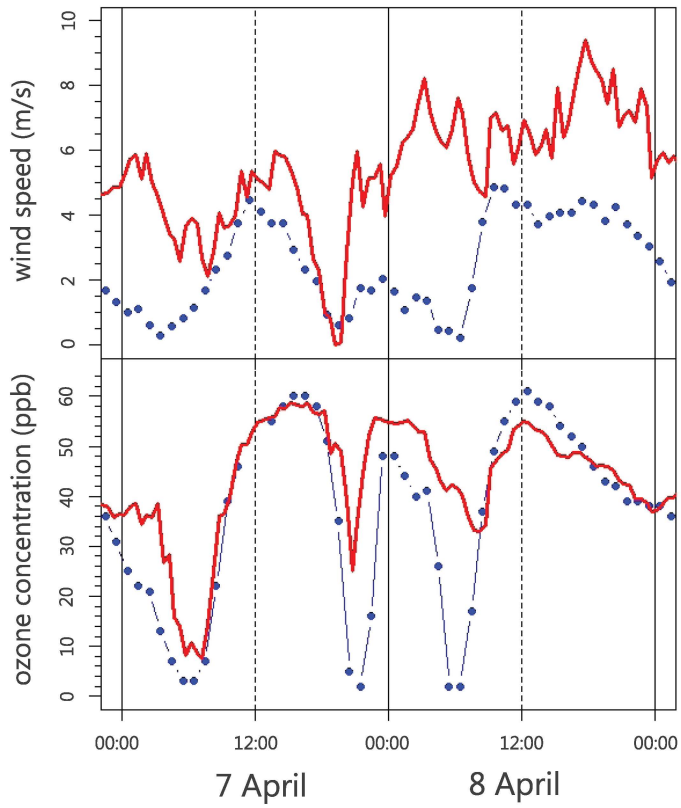



*Figure 2. A comparison of wind speeds (top panel) and ozone concentrations (bottom panel) between the Yellow Cab tower (thick red line) and the Aldine surface site (blue circles) locations.*

front move through Southeast Texas, giving clear conditions with strong nighttime cooling occurring. The spring season included multiple weak cold front passages through the region and a subsequent high-pressure system building in. During much of the summer, high pressure west of Florida leads to constant, light to moderate southeast winds. This is different from the winter scenario in that winds are often stronger at night. In Texas it appears that the jet is connected with light to moderate southeast winds in the summer, whereas it is connected with a recent frontal passage in the winter. This effect helps the urban environment by reducing the concentration of pollutants in the morning. More research needs to be done on this topic so that the jet can be better understood and forecasted. ■

**Acknowledgments**

I thank Gunnar Schade for giving me the opportunity to work on this research project, the data used, and of course the invaluable guidance and help in all aspects of the project.

**References**

1. Pope CA III, Bates DV, Raizenne ME. Health effects of particulate air pollution: time for reassessment? *Environmental Health Perspectives* 1995;103:472–480.

2. R: A language and environment for statistical computing. 2009. Available from http://www.R-project.org.

3. Karipot A, Leclerc M, Gengsheng Z, Lewin K, Nagy J, Hendrey G, Starr G. Influence of nocturnal low-level jet on turbulence structure and CO2 flux measurements over a forest canopy. *Journal of Geophysical Research* 2008;113:4–10. DOI: 10.1029/2007JD009149.

4. Ohya Y, Nakamura R, Uchida T. Intermittent bursting of turbulence in a stable boundary layer with low-level jet. *Boundary-Layer Meteorology* 2007;126:349–363.

5. Banta RM, Newsom RK, Lundquist JK, Pichugina L, Coulter RL, Mahrt L. Nocturnal low-level jet characteristics over Kansas during CASES-99. *Boundary-Layer Meteorology* 2002;105:221–252.

6. Sun J, Lenschow D, Burns S, et al. Atmospheric disturbances that generate intermittent turbulence in nocturnal boundary layers. *Boundary-Layer Meteorology* 2004;110:255–279.

7. Texas Commission on Environmental Quality. Available from http://www.tceq.state.tx.us.

# Tumor Stress in Progression of Prostate Cancer

MOZHDEH MAHDAVI



*The enzyme 2OST may be responsible for the progression of cancer from benign to metastatic.*

**Introduction**

Prostate cancer affects one in six males and is the second-leading cause of cancer death in men. In general, cancer becomes deadly at the onset of metastasis—when cancer spreads from the initial tumor to distant locations in the body, forming secondary tumors. Our lab has noted that the level of a specific enzyme increases during the shift from a benign, potentially harmless tumor to a deadly metastatic one (Ferguson and Datta, unpublished). In large quantities, this enzyme drives cells to metastasize—to become metastatic. By figuring out what factors increase production of this enzyme, we may begin to understand what controls the progression of prostate cancer. This endeavor not only helps us predict which patients are likely to develop deadly metastatic cancer but also allows us to develop drug therapies that stop the factors and block production of the enzyme, halting the progression of prostate cancer.

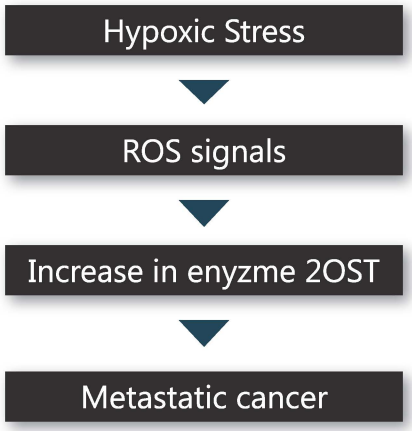



*Figure 1. Hypoxia's effect on metastasis. ROS, reactive oxygen species.*

**2OST and Cancer**

The enzyme that we believe is responsible for the progression of cancer from benign to metastatic is called 2OST. Our lab saw a fourfold increase in the amount of 2OST enzyme between benign cancer cells and metastatic ones. Furthermore, getting rid of excess enzyme made cells less metastatic, thus confirming its vital role in the progression of prostate cancer. Because 2OST may be driving metastasis, we asked what causes 2OST to accumulate in cancer cells. Further studies from our lab suggested that one factor is the stress caused by a lack of oxygen (Ferguson and Datta, unpublished).

**Cell Stress and Metastasis**

We believe that production of excess 2OST begins when cells in a tumor are starved for oxygen, a condition of cell stress termed hypoxia. As prostate cancer progresses, dividing cells form a solid tumor, leaving cells in the innermost region of the tumor with no way to get oxygen and nutrients. Hypoxic stress ultimately causes cells to break away from the original tumor and spread across the body—metastasis—to escape the stressful situation that a lack of oxygen induces. When faced with what is essentially a suffocating environment, the cells release signals that ultimately use 2OST to break them free of the oxygen-poor tumor and allow them to find nutrients elsewhere in the body.

Figure 1 outlines the specific chain of events between the onset of hypoxic stress and metastasis. As oxygen runs lows and the cells begin to suffocate, they unleash a series of signals called reactive oxygen species (ROS). Like a car key that starts a car, these signals start production of the enzyme that is required to initiate metastasis (2OST). When the signals reach the gene that produces the 2OST enzyme, the gene is turned on, producing much 2OST. The high levels of 2OST allow cells that were suffocating inside the tumor to metastasize, breaking away and finding oxygen and nutrients elsewhere in the body.

**ROS Signals and 2OST**

As mentioned, the cell releases ROS signals under stressful cell conditions. But many ROS signals activate in response to a lack of oxygen. Which of these signals actually turn on production of 2OST? I investigated three different ROS-activated signals, which I've labeled A, B, and C. I propose that these three signals play a crucial role in increasing the amount of enzyme and producing metastasis.

Figure 2 illustrates how each signal could turn on enzyme production.

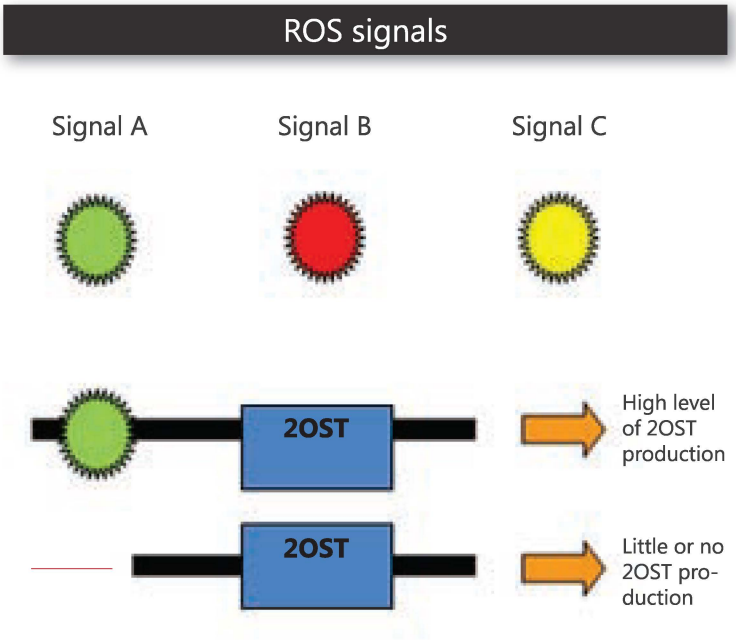



*Figure 2. ROS signals and 2OST.*

*If the signal can bind, a large amount of the enzyme will be present in the cells, whereas if the signal cannot bind—because the binding site is either deleted or destroyed or the signal is simply not in the cell—the level of enzyme present will decrease. So which signal plays the biggest part? Which of these signal deletions causes the largest decrease in the amount of 2OST?*

**The Experiment**

My research aims to investigate at the molecular level how cell stress promotes production of 2OST, ultimately initiating metastasis and driving prostate cancer to the point of lethality. Previous research by our lab has determined that ROS signals resulted in high 2OST production (Ferguson and Datta, unpublished). I wanted to ask which ROS signals (A, B, or C) start 2OST production. I addressed this question in two ways: (1) by eliminating the actual signal through a process termed RNA interference (RNAi) and (2) by eliminating the spot where the signal binds to the enzyme to activate it. Figure 3 illustrates method 1 and its results.

**Results**

The RNAi experiment showed a significant decrease in 2OST enzyme levels. When RNAi eliminated signal A in the cell, the amount of 2OST decreased by 84% compared with that in the control metastatic cell. Eliminating signal B caused a 74% decrease in 2OST enzyme, and eliminating signal C caused a 66% decrease. Such a significant decrease in 2OST levels suggests that all three signals play an essential role in 2OST production. The next step for these experiments is to determine to what extent each signal was eliminated to yield such a reduction in 2OST enzyme level. The second method of testing by deleting the binding site of the signal as opposed to the actual signal is currently under way and serves to verify the results of the first method of testing. Instead of deleting the ROS signals from the cell, I prevented the signal from binding to and turning on the gene by deleting its binding site. I created five different cell variations, each missing different binding sites. I am currently examining how these binding site deletions affect 2OST enzyme levels in the cell.

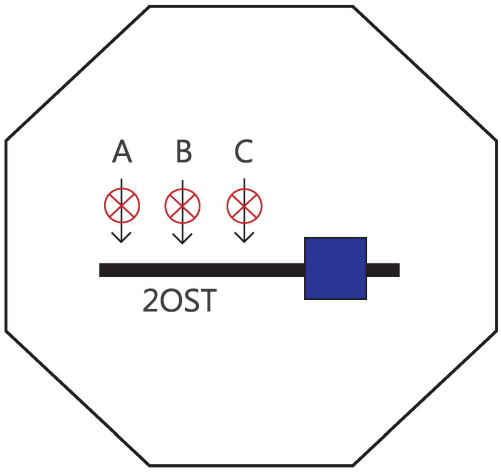
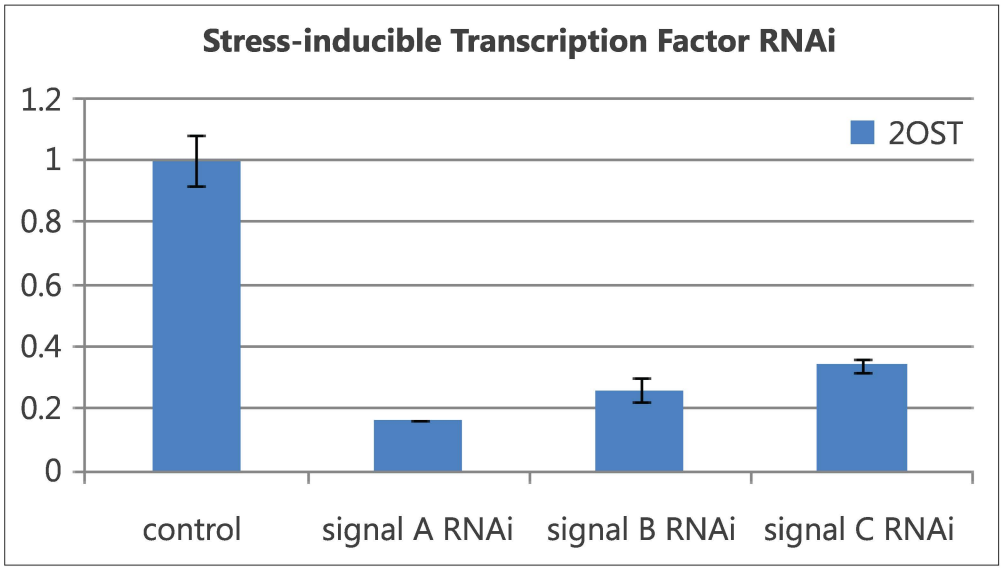



*Figure 3. Method 1: Deleting the signal and examining signal importance to enzyme production. Error bars indicate standard deviation.*



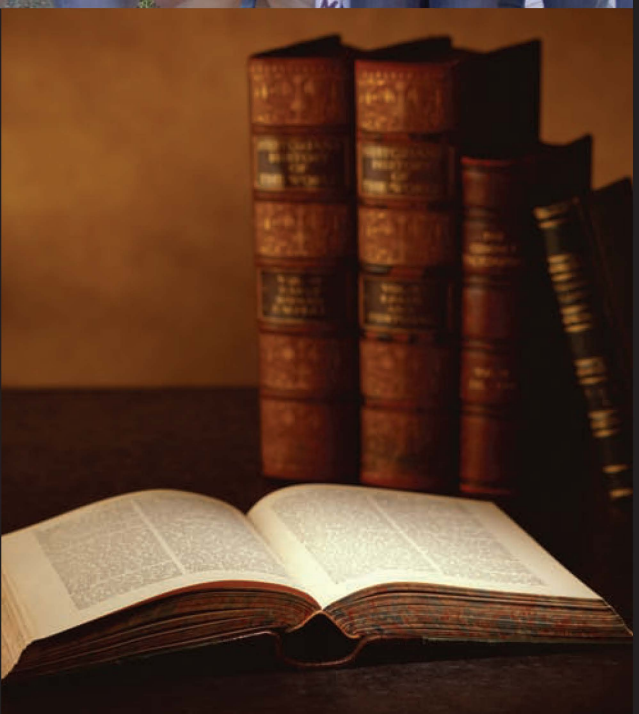

*After deleting each signal, I measured the amount of 2OST enzyme in the cell to determine whether the deletion had a significant effect. Is this signal absolutely necessary to the production of 2OST? Which signal deletion causes the largest decrease of 2OST in the cell?*

**What It All Means**

*Understanding why 2OST becomes highly expressed will help scientists develop diagnostic tools to predict the onset of metastasis.*

Understanding which ROS signal turns on 2OST may mean that we can use the presence of that signal in a patient's tumor as a test for whether that tumor is about to become metastatic and thus deadly. Fully understanding the signal that activates 2OST could let us develop drugs to block that signal. Perhaps then we will be able to prevent 2OST from accumulating and thus prevent a patient's tumor from becoming metastatic. By exploring the role of the cell stress hypoxia in prostate cancer, we hope to be able to halt progression of the disease. ■

# RESEARCH

## Undergraduate Research

## It's Not Just for Scientists

### What is Research?

- Research is the systematic pursuit of knowledge aimed at discovery.
- Research is a detailed study of a subject to discover new information or reach a new understanding.

### Research is rewarding in many ways...

- Intellectual satisfaction comes from creating knowledge. Why just memorize what someone else has discovered? What do YOU want to know?
- Research provides "soft skills" like independence, time management, teamwork, and communication skills.
- Research advisors often become life-long mentors.
- Participating in research allows you to join a professional network of colleagues.

## Discover the Possibilities!

**Start a project as a second-semester freshman or sophomore and join the Undergraduate Research Scholars Program your junior or senior year!**

**Research is a powerful resume builder!**

**For more information and an application, visit http://ugr.tamu.edu**

TEXAS A&M UNIVERSITY

# Glassworks

ALEX HLAVINKA

*In communication, simplicity is often the most productive and accessible mechanism for ensuring a strong, secure delivery that is mutually understood. This exchange of ideas need not take place solely with words and gestures. What is communication without understanding?*

In the mid-1950s, a disconnect frustrated many composers of classical music as they were surrounded by the "incomprehensibility, dullness [and] outright ugliness" that was the 12-tone system of composition, a method in which a composer uses all 12 pitches of the chromatic scale before reusing a particular pitch.[1] In this musical scene, composers who used the minimalist style emerged as a reaction against the rigid technical and perceptive features of modernism in music, especially the 12-tone technique. Among these composers was Philip Glass, whose music features common minimalist aesthetic premises. The minimalist movement represents a turn in the American classical music tradition. The importance of this shift is the further separation of American classical music from its European roots that were still exploring the 12-tone technique. Thus, Americans were making significant contributions to music composition and theory for broadcast. Glass's work sounds through a medium that encourages communication among music, performer, and listener as a result of his minimalist techniques.

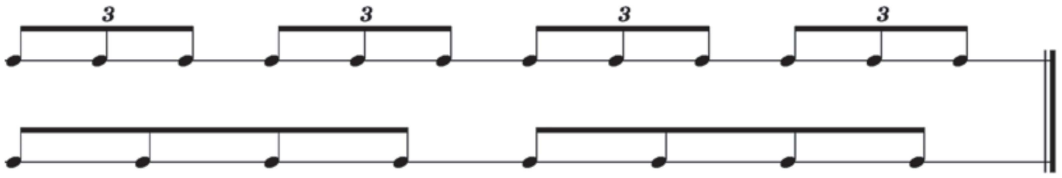


Figure 1

Philip Glass was born in 1939 in Baltimore; at the age of 15, he was admitted to the University of Chicago. At this time, he wrote his first music, a string trio in the 12-tone technique. After graduating from the University of Chicago, he began studying composition at the Juilliard School, and from 1964 to 1966, he studied in Paris under Nadia Boulanger, who helped him reestablish his compositional roots in the "theoretical aspects of music . . . harmony and counterpoint according to strict classical procedures."[2] Music critics associate the style of composition that Glass developed with the minimalist style that began in the 1960s. The pieces that appear around this time feature what Johnson calls the "minimalist technique: a continuous formal structure, an even rhythmic texture and bright tone, a simple harmonic palette, a lack of extended melodic lines, and repetitive rhythmic patterns."[3] His music shares common minimalist features such as a "proneness to let the *process* take over at times," giving time for unconventional harmonic movements to develop and mature.[4] Glass's harmonic progressions rely on distance between pitches. In this compositional style, Glass, as well as other composers of this music, led a "conscious reaction against dogmatic serialism and the repellent effect twelve-tone music had on audiences and performers," hoping to display "'personal expression' or 'inspiration'" to communicate with their listeners.[4] The piece *Glassworks*, written for his ensemble and released in 1981, demonstrates these processes, especially in the first movement, "Opening." The movement, written for solo piano, can be classified as a minimalist process-oriented work.

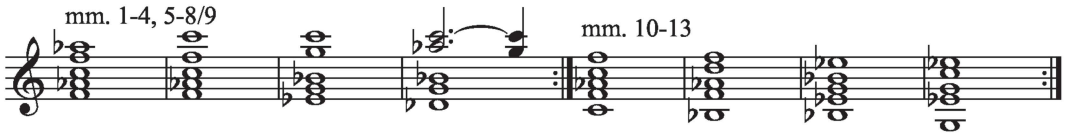


Figure 2

One outstanding feature of this piece is the consistent rhythmic pulsation that gives the piece a solid framework. This pattern, shown in Figure 1, creates *hemiola*, a rhythmic exchange of three notes against two notes within the same amount of space and time, between the right and left hands, that continues throughout the piece. As the piece develops, Glass does not alter this rhythmic figure; it does not become an integral part of the developing motion in the piece. Rather, its constant simplicity allows the composer to creatively focus his and the listener's attention on the piece's harmonic direction. One implication of Glass's compositional technique in this piece is a lack of melodic material. Glass phrases recurring harmonic patterns instead of melodies. The prominence of such rhythmic motifs is rooted in continuity of form "in the shape of an unbroken stream of rhythmic figuration flowing from the beginning of the piece until it ends."[3] In this way, Glass fluctuates chord members in a *tremolando* manner that focuses the listener on the macro experience of harmonic progression.

Rhythm and harmony, two parameters of music, are comparable to fragments when used alone; each requires more than itself to sustain and portray a musical idea. In "Opening," rhythm needs harmony to provide color, and harmony needs rhythm to continue the motion that drives the slow, yet marked, metamorphosis in this piece. In a 1972 interview, Glass noted his frustration with his search for sound and his attempt to maintain structure.[2] The "note-to-note processes arose directly from the basic ideas of additive rhythm and cyclical structuring" that allow for, on the whole, structural ambiguity, as in the "Opening" from *Glassworks*.[2] The piece presents each collection of transformations over a few measures. Glass, for the most part, does not use dynamics—variations in volume—a musical parameter that could help develop greater structural clarity by giving the performer musical "space" to fit in microcosmic ideas within the framework of the piece. Minimalist music, on the whole, steps away from the idea of structural "goals," or climaxes in phrases or pieces. The "Opening" has no discernible structure and, through listening, one understands the lack of teleologically oriented movement.

The form's ambiguity also refocuses the listener onto the harmonic development through the *da capo* instruction at the end of the piece. As the performer approaches the end and returns to the beginning, listeners do not perceive the shift because it is similar to previous shifts. At the same time, one would question how the piece, in its constant rhythmical movement, can end smoothly. Placing the piece into context is crucial; in the album version of the work, horns provide a seamless *attaca* into the next movement, forcing the end of this prelude. To the early minimalist composers, structure—yet not form—was important.[2] These composers understood the importance of a stable framework on which to meld the various musical parameters. This structure is a product of the a greater desire "to achieve purity and clarity—and especially the audibility which was its most particular manifestation . . . [through] simplicity."[2]

Embedded onto rhythm is the harmonic interface. The harmonies in the piece do not always fit into the rules of normative progression as defined by common practice. Rather, this piece exhibits the idea

Corbis Images

Philip Glass

that minimalism is "gradually [turning] into a kind of 'new tonality' . . . the deliverer of American music from the pharaoh of Academic Serialism."[5] In this Glass excerpt, one finds simplicity in mostly consonant harmonies. The listener is drawn to F as a key center. Figure 2 presents a harmonic survey of the first harmonic idea. In the first four measures of the piece, the listener is taken from an F-minor triad down to an E-flat-major chord with an added sixth. The last sonority in the first collection is interesting. One finds a revoiced $C^{7\flat 9}$ missing its third, serving as a pseudo-dominant of F. Listening is essential to establishing this identity; our ears teach us that functional dominant harmony should resolve to the tonic, or key center. In this way, the listener anticipates the resolution to F from C. Because the voices move with relatively conjunct motion, movement in an individual voice by step, change is less perceptible and harmony melds in the composer's attempt to create a seamless shift, a characteristic of minimalist music. Voices continually move conjunctly to create new harmonies that do not fit into common-practice harmonic progression. Without functional progression, sonorities are emancipated from harmonic function. This freedom may come from Glass's thought that "he had been over-preoccupied with structure . . . the limitations of treating sound itself as merely the means by which structure was to be articulated increasingly concerned him."[2] To achieve his desired aural effects, Glass does not use formal structural components.

One constantly feels the tradeoff between development and stasis as the piece slowly transforms itself into new harmonies. The process is foremost an unhurried, smooth development of harmony. Steady rhythm and lack of formal structure promotes the evolution of the harmonies produced by triadic harmonies related through smooth voice leading.

*As opposed to the 12-tone works that historically precede this style of composition, Glass's work exhibits more unified comprehensibility that brings listeners closer.*

In America, less tolerance of serialism existed.[4] Many, including Glass, felt 12-tone music's sensual intangibility. Listeners wanted music that they could understand. Composers such as Glass sought to bring communication back to music. Audiences can feel a simple, two-way conversation as opposed to a cold presence of harsh sounds of 12-tone works. The accessibility of this music may bring a more intimate feeling of joint perception to both listener and performer. ■

*Listen to the musical accompaniment of this article at: http://explorations.tamu.edu*

**References**

1. Jones RT. Introduction. In *Music by Philip Glass*, pp. vii–xvii. New York: Harper & Row, 1987.

2. Potter K. *Four Musical Minimalists: LaMonte Young, Terry Riley, Steve Reich, Philip Glass*. Cambridge: Cambridge University Press, 2000.

3. Johnson TA. Minimalism: aesthetic, style, or technique? *Music Quarterly* 1994;78(4):742–773.

4. Struble JW. *The History of American Classical Music*. New York: Facts on File, 1995.

5. Bernard JW. Minimalism, Postminimalism, and the resurgence of tonality in recent American music. *American Music* 2003;21(1):112–133.

# Heightened Forensics

## Does Suspending Meat-Baited Traps at Different Heights Matter?

JESSICA MARTIN AND JOSHUA BOLANOS



### Introduction

Does suspending meat-baited traps at different heights matter in the world of forensics and entomology? Do insects collected from exposed and putrefying meat yield data that will be significant to investigators? When forensic professionals come across an uncommon situation in the field, they experiment to determine whether the occurrence was an effect of nature or if foul play was involved. It is then up to them to do research or perform experiments to determine what occurs naturally. This process can sometimes strain investigators.

*Our goal was to design an experiment that would yield solid results for professionals while saving them time and resources.*

This experiment sought to determine height's effect that height has on decaying meat as it pertains to entomology. We sought to answer three important questions: Does height above the ground affect the genus richness and relative abundance of genera collected in meat-baited traps? Does distance from an open water source affect the diversity of genera collected in meat-baited traps? Does seasonality (as represented by average weekly temperature) affect the genus richness and relative abundance of specimens collected in meat-baited traps?

*Typical meat-baited trap: This shows the insects and putrefying meat that collected in the trap. Lick Creek Park, College Station, Texas.*

### Background

Many specific variables affect the behavior patterns of insects. The environment and its condition both have a large effect on insects' behaviors, as does the condition of their attractor. The variables range from things as simple as the scent, color, texture, content, and size of the attractor to larger-scale variables such as the climate of the environment.

*Forensic entomology is the study of arthropods in the context of law enforcement and the courts.*

More specifically, forensic entomology as it relates to using arthropods to solve crimes is usually referred to as medicocriminal entomology or forensic medical entomology. Medicocriminal entomology is useful in determining how long a corpse has been dead.

When an entomologist is called to a crime scene, he or she must know what insect behaviors occur naturally under certain conditions and what is unusual. Typically, most insects found at crime scenes consist of blowflies and their larvae. However, many forensically important beetles also exist. Upon examining the scene, the entomologist collects many species of blowflies and other insects to examine later in the lab. The entomologist will then determine what stage of the life cycle the insect is in (for the fly, stages include egg, larva, pupa, and adult) to determine how long the victim has been dead, as well as other variables.

*If an entomologist comes across insects that do not occur naturally or colonize in that specific area, one assumption may be that foul play is involved. The goal of the experiment was to determine the factors that affect the colonization of meat suspended above a surface as a way to provide data and emulate a situation that may occur in the field.*

To execute our experiment, we used a passive technique. We set up meat-baited traps and left them out to collect insects. We used chicken liver as an attractant. The traps were designed so that the insects would travel through a funnel to the meat placed at the bottom of the trap. Once the insect entered the trap, escape from the trap was difficult. To effectively collect specimens for our experiment, we set up four contraptions, consisting of several meat-baited traps. We placed two contraptions above a water surface and placed two above a terrestrial surface. We set up all traps at Lick Creek Park in College Station, Texas. We hung the meat-baited traps at different distances from the ground, with two traps at each level. Every week, we retrieved the old traps and replaced them with new meat-baited traps. We labeled the bottles to keep track of their original locations. We recorded our observations and weather data.

### Results

We used the results of the data collection to answer the experiment's questions. Our first question was whether height above the ground affects the genus richness and relative abundance of genus collected in meat-baited traps. Traps hung at the two highest distances above the ground level collected the most specimens.

The second-highest trap collected the most specimens of a single genus. These data demonstrate that height above the ground could affect the relative abundance of specimens collected and the genus richness. Our next question was whether distance from an open water source affects the diversity of genera collected in a meat-baited trap. The bottle with the most diverse collection of genera came from the trap that was hung at the second-highest distance from the water surface, demonstrating that distance from an open water source may affect the diversity of genera collected. The third question was whether seasonality, as represented by average weekly temperature, affects the genus richness and relative abundance of specimens collected in meat-baited traps. The first week that traps were in place, they collected 3,596 insects and the average weekly temperature was approximately 77°F. The number of insects collected and the average weekly temperature decreased all the way to a final week 5 recording of 1,248 insects collected and an average weekly temperature of approximately 62.7°F. Seasonality appears to affect relative abundance. We also found that as the temperature decreased, generally, the number of genera decreased. However, the genus richness was not in direct correlation with the temperature decrease. When the average weekly temperature was 70°F, the trap collected 19 different genera. When the average weekly temperature dropped to 65.5°F, the number of different genera was still 19. We saw the same kind of results when the temperature was 62.7 and 63.7°F. At both temperatures, the number of different genera was 18. Temperature may affect genus richness slightly, but according to our results the effect was not significant.

*Contraption #2 over terrestrial surface. This shows several meat-baited traps at various levels above the ground. Lick Creek Park, College Station, Texas.*

**Conclusion**

Overall, the relative abundance of specimens collected relative to each trap's height above the surface was different when we compared the water ground trap data. This conclusion indicates that for relative abundance, height above any surface matters. The traps at the second-highest level above the surface collected significantly more specimens than those at any other level. The reasoning is unknown and more research to explain the difference is needed. Traps that are located above the ground versus above the water differ significantly in relative abundance. Perhaps the temperature of water normally diminishes at a lower rate than that of the surrounding environment—insect presence is typically related to temperature. Furthermore, our data suggest that height above a general surface affects relative abundance. For genus richness, we found no significant difference in the results in terms of trap heights; therefore, height does not appear to matter in this regard. Height above a surface gave us slight variations in the number of genera collected, but in our data the difference did not appear significant. The astonishing drop in number of insects collected shows that changes in seasonality seem to affect relative abundance. As the temperature decreased, the number of insects collected decreased. Typically, the colder it is, the fewer insects you see; this trend may account for our finding. Whereas the number of insects collected decreased, the overall number of genera collected remained fairly similar throughout the experiment. It would appear that temperature does not affect genus richness significantly.

Our results indicate that suspending meat-baited traps at different heights does matter in the world of forensics and entomology. Our data illustrated that insects exhibit different colonization behaviors at different heights above either an open water source or a terrestrial surface at certain temperatures. We deem our experiment to be a success. We obtained significant results that may benefit professional researchers. Our experiment produced ample data

and is reproducible. If investigators encountered a similar situation, this experiment would indicate what they could generally expect to occur naturally. From the conclusions drawn from the experiment, a forensic or entomology professional may be able to determine whether foul play is involved or if a situation needs further investigation, depending on whether the field observations differ greatly from our results. The experiment should be repeated several times under the same circumstances so that accurate and repeatable results can be verified. ■

**Acknowledgments**

We thank our Field Entomology professor, Dr. John Oswald, for allowing us to proceed with this project in his class, as well as for his guidance and thoughtful critiques. We especially thank our group member Lillian White for her contribution to our research and experiment.

**References**

1. Amendt J, Campobasso C, Gaudry E. Best practice in forensic entomology. *International Journal of Legal Medicine* 2007;121(2):90–104.

2. Borror DJ, White RE. *Peterson Field Guides: Insects*. New York: Houghton Mifflin, 1970.

3. Byrd JH, Castner JL. *Forensic Entomology: The Utility of Arthropods in Legal Investigations*. Boca Raton, FL: CRC, 2001.

4. *Entomology and Death: A Procedural Guide*, edited by Neal H. Haskell. Mahwah, NJ: Forensic Entomology Associates, 1990.

5. Johnson NF, Triplehorn CA. *Borror and DeLong's Introduction to the Study of Insects*. Belmont, CA: Brooks/Cole, 2004.

6. Kirkpatrick RS. Nocturnal light and temperature influences on necrophagous, carrion-associating blow fly species (*Diptera: Calliphoridae*) of forensic importance in Central Texas. Thesis. College Station, TX: Texas A&M University, 2004.

7. Whitworth T. Keys to the genera and species of blow flies (*Diptera: Calliphoridae*) of America north of Mexico. *Proceedings of the Entomological Society of Washington* 2006;108(3):689–725.

# Silver Taps

STEVEN OLIVIER

The bells of Albritton
ring in my ears
as they sing songs
in this night of tears.
A brother has fallen
the lights are dimmed
and all we hear
are these sorrowful hymns.

Dressed in midnight
soldiers of tomorrow
we stand together
comforting sorrow.
We gather as one
and we feel the chill
of the cool breeze blowing
while all stands still.

The songs die out.
Hearts quietly pound.
In the deepest distance
we hear a sound.
Click-clack-click
of stomping heels
breaking the silence
that we all feel.

Moving slowly
to a haunting cadence
approaching with
undaunted patience,
the steps grow louder
with each little pop.
Each little clack
until they stop.

In front of our men
what stand like ghosts
hold the world still
with nothing to boast.
Then these ghosts
hold out their arms
point them high
and release their alarms.

Fire! Echoing
into the night,
Fire! the sound
is loud and bright.
They send their message
to God most high,
hoping their brother
shall live in the sky.

Fire! Once more
the message is loud.
Hearts have stopped.
Still is the crowd.
All is quiet
but not for long
for the trumpets play thrice
their final song.

Once to the North,
the basin of light
the song has saddened
this beautiful night.
Once to the South
dear Rebel's pride
some cannot hold
their sadness inside.

Once to the West
where the mighty Sun
sets below us
in the horizon.
But never to the East
in solemn sorrow
because for our brother
there's no tomorrow.

Everyone turns
an about face
and heads on back
to their humble place.
Tonight was the night
we said goodbye
hoping our brother's
with God on high.

The bells of Albritton
once again ring
except this time
not a song do they sing.
Its low funeral chime
is simple and dark
enough to pierce
the hardest heart.

Steps on the cobbles
are in cadence quick
hitting the concrete
and smacking the brick.
Humble are we
and be we must,
for there may be the time
they do this to us.

*"Silver Taps in the Snow" / © Cutter Howard*


*For those who are unfamiliar with Silver Taps, I wanted this poem to capture the essence of the ceremony as well as what happens during it. For those who are familiar with Silver Taps, I wanted them to keep the idea close to them. I wanted them to understand how I felt while going through Silver Taps and what it means to me.*

I wrote this poem immediately after Silver Taps in November 2009. As I was standing during the ceremony, the words began to write in my head. I felt that the opening line "The Bells of Albritton" would be a good start for the poem. Hearing our clock tower ring those memorial songs, I thought, set the tone for something so silent and yet so sweet, much like Silver Taps was. I picked this topic because it is one of Texas A&M's most beloved traditions as well as one of my favorite traditions. It shows how Aggies hold reverence dear to their hearts and are willing to come together to honor those who died while trying to graduate. On top of that, the Corps of Cadets also come together and help strengthen the reverence.

I emulated the style of Alfred, Lord Tennyson's poem "The Charge of the Light Brigade" by using onomatopoeia to incorporate the power of the 21-gun salute. My poetic influences include Don Henley (of the Eagles), Shel Silverstein, and other classic rock bands such as Pink Floyd and Billy Joel. Other poets have used this same rhyme scheme before (such as Clement Moore in his poem "The Night before Christmas"), but I thought that creating something lyrical would add to the power of the piece. The rhythm of the poem, I thought, would emulate the cadence set by many Corps outfits for this tradition and keep the poem going fluidly. I also incorporated several Aggie ideas in the poem, such as referring to the Ross Volunteers as "ghosts" and the bell tower ringing. I find that using rhyme may help strengthen creativity by bringing out use of different words that also get the point across. The lyrical structure, I believed, would help create something memorable from something so ritual or would help someone not familiar with the tradition to understand it better.

Another inspiration for me to write this poem was another Aggie poem, "The Last Corps Trip." This poem was recited at every Bonfire and Muster. Many ideas came from the poem ("I've seen them win, I've seen them lose, but I've never seen them quit"). I wanted to write something that would affect Aggieland the way that poem did. I hope that this poem would. I admit that the only research I used for this poem was experience and folklore, but I believe that this is a poem about perspective and feeling as opposed to a science project.

I titled this poem "Silver Taps" because this poem is about the tradition of the same name. The poem does not explain the ritual by its name, but I felt that the poem would explain the title. Also, the idea of taps on the concrete and performing a haunting cadence in memory of a fallen student plays an important part in the poem, so the title also refers to the taps. ■

# Teaching English Language Learners

## An Evaluation of Effective Instructional Strategies

REBECCA R. McPHERSON



Education majors seeking English as a Second Language (ESL) certification learn strategies intended to prepare them to better instruct English language learners (ELLs) in their mainstream classrooms. However, when a fifth-grade student from China moves to Texas with little formal instruction or prior preparation in English, how is this student actually treated? How do his teachers respond to having a new student who has difficulty communicating in their language? How do teachers help this student, and when do they simply ignore him?

*As a future classroom teacher, I was interested in observing and documenting the journey that beginning ESL students go through when they first arrive in the United States.*

To view public school from the perspective of a new ELL, I spent 6 months observing David, a 10-year-old who had just arrived from China, throughout his semester-long stay at an intermediate school in a small Texas town. My purpose was to identify which instructional strategies were most helpful to ELLs in order to help current and future teachers understand how they can best teach ELLs in their mainstream classrooms.

The National Center for Education Statistics reported that during the 2003–2004 school year, schools provided services to 3.8 million ELLs—nearly 11% of all students in the United States. Texas alone had 700,000 ELLs, 16% of all students, who received ELL services.[1] The types of services that ELLs typically receive are either bilingual education, including dual-language programs, or ESL support programs, which range from dedicated ESL classrooms to placing ESL students in mainstream classrooms with ESL-certified teachers. As the number of ESL students continues to increase, the number of mainstream teachers who will be working with beginning ESL students will increase as well.[2] Yet many studies indicate that "educating children of racially, culturally, and linguistically diverse backgrounds is a major challenge for school systems across the country. For too many of these students, American education has not been a successful experience."[3] If we are to improve the overall educational experience for this growing group of students, we must understand where the gap between students' needs and educational practices occurs.

In this article, I will examine strategies that mainstream teachers use for instructional purposes, specifically in math and science, when working with ELLs. These strategies include (1) using sheltered English, (2) offering visual supports, (3) maintaining high expectations, and (4) incorporating cooperative learning opportunities. For each strategy, I will include supporting research, as well as what I observed while shadowing one ELL.

### Student Profile

David (I have changed this student's name to protect his privacy) is a 10-year-old who moved to the United States from China as a fifth grader. He came with his mother, who teaches English as a foreign language at a university in China and was granted the opportunity to conduct research at a Texas university for 6 months. David was enrolled in public school as soon as he arrived in late January 2009. Although David had been taking English classes in school since the first grade as part of the standard curriculum in China, he still had a difficult time communicating in English and was considered to be a beginning-level ELL.

### Strategies: Sheltered English

Moving to a different country; trying to acquire a second language; and learning new math, science, and history concepts may sound like impossible tasks. However, ELLs face these challenges every day. "Teachers must be able to not only teach their subject matter, but they must do so in a way that makes the concepts and content comprehensible to ELLs in their classrooms."[4] This is why teachers in mainstream classrooms must implement sheltered-English strategies when teaching ELLs. This concept simply means that teachers should pay careful attention to the language that they use. For example, "the teacher can simplify the language by shortening selections, speaking in present tense, and avoiding the use of idioms."[5] Teachers can also simplify explanations of terms, repeat or rephrase to aid understanding, and speak more slowly and clearly than they otherwise would. Each of these simple strategies greatly aids in supporting the ELL's ability to communicate, increase proficiency in English, and ultimately learn the required content.

*Exemplar*

While observing David throughout his semester, I found it interesting to see how the teachers who implemented sheltered-English strategies could not only communicate with him fairly well but also teach him new academic concepts in English. For example, even while teaching the whole class, David's math teacher took special care to make sure that he understood her. Not only did the math teacher seat him closer to her so that she could check his comprehension as she presented the lesson, but she would also slow her rate of speech, take time to repeat or rephrase anything that he seemed to not understand, and make sure that he did not get behind while taking notes. The math teacher explained every assignment to David individually and constantly checked on him during independent practice. She established an open relationship with David by taking time to get to know him, which allowed him to feel comfortable asking her for help. The teacher would also write out word problems in simplified "math language," in which she set up the math equation and formula for him so that he didn't have to read the English text to demonstrate his knowledge of the mathematical concept. This was the only class in which David was always paying attention, taking notes, and following along during lecture. This teacher was determined to not let language barriers obstruct learning. By the end of the semester, David was even learning new mathematical concepts, mastering grade-level content, and scoring well on slightly modified exams.

After observing David perform so well in this positive environment, observing him in science provided a drastic contrast. In this class, his teacher used few sheltered-English strategies and thus could barely communicate with David. She was convinced that "he doesn't understand anything" and therefore that he could not learn anything about science without a Chinese translator. She stated that "he doesn't understand it, and I don't think it would make a difference at this point whether I made it more simple in English or if there are absolutely no words at all." Therefore, instead of listening or participating in lessons, David read a book. Instead of learning the meanings of new vocabulary words, he merely copied

down the correct answers from the answer key. Instead of engaging with a simple project in which he could have learned some basic but essential concepts, he took standardized practice tests that he could not read. Overall, watching him do nothing, learn nothing, and gain nothing from this class was most disheartening. By the end of the semester, still almost no communication existed between David and his science teacher. She stated, "I still don't think he understands what I'm saying. . . . He'll say something, but I won't understand. It's kind of garbled."

**Visual Supports**

In conjunction with sheltered-English strategies, teachers should support language and content learning with nonverbal ways of explaining or demonstrating. Using visual supports—including realia (real-life objects), photographs, videos, and other forms of multimedia technology—can greatly aid in an ELL's understanding, as well as enhance the lesson for all students in the mainstream classroom. Also, "the teacher can present information and ask for students to respond through the use of graphic organizers, tables, charts, outlines, and graphs."[5] In using visual supports, "the balance will change as the children get older, but appealing to the senses, colours, sounds, and movements will always help the pupils to learn."[6]

*Exemplar*

Because of being surrounded by an unfamiliar language, David would often visibly stop paying attention during the school day. This was his science teacher's constant complaint about him—his tendency to retract into his own world. Throughout the semester she made comments such as the following: "he'll just stop working"; "he doesn't want to do anything that he doesn't understand, which is most things"; "he just zones out." However, ELLs by nature become exhausted after listening to lectures or reading text in English without visual supports to help them understand. Therefore, anytime the lecture used visual supports, he immediately paid better attention. For example, during math class, David was attentive when his teacher used the SMART Board for class notes; she would draw pictures, diagrams, and use the board's interactive lesson feature to help him understand. The math teacher's perception of David was completely different; she commented that "he's always paying attention. He's always taking notes and following along with me during lecture."

**High Expectations**

Research in language acquisition suggests that, for students to learn a language, they must be exposed to *comprehensible input*. Stephen Krashen, who originally proposed this idea in 1985, defined comprehensible input as "understanding input that contains structures at our next 'stage'—structures that are a bit beyond our current level of competence."[7] That is, students make the most progress in learning their new language when the material that the teacher presents is slightly beyond their capabilities. Therefore, "input that is either too simple or complex will not help a learner make progress in spoken English."[8] Consequently, teachers must understand what their ELL is capable of by assessing that student's level of language proficiency in each domain of language: listening, speaking, reading, and writing. This approach makes it possible for teachers to teach material that is developmentally appropriate yet challenging to that student. Teachers must also believe in their students' ability to learn; teachers should furnish the needed supports while still maintaining high expectations.

*Exemplar*

ELLs are inherently capable students because they must perform in two cultures and two languages. They are gifted. They can and do learn the English language and expected grade-level content when they receive support and encouragement from teachers who challenge and engage them. David thrived in his math class, which expected him to work on the same projects and homework assignments as the other students (with slight modifications). Because of the high expectations that his math teacher set for him, he accomplished a great deal in a relatively short time. However, in his science class, which expected him only to read a library book, copy down answers on worksheets, and circle random answers on tests—a class with no expectation for him to learn anything—he accomplished nothing. Someone told him that he couldn't, and so he didn't.

**Cooperative Learning**

"It is difficult to overestimate the importance of community-building in encouraging students to open up and contribute to conversations and discussions. For this reason, games and activities that simply focus on building class atmosphere can be a crucial part of the class."[9] In addition, "they can draw pictures, compose songs, rhymes and chants, play games (word, card games), act out drama together."[6] In short, teachers should give students many varied opportunities to interact with their peers to create a classroom environment in which students are not afraid of possible failure but instead are allowed to learn naturally.

*Exemplar*

For students in some cultures, interacting with peers instead of authority figures is more comfortable. If interacting with adults was intimidating for David, interacting with peers was just the opposite. Even before he could form complete sentences, David was eager to talk to his classmates. If he couldn't think of how to say something in English, he would continue talking in Chinese. Fortunately, many of David's teachers saw his willingness to talk to his peers and used

that to his advantage. His teachers would often pair David with a classmate or ask one of the students to explain to him how to do something. In David's math class, the teacher would often allow the students to work in groups to practice answering problems, work on projects, or check homework assignments. They also had time to play math-related games together. During such times, I saw David interact in English the most. Not only did he get the opportunity to practice asking questions and making statements about the math concepts, but he got to converse socially with the other students. The only thing better than seeing David learn from his peers was getting to see his peers learn from him as well. While observing David run laps during physical education class toward the end of the semester, I began talking to one of the boys who was sitting on the sidelines, encouraging the others. When I asked whether he knew David, he told me, "He doesn't speak much English and I don't speak any Chinese, but we're friends. Keep going, David! You can do it!"

## Conclusion

Teachers have an influential role in the lives of ESL children. As I observed David throughout the semester, I was amazed at how the same child was so completely different depending on which classroom he was in. Through my observations I realized how much educators affect the lives of their students. Every teacher has the duty to learn how to best address each student's needs, including those of ELLs. By using sheltered English, supplying visual supports, maintaining high expectations, and incorporating cooperative learning opportunities in mainstream classrooms, teachers can enable ELLs to reach their full potential. ■


## Acknowledgment

I thank Dr. Edie Cassell, of the Department of Teaching, Learning, and Culture in the College of Education and Human Development, who helped guide and encourage me throughout the research and writing process.


## References


1. National Center for Education Statistics. *Public Elementary and Secondary Students, Staff, Schools, and School Districts: School Year 2003–04* (NCES 2006-307). Washington, DC: U.S. Department of Education, 2006.

2. Youngs CS, Youngs GA Jr. Predictors of mainstream teachers' attitudes toward ESL students. *TESOL Quarterly* 2001;35:97–120.

3. National Research Council. Effective instructional practices for language minority students. *Educating Language Minority Children.* 1997. Available from http://www.maec.org/instprac.html.

4. DelliCarpini M. Teacher collaboration for ESL/EFL academic success. *The Internet TESL Journal* 2008;14(8). Available from http://iteslj.org/Techniques/DelliCarpini-TeacherCollaboration.html.

5. Bradley KS, Bradley JA. Scaffolding academic learning for second language learners. *The Internet TESL Journal* 2004;10(5). Available from http://iteslj.org/Articles/Bradley-Scaffolding.

6. Bas G. Integrating multiple intelligences in ESL/EFL classrooms. *The Internet TESL Journal* 14(5). Available from http://iteslj.org/Techniques/Bas-IntegratingMultipleIntelligences.html.

7. Krashen S. *The Input Hypothesis: Issues and Implications.* New York: Longman Press, 1985.

8. Noonan FJ. Helping EFL students improve their spoken English. *The Internet TESL Journal* 2005;11(7). Available from http://iteslj.org/Articles/Noonan-Spoken.

9. Venema J. Discussions in the EFL classroom: some problems and how to solve them. *The Internet TESL Journal* 2006;12(12). Available from http://iteslj.org/Techniques/Venema-EFLDiscussions.html.


# Measuring Mechanical Stresses in Super Magnets

CHRISTOPHER BENSON

*What is required to answer some of the greatest scientific mysteries in history? High-energy and particle physicists agree that large particle accelerators, also known as atom smashers, must be constructed to answer fundamental questions of how the universe works.*

Answers to deep physical questions may allow great progress in scientific understanding and technological development, which could affect the lives of everyone. These colossal particle accelerators, the largest of which is the Large Hadron Collider (LHC) in Geneva, Switzerland (17 miles in circumference and 570 feet underground), are necessary because answers to these fundamental physical questions lie in the scattered subatomic debris from highly energetic particle collisions that the accelerators create. However, acquiring the experimental data needed to test the beautifully elegant theories of high-energy and particle physics will require building larger and more powerful particle accelerators to increase the particle collision energies to unprecedented levels. This endeavor will allow scientists to probe deeper into the workings of subatomic structures, thus unlocking greater potential for discovery.

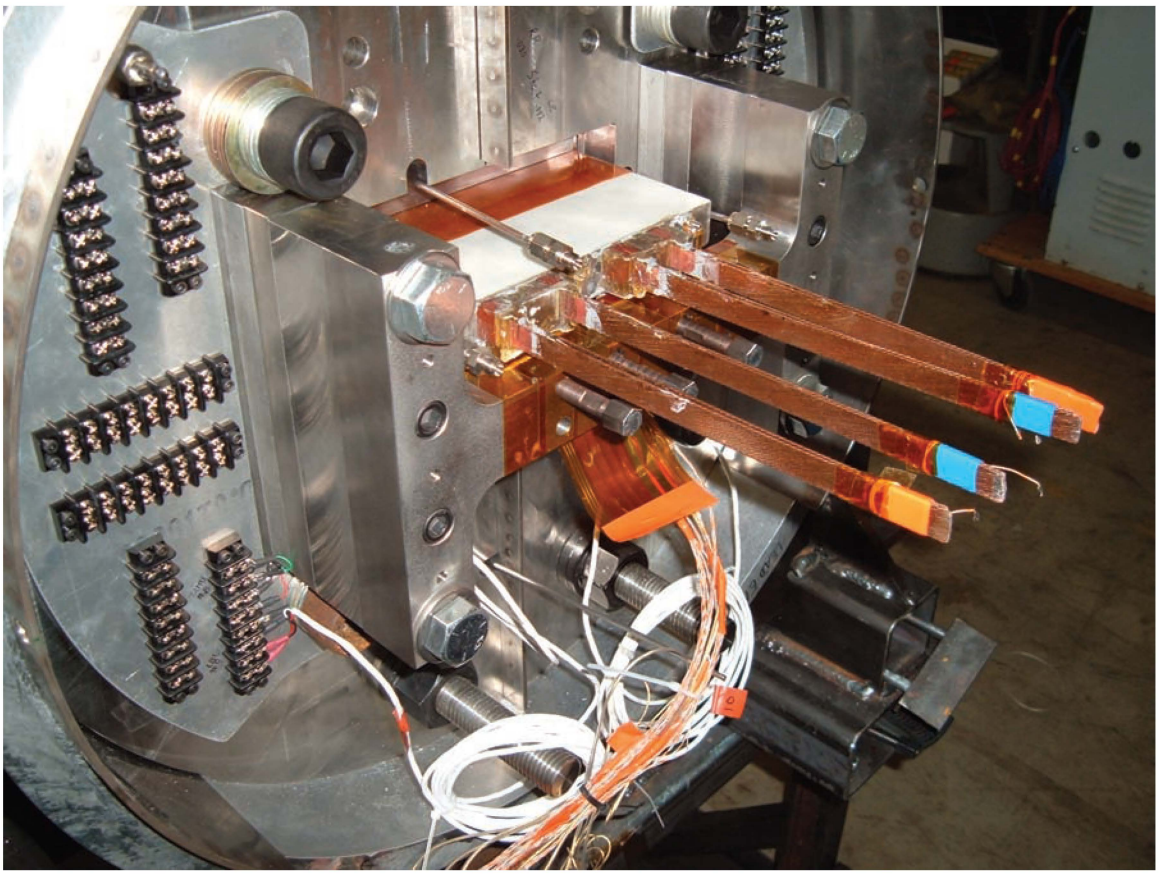
**Introduction**

The Accelerator Technology Research Lab at Texas A&M University is conducting research aimed at increasing particle collision energies of future accelerators. This approach involves designing, building, and testing a series of next-generation superconducting dipole accelerator magnets. Particle accelerators use dipole accelerator magnets to accelerate two beams of particles in opposite directions around enormous circular accelerators. The powerful magnetic fields that the magnets generate bend the beams around the circular path so that they can be accelerated by special radiofrequency cavities every revolution—similar to cars on a racetrack. This process accelerates the particles to extreme velocities, approaching the speed of light. The two beams can then be steered into each other, creating highly energetic particle collisions. However, for the particles to reach velocities greater than the current 99.9999991% speed of light that the LHC achieves, the maximum magnetic field of the magnets must be increased. This is the main goal behind the "super magnet" research at Texas A&M: to increase the maximum magnetic field while keeping the design budget friendly.

Although the final magnet has yet to be completed, by improving previous prototype designs and using computer modeling, the final product exhibits much potential. Compared to the maximum magnetic field that the current most powerful accelerator, the LHC, produces—8.3 Tesla—our magnet, TAMU 5, is projected to reach a maximum magnetic field of more than 14 Tesla.[1] This value is equal to 331,000 times the strength of Earth's magnetic field. With a maximum magnetic field of this size, if these magnets are installed in an accelerator similar to the LHC, collisions energies could be more than doubled at a relatively reasonable cost.

**Stress Management**

One of the most important problems to overcome in designing a superconducting magnet is properly managing internally induced mechanical stresses that the extreme magnetic forces, also known as Lorentz forces, cause. These forces occur inside the magnets during operation. From high school physics, recall that the magnitude of the magnetic force is proportional to the current flowing in a wire. Because the TAMU magnets use superconducting cables, which have no electrical resistance below a certain temperature, the cables can accommodate approximately 13,400 amperes of electrical current in a cross section of only 21 $mm^2$. This figure is astronomical compared with the 0.015 amperes required to stop a human heart. This process creates unimaginably strong repulsive forces between the coil packages that can measure more than 1 million pounds. Because these forces induce mechanical stresses near the maximum strength of modern materials,



care must be taken during the design process to maximize structural efficiency.

The Accelerator Research Group has approached this problem by using a unique "block coil geometry" design. Shown in Figure 1, our design is proven to decrease the mechanical stress on the outer windings from stress that the inner windings exert. This design increases the amount of electrical current that can flow in the cable because the maximum electrical current is roughly inversely proportional to the mechanical stresses on the cable. Therefore, to maximize the magnetic field, we must minimize the mechanical stresses on the windings.

This design works similarly to how a multistory building transfers the weight of the upper floors around the lower floors by diverting the load through the walls. If not for the walls in buildings, the weight of the building would be resting on your head, which would certainly decrease your performance. Our magnets work much the same way. The mechanical stresses that the inner windings induce (indicated by the red arrows in Figure 1) are transferred around the outer windings. This process effectively decreases the stress at the outer windings, thus allowing them to operate at a larger current and therefore produce a larger magnetic field. If the piers and beams did not exist, the outer windings' performance would drastically decrease, greatly reducing the overall performance of the magnet. This pier-and-beam system is critical to managing the mechanical stress in our superconducting magnets.

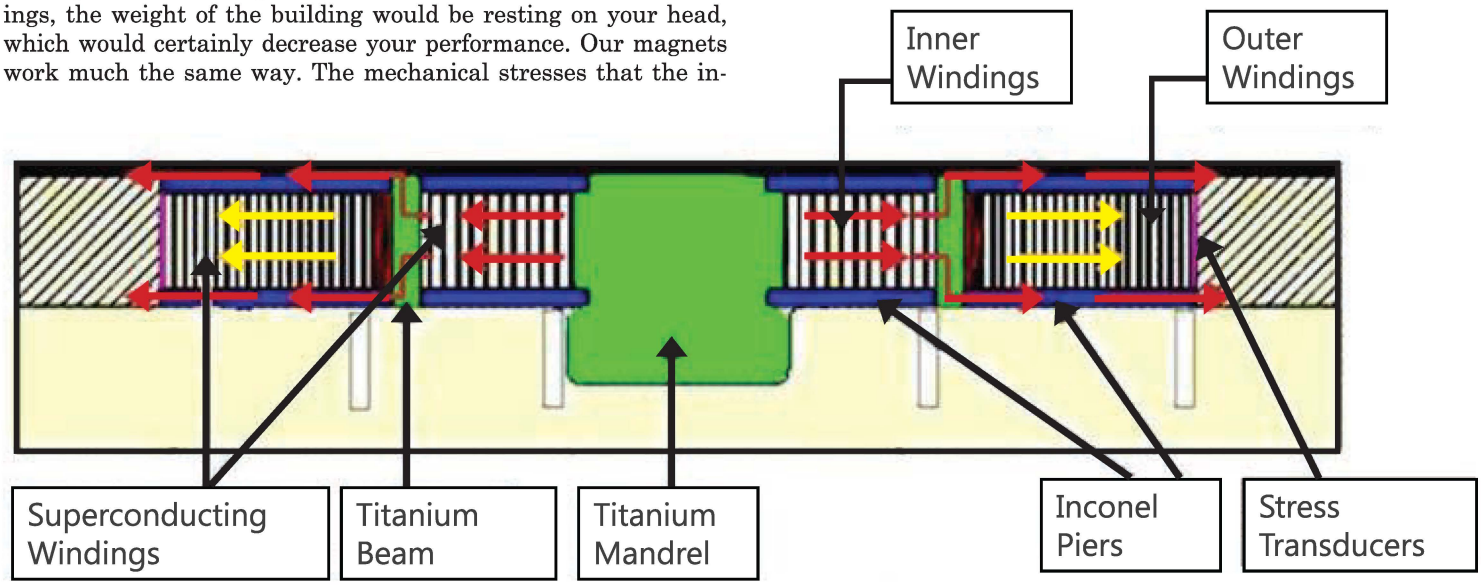
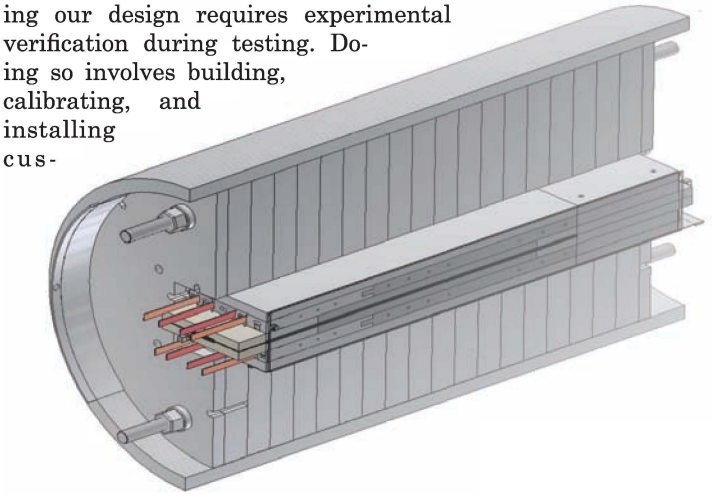



*Figure 1: Cross sectional view of a superconducting coil package. Red arrows indicate the induced Lorentz stresses from inner windings being transferred around outer windings.*

**Stress Transducers**

The pier-and-beam system offers a means of controlling the mechanical stresses in the magnets, but validating our design requires experimental verification during testing. Doing so involves building, calibrating, and installing custom stress transducers (pressure sensors) to measure the mechanical stress at certain locations inside the magnet. As Figure 1 shows, a point of interest lies on the outer edge of the outer windings. The transducer installed here will measure the maximum stress that the outer windings experience. Comparing the measurements to computer models will allow us to verify that the pier-and-beam system is behaving as designed. If the pier-and-beam system is working properly, the transducer will measure the stresses induced only from the outer windings. (These stresses are shown by the orange arrows in the figure.) However, if the stress management systems are not working properly, the transducer will measure a much larger stress because the piers and beams are not properly diverting the loads.



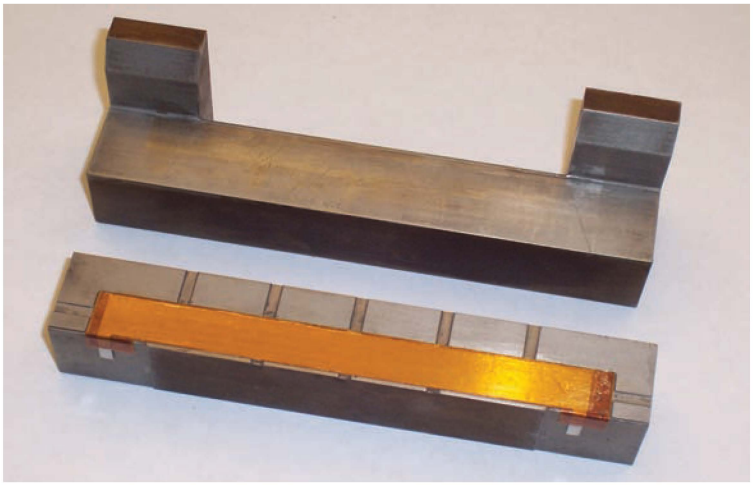
Much research has been done to improve the repeatability and reliability of these transducers. Each transducer consists of five 1/1,000-inch-thick (0.001") stainless-steel foils sandwiched between 0.001"-thick high-strength polymer layers also known as polyimide. The entire transducer is bonded together using a high-performance epoxy, with a total thickness of approximately 14/1,000 of an inch (0.014").

The inner workings of the transducer rely on measuring a change in capacitance between the stainless-steel layers. Capacitance is a geometrically dependent quantity that is inversely proportional to the distance between two objects. For the transducers, we are interested in measuring the average capacitance between the stainless-steel layers. When the transducer is installed in the magnet, the polyimide between the stainless-steel layers will be compressed as the stress being measured increases, thus bringing the stainless-steel layers closer together. This process will slightly increase the capacitance. After calibration of the transducer, the measured capacitance will directly correspond to the average stress seen on the transducer, which is also the same stress felt at that location in the magnet.

Although the transducer's inner workings seem simple, the fabrication and calibration processes have proven challenging. Earlier methods of fabrication and calibration had many problems that resulted in poor transducer repeatability. New fixtures have been designed and built to resolve most of these issues and provide necessary control, which reduces variability and uncertainties during fabrication and calibration.

*Fabrication Process and Improvements*

To achieve the accuracy and precision necessary to produce



repeatable stress transducers, new specialized fixtures have been developed to handle specific jobs. These fixtures control variables throughout the fabrication process that cause variations in thickness, texture, or layer alignment from transducer to transducer.

The first step in fabrication is to texture the polyimide and stainless-steel layers. Texturing supplies a rough surface to which the epoxy can properly bond. One of the most notable improvements has been a new texturing fixture. This fixture allows even texturing of the polyimide and stainless steel without causing pin holes, which destroy the transducer by allowing short circuits when under pressure. Previously, this step was done by hand, which produced crude and unreliable transducers.

Next, each polyimide layer is cut using a template and razor blade. Each piece is inspected under a microscope to check for tears or pin holes. Razor blades are also replaced regularly to ensure clean cuts. To improve this step, a new cutting fixture has been designed and built. This new fixture allows for a cleaner and faster cutting.

After the polyimide cutting and stainless-steel foil preparation, the entire package is then assembled by hand with a newly designed alignment and epoxy-curing fixture. Because each transducer is only 14/1,000 of an inch thick, precise placement of these layers during assembly is crucial. The new alignment and epoxy-curing fixture provides the necessary control, which reduces variability and uncertainties. The new fixture houses multiple attachments that act as guides during the assembly process. Also, all the surfaces are machined to extreme precision (0.001" dimensional tolerance), which creates an exact fit for the transducer during assembly and curing. To put these improvements in perspective: we have been able to reduce the variation in thickness across the transducer length by 70% from earlier methods. This means the thickness across the length varies by only 0.0002" instead of 0.0008". Also, by using the assembly guides provided on the new fixture, we have been able to decrease the overall epoxy thickness by 70% as well. The decrease in overall epoxy thickness increases the sensitivity of the transducer, which is a favorable characteristic. Because both results were observed in the two constructed transducers, the system is achieving increased repeatability. However, to verify that these results are consistent and that the trends hold, we will fabricate additional sets of transducers.

*Calibration Process and Improvements*

Improvements have also been made to the calibration fixtures and procedures. This part of the transducer production process is important because it relates the measured capacitance to the load, that is, stress, on the transducer. If the transducer is not properly calibrated, the data are meaningless.

All the calibration tests take place in the same testing fixture. To ensure uniform loading during testing, the testing fixture has been remachined to a flat surface. To simulate the stresses in the magnet, the transducer is then loaded in a press in incremental steps from 0 to 5,000 pounds per square inch (psi).

The calibration procedure is then done in two phases. The first phase consists of pressure cycling (0–5,000 psi) the transducer five times at room temperature (65°F) and three times while submerged in liquid nitrogen (–321°F). Tests are done at liquid nitrogen temperatures to facilitate understanding the transducer behavior at the extremely cold temperatures that will exist inside the magnet during operation (–452°F [4.2 Kelvin]). The magnet must be held at –452°F by liquid helium to maintain the temperature required for superconductivity. During testing, the capacitance and pressures are recorded to track the behavior, which yields a calibration curve.

The second testing phase will occur after the transducer goes through a heating cycle in an oven. This heating cycle simulates a magnet epoxy curing cycle that the transducer will experience once installed in the magnet. This process offsets all the previous calibrations by an unpredictable amount. After the oven heating cycle, the transducer will be tested by the same methods described in phase one. By increasing the repeatability of our transducers, we hope to be able to observe a similar calibration offset in each transducer.

## Summary

In an effort to increase the particle collision energies of future particle accelerators, the Texas A&M Accelerator Lab is taking on the challenge of developing new superconducting dipole accelerator magnets. These magnets incorporate new stress management techniques, such as the pier-and-beam system, to divert stresses around outer windings, thus allowing for a larger maximum magnetic field. However, to verify that our stress management techniques are working, custom stress transducers are used to measure mechanical stresses at critical locations inside the magnet. Because the fabrication and calibration processes required to make these transducers have proven to be a nontrivial matter, new fixtures and methods have been developed to increase the repeatability and reliability of these transducers. On the basis of observations and completed testing, our newest transducers have shown increases in repeatability. Additional transducers are being constructed to verify these conclusions and will be installed in a magnet being built during the fall of 2010.

Overall, advances in accelerator technology are important to everyone because they influence many technological developments in other areas. Technology developed to improve our magnets could one day improve magnetic resonance imaging technology, cryogenics, and many other areas. Even though atom smashing may not directly affect your everyday life, you can be certain that the technology and scientific understanding spawning from accelerator research will. ■

## Acknowledgments

I thank Dr. Peter McIntyre and Dr. Al McInturff for their formative guidance throughout this project. I also thank Andrew Jaisle, Trey Holik, and the Accelerator Research Group for their many hours of help. This project would not have been possible without them.

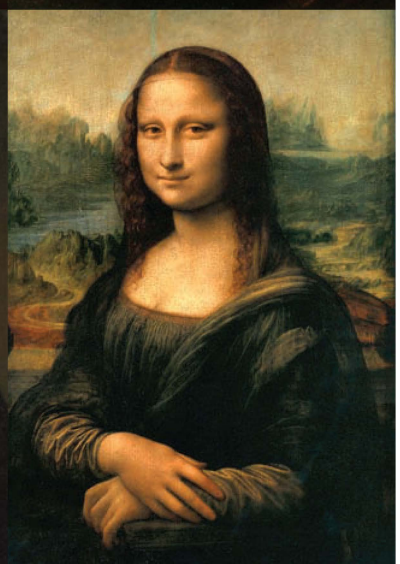
## References

1. McIntyre DP. *New Technology for Future Colliders*, p. 48. College Station, TX: Texas A&M Research Foundation, 2007.

2. Ragland B. Capacitive stress gauges in model dipole magnets, p. 24. In *Physics*. College Station, TX: Texas A&M University, 2009.

3. Siegel N, Tommasini D, Vanenkov I. Design and use of capacitive force transducers for superconducting magnet models for the LHC. In *International Conference on Magnet Technology (MT15)*. Beijing, China: LHC Project Report, 1998.

4. Goodzei CL, Anerella MD, Ganetis GL. Measurement of internal forces in superconducting accelerator magnets with strain gauge transducers. *IEEE Trans. Magn.* 1989;25(2):1463–1468.



# The "Right" Way

REBECCA RHODES



Imagine that you have just stepped through the doorway of the National Portrait Gallery in Washington, DC. Before you is a maze of hallways, each containing dozens of portraits of notable people in American history. You notice that most portraits show the individuals looking rightward, displaying their left cheek to the viewer. This common orientation is exactly what McManus and Humphrey discovered when they analyzed 1,474 portraits painted from the 16th through the 20th century.[1] Research in cognitive and developmental psychology similarly suggests that aesthetic preferences and drawing patterns are not random but, instead, stem from underlying biases in neuromuscular activity and visual perception.[2]

**Introduction**

Research has attributed drawing patterns, such as the facing of objects in a work of art, to multiple factors: dominant drawing hand, preferred stroke direction, nature of the subject matter, and reading and writing habits. Aesthetic preferences—that is, the preference for a particular orientation of objects in photographs and artwork—have predominantly been attributed to habitual glance curves resulting from reading and writing habits. Another account of aesthetic preference attributes biases to the dominance of one cerebral hemisphere over the other. Understanding how these perceptual patterns originate and the factors underlying asymmetries in drawing direction and aesthetic preference will clarify how our brains interpret and represent visual stimuli.

*The specific aim of our study was to determine whether a relationship exists between the direction in which right- and left-handed people face objects they draw and the direction in which they orient objects for photographing.*

**Background**

*Right is Good, Left is Bad?*

Many previous works have noted the preference for rightward direction in art. This pattern may emerge from a general, universal preference for "right" versus "left" that persists in many mental representations. One can find examples in common language metaphors—a good helper may be our "right-hand man," but a bad dancer has "two left feet." The "right is good" and "left is bad" concept may have evolved through the origin of our language. In Latin the word for left, *sinister*, means "evil," whereas the word for right, *dexter*, means "skillful." These concepts may have become inextricably linked to our concepts of "right" and "left."

Whatever this concept's origin, research suggests that ideas associated with "right" receive more positive attributes than ideas associated with "left."[3] However, Casasanto qualified this finding with the additional observation that the positive emotion associated with one direction versus the other can vary according to an individual's handedness, an idea that he referred to as the body-specificity hypothesis.[4] This hypothesis proposes that individuals prefer ideas associated with the side of space with which they are most familiar—left for left-handers and right for right-handers. Casasanto gave participants in his study similar descriptions of two potential employees, one description presented on the left column and the other presented on the right column of the same page. Participants were to indicate which employee they would

be most likely to hire. Most left-handed participants preferred the employee presented on the left side of space, whereas right-handers preferred the employee presented on the right side. One's handedness influences associations with the left and right side of one's visual space.

*Portraits—The Sitter versus the Artist*

Effects such as those for handedness in Casasanto's study raise an important question for aesthetic preferences in art: is the bias for displaying the left cheek in portraits a result of a preference on the part of the sitter or the artist? If the pose is a result of the sitter's choice, we may infer that people possess an inherent posing preference. However, if the pose reflects the artist's preference, we may expect differences between left- and right-handed artists.

Evidence supporting the first hypothesis comes from a study showing that posing orientation depended on the emotional context that the sitter portrayed.[5] When asked to portray the most emotion possible, such as in a family portrait, the sitters tended to show their left cheek. In contrast, when asked to portray the least emotion possible by posing as an academic scientist, the sitters tended to show their right cheek. The mechanism for this bias may stem from the specialization of the cerebral hemispheres. Because the right hemisphere controls the left side of the face and the right hemisphere is dominant for governing emotional expression, turning the face and showing the left cheek may be a natural way for humans to express emotion.[6]

*Motor Image Theory*

Directional preferences are not limited to facial profiles. Motor image theory accounts for directional patterns observed in objects by asserting that we imagine an object in the same spatial orientation in which we physically interact with it.[7,8] Accordingly, if we are right-handed, our mental image of a coffee mug should be oriented such that the handle is on the right side.

Motor image theory may predict the orientation of a mental image, but the facing direction of a drawn image is most likely the result of additional factors, such as the ease of executing certain movements. In general, both right- and left-handers find limb movements directed outward from the body easier to execute than movements directed inward, toward the body. Also, a glance pattern related to habits of reading and writing may influence a preferred stroke direction. Starting position may also affect the final facing direction of a drawn object. The relative contribution of each of these influences, however, is unclear.

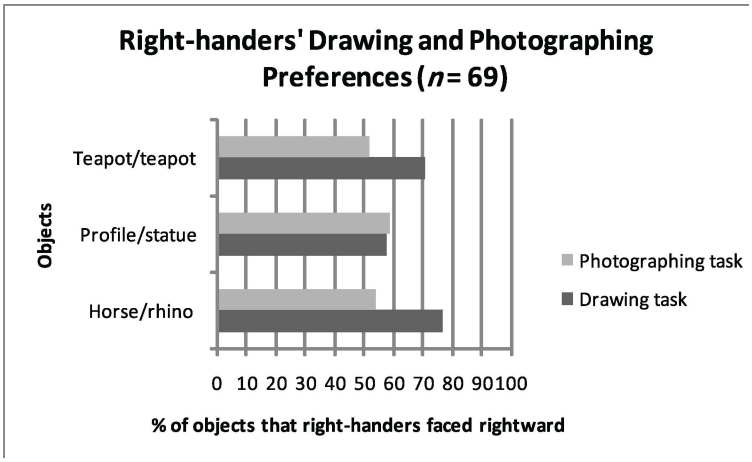
One way to clarify the cognitive factors that influence the facing direction of an object is to determine whether the preferred orientation for drawing an object correlates with the preferred orientation for photographing that object. Motor image theory would lead one to predict a single object-facing orientation in each handedness group, whether for drawing or photographing that object. Alternatively, because stroke starting position and stroke direction affect the facing of drawn objects, drawing and photographing the same object might produce a different facing, resulting in a lack of correlation between drawing and viewing directionality. Our research sought to test these two predictions.

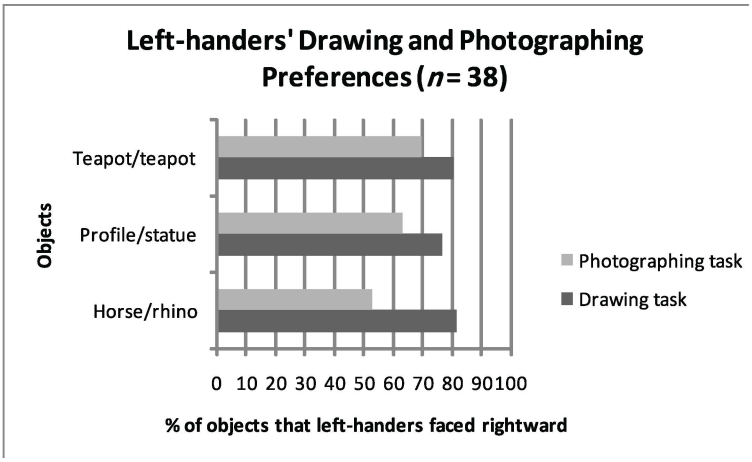
## Method

Participants were native English-speaking college students recruited from Texas A&M University. One group was strongly right-handed ($n$ = 69) and another group was strongly left-handed ($n$ = 38), as determined by self-report. Each participant performed a drawing task and a photographic viewing task. For each participant, the order in which the tasks were given was random. In the drawing task, participants were instructed to imagine and then draw each of the following items: a galloping horse, a teapot, and a profile of a face. The "galloping horse" item was included to examine the preferred direction of implied motion of an object. For the photographic viewing task, participants were given a camera and asked to take the "most aesthetically pleasing photograph" of each of the following objects, selected to correspond to the drawn objects: a wooden toy rhinoceros, a teapot, and a brass bust of the face and shoulders of a person (Nefertiti). The objects to be photographed were placed on a rotating table, and participants were asked to rotate the object into the most visually pleasing orientation before taking its picture. Participants were asked to avoid orienting the object face on. We recorded the objects' final facing direction in each drawing and photograph as either leftward or rightward. For each pair of corresponding items, we computed the correlation between facing direction and photographing direction. We did not test for differences in the strength of the correlation across handedness groups, because this measure was not of primary interest.

## Results

Results from our study showed that most right- and left-handers both tended to photograph and draw the horse and rhino directed rightward. For right-handers, 76.8% of participants drew the horse facing rightward and 53.6% photographed the toy rhino



facing rightward ($r$ = 0.315; $p$ = 0.008). For left-handers, 81.6% drew the horse rightward and 52.6% photographed the toy rhino facing rightward ($r$ = –0.043; $p$ = 0.798). For the Nefertiti statue and teapot, correlation of preferences varied according to object. Right-handers (57.4%) showed a slight tendency to draw the profile facing leftward and, in contrast, photograph the statue in the rightward-facing position (58.8%), which the statue's right cheek displayed ($r$ = –0.064; $p$ = 0.604). Left-handers showed similar tendencies for drawing and photographing. Left-handers tended to draw the profile facing rightward (76.3%) and photograph the statue facing rightward (63.2%) as well ($r$ = 0.088; $p$ = 0.600). For the teapot, right-handers again showed a slight difference in preferences. Right-handers tended to draw the teapot facing rightward (70.6%) but showed a slight tendency to photograph the teapot facing leftward (51.5%; $r$ = 0.110; $p$ = 0.371). In contrast, left-handers showed similar drawing and viewing preferences. Left-handers tended to draw the teapot facing rightward (80.6%) and tended to photograph the teapot facing rightward (69.4%; $r$ = 0.284; $p$ = 0.094).

**Discussion/Conclusions**

Our results only modestly supported the prediction, based on motor image theory, of a consistent orientation preference in drawing and viewing objects. A correlation between drawing orientation and viewing preference was statistically significant only for right¬-handers and for only one of the three pairs of items tested: the horse/rhino.

Motor image theory partially accounts for the trends observed for the teapot item. Both right- and left-handers tended to photograph the teapot in the same orientation in which they would most likely interact with it—with the handle on the right and left side, respectively. However, this theory does not account for the observation that both handedness groups preferred to draw the teapot with the handle on the left. Furthermore, the fact that both handedness groups showed the same tendency in drawing orientation suggests that biomechanical factors, such as stroke direction, are not the predominant influence. Instead, the findings are probably the result of a complex interaction between the mental image formed of an object and the mechanical ease of drawing the object. Future research should specify in the instructions how the objects are to be imagined—for example, participants might be instructed to imagine themselves pouring tea from the teapot or watching someone else pour it. Different forms of interaction with an object may yield different directional preferences.

The only significant correlation for drawing and photographing preference was for the horse/rhino item for right-handers. The findings suggest that right-handed left-to-right readers prefer to conceptualize motion as moving from left to right. Whether right-handed right-to-left readers will show an opposite preference remains unknown. Alternatively, the trend for right-handers may be a result of their preferred starting position. More right-handers (45.7%) started their drawing at the tail of the horse, rather than the head or the middle; that outward stroke movements (left to right for right-handers) are easier to execute may explain why most right-handers faced the horse rightward.

The results for the facial profile item do not support the cerebral dominance theories that accounted for portrait orientation, nor do they reflect Casasanto's body-specificity hypothesis. In our study, both right- and left-handers tended to photograph the statue so that the face was directed toward the photographer's right, with the statue's right cheek displayed. These results suggest that the more influential factor was the amount of emotion participants wanted to convey. The trend for both right- and left-handers was to orient the face in the more serious, nonemotional pose, which may partially be due to the academic setting of this study. Future research should specify the amount of emotion desired in the photograph. In the results for the facial profile drawing, right- and left-handers showed opposite tendencies in drawing the facial profile, which suggests that stroke direction and mechanical ease may have been the more influential factors.

In conclusion, our study findings support our alternative hypothesis and suggest that multiple influences affect how people prefer to orient objects in drawings and photographs; thus, motor image theory alone gives an insufficient account. More research is needed to further clarify which objects are most affected by each influence—for example, stroke direction, handedness, and habitual glance patterns. For objects with implied motion, however, our left-to-right–reading right-handers show a strong correlation between viewing and drawing preference. Further research should include right- and left-handed readers of a right-to-left script to see whether they show a correlation between drawing and visual preference for implied motion in a right-to-left direction. ■

**References**


1. McManus I, Humphrey N. Turning the left cheek. *Nature* 1973;243:271–272.

2. Vaid J, ed. Asymmetries in representational drawing: Alternatives to a laterality account. In *Spatial Dimensions of Social Thought*, edited by T.W. Schubert and A. Maass. Berlin: Mouton de Gruyter. In press, 2010.

3. Gross CG, Bornstein MH. Left and right in science and art. *Leonardo* 1978;11:29–38.

4. Casasanto D. Embodiment of abstract concepts: good and bad in right- and left-handers. *Journal of Experimental Psychology* 2009;138:351–367.

5. Nicholls MER, et al. Which cheek to turn? The effect of gender and emotional expressivity on posing behavior. *Brain and Cognition* 2002;48:480–484.

6. Borod J, Haywood C, Koff E. Neuropsychological aspects of facial asymmetry during emotional expression: A review of the normal adult literature. *Neuropsychological Review* 1997;7:41–60.

7. Viggiano M., Vannucci M. Drawing and identifying objects in relation to semantic category and handedness. *Neuropsychologia* 2002;40:1482–1487.

8. Martin M., Jones GV. Motor imagery theory of a contralateral handedness effect in recognition memory: Toward a chiral psychology of cognition. *Journal of Experimental Psychology* 1999;128:265–282.

# Understanding Grain Growth in High-Purity Niobium

## May Increase Manufacturability and Reduce Cost of MRI Machines

JOSH VERNON

*The need to reduce the cost of magnetic resonance imaging (MRI) and other diagnostic tests increases as the need to reduce health care costs also increases. Basic research can help achieve that goal.*

### Introduction

All metals behave differently because of their natural structure, chemical composition, and physical properties. Researchers can alter these behaviors with mechanical processing, thermal processing, or both. Niobium, for example, is a hypoallergenic metal with several human health applications, such as MRI. MRI machines use niobium electromagnets to take cross-sectional images of a human body. However, niobium is so brittle that it cannot be drawn into wire coils, a weakness that increases the cost of its use. However, as my research shows, changing niobium's grain structure can make the material ductile enough for wire drawing. This process would allow niobium–tin wire coils in MRI machines to be drawn into wire more cheaply than the present method of coating the niobium with tin and then heat fusing separate strands. Currently, superconducting magnet manufacturers use a niobium–titanium composite as a cheaper alternative to the heat-fusing process,[1] but improving ease of use in manufacturing is also important in reducing cost.

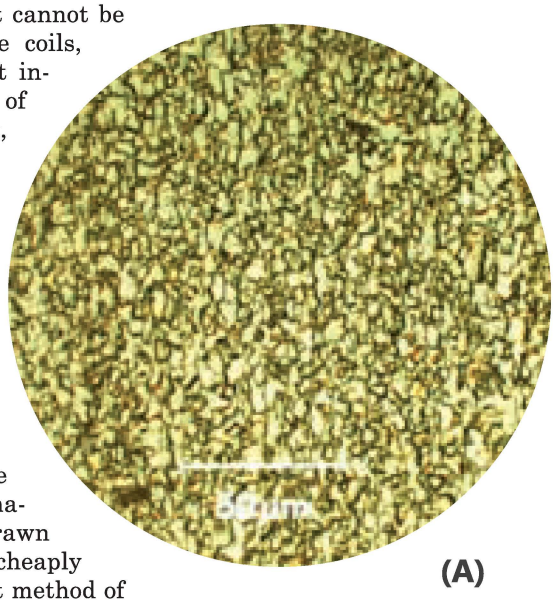



*Figure 1. Reactor-grade (RG) Nb heat treated at 700°C for 1,800 minutes.*

### Experimental Methods

Standards are important in experiments because they allow accurate result comparisons. All methods used in this experiment followed accepted testing standards or were checked through repeated experiments.

### Material Processing

After processing and sectioning the niobium samples, we heat treated specimens at different temperatures for different times to show how the niobium grain structure behaves. This procedure is important because grain structure must grow uniformly to improve the ability of niobium to be drawn into wire to form coils.

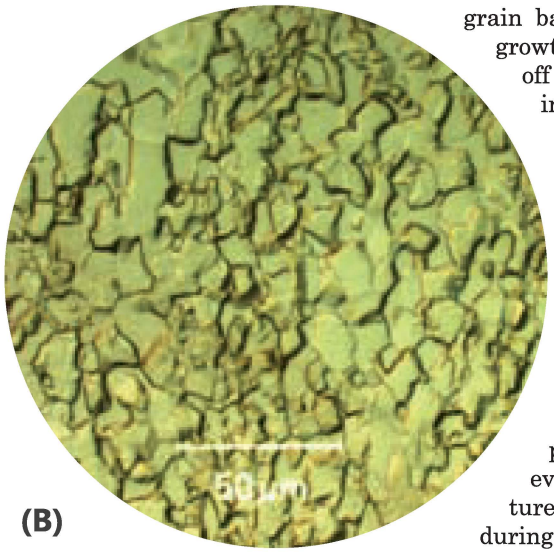
### Recrystallization

Once heat treatment begins, the first result in the heated niobium examples is recrystallization, followed by grain growth. As heat treatment temperatures increase, the time required to cause grain growth decreases. Once our samples entered the grain growth region, we measured the grain.[2–4]

### Grain Growth

At lower temperatures, we saw various grain sizes that appeared in bands in all samples. This kind of growth in bands is not acceptable for niobium's use in wire because variability creates weakness in the wire. However, the samples treated for longer periods and at higher temperatures finally showed grain growth. However, the grain growth still did not occur uniformly. Most samples showed growth bands where certain grain bands grew larger and faster than other grain bands. The difference in grain size in our niobium samples is evident in Figure 1: panel A shows much smaller grains than panel B.

Another problem: As heating time increases, the large grain bands outgrow the small grain bands. Although the small grain bands show some growth, growth tapers off over long heating times. Figure 2 shows this effect and how the grains grow with respect to time at one temperature.




Over time, grains of all metals will grow at a single temperature. However, if temperatures are increased during just one period, grains will also grow. In our sample, the grains actually grew faster if heat was increased rather than if heating time was increased. Figure 3 shows how grains grew with increasing temperature at a constant time, 600 minutes.

### Summary and Conclusions

The longer heat treatments with higher temperatures produced larger grain sizes, a change needed for changing niobium into wire. Although the samples showed different grain size bands (small bands and large bands), this banding behavior diminished at longer times, a result that suggests that constant grain growth could occur and produce uniform bands. More research is necessary to determine whether this behavior disappears and creates a uniform microstructure, but the data here suggest that this outcome is possible.

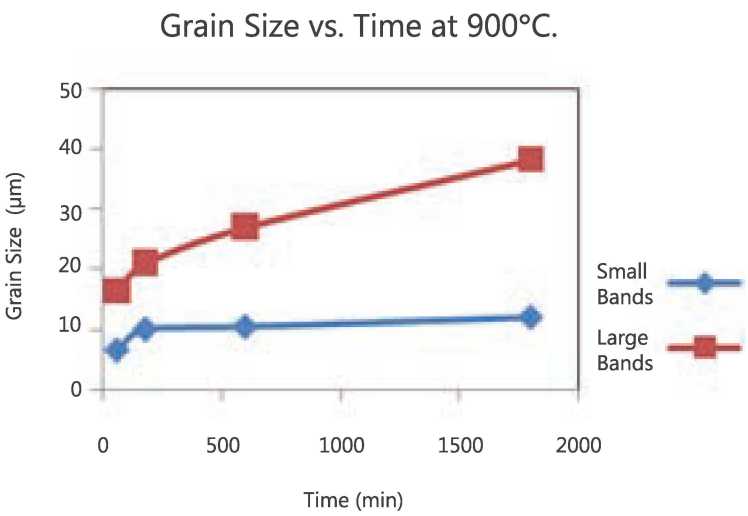



*Figure 2. Grain growth in RG Nb heat treated at 900°C.*

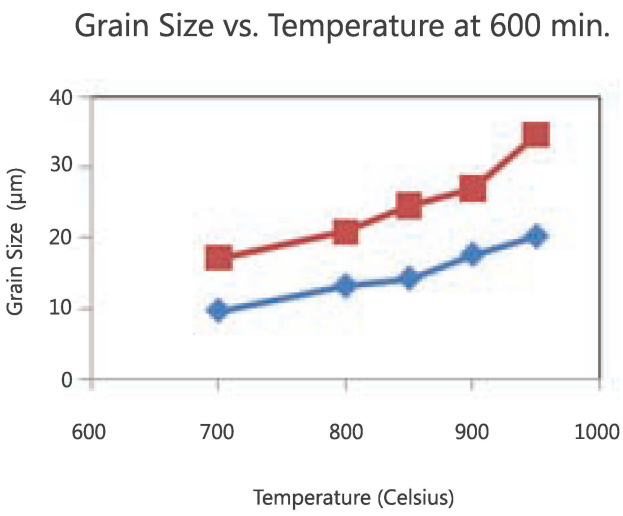



*Figure 3. RG Nb heat treated for 600 min.*

*As the grain sizes increases, so does material ductility.[5] With the increase in material ductility, niobium wire could be manufactured more cost-effectively.*

More analysis on the samples will determine whether pure niobium coils can be manufactured cost-effectively. More experimentation testing at higher temperatures and longer heating times will yield a more complete data set and will also positively determine whether the banding effect disappears. As manufacturers look for more efficient ways to produce MRIs, the processes of changing metals needed in MRI machines may become a viable option to make better materials for these machines and to lower the manufacturing cost. ■

**References**

1. *Superconductors*. HyperPhysics at Georgia State University. 12 October 2009. Available from http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html.

2. ASTM Standard E 112, 1996 (2004)e2. *Standard Test Methods for Determining Average Grain Size*. ASTM International, West Conshohocken, PA: ASTM. Available from http://www.astm.org.

3. ASTM Standard E 3, 2001 (2007). *Standard Guide for Preparation of Metallographic Specimens. ASTM International*. West Conshohocken, PA: ASTM. Available from http://www.astm.org.

4. Antoine C, Bauer P. *Technical Specifications for High RRR Grade Niobium Sheet and Rod for Use in Superconducting Cavities*. Fermi National Accelerator Laboratory. 4 April 2006.

5. Elgun SZ. *Cold Work*. Department of Mechanical Engineering, Farmingdale College. 10 November 2004. Available from http://info.lu.farmingdale.edu/depts/met/met205/coldwork.html.

# Wireless Network Coding

## What Linear Algebra and Cell Phones Have in Common

JESSICA WEAVER

### Introduction

Over the past 20 years, the English language has seen its rights usurped by the world of technology, watching as words such as "iPod" and "smart phone" became staples of our everyday conversations. These gadgets that used to exist just in the science and business worlds have now surged into the commercial arena, throwing themselves onto countless billboards and TV commercials. Items that were formerly luxuries are now necessities. A typical student cannot imagine a day without exchanging e-mails, chatting with friends on a cell phone, or submitting a homework assignment online.

However, as more people are beginning to take part in this wireless society, several problems have surfaced. The rapid growth of cell phone users has created a bottleneck in information transfer. Because only a limited amount of cellular information can be sent at a time, the availability of wireless service is now at risk. In practical terms, this means that the average user does not always have the freedom to make a call or send text messages whenever he or she wishes. Cellular traffic congestion problems are frequent in densely populated cities, such as New York and San Francisco, and at crowded events.[1] Also, the abundance and extensive use of networking applications on smart phones today are depleting cell phone batteries more quickly. Keeping information flowing between cell phone clients requires solutions for these growing issues.

*This article describes new solutions to the challenges facing the current communications systems, on the basis of new techniques such as peer-to-peer wireless networks and network coding.*


### Background

To receive information from a cell phone company, whether this is an incoming call or a YouTube clip, several events must take place. In particular, the requested data must travel from the cell tower to a mobile phone as a radio wave signal.[2] However, to avoid a text message or phone call being mixed up with another customer's, a method for sharing the wireless medium must be in place.

The travel of signals is analogous to a group of runners in a race. Just as each runner is assigned a lane to run in, each signal is assigned a designated "lane." The parallel to a lane for a signal is a particular frequency, or channel, and the collection of these lanes is referred to as the *wireless spectrum*. However, the number of frequencies is finite and restricted.[2] In addition to this limitation, the government allows only certain frequencies of the wireless spectrum for commercial use. As a result, each cellular company has only a certain number of frequencies available for sending cellular signals. Thus, increasing numbers of subscribers in the wireless community can result in congestion. In the scenario where all frequencies of a network are taken, a customer cannot make a call until someone else gets off the line.

One solution to the spectrum dilemma is to offload part of the traffic to another network. This technique takes advantage of the fact that the part of the wireless spectrum that Wi-Fi uses (from Starbucks to college campuses to government buildings) is unlicensed and available to anyone. Cell phone companies can use these alternative frequencies as opposed to committing space on their part of the spectrum, which helps service providers such as AT&T and Verizon reduce congestion by moving data traffic from 3G networks to Wi-Fi networks. Offloading helps cut back on data exchange delay, free up spectrum, and prevent customers from having to wait to place a call or to download information.[2]

### Peer-to-Peer Wireless Networks

Offloading is a possible solution to reducing traffic on the wireless network, but is it possible to take the entire process a step further? What if a customer could avoid going through the cell phone networks, alleviating congestion? One possible scenario is when cell phone users around you already have the movie, picture, or data you wanted to download and could send it over a local Wi-Fi channel, instead of receiving data through cellular providers. Peer-to-peer networking uses this idea. In this setup, one or several servers are used to locate individuals with certain information. Then the content is obtained directly from these individuals rather than from cellular providers' servers.[3] (The legal issues of this scenario are beyond the scope of this article.)

Peer-to-peer networking allows customers to transfer information among themselves; however, this freedom comes with a tradeoff. Because wireless clients are helping each other, their phones are making more data transfers than if each user were obtaining

data through the cellular provider independently. Every piece of information that is sent and received snatches away a little bit of battery life from the cell phone users. If the number of transmissions increases too greatly, customers will often find themselves with a low or depleted battery. In essence, this approach exchanges data congestion for a battery problem.

*A new technique called* network coding *offers a way to reduce the number of transmissions and increase battery life.*

**Wireless Network Coding 101**

Network coding is a technique that can assist peer-to-peer systems. Consider a setting in which a group of clients are downloading a large file (e.g., a song, a video clip) that consists of multiple packets of data from a popular Web site (e.g., youtube.com). Suppose that because of reception problems (e.g., noise, fading), each client is missing parts of the file. In this setting, no one client has all the packets, but the clients collectively have all the packets. A peer-to-peer system allows the clients to exchange missing packets locally instead of asking the base station to retransmit them. This approach reduces the load from the base station and allows the clients to recover the file even if the base station is no longer available.

Figure 1a shows an example of a peer-to-peer wireless information exchange. In this example, client 1 has packets $p_1$ and $p_4$, client 2 has packets $p_2$ and $p_3$, client 3 has $p_3$, and client 4 has $p_3$ and $p_4$. To reconstruct the file, all clients must receive all the packets. Each client can broadcast packets that it has (or a combination thereof) to other clients. One possibility is to broadcast each packet separately. With this solution, client 1 would broadcast packet $p_1$, client 3 would send $p_3$, and so forth. This scheme requires four transmissions.

Network coding is an alternative to this standard solution, and it allows for combining multiple packets of information rather than sending pieces one at a time. For example, packets can be combined through a bitwise "exclusive-OR" operation to cre-

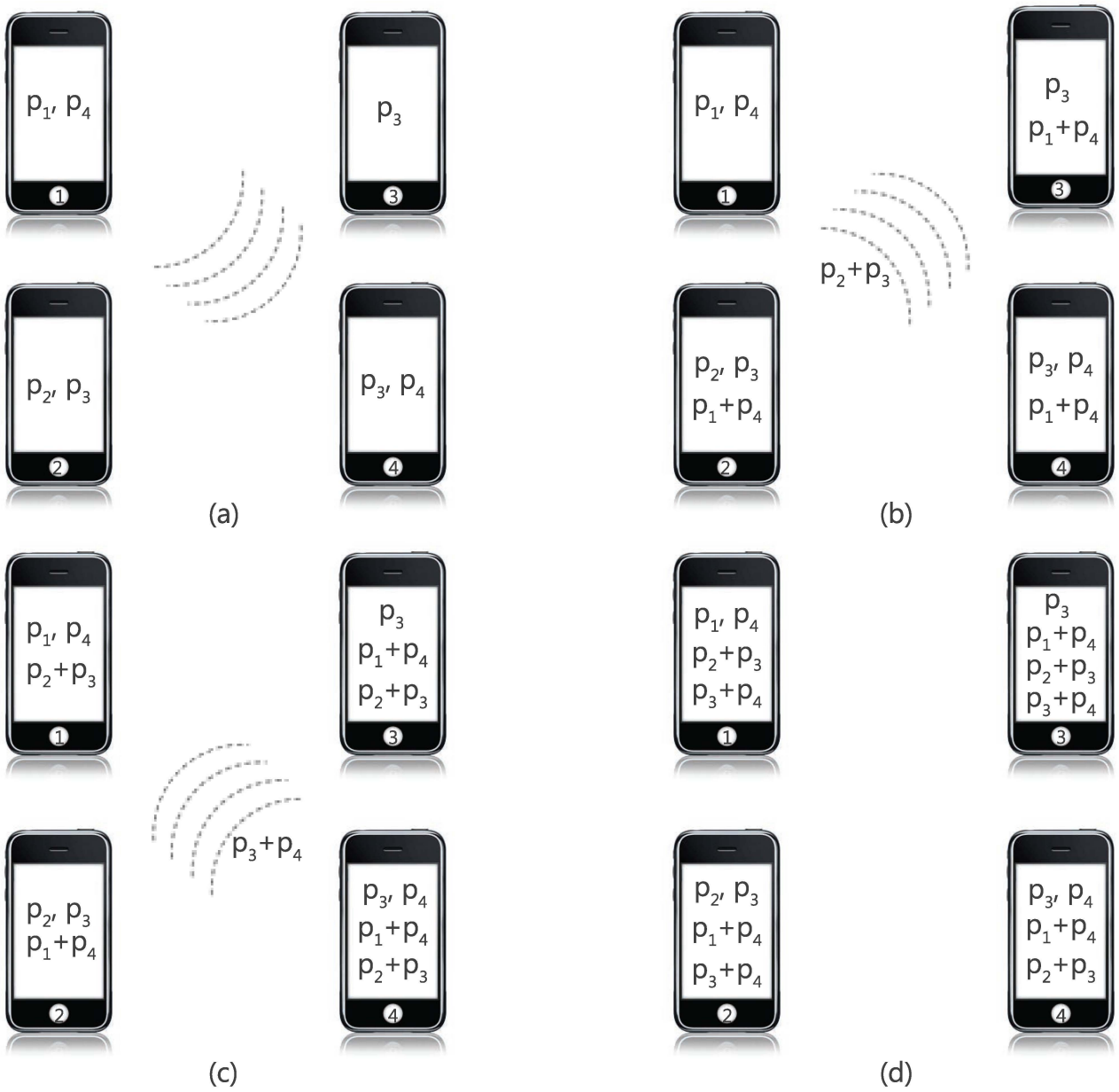



*Figure 1. Wireless information exchange (a) Initial setup, first transmission by client 1; (b) local information available to the clients at the second round, transmission by client 2; (c) local information available to the clients at the third round, transmission by client 4; (d) local information at the last round.*

ate another new, collective packet of information. This new packet is constructed to be the same length as each original packet. Thus, a network coding broadcast sends out a packet that is the same size as one of the original packets.[4]

Figure 1 demonstrates information transfer with network coding. Client 1 begins the exchange by broadcasting the combined packet, $p_1 + p_4$, to the rest of the clients. After this transmission, clients 2–4 gain more linear combinations of the packets (Figure 1b).

This addition of packets is what makes network coding unique. The parts are similar to variables in an algebraic equation that must be solved for. In particular, client 4 knows $p_4$ and $p_1 + p_4$; hence, it can now decode packet $p_1$. At the next round, client 2 transmits a combination of packets $p_2$ and $p_3$ (Figure 1c). Now client 3 can figure out $p_2$ from $p_2 + p_3$, client 4 can figure out $p_2$, and client 1 is still waiting on more information. In the final transmission, client 4 sends out a combination of $p_3$ and $p_4$. This is the final piece of the puzzle that now gives everyone enough information to figure out the complete song, YouTube clip, or whatever was being sent. Figure 1d shows everyone with the final set of information, enough for each client to decode all the data. In the end, network coding reduced the transmission count from four to three.

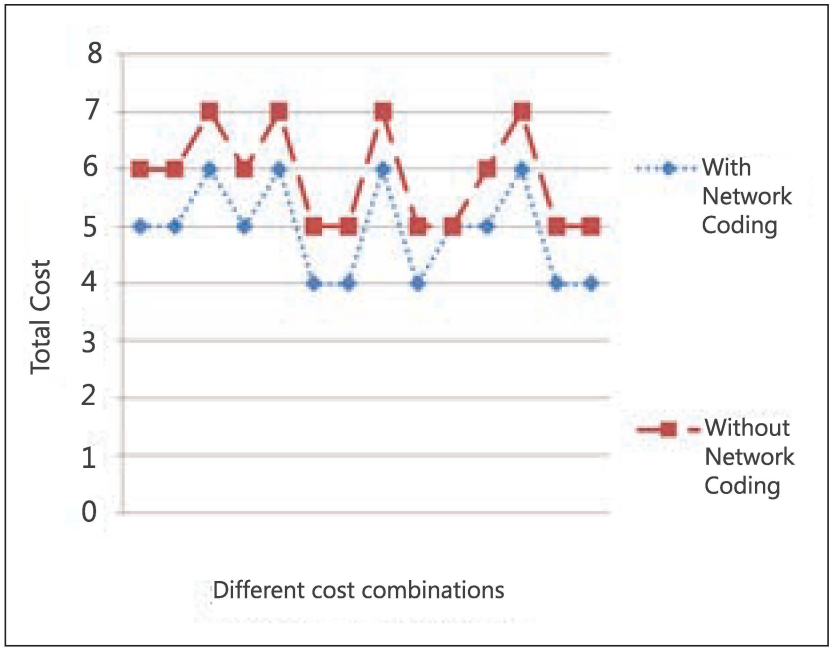



*Figure 2 Cost comparison of network coding versus nonnetwork coding.*

## Research with Battery Life

As the preceding example shows, the network coding technique reduces the number of transmissions by combining packets. This aspect of network coding was discussed in "A Randomized Algorithm and Performance Bounds for Coded Cooperative Data Exchange,"[5] and an algorithm was introduced that showed a way to transmit the new, composite packets more efficiently. However, this article does not take into account that some clients might have constraints on the available battery charge. What if some clients in the group have little residual battery power? Would this make a difference in how the algorithm was executed? My particular research extended this algorithm and considered how battery life would play into the situation. My approach was to associate each client with a transmission cost, which will be taken into account in determining what client needs to transmit at each round.

To minimize the total number of transmissions, we imposed several rules. One rule was that each client had to learn 1 degree of freedom per transaction or the transaction would not be allowed.

To evaluate the performance of the algorithm, I conducted a simulation study. In my experiment, each cell phone client was assigned a number ranging from 1 to 4 on the basis of its battery situation. A "1" represented a fully charged battery and a "4" signified that the battery was almost out. We evaluated two different settings (one that used network coding and one that did not) and compared the resulting number of transmissions. Figure 2 shows simulation results. Network coding always gave us a lower or equal number of transmissions. The simulation results show that the network coding technique can help to reduce the number of transmissions. Even though the change might not seem drastic, network coding is a helpful technique for battery-constrained mobile clients.

## Conclusion

The world of technology is in essence that of a two-sided coin. By welcoming the newest products and devices, consumers must also accept the problems these later versions bring. The battery and spectrum issues that newer cell phones bring have opened up new areas of research, one that brings peer-to-peer networking and network coding in the same arena. By using the information of surrounding users, we will be able to alleviate backup and data congestion. Current network coding algorithms still allow room for improvement, and by anticipating those changes, such as battery life in our case, we will be one step closer to improving the cellular network, keeping pace with the rapid production of cellular devices. ■


## Acknowledgments

I thank Alex Sprintson for his guidance and aid with this research and well as the permission to use certain algorithms. I also thank Graham Booker and Damla Ozgul for including me in this particular research assignment and for assistance with MATLAB programming.


## References


1. Choney S. Is 2010 the year of wireless congestion? 2010 January 4. Available from http://www.msnbc.msn.com/id/34634571/ns/technology_and_science-tech_and_gadgets.

2. Handa A. Mobile data offload for 3G networks. October 2009. Available from http://www.intellinet-tech.com/Registration.aspx?file=Data+Offload.pdf.

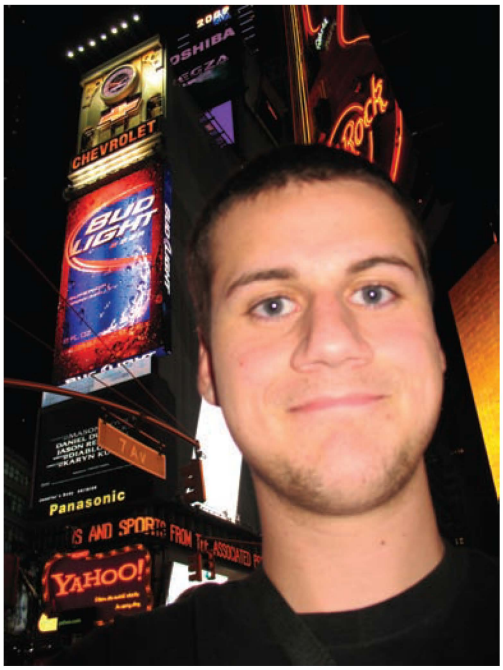
3. Lua E, et al. A survey and comparison of peer-to-peer overlay network schemes. *IEEE Communications Surveys and Tutorials* 2005;7(2):72–93.

4. Fragouli C, et al. Network coding: An instant primer. *SIGCOMM Comput. Commun. Rev.* 2006;36(1):63–68.

5. Sprintson A, Sadeghi P, Booker G, El Rouayheb S. A randomized algorithm and performance bounds for coded cooperative data exchange. In *Proceedings of the International Symposium on Information Theory* (ISIT '10), Austin, TX. June 2010.

**ALEX HLAVINKA** will receive a B.A. in music and a B.S. in economics in May 2011. Hlavinka's article is part of a longer article for a writing-intensive course. He undertook the research and aimed to simplify the material to explain the contrast between Glass's technique and the Post-Webernian dodecaphonic music that dominated the European and American conservatory "classical music scene." Hlavinka hopes to teach music and plans on attending graduate school in order to continue his studies in music.

# ABOUT THE AUTHORS



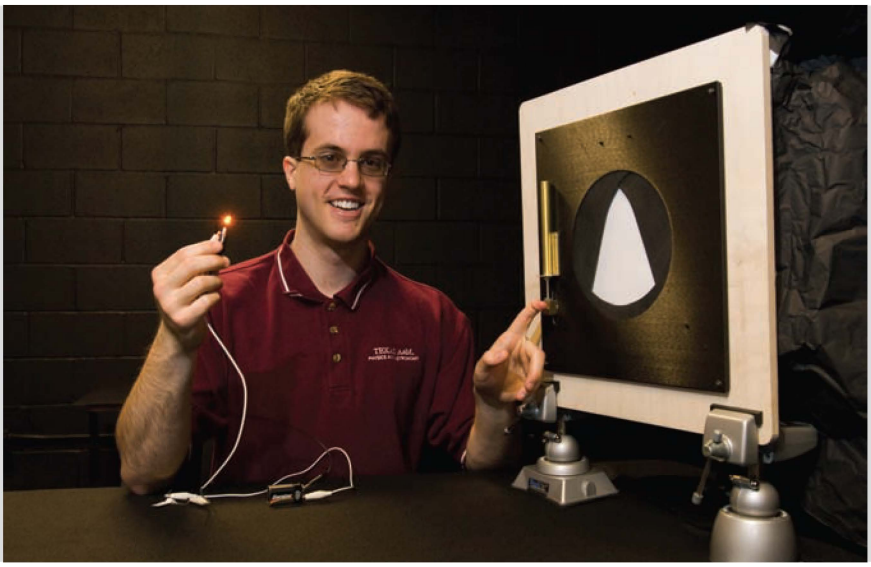

**STEVEN OLIVIER** is a Creative Writing major from Houston, Texas. He is a member of the Corps of Cadets Company E-2, a film critic for *The Battalion*, and a lyricist. He enjoys acting, singing, and playing the bass in his spare time. Olivier plans on becoming either a writer or a journalist.

**JESSICA WEAVER** is a sophomore Electrical Engineering major from Keller, Texas. Weaver became involved in research after a problem presented in a meeting with her lab discussion group. Because of her interest in network coding, she was asked to join a smaller group composed of her professor, Alex Sprintson, a graduate student, and a student finishing up his doctorate to explore possible solutions to the bottleneck in data transfer to wireless devices. Weaver hopes the future allows her to travel for a year or two after graduation, continue her education in graduate school, and/or work as an engineer for Disney.

# THE AUTHORS continued

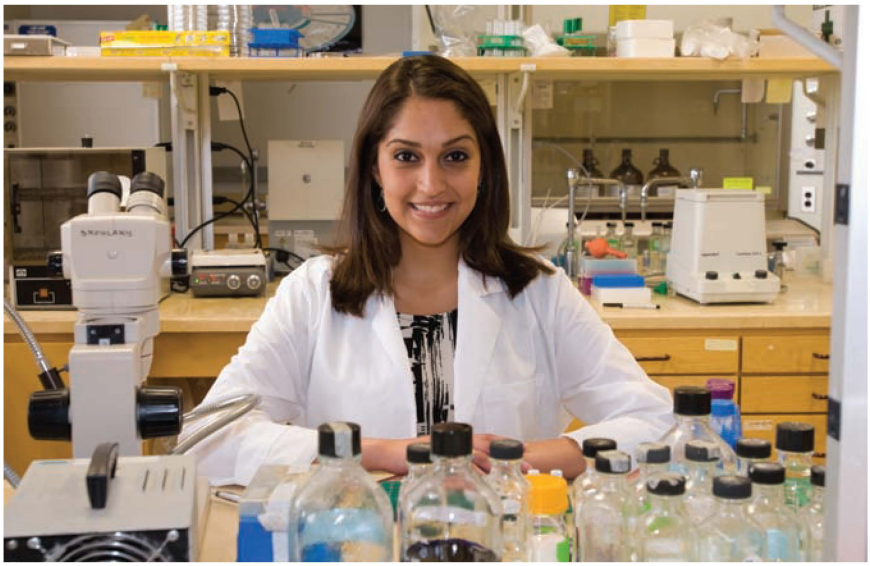
**REBECCA RHODES** is a senior Psychology major from San Antonio, Texas, with a double minor in Chemistry and Mathematics. As a former Architecture major, Rhodes became interested in how different factors influence our drawing preferences and the way we interpret art. She was also interested in seeing how manual preferences and reading/writing habits contributed to those differences. After graduation, Rhodes will be attending the University of Michigan for her PhD in Cognition and Cognitive Neuroscience.

***Honors:*** Foundation Honors, University Honors, Psychology Honors, Honors Research Fellow, Summa Cum Laude graduate, recipient of the Nicole Baxter White Award (outstanding psychology graduate of the year).



**TYLER BEHM** is a double major in Physics and Mathematics from Lawton, Oklahoma. Behm was attracted to astrophysics after watching Carl Sagan's series *Cosmos*. He sought to conduct research in England because of its history of physics discoveries. Behm also felt that the astounding nature of the universe and of recent discoveries in cosmology inspired the mysterious overtone of the introduction. He owes his interest and skills in astronomy research to his advisor. After graduation, Behm will pursue a PhD in Astrophysics that will allow him to build a career at a U.S. national observatory and lead international research projects.

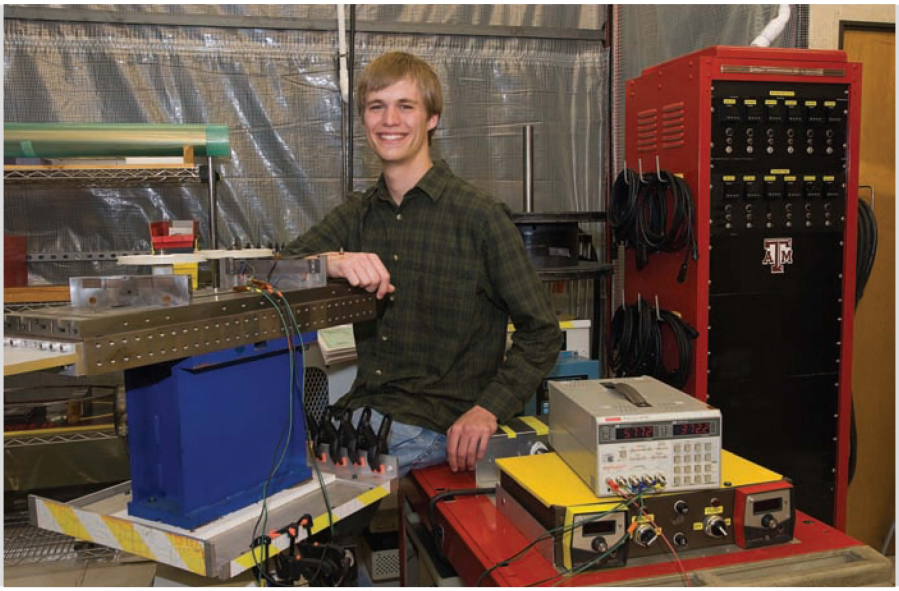
***Honors:*** 2010 Goldwater Scholar, April 2010 TV Premiere on Discovery Channel *Weird or What* (along with Chris Benson); selected as one of 14 students to watch the shuttle liftoff from Johnson Space Center Mission Control.



**MOZHDEH "Mo" MAHDAVI** is a senior Genetics major from Houston, Texas. Mo's article is based on work she did in collaboration with a graduate student, Brent Ferguson, in the laboratory of her advisor, Sumana Datta. Mo's interest in writing, honed by her job at the Writing Center, led her to submit a proposal to *Explorations* based on her research. Mo will be pursuing her PhD in Genetics at SUNY–Stonybrook this fall, hoping to move into neuroscience.

**CHRIS BENSON** is a junior from Houston, Texas, who will earn double B.S. degrees in Mechanical Engineering and Physics. His article is based on the research that he conducts in Dr. McIntyre's Accelerator Technology lab. Dr. McIntyre's lab is developing state-of-the-art superconducting magnets at Texas A&M. Benson felt that the process of developing these magnets, as well as their use, was interesting and worth writing about. He hopes to pursue a PhD in Physics and perform research in accelerator technology and high-energy physics.

***Honors:*** Full scholarship for Fundamentals in Accelerator Physics course at the United States Particle Accelerator School at the Massachusetts Institute of Technology. TAMU Honors Undergraduate Research Fellow. April 2010 TV Premiere on Discovery Channel *Weird or What* (along with Taylor Behm).



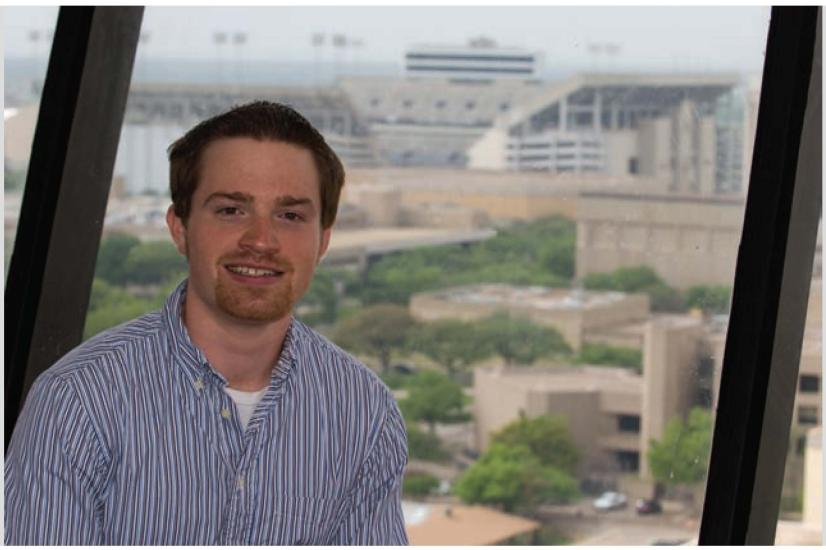
**JOSH VERNON** received a B.S. in Mechanical Engineering in December 2009. He also earned a minor in Technical Communication and a certificate in leadership. Vernon, from Houston, Texas, had a strong interest in materials and talked to a materials professor, from whom he took a class. He notes that "I got involved with his research and really enjoyed it. I completed the Undergraduate Scholars program and wrote a full thesis on the project, 'Grain Growth in RRR Nb for Superconducting RF Cavities for Linear Accelerators.' He then decided that the project might have some merit with a nontechnical audience. "I learned about *Explorations* from Dr. Elizabeth Tebeaux, who encouraged me to write for the journal." Vernon and his wife, Melissa, currently reside in Kansas City, Kansas, where he is employed with Rockwell American and is completing their training program. Vernon hopes to become an automation field service engineer and later attend graduate school.

**JESSICA MARTIN** is a recent 2009 graduate with a bachelor's degree in Entomology, specializing in Forensic Science. Martin's article was part of a large-scale research project that involved insects in her Field Entomology class. She collaborated with Joshua Bolanos to create a forensic entomology project. With an interest in forensic science and research, Martin hopes to further pursue this type of research by working in a crime laboratory and in a research laboratory. However, she has not ruled out becoming a crime scene investigator.

# THE AUTHORS continued

**REBECCA McPHERSON** is a senior Enterdisciplinary Studies major from Duncanville, Texas. McPherson worked with a professor in the Department of Teaching, Learning, and Culture who was responsible for helping a Chinese mother and her son, David, move to the United States. McPherson offered to tutor David in English and began observing him in a formal school setting to see how mainstream teachers work with English Language Learners (ELLs) in their classroom. This experience not only compelled McPherson to write her article but also profoundly influenced her to teach English as a second language (ESL) or with work with ESL students in her classroom. McPherson will be teaching elementary school and working with ELLs in Richardson ISD. She will also visit David and his mother this summer in China.

***Honors:*** Distinguished Honors Scholar for the College of Education and Human Development, University Honors.



**BRIAN HAINES** is a senior Meteorology major. Haines' hometown of Houston, Texas, and the pollution problems that occur there caused him to become interested in this research. After he began his research, he felt compelled to write his article to tell others what he had learned. Haines will attend Texas A&M next fall for graduate study in Atmospheric Science.

***Honors:*** Honor Society of Phi Kappa Phi.

**CAMERON BROWN** is a senior Industrial Distribution major from Austin, Texas. Brown was inspired to write his article by the novelty and effectiveness of the OPAT business model. Although he did not have the resources to make a real purchase, he still understands the opportunity and distinguishing characteristics of the business model. He was interested in how this model affected human purchasing behaviors. Brown will travel to Mexico next year to teach English. After graduation he hopes to start his own business that allows him to continue learning and traveling.

explorations
THE TEXAS A&M UNDERGRADUATE JOURNAL

# Submission Guidelines

## WHO MAY SUBMIT PROPOSALS

Any undergraduate student at Texas A&M who is pursuing research, creative, or scholarly work with a Texas A&M faculty member.

## FORMAT FOR THE PROPOSALS

A paragraph of about 250 words that includes the following:

- Subject and purpose of the proposed article
- Statement of its importance to the student's field of study (and to others outside the field, if possible)
- What topics the paper will include
  *NOTE: Because* Explorations *targets a wide range of readers, authors will be expected to present their topic in* ***nontechnical*** *language. Necessary technical terms must be defined.*
- Title of the paper (Develop an interesting title that suggests the content or focus of your article.)

## FORMAT FOR CREATIVE WORKS

Both your creative work and a "sidebar" that explains the background to your piece. The sidebar must include:

- Why you chose this topic
- Who your creative influences are
- Why you chose this style
- Why this style helps you get across the idea that you are aiming for

We want the readers to understand as best they can what your goal was in creating this piece and what your creative process is like.

Your creative work and sidebar should be no more than 3500 words with your sidebar being a minimum of 500 words long. For example, a short story of 2500 words leaves 1000 words for the commentary and scholarly analysis part of the article.

## DEADLINE FOR SUBMISSIONS:

To be announced. See http://ugr.tamu.edu/explorations.

## SUBMISSION INSTRUCTIONS

1. Complete online application at http://ugr.tamu.edu.
2. On your application, be sure to include your name, major, undergraduate status, faculty advisor, and a phone number where you can be reached most easily. We will contact you by e-mail if your proposal is accepted and provide you instructions for preparing your article.

An online version of *Explorations* can be found at http://explorations.tamu.edu.

## QUESTIONS?

Sumana Datta
Executive Director of Honors and Undergraduate Research
ugr@tamu.edu
979-458-0039

Proudly Supported by