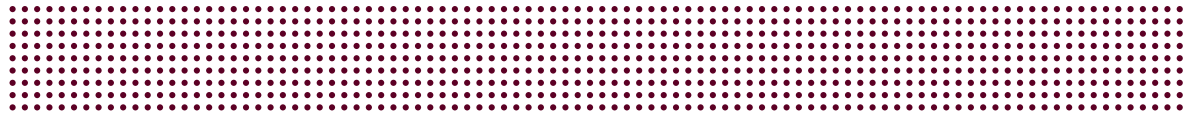


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THE TEXAS A&M UNDERGRADUATE JOURNAL

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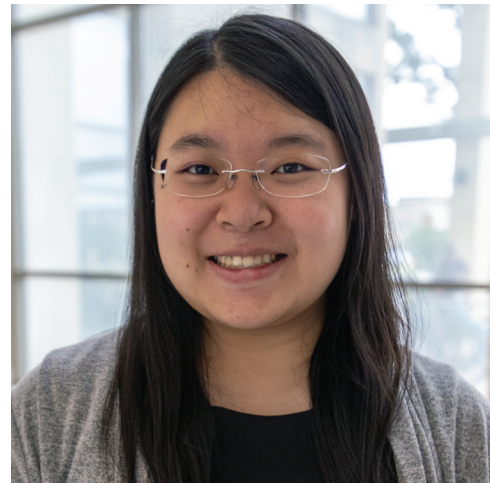


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## Cover artwork by

Judy Yang '18  
*an original digital  
painting inspired by the  
journal's 10<sup>th</sup> anniversary*



## Judy Yang '18

*Judy Yang is a graduate student studying accounting and minoring in traditional art from Arlington, Texas. Judy started off as the Volume 7 cover artist in 2015 and has been a part of Explorations since her sophomore year. Inspired by students' passion for research, Judy's cover art is based on the goals and purpose of Explorations and aims to illustrate a student's path to explore the unknown. After graduation, Judy will be working at PricewaterhouseCoopers as an auditor.*

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# FROM OUR FACULTY



## Dr. Sumana Datta

Founder of *Explorations*

Executive Director, LAUNCH

Assistant Provost, Undergraduate Studies

Associate Professor, Biochemistry

In 2008, I joined a small group of faculty and administrators who were debating how to develop a new, successful journal for undergraduate research after the previous science and engineering focused journal had died. At the core was our belief in the extraordinary quality of what happens every day on our campus and the transformational ability of that experience—the creation of new knowledge and scholarship by intelligent, curious, enthusiastic undergraduates in partnership with some of the top faculty researchers and mentors in the country. Our goal was to convey the excitement and sophistication of the remarkable scholarship being undertaken and produced by undergraduate/faculty teams on our campus not just to the rest of campus but to the entire Aggie family.

**As our discussions moved forward, three ideas coalesced into our guiding principles:**

1. Pieces published in the journal should reflect accomplishments across all disciplines represented by Texas A&M University, not just STEM fields.
2. Published works had to represent the highest quality scholarship on campus.
3. Each item would be written for the general public so that the new journal was understandable to all members of the Aggie family and publication of results did not jeopardize the future publication of studies in a professional journal by the research team.

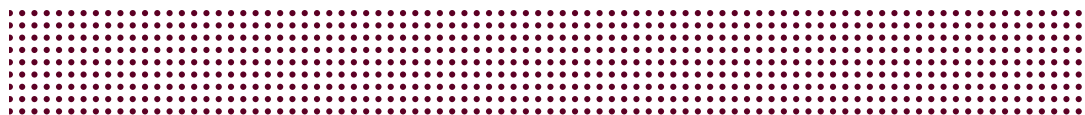
***These principles informed our organizational strategy and roles undertaken by students and faculty:***

1. Student input and involvement was critical as authors/artists and as managing editors/reviewers/leaders to ensure that the new journal was reflecting the interests and values of our undergraduates and especially our undergraduate researchers.
2. Faculty input and involvement was critical as supporters/mentors and as reviewers/editors to ensure the quality of the work being showcased, obtain faculty approval for publication of the results that stem from faculty mentorship, oversight, and investment, and provide training, mentorship, and insight for the students involved in running the journal.

In 2009, the first issue of *Explorations: The Texas A&M Undergraduate Journal* was published, with eight pieces ranging from engineering, geophysics, and toxicology to international studies, politics, and literature.

It has been one of my greatest pleasures over the past decade to see *Explorations* grow and mature, shining a spotlight on outstanding research, scholarly, and creative accomplishments by undergraduates in all disciplines in collaboration with their faculty mentors. *Explorations* authors and artists as well as student editors and board members have gone on to prestigious graduate and professional programs, been awarded national fellowships, and accepted impressive job offers. I expect no less from the accomplished scholars highlighted in this, the 10<sup>th</sup> issue of *Explorations*, or those who have worked so hard to put it together. Remember these names, you'll be seeing them again in the future!

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# Building an Invisible Wall: Real-time Methods to Improve Power Grid Cybersecurity

By Megan Culler

## INTRODUCTION

Reliable power is a cornerstone of the function of modern society. People expect the lights to turn on when they flip a switch and are inconvenienced if the power goes out. Our reliance on energy can make power grids a target for adversaries who wish to disrupt power service. While most blackouts are temporary and cause minor inconveniences, large scale blackouts can cause billions of dollars in damages and full recovery can take months. The August 2003 blackout in the northeast part of the United States caused an estimated \$6.4 billion in financial loss.<sup>1</sup> Moreover, the mortality risk of those affected by blackouts escalates for a variety of reasons. Cases of illness increase due to lack of potable water, lack of heating or cooling, and difficulty in obtaining necessary food or medicine while grocery stores or pharmacies are closed.<sup>2</sup> Contacting emergency services may be impossible due to downed communication networks. In addition, individuals who rely on home medical equipment can be in great danger.<sup>3</sup> Finally, blackouts can cause *physical* damage to vital equipment, not only to components of the power grid, but also in operations that need continuous power. The potential for disastrous consequences makes the grid a valuable target for adversaries, which motivates my research to explore attack detection methods and ensure the reliability of power grids in the modern cyber-connected world.

Utility providers are better equipped to handle large scale blackouts that occur from regular part failure and maintenance than they were ten years ago. Control systems now prevent blackouts from cascading across a wide area. Operators can prepare the system for large weather events. Prediction models also account for oth-

er events that affect power usage, such as geopolitical events, seasonal trends, and social phenomena that cause power usage spikes, like the Super Bowl. However, cyberattacks are both hard to predict and dangerous to the stability of the system. Usually, when people think of cyberattacks, they imagine a hacker trying to steal a social security number or credit card details. In the context of power grids, however, attackers often want to cause a physical outcome that changes the behavior of the power system.<sup>4</sup>

An adversary's goal in attacking a power grid may be to deny service to a particular group of customers, cause a large scale blackout, or damage the reputation of a local utility provider. All of these are denial-of-service attacks in some capacity. In a direct attack, overloading transmission lines causes physical damage to parts, and flipping breakers shuts off service to customers. In false data injection attack, an adversary can force an operator to make bad decisions by displaying false information. One example would be to indicate that the system is close to operating capacity. In this case, an operator might cut power to some customers to avoid a total blackout as demand rises. However, if the system is actually operating within acceptable limits, the company loses money and denies power to some customers. Alternatively, an adversary could inject data that indicates the system is stable, when in reality they are forcing the system to the limits of sustainable operation. They may even indicate that more power is needed when the system is at capacity, causing the operator to increase generation and overload lines without knowing that they are causing power flow violations.<sup>5</sup> Of the two injection attacks, the latter would be considered an unobservable false data injection attack since the data injected suggests that the system is still stable.





## METHODS

The goal of this work is to identify unobservable false data injection attacks through sensor verification of power grids in a cyber-physical context. Unlike pure information networks, cyber-physical systems have two layers that work together to control the system. The physical layer has physical components that can be mapped in the real world, and its interactions can be easily modeled. The cyber layer is slightly more difficult to model since it is harder to visualize communication or control channels. However, modeling both layers, and more importantly, the interaction between the layers, is the key to this project.

In order to maintain stable control of a system, an operator needs the ability to make good decisions about the usage of the available generation units. These decisions can only be made by analyzing the data about the current voltage and power levels at various locations or “nodes” throughout the system. If this data cannot be trusted, a necessary component of stable operation is missing. Determining the trustworthiness of the data from the sensors at each node motivates this research. A real-time verification technique is used to score the trustworthiness of each sensor.

Data for this project is collected from models in PowerWorld, a software that allows users to visualize power systems and perform complex analysis. It is not feasible to collect data from actual power grids for attack detection research, and utilities rarely share the power and voltage information from their systems. This project used a simple eight-substation power network model, originally developed as a live data feed model in PowerWorld. Substations are modeled with multiple nodes and breakers, which connect the data collected from sensors to the controls of the physical system. Added protective relays and control networks were developed by experts based on real utility controls.<sup>6</sup> Despite its small size, this network, shown in Figure 1, is well tested and accurately models real systems. A total of 52 nodes are defined within the eight substations, which each measure voltage, current, real power, and reactive power. Real power is measured in the mathematical real space and reactive power is measured in the mathematical imaginary space.

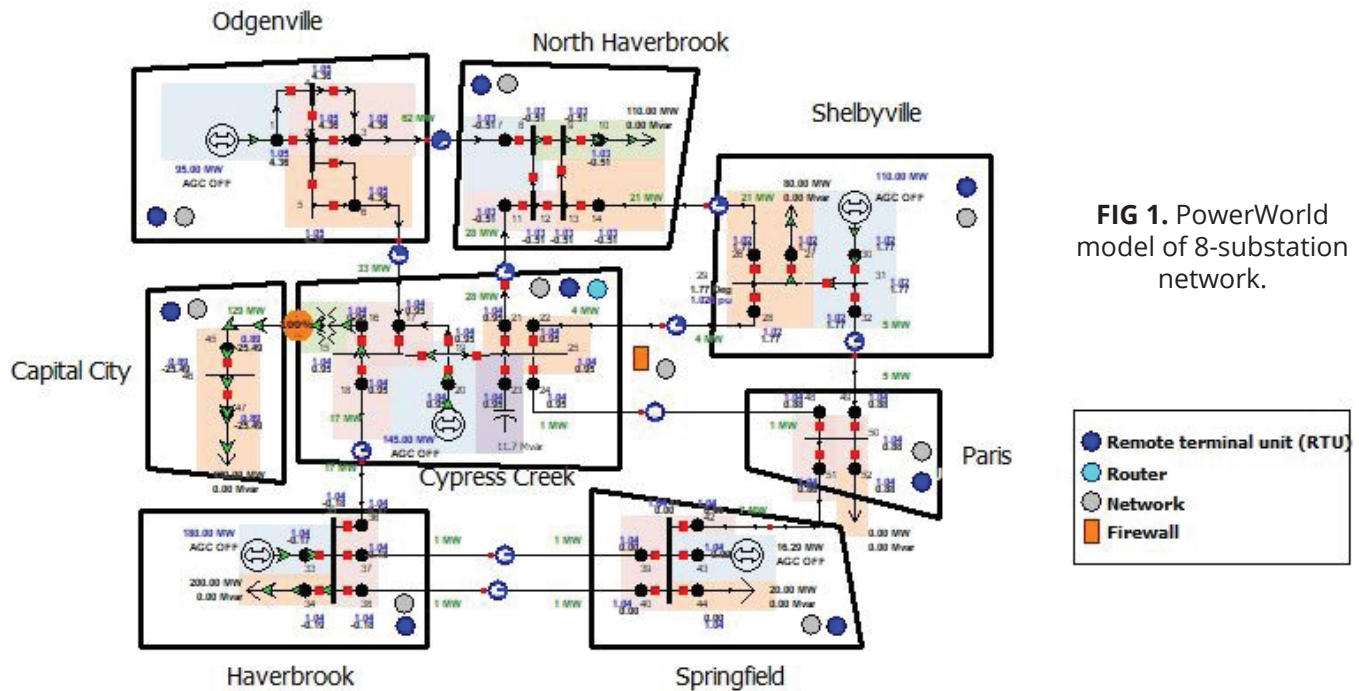
A technique for real-time probing of the system is used to determine if an adversary currently has control over any substations. Two cases are initialized, one run with normal operation, and one run as if an adversary has control over a single substation. A small probe signal is sent through each system in both versions. The probe is large enough to cause a measurable change in sensor data but also small enough so as to still make the

system solvable. Measurements are taken before and after the probe is sent. The results from the normal power flow solution indicate what an operator would expect to see, while the results from the compromised power flow solution indicate what would actually be observed if the system was compromised. We compare the results to determine if any nodes have been compromised.

A variety of probing techniques were tested to achieve the most reliable detection of the specific substation under attack. The first probe tested was a small change to the voltage at a single generator node. Although operators usually want to keep voltage levels very stable at generators, very small deviations are allowable. The feasible probe size is limited to keep the voltage stable in this case. The second probe tested was a real power probe, which is analogous to increasing the output of a generator by a small amount for a short period of time. A change of this size will not unbalance the system since mid-size generator outputs are always changing to respond to changing demand. Finally, a reactive power probe was tested at load nodes, which is where the power is consumed. This type of probing is realistic because it acts like regular voltage control at a load.

In the attacked power flow simulation, one substation was compromised for experimentation as follows. The adversary forces the sensors for the generator at this substation to indicate that at 50 megavolt-amperes-reactive (a unit of reactive power) less reactive power is generated than what is actually true and shows another node in the system as having low voltage. By doing this, the adversary tries to make operators increase generator output above acceptable levels by showing false low measurements. The operator then sends the probe through the system to test the validity of the measurements they see. The power flow simulation is resolved for two cases. The first solves the attacked case, showing what the operator would actually see. The second solves the power flow under normal operating conditions, which is what the operator expects to see. Sensor measurements were collected and compared between the attacked (observed) case and the normal (expected) case.

For each simulation, four final state value measurements were collected at each node. These were voltage magnitude, voltage angle, real power, and reactive power, which together allow an operator to calculate any other value of interest in the system. On their own, they reveal critical information about the system since all of these values typically have strict bounds into which they should fall. Comparisons between the expected and observed simulation cases can reveal critical information about the state of the system.



**FIG 1.** PowerWorld model of 8-substation network.

## RESULTS

The first probe, the modified voltage at a generator, did not produce very promising results. The results for realistically-sized probes were too small to be observable within the normal fluctuations of the system.

For the real power probe, the compromised substation clearly indicated different behavior than expected in the real power measurements and voltage angle measurements. The results were consistent regardless of the placement of the probe and scaled with the size of the probe, suggesting a true correspondence between real system values and the probe's influence.

Finally, the reactive power probe had promising but less clear results. The measurements also showed potential to identify the compromised substation based on voltage angle. However, unlike the real power probe, the reactive power probe results did not clearly identify the compromised substation for all probe source nodes. Since operators cannot foresee attack locations, a collection of probes from different sources are required to identify the compromised substation with a reactive power probe.

The real power probes seemed to be the most efficient at correctly identifying the compromised substation, as shown in Figure 2. This probe not only gave the most consistent results regardless of probe source location, but also represented the case that is most feasible to implement. The voltage probe was limited by the desire to keep voltage levels fairly constant in a system in or-

der to protect power flow. The reactive power probe is a signal that would be harder to control, and the results depended strongly on the source location, which in a larger system, would make it much more difficult to find the compromised substation.

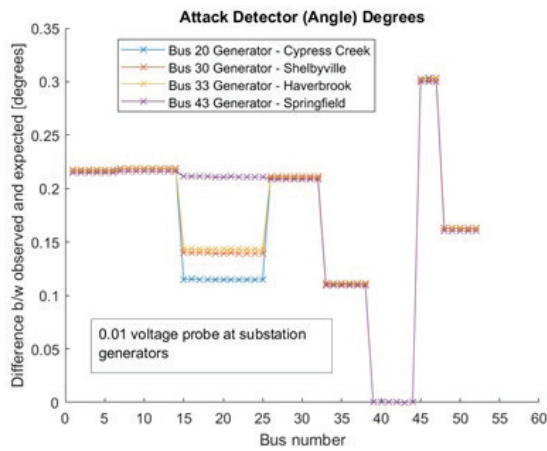
## FUTURE WORK

The results indicated that the real-time probing solution could discover the location of a compromised substation with a high degree of accuracy. Although this was a good first step developing new security awareness, there is still more work to be done.

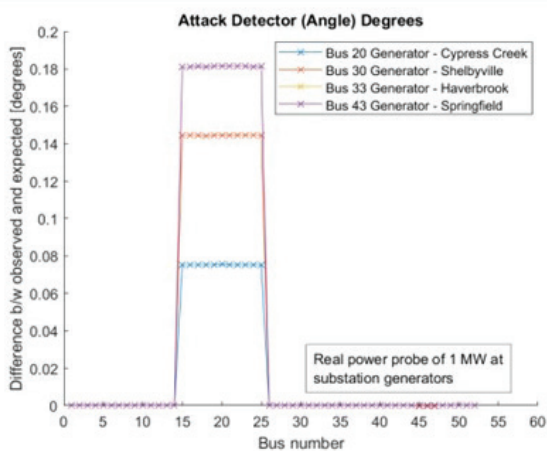
All probes tested here were simple, time-independent additions to the current values. Probe shapes that vary with time or scale based on current system parameters might have different effects on the system. The probes could take many forms without compromising the integrity of the system, and future work may reveal what type of probe is most effective at identifying attacked substations without changing the stability of the system. In addition, all tests for this experiment focused on a single probe from a single node. However, combinations of different types of probes, or experimenting with sending multiple probes from different nodes simultaneously, might make the probing technique more robust.

The next step of this project is to expand beyond the scope of the eight-substation model to verify the accuracy of the probing solution. Larger systems should be tested, and cases when multiple substations are compro-

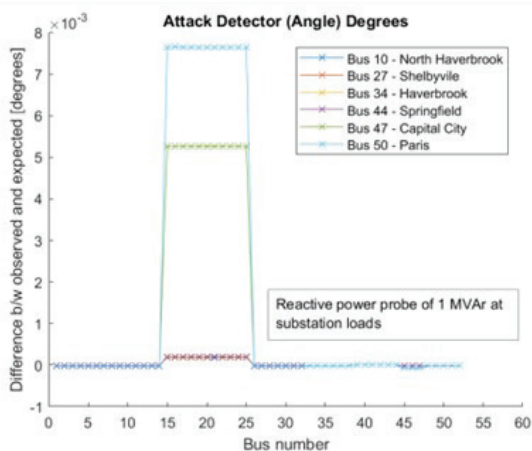




(A)



(B)



(C)

**FIG 2A-C.** (A) Difference between expected and observed results for A voltage probe, (B) real power probe, and (C) reactive power probe.

mised must also be considered. If it is possible for hackers to access one substation, it is likely that they can use their current knowledge to work their way deeper into the system. We can simulate this case by expanding the attack area in our simulations.

This project explored the effects that cyber-attacks can have on physical systems and proposed a method to detect cyber intrusions using physical signals. Improving the modelling of cyber-physical connections will be key to developing these detection methods further, and future work will include developing new models and visualization tools, and validating the models that are currently used. The cybersecurity realm is still in its early stages, and is an exciting and vital area of continuing study.

## ACKNOWLEDGMENTS

This work was supported by the National Science Foundation under Award #1446471. I would like to thank my research advisor, Dr. Kate Davis, for her support and guidance. Thanks also go to the Undergraduate Research Scholars program at Texas A&M for help with the research process and Donald Okoye and Hao Huang for their aid.

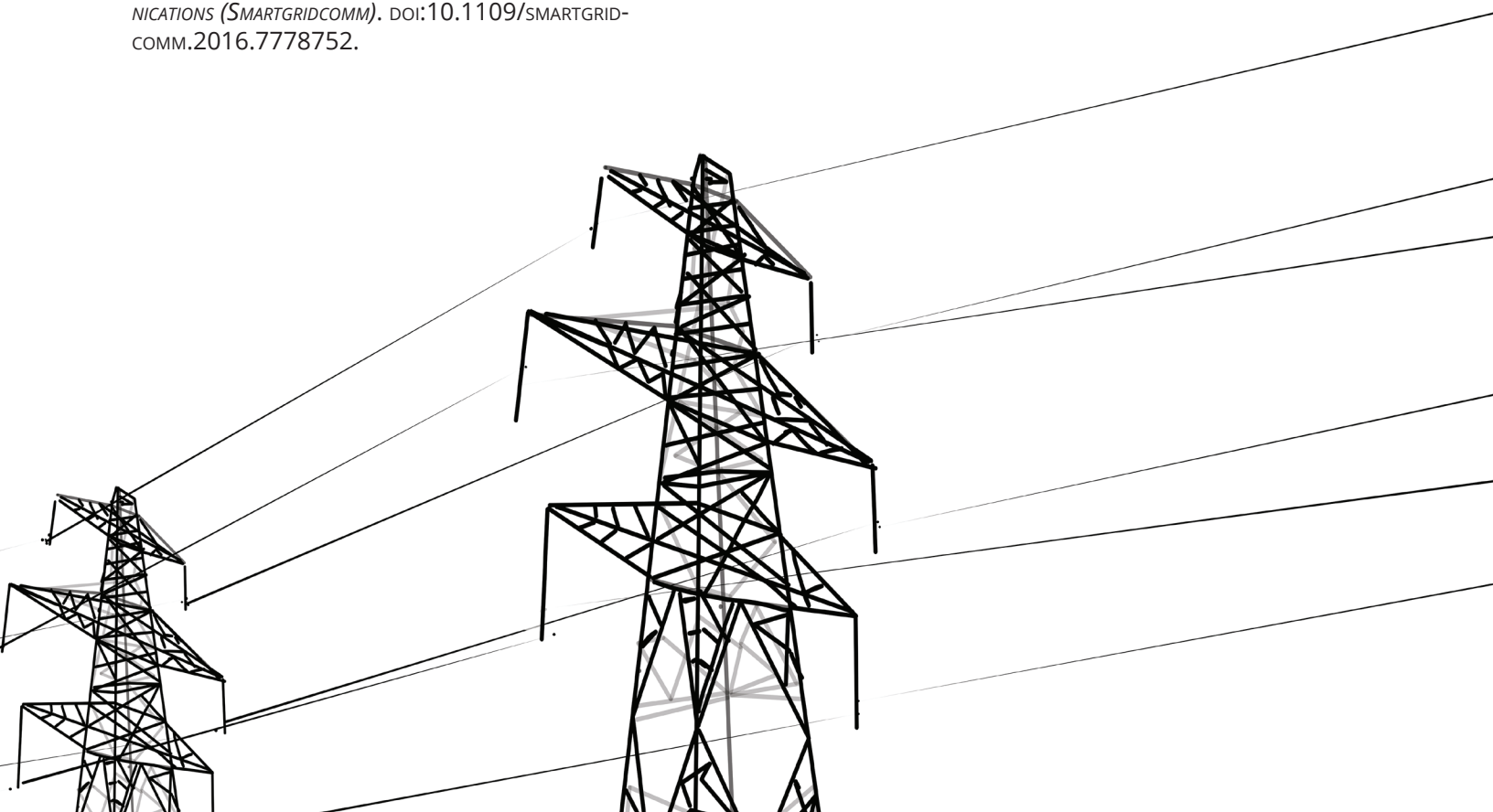
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### Megan Culler '19

*Megan Culler is a junior electrical engineering major from Albuquerque, New Mexico. Megan completed her research while participating in the 2017–2018 class of the Undergraduate Research Scholars under the guidance of Dr. Katherine Davis. Megan hopes to attend graduate school to get a Master's in electrical engineering. After her education, Megan plans to work in industry or government, where she will combine her interests in electrical engineering and cybersecurity.*





# Challenges Inhibiting Malaria Aid in the Democratic Republic of the Congo

By Brittany Gardner

## INTRODUCTION

Malaria is an incredibly difficult disease to combat, especially in high-transmission zones. A plethora of complex, multifaceted issues contribute to the pervasive nature of malaria in Sub-Saharan Africa, and oftentimes these issues merely isolate poverty as the single cause of high malaria transmission rates. Most societies choose to treat malaria directly through the use of antimalarial commodities rather than addressing the root causes, because the root causes are often difficult to determine and unrelated to the disease itself. This is especially true in Africa, where the malaria burden remains the highest globally. The Democratic Republic of the Congo (DRC), a large country located in central Africa, constitutes 10% of the approximate 407,000 annual malaria-related deaths in Sub-Saharan Africa.<sup>1</sup> Factors such as socio-economic turmoil and lack of infrastructure impair malaria prevention and treatment access. Consequently, an increase in mortality levels due to malaria results in economic repercussions, including but not limited to reduced working time, productivity, and family income.<sup>2</sup> Currently, aid organizations such as the President's Malaria Initiative focus on improving the supply chain movement of antimalarial commodities so that supplies reach the desired locations when required. However, this current method of supply chain design does not account for the majority of challenges facing the DRC regarding malaria. Failure to focus on the holistic spectrum of issues surrounding the causal factors related to malaria results in a narrowly-focused methodology that ultimately hinders effective aid. These issues are critical to understand because malaria-related mortality is preventable and impairs the industrialization of the DRC.

Often transmitted through the bites of female *Anopheles* mosquitoes, malaria is a treatable and avertable infectious disease caused by unicellular organisms of the genus *plasmodium*. Once malaria transmission occurs, the host will begin displaying flu-like symptoms after 10–28 days; although, in some cases symptoms may remain dormant for months or even years. In geographic locations where malaria is pervasive, it is rare that individuals live their whole lives without serious complications. Instead, most victims exhibit significant malaria-induced maladies, sometimes resulting in death. Not only are approximately 32% of outpatient visits in the DRC directly attributable to malaria, but 36% of deaths are caused by malaria-related illness.<sup>3</sup> Only a mere 30% of the Congolese people have access to medical aid.<sup>4</sup> The scarcity of accessible health care causes these entirely preventable malaria-related deaths.

Mainstream opinion suggests that the issue of malaria will be effectively resolved through the continued donations of antimalarial commodities and the eventual elimination of poverty in the DRC.<sup>5</sup> However, this model is unrealistic. Poverty is too large of an issue to readily combat because it is the result of larger socio-economic and political issues. Antimalarial commodities are effective and have led to the drastic decline—from 52.5% in 2005 to just 24.6% in 2015—in the incidence of malaria in the DRC.<sup>6</sup> Nevertheless, the decline in malaria mortality has only further complicated the Congolese people's desire to prevent malaria. A factor contributing to this com-



plication is that malaria in the DRC is viewed as part of everyday life, no differently than how we view contracting the flu in the United States. The debilitating mindset of malaria as just another everyday disease causes new victims not to seek treatment. Because of this, *plasmodium* is spread to more vulnerable populations and results in a higher mortality rate. This research seeks to identify the causal factors inhibiting the current success of cost-effective, long-term malaria aid in the DRC while focusing on the distribution of effective aid in order to redefine the structural method to combat malaria.

## METHODOLOGY

This research employs a qualitative knowledge-based interview with subject matter experts alongside a semantic analysis to aggregate the factors and conditions that have an effect on the cost of malaria prevention and treatment efforts within the DRC. The aim of this research is to optimize humanitarian aid by eliminating repetitive data accumulation processes in order to create a more holistic view of supply chain improvement in the DRC. As part of this study, ten individuals experienced with malaria-aid and DRC-centric issues out of a recruitment pool of 30 people were interviewed via email and phone calls. Fifty percent of the participants were involved in the DRC for more than ten years, and 70% of the participants were doctors and malaria aid workers. The questions utilized in this study had three purposes: to verify the interviewees' practical knowledge on the current state of malaria, to gauge interviewee opinion on the current antimalarial supply chain processes, and to investigate the availability and effectiveness of current prevention and treatment efforts from a sociological and cultural perspective. The data were subsequently inputted into a program for the purposes of information analysis, conclusion development, and juxtaposition of results with the literature review.

## RESULTS

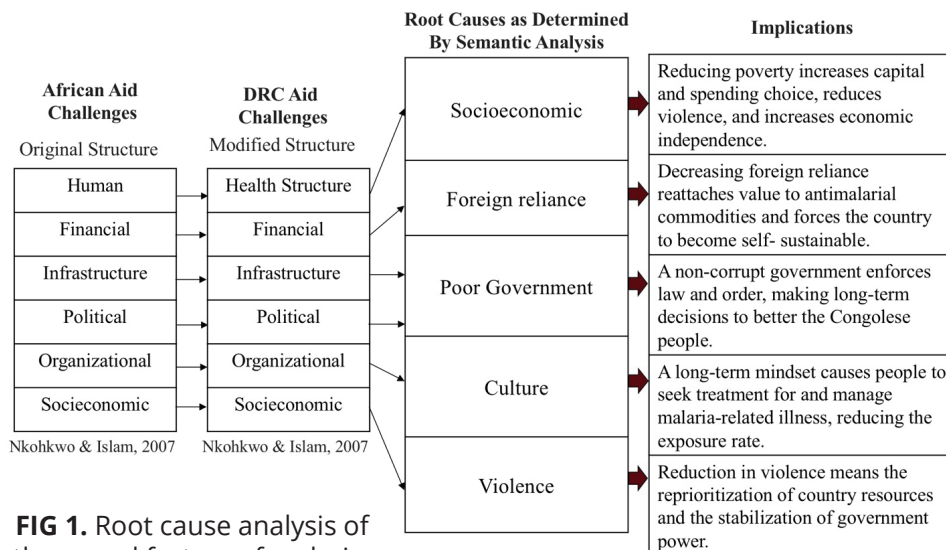
Ninety percent of the participants stated that treatment and prevention methods for malaria were adequate to meet demand. Currently, the rate of malaria mortality remains high even though the antimalarial commodities are sufficient to meet demand. While the treatment methods are available, too often they are inaccessible to the people who need them. Some of the issues contributing to this disparity between the availability of the commodities and the demand include inability of the population to follow the guidelines given by the DRC Ministry of Health, lack of funded means to access care, stock-out rate, and the physical distance between those

populations needing services and the existing health structures. One interviewee said:

“MOST PEOPLE DON’T LIVE WITHIN ACCESS OF EFFECTIVE MALARIA CURES OR TREATMENTS. A LOT OF TIMES THE GOVERNMENT HEALTH CENTERS USUALLY DIDN’T HAVE MUCH MEDICINE. IT WOULD OFTEN GET SOLD OUT ON THE SIDE WHEN IT WOULD FIRST ARRIVE, AND SO MEDICINE WAS NOT READILY AVAILABLE.”

Additionally, the few roads that exist remain in a state of disrepair, and electricity and cell phone reception are inaccessible in parts of the country. Interviewee three noted that if the goods and supplies somehow do get delivered, it is “usually from the capital city distributed by air, which is expensive, just because the roads aren’t passable.” The equatorial forest inhibits transit, and the lack of urbanization throughout the country leads to externalities that impede the management of the disease. Financial inaccessibility demotivates the population, as wages in many sectors outside of public health are insufficient. Politically, the DRC has a history of violence that has given rise to dozens of armed groups, leading to an unstable government incapable of attaining order. Historically, poverty accompanies malaria and creates a mentality of short-term gain where individuals focus more on their day-to-day lives instead of a long-term perspective where people focus on their future well-being. This exacerbates the current in-country issues because those who have developed a resistance to *plasmodium* do not seek treatment and, instead, decide to live with malaria, expediting malaria transmission. Furthermore, the DRC does not have the capital to fund necessary malaria aid; instead, it relies almost entirely on foreign aid. These foreign entities may place restrictions on the money by only allocating it for a predetermined set of initiatives that may not align culturally with the DRC. Interconnectivity between health structure layers is severely lacking. Communication disparities and dozens of concurrently-operating supply chains lead to the inability to meet demand, a lack of historical use data, and increased cost of providing aid.

From the key findings of the research, the team discovered that malaria was a systemic challenge comprised of self-sustaining issues rather than, solely, a supply chain issue. An endeavor to fix the supply chain issue would be inefficacious in decreasing the rate of malaria mortality in the DRC because it is a societal problem that necessitates an approach focusing on the root causes. Figure 1 indicates the root causes of the challenges to eliminating malaria in the DRC. The DRC’s impoverished conditions lead to violence that, in turn, destabiliz-



**FIG 1.** Root cause analysis of the causal factors of malaria.

es effective government and renders the government incapable of funding malaria aid. This reliance on foreign aid becomes ingrained in the country and weakens the culture, promoting poverty by inhibiting self-sufficiency. This is a departure from the traditionally-held belief that malaria will be solved through the elimination of poverty and the use of antimalarial commodities and, instead, pinpoints five systemic issues—socio-economic turmoil, foreign reliance, poor government, cultural issues, and violence—that create a self-propelling cycle of malaria in the DRC. Antimalarial commodities merely treat the symptoms of malaria; however, malaria can be best combated through addressing the five root causes of malaria in the DRC.

## ANALYSIS

Although the current approach to eliminating malaria focuses on poverty, this is difficult and ultimately ineffective because of the deep associations between malaria and poverty. To eliminate malaria, humanitarian aid must migrate from a platform of simply providing supplies to one which stimulates intra-country aid efforts and spearheads economic independence. This can be done by heavily subsidizing antimalarial commodities, enabling in-country production, and offering the commodities in exchange for an alternative form of payment if an individual cannot afford the cost.

Currently, value is not attached to antimalarial commodities in the DRC, which decreases the usage and adoption of these items. The mentality of the Congolese people that antimalarial commodities will continue to be provided at no cost to them creates a systematic reliance that detaches value from the commodity. For example, the government has made it illegal to sell insecticide-treated mosquito bed nets because it does not want

citizens to sell the cost-free nets provided by aid organizations. Not only does this prevent people from buying the nets when needed, it inhibits in-country production. Malaria is a systemic societal problem from which a supply chain issue is created, meaning that if the supply chain issue were to be eliminated, malaria-related mortality would hardly be impacted. The current mortality rate is a consequence of combined issues (Figure 1), and in order to break the cycle, we must begin to eliminate these systemic issues. When one of the issues is eliminated, the rest become infinitely easier to tackle.

Helping the Congolese people adopt a long-term mindset by expanding their understanding of normalcy—a life without malaria—can heighten resolve and induce the citizens to seek and manage malaria-related illness, thereby reducing the exposure rate. Mitigating violence has great potential to stabilize governmental power and reprioritize the country's resources. Furthermore, reducing poverty can create prosperity by allowing the Congolese people to have options when spending, thus leading to increased economic independence and reductions in violence. These actions would ultimately reattach value to antimalarial commodities and enable the country to become self-sufficient. Finally, a non-corrupt government would possess an increased ability to enforce law and order, enhancing their ability to make long-term decisions to better the Congolese people.

## DISCUSSION & CONCLUSION

In conclusion, this root cause analysis moves the current approach of combating malaria-related mortality from a mindset that forces an overreliance on external aid and cripples the country's ability to become self-sufficient to a mindset that focuses on increasing in-country production and antimalarial commodity usage. Although antimalarial commodities contribute to the decline of malaria, malaria in the DRC will only be eradicated upon the elimination of the country's societal challenges. The results of the study demonstrate the interrelation between supply chain and non-supply chain issues, provide key insight for malaria aid organizations on the spectrum of challenges affecting the DRC malaria, and assist in creating a holistic approach to reduce malaria-related mortality. The aforementioned approach incorporates an integrated view of the supply chain in conjunction with socioeconomic, cultural, and political issues. This



model may beget the government's capability to enforce law, provide education, promote gainful employment, and, ultimately, reduce reliance on foreign aid. When the Congolese people reprioritize malaria as a significant systemic issue and begin to target the operational inefficiencies that exist in the DRC, more than 40,000 preventable malaria-related deaths annually will drastically decline.<sup>1</sup> This decrease in unnecessary deaths will allow the DRC to become a more industrialized nation, ultimately bettering the Congolese people by increasing the country's stability and presence on the international stage.



## Brittany Gardner '18

*Brittany Gardner is a senior supply chain management student with a certificate in professional development from Spring, Texas. Brittany completed the work for this article while participating in the 2017–2018 class of the Undergraduate Research Scholars under the guidance of Dr. Malini Natarajarathinam and Dr. Wei Lu. Upon graduation, Brittany will begin work as a management consultant for PricewaterhouseCoopers.*

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# Dare to Be First:



# A New Approach to Feminism

By Caroline Yang Piazza

## INTRODUCTION

When was the last time you did something for the first time? *Dare to Be First* is a campaign designed to inspire girls and women to be trailblazers by highlighting historical female figures from the past and how they rose above to defy all odds and do something for the first time. The campaign involves an analysis of the history of feminism in the United States and the identification of women in history who were considered to be “Firsts,” which is a term used to signify women who were the first to achieve a particular accomplishment or goal that only men had previously done. One major goal of *Dare to Be First* is to inform people that feminism is a movement fueled by a desire for gender equality. This article demonstrates how a campaign such as this one starts from a small idea and eventually becomes an entire movement and how graphic design and social media can be used as tools for success.

### WAVES OF FEMINISM IN THE UNITED STATES

While there is no true beginning or end to the feminist movement for equality in the United States, a great starting point is the first-wave feminism movement. In the late 19<sup>th</sup> and early 20<sup>th</sup> centuries, women in the United States were not awarded the same legal rights as men. Women were forbidden from owning property, signing legal documents, serving on juries, attending universities, or having legal custody of their children. Much of the activism at this time was centered on women’s suffrage which was granted to women in 1920 in the 19<sup>th</sup> Amendment of the United States Constitution. Leaders of this movement, including Elizabeth Cady Stanton and Susan B. Anthony, would not have referred to themselves as “feminists”; rather, they would have called themselves “suffragists.”<sup>3</sup>

The term “feminist” gained popularity at the beginning of the second wave of feminism. This movement began in the 1960s and was fueled by the desire of women to gain social equality. At this time, a wom-

an in the United States was expected to marry in her early 20s, start a family quickly, and devote her life to homemaking even if she had a college education.<sup>1</sup> Betty Friedan’s book, *The Feminine Mystique*, is largely credited with being the spark that started the second wave of feminism. Friedan’s book was highly controversial at the time of its publication because her book challenged the notion that housewives were content with staying home and solely being the caretakers of their families. In reality, many of these women felt trapped and unfulfilled in their lives because they had to put their dreams on hold. The second wave of feminism focused mostly on workplace and salary equality and societal and cultural change, and it sparked a change in the United States where women finally began to feel like they had a voice.

The third wave of feminism started in the 1990s.<sup>4</sup> The idea behind this wave was expanding the parameters of feminism in order to include women of all races, classes, and sexual orientations. Leaders of the third wave sought to break away from the stereotypical definition of a “feminist” at this time, which was wrongly stereotyped as a woman who hates men, does not shave her legs or armpits, and does not celebrate her own femininity. The idea was to change the face of feminism to let people know that being a feminist was not defined by a specific identity or lifestyle. In addition to being more inclusive, third-wave feminism focused on bringing issues to light and exposing people and events that do not demonstrate gender equality. The third wave of feminism is a great example of the idea that there will always be the need for adaptation and progress as our society goes through generational and cultural change, and its specific emphasis on diversity and bringing women’s issues into the light signifies the beginning of modern feminist movements in the United States.

### WOMEN’S HISTORY AT TEXAS A&M UNIVERSITY

Texas A&M University was established in 1876 as a military institution. It was not until April 27, 1963, that Texas A&M opened the doors for women to enroll

on a “limited basis.” According to an article released by Texas A&M in celebration of the 50<sup>th</sup> anniversary of the attendance of women, the “intent was for women to be allowed to enroll at Texas A&M if their desired fields of study were not available anywhere else in the state. However, women soon started enrolling in ever-increasing numbers, and no institutional attempt was made to limit the areas in which they could study.”<sup>6</sup> In 1969, the university allowed women to enroll in unrestricted numbers. Since the admission of female students at Texas A&M 50 years ago, there have been numerous changes to how the university runs its administration and practices inclusiveness. Examples of this are the campus making an effort to incorporate women into faculty, athletics, Corps of Cadets, and student body life in general. According to the Texas A&M Student Demographics from fall 2017, the campus is currently made up of 47.27% women.<sup>7</sup> There are many successes as a university that can be greatly attributed to all of the women who have attended or worked at Texas A&M. In the last 50 years, there have been numerous accomplishments achieved by women at Texas A&M, range from the first female Dean of Engineering to the first female collegiate All-American athlete, the first woman leader of the Corps of Cadets, and the first female student body president.

#### WHY THIS CAMPAIGN, AND WHY NOW?

The United States is currently in the fourth wave of feminism. Jennifer Baumgardner released a book in 2011 that defined the fourth wave as having started in 2008 and as different than past waves because of the use of newer forms of technology. Social media has gained tremendous popularity in the last decade, and other forms of technology have shown us how fast and easy information can be spread across the world today. The fourth wave of feminism combines political, psychological, and spiritual factors all into one and is fueled by the digital age, making communication and the spread of information easier than ever before.<sup>2</sup>

One of the main problems with the current wave is that social media can warp perceptions leading to people having stereotypical ideas about feminists, making it hard for perceptions in society to move forward and become more positive. Many people believe that there is a certain type of person who is a feminist. Additionally, many still do not entertain the idea that a man can be a feminist, too. Being able to provide “education and clarification of what beliefs fall under ‘feminism’ are vital in creating equality and positive change in society.”<sup>5</sup>

An approach that may spark fresh ideas into society is the idea of looking at women in history as a di-

rect reference. Studying famous women in history and analyzing their stories can explain much of why things are the way they are today. Their individual cases can oftentimes display acts of courage and unprecedented strength. The most impactful historical female figures all had one thing in common: they were the first to do something amazing in their fields and set chain reactions for generations that came after them.

The difference between other campaigns and *Dare to Be First* is that it does not focus on the heavier and political issues. Rather, *Dare to Be First* takes an empowering and light-hearted approach by highlighting women in history and their past accomplishments and demonstrating how their accomplishments have had a lasting effect on women today. The campaign is designed to inspire girls and women to be unafraid to embrace their true selves and have the freedom to practice any interest they have. This approach was selected because the fight for women’s rights is multidimensional and many people have opposing opinions on different women’s rights topics. The goal was to take an approach that the majority of people could agree upon, which is using stories from history to show that trailblazing women will inspire and empower later generations to do the same.

## DESIGN, DEVELOPMENT, AND METHODS

The right aesthetic for this campaign was chosen by figuring out who the target audience was and how the aesthetic of the campaign would be used to target this specific group. It was important to consider the targeted audience for the campaign: girls, women, and leaders of movements that align with *Dare to Be First*’s beliefs. The color palette (Figure 1) was chosen because of its use of bright colors such as yellow, orange, and pink to represent a bright future and femininity. The navy blue was chosen as a reminder of seriousness. The fonts chosen on the official logo (Figure 2) follow the same meanings as the colors. The script font chosen for “first” was designed to represent free-spiritedness and freedom, and the thin, simplistic and clean font chosen for “DARE TO BE” represents a clean, stable, firm, and modern approach. The logo was initially created as a sketch on pen and paper and then transferred to Adobe Illustrator to vectorize it and clean it up. All of the graphics in the DTBF campaign were made in Adobe Illustrator.

#### DELIVERABLES

The *Dare to Be First* campaign had two main deliverables. The first was an environmental installation





**FIG 1.** *Dare to Be First* Color Palette.

that was on display at the Memorial Student Center on November 7 and 8, 2017 (Figure 3A & 3B). The second is a short promotional video that highlights four modern women embracing their unique abilities and compares them with women in history who paved the way for them to be able to practice these talents today. Other secondary deliverables included stickers, posters, interactive note cards, and social media graphics.

#### ENVIRONMENTAL INSTALLATION

The inspiration for the environmental graphic originated from Lee Taekeyom, a professor at Appalachian State University. Lee partnered with Texas A&M professors of the Visualization Vertical Studio course, Sherman Finch and Anatol Bologan, to have students in their class complete projects inspired by his idea of creating a live 3D typography piece designed for display in

public areas around Texas A&M University's campus. Each group in the class had the option to create a piece with any theme, aesthetic, and purpose, as long as it met the criteria of being large scale, displayed in a public setting and used typography to convey its message. At this point in time, *Dare to Be First* already had developed a concept based on highlighting the accomplishments of women in history. Since the environmental installation would be unique to A&M's campus, the idea arose to put a timeline of Aggie women's history on one side of the installation and a powerful typographic image on the other, combining an art piece with an educational one. Thus, the idea for the *Dare to Be First* environmental installation was born.

Building the installation was a lengthy process and required three people and four nights of labor to complete. The building process for the installation took place over several days between October 30 to November 3, 2017. The base for the installation was a ten-paneled canvas room divider purchased online that was just under seven feet tall and 14 feet wide. Each panel of the installation was carefully printed onto semi-matte paper and cut with an X-ACTO knife to fit the panels. Then, spray adhesive glue was carefully applied to the panels and paper, and they were cemented into place with the help of three sets of hands. This process was continued for all 20 panels (front and back of ten panels) and left to dry for about three days.

On November 7, 2017, the *Dare to Be First* Environmental Installation was installed in the 12<sup>th</sup> Man hallway on the first floor of the Memorial Student Center on Texas A&M University's campus (Figure 3A & 3B). It remained there until the evening of November 8, 2017. While the installation was up, my campaign partners, Alex Hueste and Eman Al-Zubeidi, and I stood by the exhibit to answer questions and have discussions with people who were interested. The location of this exhibit was in an extremely high traffic area on Texas A&M's campus which led to a great deal of interest and many visitors stopping by. Additionally, the *Dare to Be First* Environmental Installation was also on display during the Texas A&M Department of Visualization's semi-annual show in the Langford Architecture Building C on December 7, 2017, along with a documentary video that chronicled the entire journey from start to finish.

Four uniquely talented women were chosen to represent the *Dare to Be First* campaign as spokeswomen: a biomedical engineering PhD candidate, a hip-hop dancer, a violinist, and a powerlifter. These four women were interviewed and filmed performing their talents. The four women "Firsts" from history that were chosen to compare them with were Marie Curie, Perla Primus, Emmanuelle Boisvert, and Karyn Marshall. Marie Curie



[@BEAFIRST.CAMPAIGN](https://www.instagram.com/BEAFIRST.CAMPAIGN)

**FIG 2.** Official *Dare to Be First* logo.

was the first woman to earn a Nobel Prize in 1903 for her work in chemistry, and she was compared with the PhD candidate. This pair represented the scenes in the video, “Dare to Be Bright.” Perla Primus was the first African American modern dancer to gain popularity in 1943 for her talents, and she was compared with the hip-hop dancer. This pair represented “Dare to Be Bold.” Emmanuelle Boisvert was the first female concertmaster of a major symphony orchestra in the United States in 1988, and she was compared with the violinist. This pair represented “Dare to Be Heard.” Lastly, Karyn Marshall was the first woman to lift over 300 lbs. in 1987, and she was compared with the powerlifter. This pair represented “Dare to Be Strong.” We felt that it was important to make the connection between the women from history and the women in today’s world because without the “Firsts,” all four of the spokeswomen may not have had the opportunity to embrace their unique talents today.

Each woman was filmed demonstrating their talents and being interviewed (Figure 8A, 8B, 8C, & 8D). The scenes for the video were filmed using a Canon EOS-5D Mark II. In a few of the scenes, dramatic lighting was set up to create a focal point. The other two scenes were filmed in the natural environment of where the women practiced their talents. Alex Hueste and I assisted, but Eman Al-Zubeidi was responsible for the majority of the filming and editing of the video. It was edited and rendered using Adobe After Effects.

In addition to the main deliverables, there were several supporting elements to the *Dare to Be First* campaign. The most notable designs are the ones on the @beafirst.campaign Instagram account that were posted to gain a following and generate interest in the campaign (Figures 6A, 6B & 6C, and Figures 7A, 7B, 7C & 7D).

## CONCLUSION

The *Dare to Be First* campaign is an effort to confront old issues with a new approach. Feminism and women’s rights in the United States remain a controversial topic due to many conflicting opinions in society. The fight for equality is extremely complicated and “operates in occupational, educational, judicial, economic and social—including romantic—sphere[s].”<sup>8</sup> There is no one right or wrong opinion, and there is no exact start or end to the fight. While there will always be issues and disagreements in the discussion of feminism, *Dare to Be First* offers a refreshing and easily agreeable approach. By using examples of women from the past and displaying how their hard work paved the way for women today, it is clear to see how their resilience has left a lasting and positive impact for future generations. *Dare to Be First*

follows a feminine and trendy aesthetic that incorporates a series of contrasts between history and the present and between seriousness and freedom in the design. Its use of bright, bold colors and fun scripts was created to attract a wide range of female audiences, from young to old. The campaign is an example of a modern and trendy marketing approach and aligns with the values of successful marketing strategies in 2018.



FIG 3A. Front side of installation at a left angle.



FIG 3B. Front side of installation at a right angle.



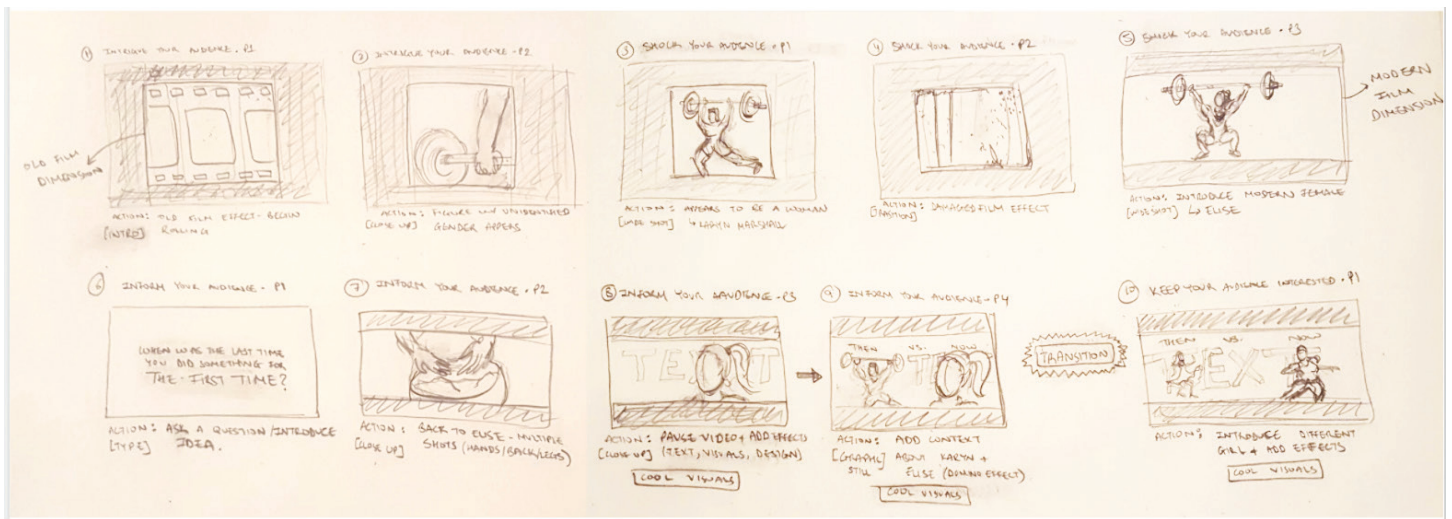


FIG 4. Storyboard for the *DTBF* promotion video. (Credit to Eman Al-Zubeidi).

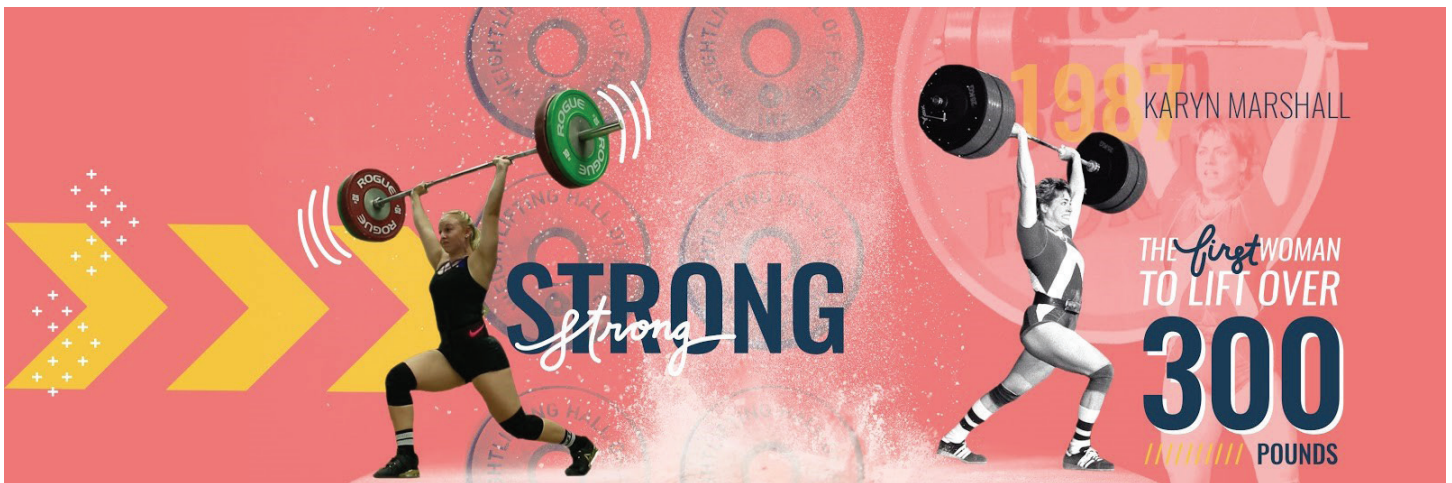


FIG 5. Final design elements for one scene of the *DTBF* promotion video. (Credit to Alex Hueste)



FIG 6A, 6B, & 6C. Social media posts counting the days before the installation was revealed.





FIG 7A, 7B, 7C & 7D. Social media posts counting the days before video release.



Scan to Watch:  
*Dare to be First*  
Promotional  
Video.



FIG 8A, 8B, 8C, & 8D. Scenes from *Dare to Be First* promotion video footage.

## ACKNOWLEDGMENTS

I would like to thank my campaign partners, Alex Hueste and Eman Al-Zubeidi, for their dedication to our cause and our friendship. Alex is responsible for the creation of the majority of the design elements, including the logo design, environmental installation design, and graphic elements from the promotional video. Eman is to credit for the majority of the film production and editing in the promotional video. However, we all worked tirelessly and cohesively as a team to give the *Dare to Be First* campaign life.



### Caroline Piazza '18

*Caroline Piazza is a graduating senior visualization major from Plano, Texas. Caroline participated in the 2017–2018 class of the Undergraduate Research Scholars where she completed her thesis, which culminated in this article, under the direction and guidance of Professor Anatol Bologan. After graduation, Caroline hopes to begin working toward her goal of becoming a corporate art or creative director.*

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# ASSESSING EFFORT IN DELEGATED TASKS

*By Cameron McCann*

## INTRODUCTION

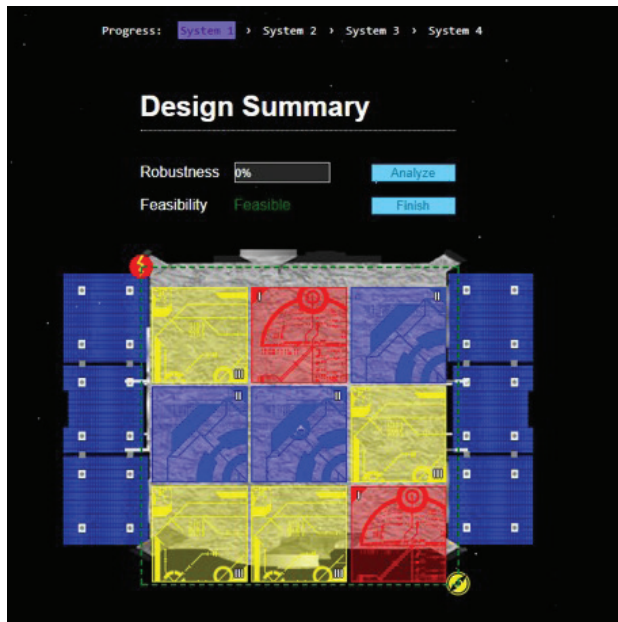
Many are excited for the coming space missions, especially those involving Mars. Some look forward to the chance of discovering other living organisms in our galaxy, while others desire to see the day humans step foot on Mars. Whatever the drive, the fact remains that, as we seek to travel farther into space, missions will continue to increase in distance, size, complexity, and cost. From designing the spacecraft to the moment astronauts return home, the ability of all personnel to cooperate and properly perform tasks in a team-centered environment will be critical to the success of any space mission. In an effort to obtain evidence to create a behaviorally-informed systems design model, our exploratory study focused on two common design delegation approaches, Requirements Allocation (RA) and Value-Driven Design (VDD), to analyze whether or not the framing of instructions influenced an individual's effort while completing a task. In the RA approach, instructions communicate specific requirements about the desired outcome of a project, while the VDD approach communicates certain values about the desired outcome of a project (Table 1). We focused on these two approaches because there is ongoing debate over the efficacy of these two approaches. Some researchers believe approaches that communicate clear standards, such as RA, guarantee the coordination of multiple tasks but acknowledge that these approaches fail in other areas, such as enabling knowledge sharing.<sup>1</sup> Some researchers argue that comparable results could be obtained without the associated costs by focusing on values-driven approaches, such as VDD.

Psychological studies have revealed that the framing of statements and questions can affect individuals' perceptions and decisions.<sup>2,3</sup> Additionally, researchers demonstrated that the framing of incentives (positive or negative) can cause participants' effort to significantly differ.<sup>4</sup> This led us to question whether the difference in framing of instructions between the RA and VDD approaches could influence individuals' effort during a decision-making task. With approaches equivalent to the RA approach, research in economics and psychology has shown that individuals (e.g., an employee) experience negative effects on their effort and performance when an individual of a higher position (e.g., a boss) decides to communicate minimum requirements on tasks.<sup>5,6</sup> This could be because external control (i.e., having specific parameters to meet when performing a task) lowers individuals' intrinsic motivation.<sup>7</sup> Although, some researchers suggest that these negative effects are reduced when the external control is perceived as legitimate or necessary.<sup>8</sup> Furthermore, evidence shows that individuals' performance tends to decline as they reach their goal, perhaps due to the disappearance of intrinsic and extrinsic motivation.<sup>5,9</sup> Based on this prior research in the social sciences, we hypothesized that the RA approach will have a higher rate of effort disutility than the VDD approach. Disutility of effort occurs at the point in time when an individual perceives his/her/their effort to be less beneficial or counterproductive. As a result, we predicted that participants would experience less beneficial, if not adverse, effects on his/her/their effort when given instructions that included specific requirements to meet (RA) than those given value-driven instructions (VDD).

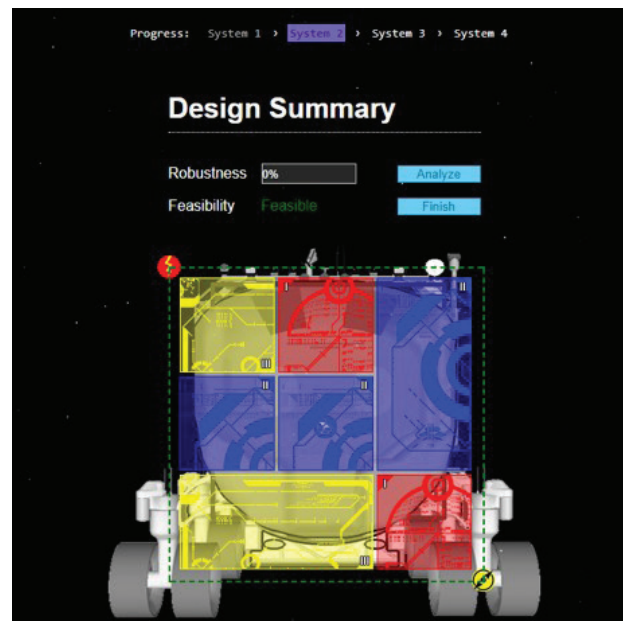
**TABLE 1.** An example of instructions for building a spacecraft comparing the RA and VDD approaches.

Requirements Allocation (RA)		Value-Driven Design (VDD)
Instructions: Build a spacecraft to reach Mars that reaches a velocity of 11.2 km/s.	vs.	Instructions: Build a spacecraft to reach Mars, while maximizing its velocity.





**FIG 1.** First level of Manned Mission: Mars game.



**FIG 2.** Second level of Manned Mission: Mars game.

## METHODS

The 109 Texas A&M University undergraduate students who took part in the experiment came to the lab to play a computer game called “Manned Mission: Mars.” Participants were randomly assigned to one of the following two conditions: requirements allocation (55 participants) or value-driven design (54 participants).

### GAME DESCRIPTION

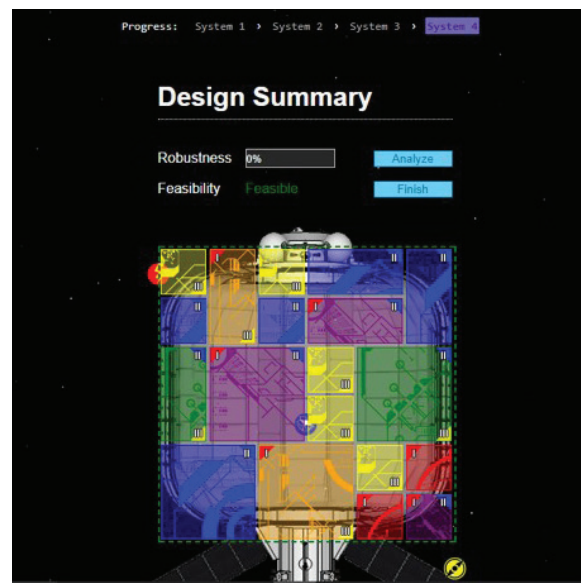
At the beginning of the game, participants were informed that their job was to configure several different spacecraft systems for a Mars mission. Each of the four levels of the game (Figures 1–4) was a different spacecraft system, which was represented as an assortment of components—the colored blocks. The participants’ objective was to rearrange these components in an effort to increase the robustness of these systems—the participants’ score on the game—which was represented by a percentage. The first level of the game started off with three different component colors: red, blue, and yellow (Figure 1). The on-screen directions informed participants that the robustness of the system increased if certain colored components were placed near specific vicinities of the system: red toward the top left, blue near the center, and yellow toward the bottom right. While rearranging the components, participants could analyze the system by clicking the “Analyze” button to see how the robustness score changed. They were allowed to analyze the system as many times as they wished before submitting it and moving onto the next level.

As seen in Figure 1, the first level contained nine square components. The second level replaced four of these square-shaped components with two rectangular-shaped ones (Figure 2). The third level introduced two new colors—green and orange (Figure 3). These new colors were mixtures of two existing colors (e.g., blue and yellow forming green; red and yellow forming orange), with the two primary colors indicated in the corners of the component. In relation to the robustness of the system, these new components were considered the two colors from which they were made; this introduced the challenge of finding the optimal position for these new components. The fourth level, seen in Figure 4, added a purple component—composed of red and blue. This ultimately resulted in a total of six different colors in the fourth level: red, blue, yellow, green, orange, and purple. In addition, this level increased the number of components from seven in the third level to nineteen.

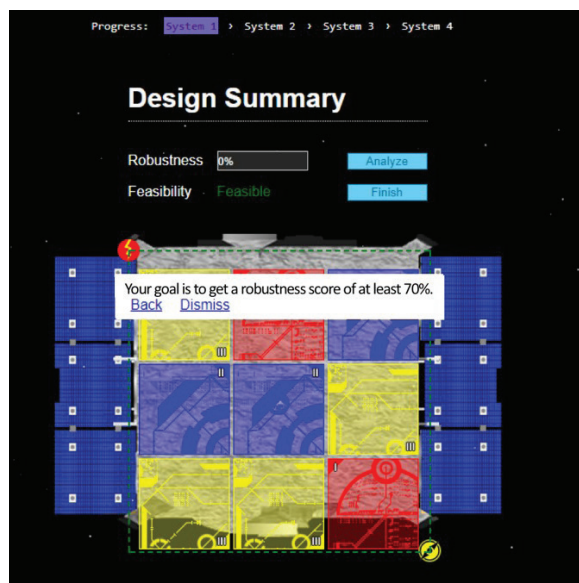
Throughout the game, the computer recorded the participants’ effort for each level. This was measured by the amount of time spent on the level, the number of components moved, and the number of times students analyzed the system by clicking the “Analyze” button. The only difference between the two conditions was the framing of instructions before each level. In the RA condition, instructions described the task by the need to meet a specified robustness threshold (Figure 5), and this threshold varied across levels. In each level, participants were randomly assigned one of the following five robustness thresholds: 60%, 70%, 80%, 90%, or 100%. In the VDD condition, instructions described the task by the need to optimize the robustness score (Figure 6).



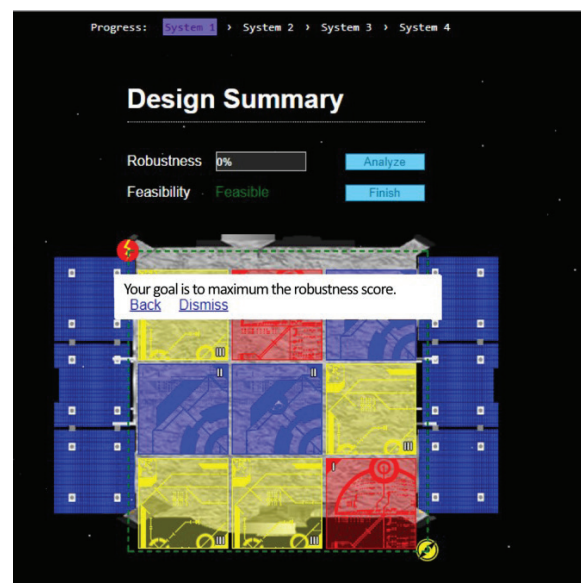
**FIG 3.** Third level of Manned Mission: Mars game.



**FIG 4.** Fourth level of Manned Mission: Mars game.



**FIG 5.** Example of RA condition's instructions for the first level of the game.



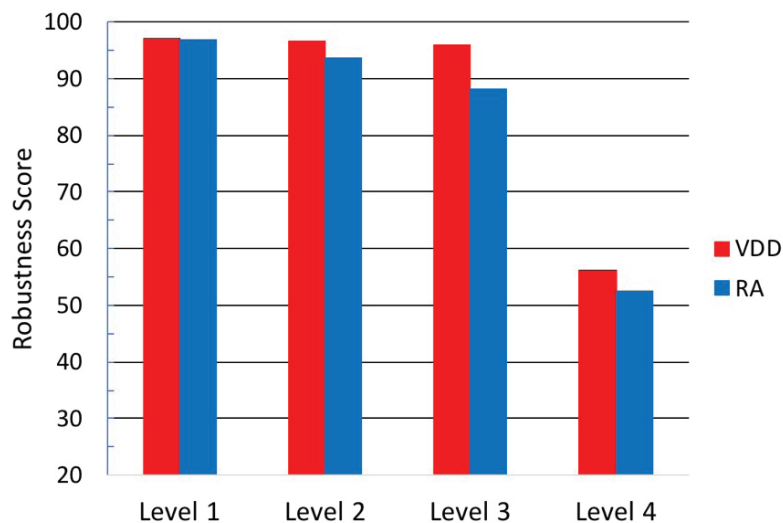
**FIG 6.** Example of VDD condition's instructions for the first level of the game.

## RESULTS

Our preliminary results showed that, on average, participants in the VDD condition attained higher robustness scores than participants in the RA condition in every level of the game with significantly higher robustness scores in the third level (Figure 7). The threshold for robustness varied in the RA condition, and therefore we also assessed the robustness score by the specific thresholds provided. However, this represented a comparison among six groups [i.e., VDD, RA(60), RA(70), RA(80),

RA(90), and RA(100)], resulting in small sample sizes for each group compared to the VDD condition, making the statistical comparisons less reliable. Therefore, we looked for patterns in the data.

The most common pattern in the data was that the RA conditions used more effort (i.e., time spent on level, components moved, number of times system was analyzed) than the VDD condition but finished with a lower robustness score, suggesting the RA conditions in these cases were working less efficiently than the VDD condition. This pattern was present in all four levels of



**FIG 7.** Bar graph comparing robustness score of RA and VDD on each level.

the game, although more prevalent in the lower levels, and was present for seven of the comparisons. Three other patterns occurred commonly (three times) in the comparisons: 1) The RA conditions spent less time but moved more components and analyzed the systems more compared to the VDD condition and finished with a higher robustness score. This pattern shows that the RA condition, in these cases, is exerting more effort—moving more components and clicking “Analyze” more—in a shorter period of time. This pattern is present in the first and third levels of the game. 2) The RA conditions spent more effort (i.e., time spent on level, components moved, number of times system was analyzed) than VDD and finished with a higher robustness score. This pattern is present in the second and fourth levels. 3) Unlike the other patterns, the RA conditions exerted less effort (i.e., time spent on level, components moved, number of times system was analyzed) and finished with lower robustness scores than the VDD condition. Unlike the previous two patterns, this one is noticeable in three different levels: the second, third, and fourth.

## CONCLUSION

As exploratory research, this study works toward helping us figure out the best research design and data collection methods to use in future studies to evaluate decision delegation approaches. Our study sheds light on the possibility that the framing of instructions has an effect on individuals’ effort during a task. Furthermore, our preliminary results suggest that individuals operating in the RA approach experience greater rates of effort disutility than those in the VDD approach, as we hypothesized, but further research must be conducted to con-

firm this. As alluded to earlier, a limitation of the methodology is the resulting small sample sizes of the RA condition after categorizing participants based on the provided robustness threshold. We plan to address this in a future study to obtain a more reliable comparison between the different approaches. Additionally, in future studies we plan to collect measurements within each level, allowing us to see how participants’ performance and effort fluctuate throughout a task, which would result in a better understanding of effort in this context. Furthermore, we will narrow the participant pool to engineering students and practicing engineers in later studies.

The results of our study are widely applicable to life in the workplace and are increasingly relevant as positions change. We have seen common workplace jobs become more team-oriented, with projects increasing in complexity and intricacy, relying heavily on the cooperation and communication of many, often specialized, individuals. For the completion of such projects, agencies, businesses, governments, and organizations must delegate tasks to individuals in the most effective way possible. To do so effectively requires a clear understanding of how the frame of the task affects individuals’ effort and attention. A great example of this is space exploration, where attention to details and maximizing effort can be vital due to the complex and dangerous nature of space missions. From designing the spacecraft on earth to the actual mission in space, the delegation of tasks and the way they are communicated are an important process of a mission that should not be overlooked.

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# “PICKING UP THE GUN”: The Black Panther Party and the Mulford Act

*By Sarah Porter*

## INTRODUCTION

Although today, the Republican Party is often identified as a defender of the right to bear arms, Americans witnessed vastly different attitudes among policymakers during the 1960s. Many staunchly conservative Republicans including Ronald Reagan, who served as California’s governor and was later elected president of the United States, lent support to bills that implemented new restrictions for gun owners. These efforts were not only grounded in a desire to reduce gun violence in American cities but were also framed by the transformations and divisions that emerged within the civil rights and Black Power movements during the late 1960s. The advocacy of armed self-defense by increasingly militant groups, including the Black Panther Party for Self-Defense (BPP), sparked fear among policymakers, who translated these anxieties into legislation designed to undermine these forms of social activism.

One piece of legislation that plainly demonstrated the manner in which legislators utilized gun control to impede social and political activism was the Mulford Act. Enacted in California in 1967, this state-level initiative prohibited the open carry of loaded firearms in public spaces. Both the development and passage of the Mulford Act were inextricably linked to the emergence of the BPP and highlighted the unique obstacles that this organization faced. The BPP’s militant posture and revolutionary platform elevated the group to the national stage, but its controversial image simultaneously handicapped its efforts. Because the BPP relied on strategies that were not widely used by mainstream civil rights activists, the group faced new forms of legal repression. Policymakers successfully employed gun control legislation like the Mulford Act to undercut the BPP. By criminalizing the BPP’s use of weapons on California streets and prompting a shift toward new forms of organizing,

the Mulford Act weakened the BPP and precipitated a change in course for the organization.

## THE BLACK PANTHER PARTY

Although popular interpretations of the civil rights movement emphasize the strategy of nonviolence, these accounts neglect the rich legacy of self-defense among African Americans and fail to acknowledge the legal repression with which these efforts were met. The work of activists such as former Nation of Islam spokesperson Malcolm X and militant NAACP leader Robert F. Williams facilitated the development of the BPP. Inspired by their calls for armed self-defense, Huey Newton and Bobby Seale founded the BPP in Oakland, California in October 1966. The organization represented an alternative to the nonviolent civil disobedience championed by Martin Luther King Jr. and the Southern Christian Leadership Conference. In contrast to King, the BPP rejected nonviolence as both a tactic and a philosophy, emphasizing instead the importance of physical survival to the continuing struggle for civil and human rights.

The BPP also sought to foster a sense of self-reliance among African American communities. In order to achieve this, Newton and Seale constructed a Ten Point Program articulating demands for self-determination, equal access to education, decent housing and “an immediate end to POLICE BRUTALITY and MURDER of Black people.”<sup>1</sup> This final demand became a centerpiece of the BPP, which addressed issues of police violence by assembling patrols to monitor police activity. Taking their inspiration from similar citizen groups in Los Angeles, the BPP adapted the community patrols to its program by carrying them out while armed. Previous groups relied on cameras and tape recorders to corroborate reports of police misconduct, but little action was taken by departments to rectify these abuses. By using intimidation, the BPP hoped its patrols would produce a



tangible change in police behavior. The group not only used firearms but also relied on a thorough knowledge of the law as another weapon. Members studied the Declaration of Independence, the US Constitution, and the California Legal Code, and they used these documents to inform themselves and others of their rights as citizens. The BPP's patrols bolstered the group's image and often served as recruiting tools as well. Community residents subjected to police harassment were often aided by BPP members, who provided assistance through legal knowledge and bail funds, and according to Newton, "many citizens came right out of jail and into the party."<sup>2</sup> The use of guns by the BPP represented a tactical strategy as well as a powerful visual symbol. The image of intimidating black men brandishing weapons and boldly defying the white power structure offered a refreshing alternative to those disillusioned with the hollow legislative victories of the civil rights movement.<sup>3</sup> In promoting a revolutionary platform, Newton and Seale understood that violence was inevitable. They embraced the notion that Mao Tse-Tung put forth in his *Little Red Book*: "In order to get rid of the gun it is necessary to pick up the gun."<sup>4</sup> By picking up the gun, the BPP sought to challenge the police monopoly on violence in urban communities of color.

The BPP's image resonated with many African American communities, and the organization began to

gain recognition throughout the Oakland area. However, the BPP represented a threat to the white establishment and the Oakland police, and lawmakers immediately sought a solution. On April 5, 1967, legislator Don Mulford introduced a bill that would prohibit citizens from openly carrying loaded firearms in public spaces.<sup>5</sup> Mulford introduced the legislation a mere six weeks after the BPP had engaged in a confrontation with San Francisco police, further underlining the bill's objective. While escorting Betty Shabazz, the widow of Malcolm X, to an event to commemorate her husband, Huey Newton had a brief scuffle with a reporter, leading police to intervene. A standoff between Newton and the officer ensued, and reports of the incident likened the BPP's armed escort to a "frightening army."<sup>6</sup> Mulford's bill was a direct response to the BPP's use of firearms as a mode of protest. Mulford even boasted of his intent to sabotage the organization by calling into an Oakland radio program during a feature including BPP members to publicly announce his proposed bill.

The Mulford Act was hardly the first effort to disarm African Americans. For instance, certain Black Codes passed following the Civil War required African Americans to obtain special permits to possess a gun. While earlier legislation was more explicit about its intent to target African Americans, measures like the Mulford Act and its prohibition of public carry technically applied

evenly to the entire population. However, gun control legislation like the Mulford Act could be used to target specific groups through application. Furthermore, the Mulford Act did not apply to law enforcement, meaning that police officers had new leverage over the BPP. Newton claimed that the BPP never perceived vigilante groups like the Ku Klux Klan to be its primary threat. Rather, it was state forces such as the National Guard and local police that posed the most danger to the organization. The BPP's central opposition was law enforcement, and by disarming the BPP while allowing law enforcement to retain its weapons, the Mulford Act would shift the balance of power to favor police officers.

In order to voice their opposition to the bill and raise awareness of the brutality that African Americans faced at the hands of law enforcement, the BPP decided to travel to the state capitol in Sacramento. The family of Denzil Dowell, an unarmed



**FIG 1.** Members of the Black Panther Party march into the California state Capitol, May 2, 1967. Photo Credit: Wade Sharrer, Sacramento Bee.



black man who was shot and killed by a California police officer, had approached the BPP for aid earlier that month. In response, the BPP met with the county district attorney and appealed to the sheriff's department for further investigation into the shooting. Having exhausted the appropriate legal channels with no success, the BPP decided to use the trip to Sacramento to publicize the issue. The threat posed by the Mulford Act resonated even more within the context of the Dowell shooting. Members of the BPP traveled to the capitol on May 2, 1967, and boldly entered the building armed (Figure 1). Seale delivered a passionate executive mandate to legislators and the media, declaring that "the time has come for Black people to arm themselves against this terror before it is too late" and that "the pending Mulford Act brings the hour of doom one step nearer."<sup>7</sup> Seale's statement highlighted the importance of self-defense in the lives of African Americans and underlined the fact that the Mulford Act did not only pose a threat to the BPP but entire communities. The demonstration in Sacramento was legal, but upon departure, BPP members failed to remove the ammunition from their firearms, violating an obscure fish and game code.<sup>8</sup> This mistake furnished an opportunity for authorities to arrest twenty-four members of the group. Even before the Mulford Act had taken effect, the authorities pursued legislation as a means to suppress BPP activities.

## AFTERMATH

Although the BPP's protest received widespread coverage and elevated the organization's image nationally, the state response created an array of obstacles for the group. Rather than deterring the passage of the Mulford Act, the Sacramento demonstration accelerated its progress and encouraged Mulford to reexamine and stiffen the bill. An article in the *San Francisco Chronicle* revealed that the BPP's "invasion" allowed Mulford to declare his bill an issue of urgency, which meant it could be enacted immediately with Governor Reagan's signature.<sup>9</sup> The bill was signed into law on July 28, 1967, and effectively criminalized the BPP's use of weapons in police patrols. The arrests in Sacramento further exacerbated the situation. Although Newton had wisely remained in Oakland and was able to bail the group out, the \$40,000 expense diminished the organization's funds. Many key members, including Seale, received six-month jail sentences, and their absences frustrated efforts to mobilize the group. As BPP member Kathleen Cleaver described, "The party had no funds to continue renting its storefront office in Oakland, and no meetings were being held."<sup>10</sup> The repercussions of the Sacramento demonstration hobbled the BPP and testified to the determination of policymakers and law enforcement to undercut its efforts.

Additionally, the passage of the Mulford Act initiated a shift in BPP programs. The use of community patrols had functioned primarily as a survival program, and the BPP turned to new programs to promote self-preservation among African American communities. In 1968, the Oakland chapter launched the first Free Breakfast for Children Program, and soon thereafter established free health clinics, liberation schools, transportation programs, and drug rehabilitation services across the country. Each of these initiatives moderated the BPP's image in the public eye, promoted self-reliance in black communities, and instilled residents with a revolutionary consciousness. While the expansion of local programs, prompted in part by the Mulford Act, was remarkably successful and garnered support from many moderate institutions including churches, these efforts elicited intensified state repression.<sup>11</sup> J. Edgar Hoover, the director of the Federal Bureau of Investigation, targeted the BPP's community activism relentlessly by spreading inflammatory propaganda and discouraging community support. Realizing that these programs were incredibly effective methods of forging relationships with moderate sectors, Hoover sought to undercut the BPP by authorizing unwarranted raids, generating discord among members, and employing direct violence at times.<sup>12</sup>

The passage of the Mulford Act also prompted a shift from armed self-defense to armed resistance for both Newton and the BPP. From the start, Newton had envisioned the BPP as the foundation for a truly revolutionary program that provided an alternative to the spontaneous and chaotic violence that erupted in cities like Watts, CA, and Detroit, MI, during the late 1960s. By strictly adhering to the law, Newton aimed to promote uniformity and to provide the groundwork for a legitimate revolutionary force. However, because the law no longer facilitated the BPP's agenda, Newton refocused his sights and looked for solutions that did not flow through traditional legal channels. Building upon rights and freedoms that underpinned the Declaration of Independence, Newton advocated for the alteration or abolishment of destructive governments, as the original American revolutionaries had done so zealously. Newton's ideological evolution was visible in an issue of *The Black Panther* from June 20, 1967. Stating "the people should not respect rules that are not serving them," Newton went on to claim that "it is the duty of the poor to write and construct rules and laws that are in their better interest."<sup>13</sup> Throughout the summer, Newton's writings revealed his shifting perceptions of the BPP's role in the wake of the Mulford Act. Identifying the police as an occupying force, Newton designated the BPP as the legitimate representative and vanguard party of black communities. The waves of urban rebellions that con-

sumed American cities during the summer of 1967 validated Newton's conviction that the time for revolution was approaching, and he sought to place the BPP at the forefront of this resistance. In this manner, the Mulford Act signaled a new direction for the BPP and ushered in an era of violent confrontation.

## CONCLUSION

The passage of the Mulford Act represented a determined effort to undermine African American dissent during the late 1960s. New forms of activism spawned new strategies of repression, and the BPP's reliance on firearms and legal knowledge made gun control legislation a viable route to undercut the organization's efforts. The Mulford Act ultimately crippled one of the BPP's central programs, while simultaneously propelling monumental shifts within the organization and leading to increased clashes with law enforcement. Efforts to neutralize the BPP, as evidenced by the Mulford Act and other firearm restrictions, offer compelling examples of how legal repression was used to curtail activism during this period. The historical connection between gun control and efforts to sabotage the BPP offer contemporary audiences a new lens through which they might view current debates on gun control and understand its repercussions for minority groups.



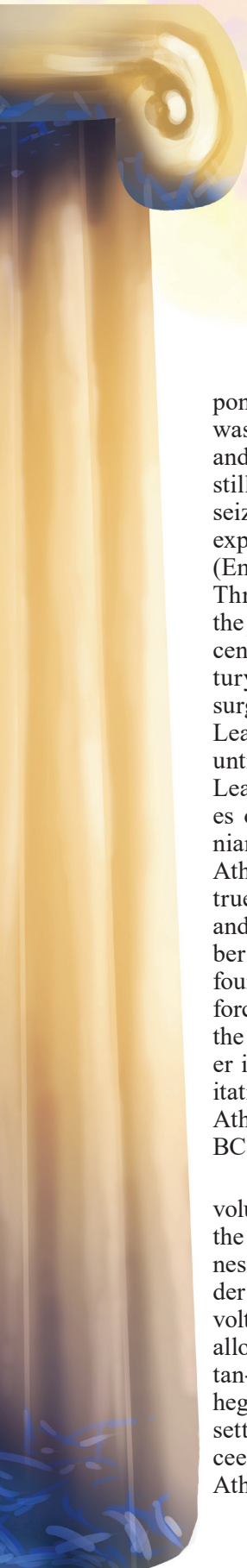
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# The Second Athenian League: A More Equal Confederacy

*By Patrick Grigsby*

Following its disastrous defeat in the Peloponnesian War (431–404 BC), the *pólis* of Athens was deprived of its navy, its “Long Walls” to the sea, and its prized empire. Further catastrophes were still to come as an oppressive pro-Spartan oligarchy seized power in the city, and the Lakedaimonians expanded their rule into the former Athenian *Arkhē* (Empire). However, following the Athenian general Thrasybulus’ restoration of democracy in 403 BC, the *pólis* was able to not only survive into the fourth century, but actually restore much of its fifth-century power and authority. Key to this Athenian resurgence was the creation of the Second Athenian League in 378 BC. This alliance, which was to last until it was superseded by the 338/337 BC Hellenic League, made concrete attempts to correct the abuses of its predecessor organization, the First Athenian League. Unlike the First League, the Second Athenian League functioned for several years as a true devolved confederacy, with considerable power and leadership reserved to member states. A number of guarantees inscribed on the Second League’s founding document, the Decree of Aristoteles, enforced this decentralized structure by prohibiting the methods Athens had used to accumulate power in the First League. However, the practical limitations of a devolved alliance were revealed when Athens reclaimed its hegemonic status in the 350s BC, and the League was discarded soon after.

The Athenians used astute diplomacy and voluntary incentives rather than coercion to form the Second Athenian League. During the Peloponnesian War, the oppressiveness of Athenian rule under the First Athenian League led to a series of revolts by allied states that destabilized the *Arkhē* and allowed the Lakedaimonians (inhabitants of Spartan-ruled territories) to assert themselves as the sole hegemonic power in Greece.<sup>1</sup> Following the peace settlement of 404 BC, the Lakedaimonians proceeded to commit many of the same mistakes as the Athenians by occupying recently “liberated” cities

and imposing puppet regimes called “Committees of Ten” instead of allowing them to create autonomous governments. Xenophon records the outrage this provoked, with one particularly rueful Theban ambassador saying, “The Spartans, now that things have gone well for them, think it perfectly proper to set up their own helots [serfs] as governors, and meanwhile treat their free allies as though they were slaves.”<sup>2</sup> These ill-advised actions created the impetus for an alliance of states opposed to further Lakedaimonian expansion.

In the First Athenian League, Periklēs had pursued a program of Athenian naval dominance as the key to the *pólis*’ security and the maintenance of its maritime empire. Even with the steep population decline associated with the Peloponnesian War, the farmlands of Attika were incapable of feeding the city of Athens on their own, which depended on imported grain from the Black Sea region.<sup>3</sup> The city’s grand natural harbor at Piraeus and large pool of citizens with maritime experience meant the Athenians had the infrastructure and skills to maintain this naval advantage as they had done in the period of the First League (Xenophon, VII.1.3–6). However, after 404 BC, Athens did not have the military might to reconquer its former *Arkhē* by force alone. To do so would have paradoxically required the resources and financial support of the *Arkhē*.

The Athenian solution to this quandary was the truly innovative creation of what may be called a devolved multilateral alliance that would unify the former *Arkhē* under Athenian leadership without threatening members’ autonomy. In 394 BC, an Athenian fleet under Thrasybulus visited many former Athenian subject *póleis* as an extension of Athenian naval efforts against the Lakedaimonians. In several of the *póleis*, including the important cities of Byzantium and Rhodes, Thrasybulus assisted popular pro-Athenian revolutions but made no further attempt to interfere in their internal affairs.<sup>4</sup> This was a farsighted move, as it drove out the Lake-

daimonians in areas important to Athenian interest while establishing friendly governments that did not require garrisons to maintain (Xenophon, IV.8.27). Thrasybulus' light hand seems to have made him genuinely popular. Xenophon states that "the common people of Byzantium were glad to see as many Athenians as possible present in the city" following the democratic revolution (IV.8.27). Elsewhere, he notes that Thrasybulus tried to "win over" Aegean cities and "make them friends of Athens" rather than conquer them outright (Xenophon, IV.8.28). It appears that the democratic factions in these cities now increasingly saw the Athenians as liberators from unpopular Lakedaimonian governments. In 384 BC, the Athenians began experimenting with a more decentralized method of exerting influence in the Aegean Sea when they signed a bilateral, mutual defense alliance with the island of Khios.<sup>5</sup> The Khians had revolted against the First Athenian League in 412 BC, and it was perhaps to assuage fears of recreating the First League's abuses that both sides pledged the alliance on "the basis of freedom and autonomy" (Cargill, 9). Certainly a maritime power like Khios had more closely aligned objectives with Athens than with Sparta, while Lakedaimonian overreach had spoiled any goodwill most island *póleis* had towards the Peloponnesians. In 378 BC, the Athenians took the next logical step in these efforts by inviting friendly governments to join with them in a Second Athenian League. Several island *póleis* accepted Athens' invitation, including the major cities of Mytilene, Methymna, Rhodes, and Byzantium (Cargill, 52).

Because it was designed to protect member states' autonomy, the Second Athenian League created a governing structure that balanced the needs of the Athenians with those of their allies. It should be noted that the Second Athenian League was a form of hegemonic alliance with some important caveats (Sealey, 404). Rather than vest all power over League policy in the governing Athenian Assembly, as would have been typical, the Second League conferred decision-making power in both the Assembly and an independent *synedrion* of the allies (Sealey, 410). The *synedrion* was composed of *synedroi* (representatives) from all League member states, each of whom received one vote (Diodorus of Sicily, XV.28.4).

Diodorus of Sicily records a requirement of the League that "every city great or small should be on an equal basis...and that all should continue to be independent, accepting the Athenians as leaders" (XV.28.4–5). Interestingly, the Athenians themselves did not have even one vote in the *synedrion*. Other hegemonic leagues created the veneer of representation by vesting power in a leadership council with representatives from the alliances' member states but then granting the hegemon unilateral power on the council. By keeping the Athenians out of the *synedrion* completely, it would appear that the founders of the Second League were attempting to preserve freedom of action for the non-hegemonic states. Furthermore, the *synedrion* selected its own presiding officers from among the sitting *synedroi*, chose when to convene, and set its own agenda (Cargill, 115).

The decentralized nature of the Second Athenian League could also be seen in the interactions of the Assembly and *synedrion* (Xenophon, VI.5.49). Decisions that affected the entire League required the approval of both the Assembly and the *synedrion*. The process could begin in either body, and both the Assembly and *synedrion* could pass either decrees or resolutions (Cargill, 117). Resolutions passed by either body were simple statements of fact and had no legally-binding power. Decrees did have legally-binding force and could also be passed by either body as well, but decrees passed by the *synedrion* did not have legal force until also approved by the Assembly (Cargill, 117–118). Decrees passed by the Assembly that dealt with the entire League also had no legal force until approved by the *synedrion*; although, sometimes the Assembly would pass a decree that would only be binding in Athens until such a time as the *synedrion* approved it. However, if the *synedrion* did approve such a decree, it would become legally binding for the entire League (Cargill, 120). This creative balancing act succeeded for several years in maintaining Athenian freedom of action while allowing them to exercise effective but limited leadership within the framework of an alliance. Likewise, the allies were able to benefit from the stability and protection offered to members of a hegemonic alliance while also maintaining some independence from Athens' foreign policy and goals.



The Second Athenian League also attempted to prevent the concentration of power in Athens through a series of prohibitions and guarantees. Publicly displayed on the Stele of the Decree of Aristoteles in Athens, these guarantees stated that each member would be “free and autonomous,” that each member could “govern [himself according to the] constitution which he prefers,” and that a member would not be obliged to “receive a garrison nor accept a governor, nor pay tribute.”<sup>6</sup> These were almost certainly directed against the abuses of the First Athenian League (Sealey, 412). By this constitution, the League *syntaxis* (budget) could only be spent for military expenses of the alliance and only after approval from both the Assembly and *synedrion* (Sealey, 124–125). Athenian citizens were also prohibited from owning property in the territory of a League member (“The Stele of the Decree of Aristoteles”, lines 35–46). Enforcement of these provisions was to be carried out by the *synedrion* of the allies and not Athenian law courts, mitigating against a possible corruption of justice by sympathetic juries (“The Stele of the Decree of Aristoteles”, lines 35–46, 51–63).

The Second Athenian League was an important milestone in the conceptual evolution of multilateral alliances, but its devolved structure was also a weakness. By delegating considerable freedom and independence to the League’s member states, Athens had been able to secure the cooperation of most of the powerful maritime *póleis* in the Aegean and Ionian Seas. After Lakadaimonian power was decisively defeated at the Battle of Leuctra (371 BC) and broken completely at the Battle of Mantinea (362 BC), the League lost its *raison d’être*, and the priorities of most League members and Athens itself began to diverge (Xenophon, VI.4.19, VII.5.26–27). It seems the island allies of Athens refused to become involved in Athenian foreign policy ventures that did not affect them. There is no mention in Diodorus or Xenophon of member states sending support to the Athenian land forces fighting the Peloponnese during the 360s. In 366 BC, the Thebans seized the important border town of Oropus in Attika. Desperate to retake it, the Athenians invoked the mutual defense clause of the Decree of Aristoteles but became “discontented with their allies because while they themselves were going to much trouble on their behalf, not a single one of the allies had given them any help in return” (Xenophon, VII.4.1). The refusal of “a single one” of the allies to come to Athens’ aid in this incident was a flagrant violation of the League’s founding charter. However, the Athenians had so thoroughly limited their ability to coerce member states that there was nothing they could do without fundamentally changing the structure of the League. A similar (but more nuanced) shift in Athenian foreign policy took

place in the late 360s. Jack Cargill proposes that the last new member of the League, the Zakynthian democratic faction, was added in 374 BC and that the Athenians stopped recruiting other states into the alliance after that date (66). Athenian power continued to expand well into the 350s, but now the Athenians began again concluding bilateral treaties of alliance with friendly states and outright annexing hostile states (Cargill, 83). Bilateral treaties between Athens and an independent state were less binding than admission into the League but also more flexible and situational. Certainly this type of alliance did not constrain Athens to follow the limits placed on its power by the rules governing the League. Athens’ decision to simply reconquer former members of its *Arkhe* during the 350s is indicative of resurgent Athenian military power.

The Second League was a necessity of 378 BC when Athens was still very weak and preparing to go to war with Sparta. Athens’ unique dilemma of having the expertise to lead a successful hegemonic alliance but not the resources to create it led directly to the innovative structure of this alliance. Neither completely unilateral nor completely equal, the alliance allowed Athens to call on the resources and voluntary support of its former *Arkhe*, which in turn received the protective benefits of a hegemonic league even while maintaining their autonomy. Strict limitations on Athenian power and the structure of decision making in the League made the alliance successful for several decades. However, Athenian victories and a sustained military buildup in the 370s and 360s restored the *polis*’ coercive power (Sealey, 430–431). No longer forced to rely on voluntary cooperation, the Athenians began to exercise more direct rule in the Aegean, and in the 350s, the Second League evolved into a Second Athenian Empire.

## ACKNOWLEDGEMENTS

This paper is deeply indebted to Dr. Christoph Konrad who encouraged and guided my research on the Second Athenian League as part of an independent Honors Contract in his HIST 426 class. Primary sources for the period discussed (c.404 BC–350 BC) are unfortunately scarce. The most reliable account comes from the fourth-century Lakadaimonian author Xenophon, who recorded political affairs in Greece between the final stage of the Peloponnesian War (411 BC) and the Battle of Mantinea (362 BC). Diodorus of Sicily, writing in the first century BC, had access to now lost contemporary sources and is a useful supplement to Xenophon. I used the fifth-century Athenian historian Thucydides for information on the structure and failures of the First Athenian League. The 377 BC Stele of the Decree of Ar-



istoteles, which partially survives, recorded the original membership and constitution of the Second Athenian League. I have relied on Dr. Jack Cargill's translation of the stele throughout my work. It should be noted, however, that much of his translation relies on conjecture to make sense of parts of the stele that have been damaged. With regard to secondary sources, I relied on relevant chapters from Dr. Raphael Sealey's *A History of the Greek City States ca. 700–338* for an overview of Greek history during the early fourth century BC. Cargill's *The Second Athenian League* was my main source of information for the organization of the Second League.

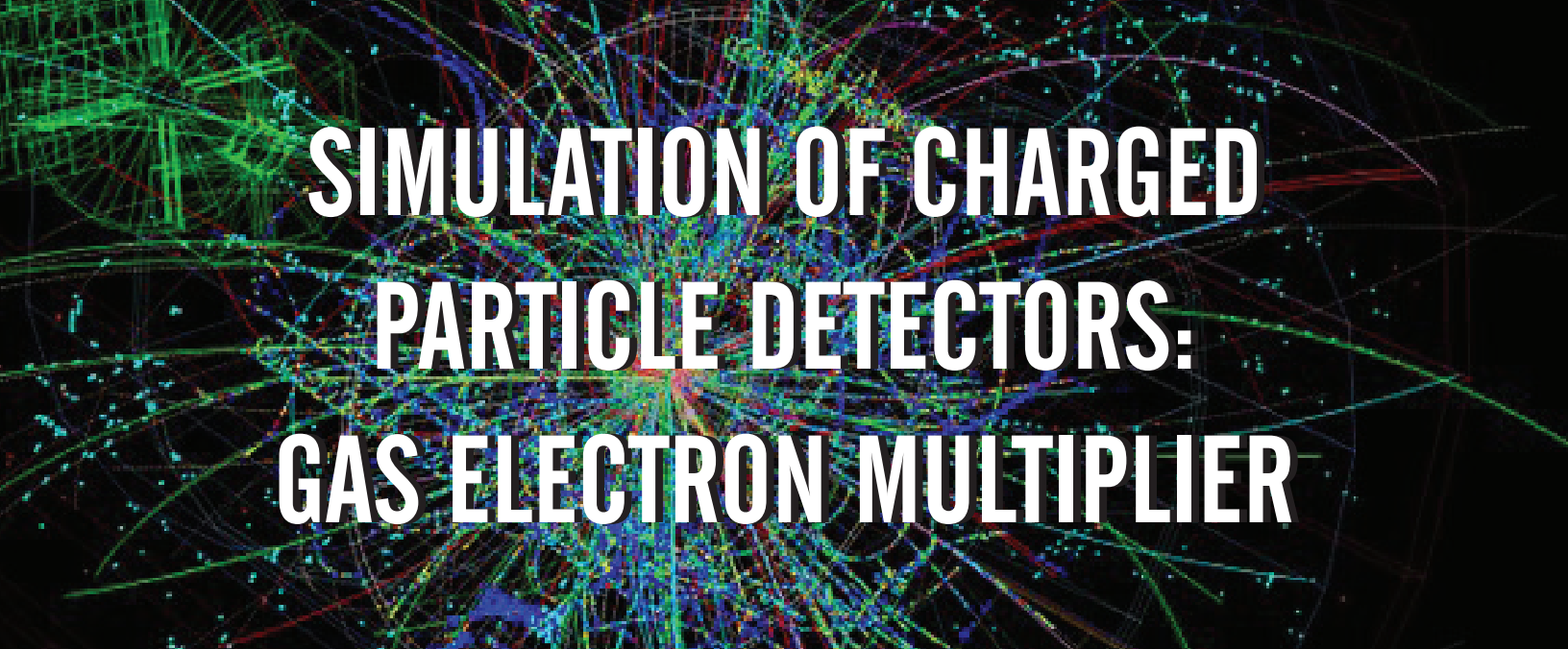
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## Patrick Grigsby '18

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# SIMULATION OF CHARGED PARTICLE DETECTORS: GAS ELECTRON MULTIPLIER

*By Taif Mohamed and Shaikha Al-Qahtani*

*THE WORK PERFORMED BY THIS TEAM CONTRIBUTES TO THE STUDIES BY THE EUROPEAN COUNCIL FOR NUCLEAR RESEARCH (CERN) TO BETTER UNDERSTAND THE FUNDAMENTAL PARTICLES THAT MAKE UP OUR UNIVERSE. THE TEAM IN QATAR IS PART OF THE COMPACT MUON SOLENOID TEAM, AN INTERNATIONAL SCIENTIFIC COLLABORATION BRINGING MORE THAN 2,000 SCIENTISTS TO WORK TOGETHER.*

## INTRODUCTION

CERN is a French abbreviation, which stands for The European Council for Nuclear Research. It is the largest center for scientific research in the world. The purpose of the experiments in CERN is to answer questions about the origins of the universe and matter. The experiments are done with particle accelerators and detectors. CERN is known for containing the largest particle accelerator in the world, the Large Hadron Collider (LHC). In 2012, after three years of operation, the LHC made history in the physics world; a new particle was observed in the accelerator that resembled the Higgs boson, which had been predicted by the standard model theory.<sup>1</sup> This achievement opened the door for more discoveries and a gateway to new physics. In order to continue the discovery of new physics, scientists must increase the energy and luminosity of the LHC. However, current technologies might not be able to cope with the changes, and thus, an upgrade is needed. One of the experiments on the LHC that will be upgraded is the Compact Muon Solenoid (CMS) experiment. The CMS's detector technology was designed to accurately detect muon particles. Muons are charged particles that resemble electrons but have a much greater mass; they are present in the most important physical processes. A new detector known as the Gas Electron Multiplier (GEM) would be added

onto the muon chambers. This research aims to optimize GEM operation and efficiency by comparing the effect of two different etching techniques on the detector gain.

## GAS ELECTRON MULTIPLIER

The Gas Electron Multiplier (GEM) is a gas-based detector that identifies external charged particles when they enter the detector and collide with gas particles, effectively ionizing them. The ionization of gas particles in the detector leads to the release of electrons, which can be detected as an electric signal. Additionally, layers of GEM foil, consisting of a copper/Kapton/copper setup and a high density of holes, amplify the electrons' signal before reading it at the printed circuit board (PCB).<sup>2</sup> Figure 1A illustrates the amplification of the signal in the holes due to the high electric field existing there. Because of this functionality, the triple GEM detector, made up of three GEM layers as shown in Figure 1B, is a strong candidate to be installed in the Compact Muon Solenoid (CMS) experiment in the next upgrade.

The goal of using GEM detectors is to create a signal strong enough to be differentiated from background noise. The performance of the detector, in that sense, can be affected by several factors, including hole size and shape, the electric field existing in gas gaps, and the gas mixture, among others. Our study focused on the

effect of different manufacturing processes on hole size and shape.

## GEM MANUFACTURING PROCESSES

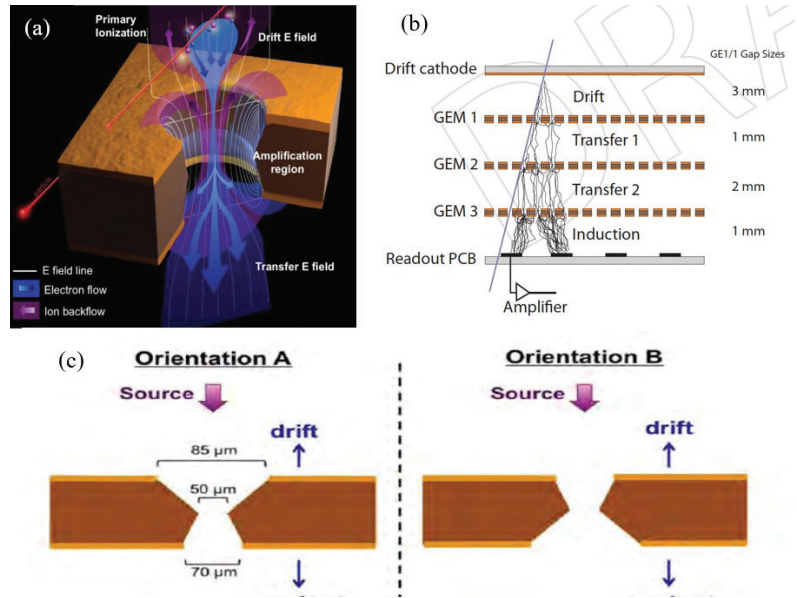
Holes are made in the GEM layers using chemical etching, which presents the difficulty of getting precise hole size and shape. The standard manufacturing process for the GEM has been the double mask technique, which results in a symmetric double-conical shape of the holes. For the required size of GEM layers (1 m x 0.5 m), however, this process is too complicated and expensive. Alternatively, we propose the single mask technique to produce these GEM layers. The effect of using the single mask is different hole diameters on the upper and lower sides of the GEM.<sup>3</sup> Two orientations of the GEM were identified, where orientation A exhibited a larger upper hole diameter than B, as shown in Figure 1C. Changing the orientation of the GEM layer can cause a significant difference in gain, which is defined as the number of electrons produced through primary and secondary ionizations due to the detection of a single muon divided by the number of primary ionizations. The ultimate goal of this study is to identify the most optimal configuration of triple GEM that maximizes the gain.

## METHODS

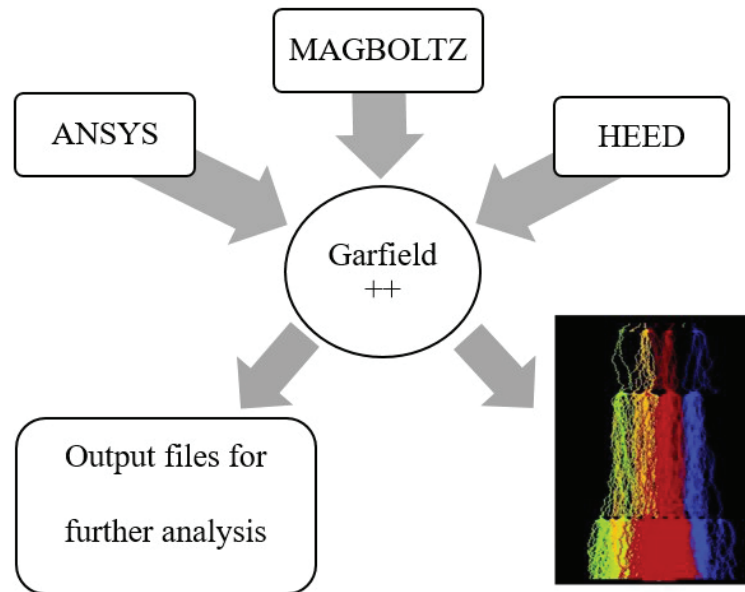
We used three main simulation software to complete our studies—HEED, ANSYS, and Garfield++—and we made use of a supercomputing facility due to the need of high computing power. Figure 2 shows the logical flow of the simulation. In order to compare the different manufacturing processes of the GEM, three main configurations were defined for every simulation: double mask, single mask orientation A with the wider hole on the top, and single mask orientation B with the wider hole on the bottom.

## ANSYS

ANSYS is a computational fluid dynamics package based on the Finite Element Method.<sup>4</sup> We used ANSYS to define the detector geometry and to compute the electromagnetic field map throughout the detector. To

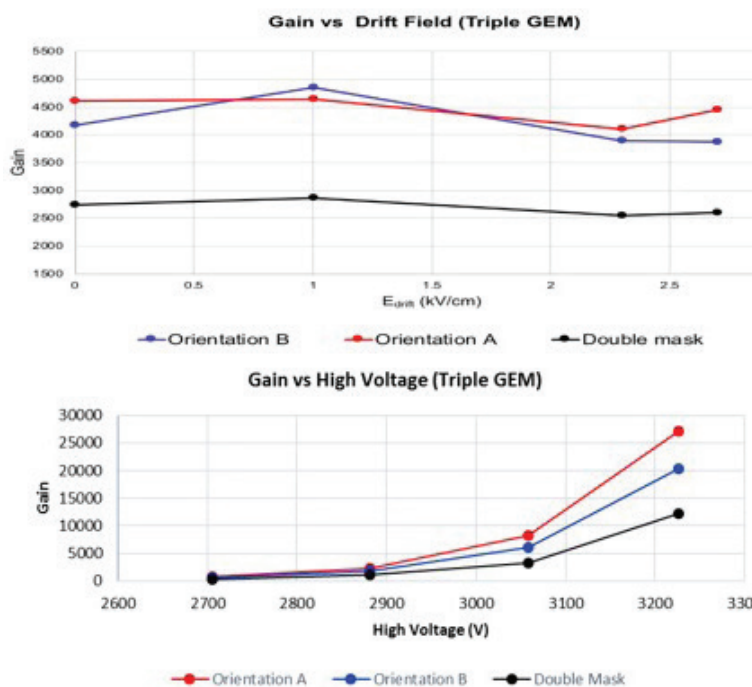


**FIG 1A-C.** (A) Electron multiplication in GEM hole (B) Triple GEM detector (C) Asymmetrical GEM holes due to single mask



**FIG 2.** Logical flow of the simulation.





**FIG 3.** Results of drift field study (top) and high voltage study (bottom).

obtain an electromagnetic field map, ANSYS divides the entire detector into a mesh of nodes and computes the electromagnetic field values at these nodes. Then, ANSYS displays the solution in the form of four list files, which are essential to the Garfield++ simulation.

## GARFIELD++

The list files, obtained from ANSYS, are then used in Garfield++, which employs Monte-Carlo simulation methods to simulate the interactions of the electrons as they are produced and flow through the detector, ionizing more gas particles on the way.<sup>5</sup> Garfield++ uses Magboltz to calculate the electron properties as they interact with the gas in the detector.<sup>6</sup> It can then conclude how many secondary ionizations may result from each primary ionization and compute the gain.

## HEED

HEED is a software tool that simulates charged particles passing through a gas and computes the energy loss by taking into account the collisions between the atoms.<sup>7</sup> This program shows the number of primary electrons produced and the number of clusters per cm in the GEM. The geometry of the GEM from ANSYS is the input to HEED. Then, the output of HEED, the number and position of primary electrons, is the input of Garfield++. Thus, instead of using the random function to generate random electrons, HEED simulates the actual primary electrons, which makes the simulations more realistic.

## RESULTS

For a triple GEM detector, we conducted simulations that studied the gain at different values of the electric field in the drift gas gap and for different values of voltage at the drift cathode, called the high voltage. The gain of each simulation was recorded, and the graphs displayed in Figure 3 were produced to compare the effect of each configuration on the performance of the GEM detector. Results show that with the current voltage divider, installing the GEM in orientation A would yield the highest gain, and consequently, the highest chances of accurate detection.

## CONCLUSION

Our work is still ongoing as we are enhancing the simulations for a more thorough study of these two manufacturing processes for the triple GEM detector. The results clearly showed that the GEM layer orientation has a significant effect on the performance of the detector. Therefore, the results of our simulations and analysis will be crucial during the assembly process, and we aim to share our findings in order to facilitate a successful upgrade for the CMS muon detector.

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# Raman Spectroscopy:

## HOW TO KEEP OUR ANIMALS AND US HEALTHY

*By Danielle Yarbrough*

### INTRODUCTION

The animal feed industry in the United States is worth almost \$300 billion annually in sales, and livestock animals consume over 17 million tons of feed each year in the state of Texas alone. This industry affects people around the world who come into contact with various animal-sourced products. In order to meet the demand for these products, animals must grow quickly and remain healthy; this is commonly accomplished by adding antimicrobial drugs to the animals' feed supply. The Food and Drug Administration (FDA) has carefully regulated the use of feed additives over the years and has allowed their frequent use due to their benefits to animal health and growth rate. However, these drugs could potentially cause adverse health effects such as antimicrobial resistance in animals and in humans who consume animal products. Due to the growing knowledge of these adverse effects, the FDA has become increasingly concerned with the widespread use of many antimicrobials and other drugs as additives. The FDA's concerns have led to the limitation and, in some cases, the banning of these drugs in animal feed. Due to this increased concern and regulation, finding quick and reliable methods of detecting antimicrobial agents in feed has become extremely important.

The currently used mainstream methods for antimicrobial detection in feed, such as High Performance Liquid Chromatography, are highly accurate, but they are also costly, inconvenient, and impractical for rapid testing on a large scale, such as that of the feed industry. Therefore, analysis labs need a faster, more practical method of screening feed samples for contaminants. For regulatory purposes, the FDA's limitations on antimicrobials must be met. This can only be done through the accurate classification and quantification of the concentration of antimicrobials in feed samples. If a feed sample is tested and found to have an antimicrobial concentration that is even slightly above the allowed limit, that batch of feed must be removed from the market as quickly as possible. This process is paramount to keep the

public safe and healthy. To do this, my project explores the use of Raman spectroscopy, specifically Surface-Enhanced Raman Spectroscopy, as a testing method that offers new approaches to achieve the goal of protecting the public.

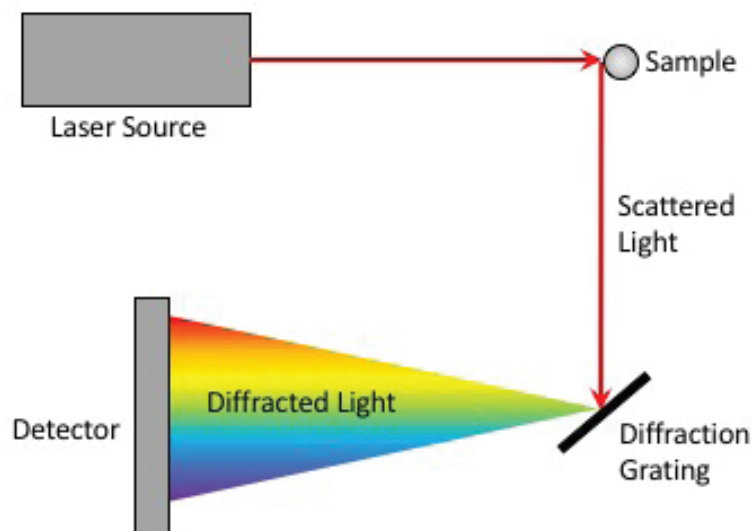
Raman spectroscopy is used to identify the molecular structures of compounds and the amount of those compounds present in feed samples. In my project, I used a Raman spectrometer to apply laser pulses to liquid samples that were enhanced with a nanoparticle solution. The laser pulses cause vibrations in sample molecules; these vibrations shift the light frequency by specific amounts depending on the shift in energy level of each chemical bond. This shift, called a Raman shift, is unique to each molecule and allows for the identification of specific target analytes or in my case, the different antimicrobials. A detector measures this shift in light frequency and outputs the data as unique spectral plots. This process is shown in a simplified form in Figure 1.

The ultimate objectives of this project are (1) to collect qualitative spectral data for four antimicrobials and (2) to create accurate classification and quantification models for antimicrobial detection through the use of Raman spectroscopy using the data from one antimicrobial. Ideally, these models can open doors to future utilization of Raman spectroscopy in the feed industry. By building on the results provided by the models, feed production facilities can ensure the safety of their products in a faster and more cost-effective way than current methods.

### METHODS

I chose four antimicrobials that are of concern to the FDA: monensin, decoquinate, lasalocid sodium, and chlor-tetracycline. Initially, the lab ordered and obtained these antimicrobials in a pure form. Lab technicians extracted the antimicrobials using different extraction solutions, and I used the resulting solutions as the calibration standards for testing. A solution of gold or silver nanoparticles was add-





**FIG 1.** Diagram of Laser Testing Process.

ed to the sample antimicrobial solutions to greatly enhance the signal received by the detector in the Raman spectrometer. Samples were tested three times each for qualitative analysis and ten times each if they were to be analyzed quantitatively. During the testing process, the Raman spectrometer subjected samples to the laser in pulses and recorded the Raman shifts for each test. These Raman shifts and the corresponding intensities were recorded as peaks in spectra as shown in Figure 1.

For the qualitative analysis conducted on all four chosen antimicrobials, the spectral data were processed, and the graphs were visually analyzed for peaks unique to each antimicrobial. In addition, the unique peaks were analyzed to determine if the intensity increased as the concentration increased, as seen previously in Figure 2.

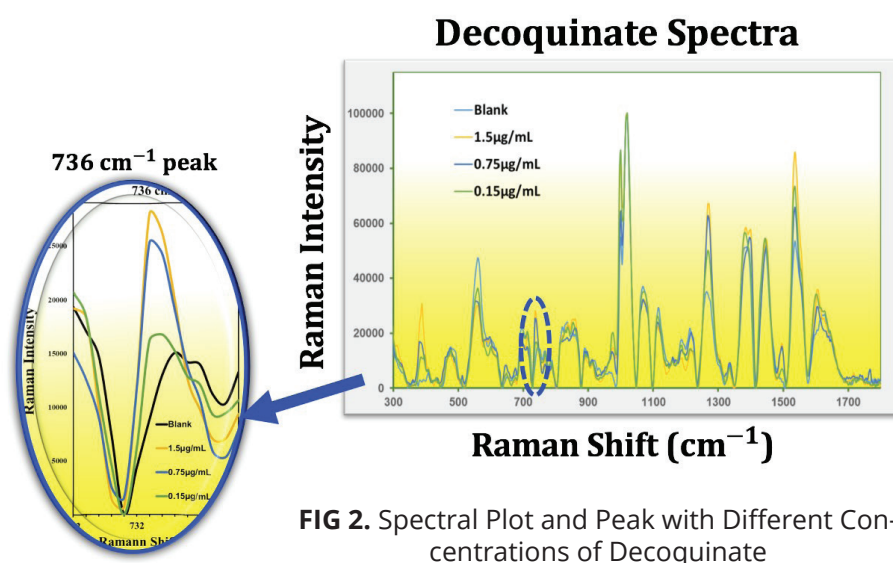
For the quantitative analysis conducted on the monensin data, the spectra were analyzed using statistical methods. These methods each used a different algorithm to simplify the complicated data into clear results that could be analyzed. For this, I first processed the raw spectra to obtain data that could be analyzed easily. Then the spectral data were converted into numerical data, and those data were processed with statistical analysis methods with the help of my mentor. The methods used for the classification models were basic linear discriminant analysis, k-nearest neighbor method, and partial least-squares discriminant analysis. The methods used for the quantification models were multiple linear regression, principle component regression, and

partial least squares regression.

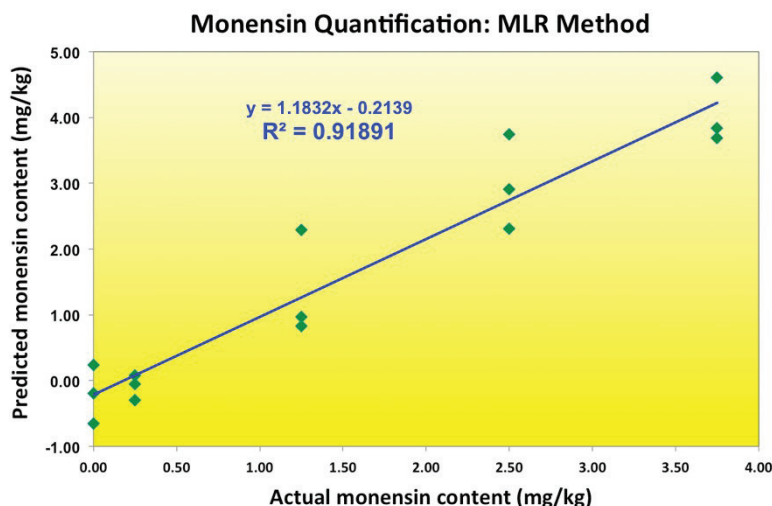
Once the above statistical methods were performed, the two models, classification and quantification, were created. The successes of each statistical method were compared to the other methods used. The classification models were made with six categories of samples: one for blank samples and one for each of the five different concentration levels in the calibration standards. The success of each model was measured by the percentage of correctness with which it classified the sample in its appropriate category. The quantification models were created to plot the known concentration of monensin in calibration standards versus the model's predicted concentration of these same samples, and success was measured by the value of the correlation coefficient. Finally, the models were validated by testing other calibration standards of known concentration and determining how well the models classified these new samples or quantified the exact concentrations in the samples.

## RESULTS

Upon analysis, the spectra revealed unique peaks for all four antimicrobials tested. For the most part, these peaks had increasing intensities according to the concentration of antimicrobial present. Each antimicrobial present was identified, and the relative concentration present in the samples was determined by visually analyzing the spectral plots. For more exact classification and quantification of the monensin content in samples, the statistical models for monensin were analyzed and compared. Each statistical method had varying degrees of success in creating a reliable model that could predict the concentra-



**FIG 2.** Spectral Plot and Peak with Different Concentrations of Decoquinat



**FIG 3.** Monensin Quantification Plot.

tion of monensin in the samples.

As stated previously, for the classification model, the success of each statistical method was rated by the percentage of correctness with which it classified test samples into preset categories based on concentration level. This correctness for each method is shown in Table 1.

As seen in the table, the k-nearest neighbor method and the partial least squares discriminant analysis both classified samples with 97.6% accuracy in the validation tests. This indicates an important result: the k-nearest neighbor method, the partial least squares method, or both would be best used to create an accurate and reliable classification model.

Success for quantification was measured by the correlation coefficient, or value, of each data set and how close its value was to one. A value very close to one indicated that the model's predicted concentration matched the actual known concentrations of monensin in samples. The results for standard Raman testing are shown in Figure 3 and Table 2.

It may seem that the values listed in Table 2 are low values; however, it is acceptable to have numbers as low as 0.7 in the feed screening process due to variability of samples as well as the extremely low concentrations at which the tests are run. As seen from the table, the multiple linear regression method had the most success overall with the highest values. This indicates an important result: the multiple linear regression method provides the best method for giving an accurate quantification model

**Table 2.** Value Comparison.

Method	Value
<i>MLR</i>	0.91891
<i>PCR</i>	0.74573
<i>PLS</i>	0.89349

for samples.

With this knowledge, the methods with the best results can be applied to other antimicrobial samples to create similar classification and quantification models. These models can then be used in simple and efficient testing of feed samples on a larger scale. Finally, it is important to note that both the classification and quantification models showed a promising ability to predict antimicrobial concentration down to the parts per billion level. This ability could be further improved upon with additional study and data collection. The added study would preferably include the testing of as many more samples as possible, as well as spreading out the scope of the project to include other antimicrobials or chemicals of concern to the FDA.

## CONCLUSIONS

Ultimately, in this project, I showed the ability of Raman spectroscopy to accurately detect specific concentrations of four antimicrobials in feed samples. Not only was Raman spectroscopy shown to be as accurate as current methods, but it was found to be much more rapid and straightforward. In addition to demonstrating the benefits of Raman spectroscopy itself, I also was able to utilize statistical analysis methods, which created the classification and quantification models that can aid in detection of any banned or restricted antimicrobials. The models from this project can be easily applied to other antimicrobials in feed samples and can be scaled up to rapidly screen samples in an industrial setting. By utilizing Raman spectroscopy testing methods and prediction models such as the ones created in this project, the feed industry can save money and time on regulatory product testing. More importantly, feed producers can quickly detect and discard any contaminated and possibly harm-

**TABLE 1.** Classification Correctness Results

Method	<i>Linear Discriminant Analysis</i>		<i>K-Nearest Neighbor</i>		<i>Partial Least Squares DA</i>	
Model Type	Resubstitution	Validation	Resubstitution	Validation	Resubstitution	Validation
Correctness (%)	97.6	78.6	97.6	97.6	97.6	97.6

ful feed that may otherwise get through the production process undetected. Finally, this technique can reduce the risk of the adverse health effects from antimicrobial contamination for the people who consume or use animal products in the state of Texas and the U.S as well as around the world.

## ACKNOWLEDGEMENTS

I would like to thank Dr. Kyung-Min Lee, Dr. Timothy Herrman, and Prabha Vasudevan for their mentorship and instruction. I would also like to thank the Office of the Texas State Chemist for allowing me to use the laboratory space and equipment throughout the length of my project.



### Danielle Yarbrough '19

*Danielle is junior chemical engineering major with a minor in biochemistry from Winnsboro, Texas. Danielle performed the research for this article under the supervision of Dr. Timothy Herrman and plans to continue it by attending graduate school beginning in the fall 2019 semester where she will pursue a doctorate in biochemistry. Danielle's goal is to begin a career research in the pharmaceutical or medical industry, specifically in the field of nanoparticles and their use in immunotherapy.*

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# DANCING IN VIRTUAL REALITY

*By Sarah Behseresht, Hannah Juenke, and Kali Taft*

**FIG 1.** Interacting with Virtual Reality equipment.

## VIRTUAL REALITY IN THE DANCE WORLD

While technology has been incorporated into dance for years, there has been a recent push to make performances increasingly interactive based on the swells of audiences' desires to participate.<sup>1</sup> This might look like asking audiences to make decisions that prompt choreography or a set phrase with a specific chosen word; in this way, audiences could contribute to the performance and therefore feel a connection with the dancers and the art being created. One way to accomplish this sense of interaction is through virtual reality. The goal of this research is to include audiences by transporting them to a virtual world. Virtual reality allows them to see what the dancer is seeing and connect with the movements of the dancer behind the screen.

Body movement is one of the first areas that gave rise to the motion capture technology of many gaming devices and virtual reality.<sup>2</sup> Dance incorporates the whole body in movement, so it is a perfect pair for technology that maps motion. A study was completed in which angular movements and velocities were recorded by eight cameras using optical motion capture technology that translated into the ability to create a system that mirrored the user's movement onto a virtual being.<sup>2</sup> These advances in technology and virtual reality are a useful training tool to view the body in a unique way and help

with advancements in the health and fitness industry.<sup>3</sup> Virtual reality equipment has recently made its way into the aspect of dance performance, increasing the audience interactions and relationship with the creative process, and it will likely make large advancements within the next few years.

Virtual reality contributes to media and technology in many ways and is continuing to move forward in its advancement and depth.<sup>4,5</sup> As the equipment becomes more accessible to the public, it will likely progress toward becoming more prevalent in artistic mediums such as dance.<sup>5</sup> These advancements open up a new realm of opportunity for the creative artist to merge the worlds of technology and movement. Our research seeks to further the incorporation of virtual reality in modern dance.

## PROJECT DESCRIPTION

This choreographic work demonstrated the use of dance and technology to explore the expanding idea of what captures the attention of modern audiences in the performing arts. We planned to accomplish this goal through collaboration with the Visualization Department at Texas A&M to merge our areas of interest. Weekly meetings were held with the Visualization Department to keep an agenda with the updates in the technology equipment, as well as weekly rehearsals with the dancers to generate movement and develop the choreography of the piece. The majority of our choreographic vocabulary was influenced by the virtual reality equipment, including

the sensors that the dancer wore around their wrists, the headset that allowed the dancer to see the images being displayed, and the cord attaching the headset to the computer. These props were a large determinant of the movement parameters. The cord presented itself to be the most limiting factor in the radius that the dancer was able to use, and the headsets and sensors determined the amount of movement the dancer could most efficiently perform. Another factor that influenced the choreography was the image being projected on the scrim in front of the dancer. In order for shapes to show up on the scrim, the dancer had to move in such a way that these shapes were formed in a manner that visually corresponded to our desired aesthetic. If movements were too small or intricate, the images on the screen would not be visible. These limitations presented a positive challenge for the creative process of the dance, since working around these obstacles required us to think of innovative movement that still translated as modern dance performance. The framework of this experimental process involved three main components that we designed. These components were pieced together to create the work.

## VIRTUAL REALITY TECHNOLOGY

The first component consisted of the virtual reality technology designed by the Texas A&M Visualization Program. This technology included virtual reality goggles that one person, the dancer, wore and a controller that created lines or shapes in accordance with her movement that was projected on a screen for the audience. Incorporating this component required trial and error and visual exploration to determine how the images created by the technology corresponded with the location and quality of the dancer's movements.

## CHOREOGRAPHY

The second component to this study was the choreography of the dancer. The choreographer of this piece was in close communication with the researcher in charge of learning the technology because that information was essential for creating a compatible set of movement patterns for this piece. A majority of the movements were designed based on the shapes created by the controllers, which played an important role in the overall portrayal of the virtual reality technology seen by the audience. Since certain motions had a more significant effect on the virtual reality equipment, a majority of the choreographer's role involved discovering which movements created specific image qualities. For example, certain motions such as circling the arms with the controllers had a greater effect than other motions because the image displayed on the screen was more dramatic. Therefore, throughout the entirety of the piece, there were moments when the scrim was illuminated due to the large motions performed by the dancer, as well as moments of stillness, so that the dancer in front of the

scrim could be seen by the audience. During the piece, there were three main movements that were repeated often due to their ability to create aesthetically pleasing images on the scrim. These moments included, as stated earlier, large circling motions of the arms, flicking of the wrists, and wave-like motions of the arms up and down. The dancer using the virtual reality equipment mostly performed choreography that involved the use of her wrists and arms because the sensors for the virtual reality equipment were located on her wrists. Therefore, the choreography for the dancer in front of the scrim consisted of motions that focused on her lower body to serve as a contrast to the dancer using the virtual reality technology. Even though there was repetition in the phrases of movement within this piece, the output displayed by the virtual reality technology was always different than the previous images projected, therefore creating a unique viewing experience for each performance of the piece.

## LIGHTING, COSTUMING, AND MUSIC

The third and final component of this project was the lighting, costuming, and music. These three important aspects of a theatrical stage space were used to highlight the dancer and the virtual reality technology without detracting from it. The lighting needed to allow the audience to see both a projection on a screen and the dancer behind the screen creating the pictures with the movements. The costume corresponded with what looked best in the lighting that was chosen. Also, the costume had to somehow fit the controller inside of it without being noticeable to the audience. The music was a very important part of this performance because some of the cues of the controller were based on changes in the music, and the choreography had to rise and fall with the music or juxtapose the sharp and smooth qualities of the music to make for a more interesting dance.

All three aspects of this research had to occur harmoniously, so all three of the collaborators had to work through the decisions and the choreographic process to create an interesting and innovative dance work together.

## PROCESS AND REFLECTION

Our creative works research began eight months prior when we first began discussing the collaboration between virtual reality and movement in live performance. Christine Bergeron, the director of dance at Texas A&M University, and Jinsil Hwaryoung Seo, an assistant professor with the Visualization Department, were awarded a grant by the Academy for the Visual and Performing Arts to fund the technology required for creating a virtual reality program. Our first semester working on this creative works research mostly included



**FIG 2.** Design of technology on scrim



weekly meetings with our virtual reality program developer, Michael Bruner, from the Visualization Department. There were several limiting factors that affected our movement, which we had to consider before starting the choreographic process.

When choreographing with a prop, it is important to fully understand the prop's advantages and limitations. The goggles, the scrim, and technology program were all considered props that affected every decision made in the choreographic process. Movement with all of these added materials was quite difficult, but the goggles posed a great challenge, as they prevented the user from using vision and proprioception in space while moving. Vision is particularly important in dance for balance, turning, and traveling through space, and the use of movement was further inhibited by the cord attached to the goggles. Because of the cord, the dancer was constrained to a specific radius from movement. Vision impairment required a higher level of caution when jumping or changing direction to make sure the dancer did not disconnect the cord. The next prop was the scrim, which was primarily used as a way to set the scene and display the images, but during the second semester of development, we incorporated the scrim as a prop and explored its purpose on stage. We also had choreography for lifting the bottom of the scrim and crawling underneath it to pass through the two different worlds portrayed in the final piece. While using props presented a challenge, they created the necessary parameters to enhance the overall performance. Without some of these parameters, our creativity would not have been pushed out of normal limits.

During the first semester of this research, we discovered that certain motions caused the intensity of the display to become brighter and that several shapes such as circles displayed more effectively than others. With these ideas in mind, we made sure to include these motions within our set phrase work for the choreogra-

phy. As we became more comfortable with the technology, we explored movement choices and the creation of a solo piece for Sarah Behseresht. The cumulative choreographic work was made up of a brief phrase composed by each group member and integrated technology in such a way that the audience could interact. In the second semester of working on this creative works research, we already had set a strong foundation of choreography and an understanding of the program, but we realized we needed to continue to refine our work and create more of a narrative between the technology and our choreography. We added another dancer to the piece, team member Kali Taft, and explored the idea of dimensionality: if two worlds came together and lived in the same space. This idea was demonstrated by the incorporation of one dancer behind the scrim with the goggles on and the other dancer in front of the scrim without goggles. The dancer in the front would dance in reaction to the technology reflected on the scrim, whereas the dancer with the goggles initiated the images. Through the addition of this component, we found more purpose and meaning to our work and dove deeper into the realm of choreography and interaction between humans and technology, which was more than just an exploratory curiosity. One of our largest realizations was present in attempting to create each aspect of the project individually. It was evident from the start that we could not create choreography without using the time and space of the program. In contrast, the software developers needed our presence in the timing of the virtual reality equipment. Merging two different art forms requires the experts of both sides. This was apparent throughout our experimentation. Most of our progress was made when we were able to set hours to work with the technology in the performance space. In doing this, we were able to develop layers and create depth to our choreography by incorporating the use of the virtual reality equipment into our storyline. The feedback on the performance was



quite positive. Many people who attended were able to see the progress from the first tested performance to the culminating product.

Within the community of dance, incorporation of technology has become an extremely relevant and present topic. Not only has technology changed the interaction of performance, but it has opened up questions for further expansion in the future regarding the concept of combining live performance and technology.<sup>1</sup> New artistic experiences are possible, which allow dancers to be pushed further into the depths of their creativity. As choreographers and dancers, we are always looking for new ways to stretch the mind, discover fresh approaches to pair with dance, and bring innovative ideas into the dance world and to audiences. The audience's creative experience will be enhanced as well, because the addition of technology will enable them to view the performance in a new light. Stepping out into the forefront of this field was an amazing experience, one that would not have been possible without the LAUNCH: Undergraduate Research office allowing us to creatively research an area that we would not have experienced otherwise.

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### Sarah Behseresht '18

*Sarah Behseresht is a graduating senior dance science major hailing from the Woodlands, Texas. After graduation, Sarah plans to continue her studies by pursuing a doctorate in occupational therapy through which she hopes to prolong dancers' careers and expand the horizons of therapy for dancers in clinical settings.*



### Hannah Juenke '18

*Hannah Juenke is a graduating senior dance science major originally from Houston, Texas. Hannah notes that her involvement in with undergraduate research has enriched her time at Texas A&M and lead her to pursue further graduate study through a doctorate in occupational therapy.*



### Kali Taft '18

*Kali Taft is a graduating senior dance science major from Cleveland, Ohio. Through this research, Kali furthered her ambition of becoming a professional dancer. In this career, Kali hopes to continue the work started here by combining dance with different forms of media.*



# INTERACTIVE BUILDINGS OF THE FUTURE

*By Zach Kitowski*

## INTRODUCTION

From watches to cars to agricultural techniques, artificial intelligence and innovative software applications continue to affect more and more of the physical world. These new technologies are integrated into everyday life to increase efficiency and ultimately give people the freedom to spend more time doing what they want. Virtual assistants like Alexa and Google Home have changed the way people interact with their environment. A person's voice is now all that is needed to learn about the weather or turn the lights on and off. While smart home technology is more convenient than previous innovations, it still requires active participation from the user through verbal commands. An ideal smart home device would already know what the user wants and would make decisions based on that knowledge. Additionally, this device would sense changes in the physical environment, such as temperature, weather conditions, or health changes experienced by the building's inhabitants. The device would even be able to update the building configuration to create an optimal response with minimal human interaction time. Updating the building configuration might involve changing the thermostat, opening or closing a window, or sounding a security alarm. Research in this field is necessary to explore how different technologies can be used to create smarter buildings.

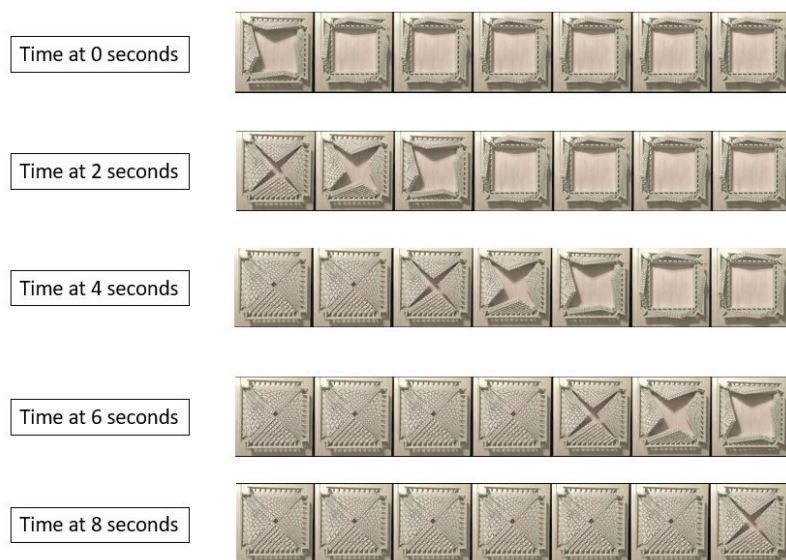
My research project, Project AURA, begins to ask questions about what we should expect from buildings in the coming years. The buildings of the future will enable people to minimize their power usage and environmental impact while simultaneously maximizing their human comfort and security. For

example, a smart building could turn off its lights whenever there is no one inside, which could decrease energy consumption by at least 35–40% and up to 75%.<sup>1</sup> Imagine the positive impact this would have on energy efficiency if every building could be equipped with this smart technology.

## METHODS

Project AURA centers on creating smart-building technology that is both functional and elegant; it explores alternative approaches to voice recognition to expand the ways that a person can interact with their building space. A focus on human-centered design is fundamental to the creation of an interactive building that people will want to use. The final version of this project was featured in the iMotion Exhibition within the Stark Galleries in the Texas A&M Memorial Student Center from May to July 2018. Using different human interactions to signal specific structural responses, this exhibit allowed visitors to personally experience this project and envision what a future smart-building might look like.

Project AURA implements interactive window blinds by combining robotic and architectural techniques. These interactive blinds stem from an architectural design completed by Dr. Negar Kalantar and Dr. Alireza Borhani, faculty members at Texas A&M University, in which the window blind structure opens and closes similar to the way a flower's petals fan out when it first blooms. The end goal was to create multiple blind structures, or AURA structures, that would move automatically based on sensory input. One AURA structure is defined as one of the square window pane structures seen in Figure 1.

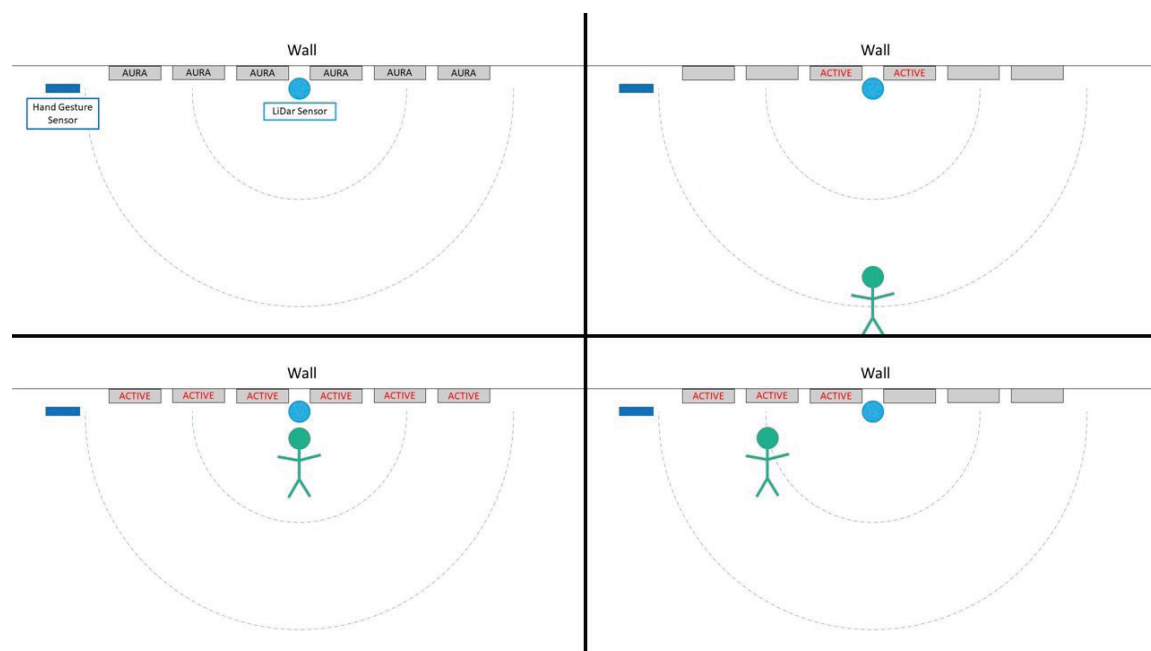


**FIG 1.** A time lapse showing how 6 AURA structures close sequentially.

To begin this project, I needed to find a way to automate Dr. Kalantar's and Dr. Borhani's manual window blind design, so I began by creating an automatic response in one AURA structure using sensory input. After multiple ideas and iterations, two servo motors were placed under the base of two of the fan blades, and an Arduino microcontroller was programmed to rotate the servo motor to a certain degree to open or close the AURA structure. Reliability testing was performed on the motors to ensure that they would not malfunction or overheat during a full day of use in the exhibition. I explored different motion, hand gesture, proximity and LiDAR sensor technology to see how I could program the Arduino microcontroller to create a unique opening or closing of the AURA structure based on sensory input from a person. A distance and hand gesture sensor and a LiDAR sensor were initially chosen as the final sensors to be incorporated into the AURA controller system. The distance and hand gesture sensor was ideal for sensing the speed and direction of a person's hand waves. Both of these capabilities provided greater

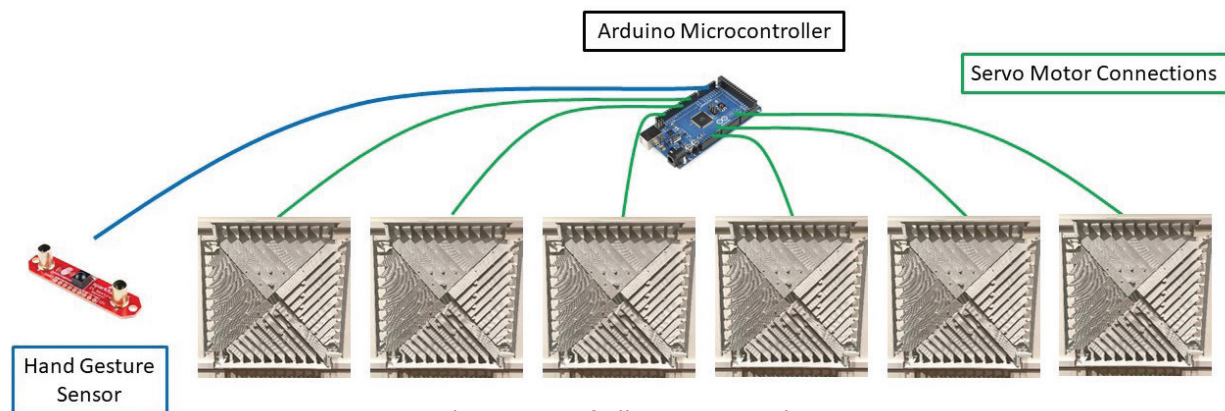
freedom in the AURA control scheme options. LiDAR sensors send out light energy in the form of a pulsed laser like a radar or sonar system to sense how close a person is to the sensor and how many people are present.<sup>2</sup> LiDAR has a large sensing distance of 40 meters, which was vital for determining where people are in a room. One possible configuration of the AURA structures and the LiDAR sensor can be seen in Figure 2.

The second phase of this project consisted of designing an array of six AURA structures that could communicate with each other to create macro response settings. One of the major challenges with this project was designing the system to run consistently for the entire two-month exhibition. Due to the exhibition running for 11 hours a day for 61 total days, I wanted to create a system that minimized the number of times the structures opened and closed whenever no one was present in the room to mitigate any reliability or wear on the structures and motors. This led me to focus on a macro setting mode enabling a person to generate and control a response in all six of the structures by accepting a hand gesture to cascade open or close all six structures. The control system can dynamically change the open or close direction immediately following a new gesture. The LiDAR sensor was not incorporated into the final design due to the inconsistency of the sensor to start up correctly and concerns about increasing the rate of opening and closing of the structures due to the added sensory input. The final system layout of the six AURA structures is shown in Figure 3.



**FIG 2.** AURA structure system with a LiDAR and hand gesture sensor implementation.





**FIG 3.** System architecture of all 6 connected AURA structures.

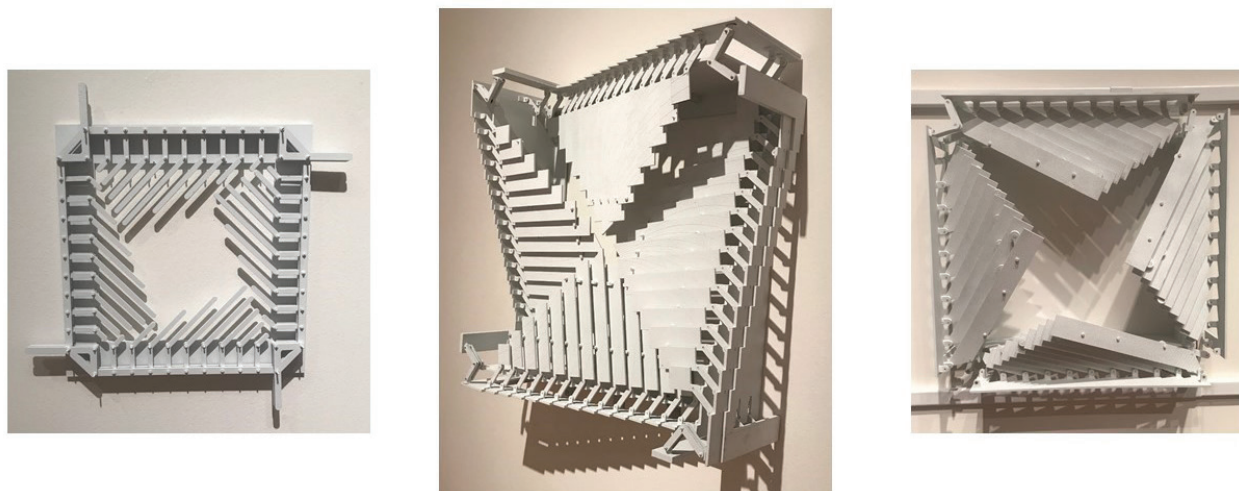
Being the sole researcher on this project, I programmed each of the microcontroller options and validated their successful operation. Processing sensory data and moving multiple servo motors at the same time was an extremely complex task. I used a timer function to control how often the servo motor rotated after a given number of seconds (it normally rotates one degree at a time with a timing delay). I also set a direction and end-goal angle state for each motor that could be updated based on the sensory input. The final result of this complex system was an array of six AURA structures that people can simply interact with to easily open or close the structures.

## RESULTS

The array of AURA structures, combined with an Arduino microcontroller, encouraged human interaction by creating an interesting and aesthetic response that the user can control. The beauty of this design is that the user has multiple options for controlling the array of AURA structures and that the Arduino microcontroller can update the system in real time by continuously

processing sensory data from its interactions with people in the room. As a result, the user feels as though the building is alive and responsive. While people enjoyed opening and closing these blinds, the array of AURA structures still functionally act as blinds; however, the person can control them in a way unlike anything previously created. During the exhibition, people of all ages and backgrounds interacted with these AURA structures and saw a glimpse of what their future might look like if their homes or businesses utilized these structures. It was amazing to see people's faces light up once they could see my AURA structures move and see the progression of the AURA architecture design within the exhibition. My project was a centerpiece of the exhibition as it was the only piece to move and was the culmination of years of iterative designs. My role for this exhibition was vital in bringing these designs to life and taking them to the next level as they became fully functioning structures. This progression can be seen below in Figure 4.

In talking with people at the exhibition, I could feel their excitement as they imagined new ways these AURA structures could be used within a building or home. This excitement was contagious as people from



**FIG 4.** Evolution of the AURA structure design.

(FROM LEFT TO RIGHT) AURA I - 2012, AURA III - 2013 and Interactive AURA 2014–2018



**WATCH:** AURA structures in motion at the gallery.

other parts of the museum were drawn to the AURA structures to see why and how the structures were moving. The most popular questions I was asked were “What is next for this project,” and “When can I buy one?”

## ADVANTAGES

While my research specifically focused on one aspect of creating an interactive building, it does show on a small scale the capabilities of current mechanical and software technologies. Increasing the quantity and size of the AURA structures utilized by one microcontroller has a minimal effect on the system complexity. On a larger scale, the AURA structures could be placed in the side of smart buildings to act as blinds and drastically decrease a building’s energy costs. The AURA system makes it easier to close the blinds on a hot, sunny day. This simple action could decrease the heat gain of a room by 45% and increase user productivity and overall happiness of building inhabitants through its interactive nature.<sup>3</sup> Furthermore, this project will gather feedback on how people like to interact with their building space, which will be valuable to ongoing research projects specializing in human-computer interaction in the fields of architecture and robotics.

## FUTURE WORK

With this project being part of the Center for Infrastructure Renewal, my goal was to start the conversation about how buildings can be modified to beautifully interact with their inhabitants while decreasing energy consumption. Researchers at the Center for Infrastructural Renewal find innovative solutions to some of the nation’s toughest problems surrounding construction, material design and infrastructure systems. Project AURA takes the ideas of a futuristic building and brings them into the physical world. There still remains work to be done in the creation of a complete interactive smart building. However, I believe that this project will be a launching pad as we continue to look at how buildings can adapt to improve the quality of human life.

## ACKNOWLEDGEMENTS

I thank Dr. Kalantar and Dr. Borhani for giving me the opportunity to expand upon her building struc-

ture design. I thank Dr. Dylan Shell, a computer science faculty member at Texas A&M University, for giving me the opportunity to work in the Distributed AI & Robotics Lab. I also thank my friends Ryan Hernandez, Shelby Cielencki, Meagan Gimbert, and Austin Keith for their support and help in installing the AURA structures in the gallery.

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## Zachary Kitowski '18

*Zach Kitowski is a graduating senior mechanical engineering major with a minor in computer science from Colleyville, Texas. Zach performed the research for this article under the supervision of Dr. Dylan Shell and plans to continue it by attending graduate school beginning in the fall 2019 semester. Zach’s eventual goal is to launch his own company after the completion of his education.*

# LITIGATING WOMEN: THE PATH TO INTERMEDIATE SCRUTINY IN AMERICAN LAW

*By Claye Epperson*

## INTRODUCTION

Constitutionally, women have a big problem—they are not mentioned. Unfortunately, the Framers left them out of the nation’s founding document. The historical context of the contemporary Constitution makes it clear that white, propertied men were the only inhabitants who qualified as citizens.

Almost a century later, women anticipated that the ratification of the 14th Amendment in 1868 would improve their lot. The first section guarantees that:

ALL PERSONS BORN OR NATURALIZED IN THE UNITED STATES, AND SUBJECT TO THE JURISDICTION THEREOF, ARE CITIZENS OF THE UNITED STATES AND OF THE STATE WHEREIN THEY RESIDE. NO STATE SHALL MAKE OR ENFORCE ANY LAW WHICH SHALL ABRIDGE THE PRIVILEGES OR IMMUNITIES OF CITIZENS OF THE UNITED STATES; NOR SHALL ANY STATE DEPRIVE ANY PERSON OF LIFE, LIBERTY, OR PROPERTY, WITHOUT THE DUE PROCESS OF LAW; NOR DENY TO ANY PERSON WITHIN ITS JURISDICTION THE EQUAL PROTECTION OF THE LAWS.<sup>1</sup>

Historically situated after the Civil War during Reconstruction, the 14th Amendment is clearly intended to expand the definition of citizenship. Presumably, all natural-born Americans, including women, were declared citizens by its ratification.

However, the second section of the 14th Amendment introduces a gendered word into the Constitution for the first time. That gendered word—“male”—is repeated three times and is invariably used with the ideas of citizenship: “male inhabitants of such a State,” “male citizens,” and again “male citizens.”<sup>2</sup> The second section emphasizes the importance of the historical context of the amendment: it was intended specifically and only to extend citizenship to male former slaves. Left out of the new definition, women were not made full citizens, as

“the grand phrases of the first section of the fourteenth amendment would have, at best, qualified application for women.”<sup>3</sup>

Excluding an entire class of people from constitutional guarantees does not prevent that same class from encountering constitutional issues. Women certainly faced legal problems, such as discrimination, but if the Constitution is the sole source of legal relief, what were women supposed to do?

## COLLABORATION AMONG LAUNCH: URS, HISTORY, AND THE TAMU SCHOOL OF LAW

As part of a new interdisciplinary research program developed by Undergraduate Research, my faculty advisors (Dr. Katherine Unterman in Department of History, Dr. Randy Gordon at the School of Law) guided me as I searched for an answer to this question. I found this answer by synthesizing information from legal and historical sources. Legal materials supporting the research comprised case facts, oral arguments, briefs, opinions, and law journal articles; a variety of primary and secondary historical sources, such as autobiographies, monographs, and journal articles were used as well. Specifically, I focused the scope of my research on litigation involving sex-based discrimination because discrimination against sex is highly visible but was not protected under the 14th Amendment like other biological traits, including race. Combining these varied sources contributes a more complete and interdisciplinary answer not offered by either history or law alone: twentieth-century female litigators and activists brought cases to the Supreme Court, urging the Justices to consider sex as a class protected from discrimination under the equal protection clause of the 14th Amendment, and they eventually succeeded in establishing the intermediate scrutiny test.



# SEX-BASED DISCRIMINATION LITIGATION

## LEVELS OF REVIEW

The intermediate scrutiny test is the middle component of a three-tiered hierarchy of tests that courts use to evaluate discrimination claims. The vast majority of discrimination cases are evaluated using the “rational basis test.” Governments, in order to function, divide people into categories all of the time. For example, most states categorize people as either under or over the age of twenty-one to regulate the sale and consumption of alcohol. Classifications such as these are necessary and pass the rational basis test because they are rationally related to a legitimate governmental interest, like public safety. As long as the government can demonstrate such a relationship, discriminatory laws pass the rational basis test.

However, some classifications are inherently suspect and are defined by immutable characteristics—things one cannot control about oneself—such as race, national origin, or alienage. When a law divides people based on a suspect classification, judges review the law under the strict scrutiny test. To survive strict scrutiny, the government must prove that the classification is necessary to achieving a compelling interest and that the law does so in the least injurious way possible. Generally, discriminations on the lines of a suspect class are invalidated. *Brown v. Board of Education*, the case that overruled the “separate but equal” doctrine that allowed for racial segregation of educational facilities, is a good example of how the strict scrutiny test was applied to nullify a suspect class discrimination. This is the most active form of judicial review, while the rational basis test is the least active.<sup>4</sup>

Intermediate scrutiny is somewhere in the middle: it is more strict than rational basis but is not as stringent as strict scrutiny. The test was not enunciated until 1976 in the *Craig v. Boren* decision.

## THE PATH TO INTERMEDIATE SCRUTINY

Although biological sex is an immutable trait, it is not considered a suspect class. In fact, for the majority of American history, sex-based discrimination claims were evaluated using the rational basis test. *Muller v. Oregon*, which reached the Supreme Court in 1908, clearly illustrates this judicial tradition.

Curt Muller owned a laundry in Portland, Oregon. On Labor Day in 1905, he forced one of his female employees to work for more than ten hours. This directly violated Oregon’s Ten-Hour Women’s Labor Law, rati-

fied in 1903, that limited women’s work in certain industries, including laundries, to ten hours per day, six days per week. Louis Brandeis (who later became a Supreme Court Justice) argued the case on behalf of Oregon. With the help of progressive reformers Florence Kelley and Josephine Goldmark, Brandeis submitted 111 pages of information from reports on factory and medical commissions; expert testimony from doctors, academics, and factory and sanitation inspectors; and sociological data to demonstrate that labor and work environments have a direct relationship to health. Furthermore, his argument stressed that dangerous work had particularly negative effects for women, and by extension, society. Thus, Brandeis reasoned, women deserved particular protections not afforded to men, like those in the Ten-Hour Law.<sup>5</sup> The Court unanimously decided in favor of the law, reasoning that sexual differences “justify special legislation restricting or qualifying the conditions under which [women] should be permitted to toil.”<sup>6</sup> Repeatedly, the Court employed similar reasoning: sex-based classifications were routinely upheld as protections for women.

Some of these “protections” were not as well disguised as others; outright sexism motivated numerous sex-based discriminations. For example, a bartender’s union in Detroit, Michigan was worried that when their brothers in arms returned from Europe, women would have taken all of their jobs. The union successfully lobbied the Michigan legislature, and in 1945, the state enacted a law that prohibited all women, except those who were the wives or daughters of male bar owners, from being bartenders. Attorney Anne Davidow represented a group of female bartenders who challenged the law under the equal protection clause in *Goesaert v. Cleary*. Davidow presented a radical argument to the Court, claiming that the law was an “unjust and unfair classification as to sex.”<sup>7</sup> No one had ever argued before that the sexes were entitled to equal protection of the laws. Still, the Court upheld the law, reasoning that prohibiting women from bartending saved them from the dangerous revelry of bars and prevented potential moral decay.

Social currents began to change in the late-Sixties and early-Seventies as second-wave feminism rushed across the country. Attorney Ruth Bader Ginsburg (who later became a Supreme Court Justice) used her position as General Counsel for the Women’s Rights Project at the American Civil Liberties Union to develop a long-term litigation strategy that aimed to have sex declared a suspect class. She strongly held the conviction that the protections afforded to women were not benign, but rather oppressive, arguing that what society perceived as a pedestal for women was actually a cage. Ginsburg incrementally established precedent by bringing case after case before the Supreme Court. In more than thirty-five

Supreme Court cases, she protested assumptions about gender roles, arguing that those stereotypes disadvantage both men and women but ultimately prove most harmful to women. At first, she urged the Court to evaluate sex-based discrimination claims using strict scrutiny, as it did with racial discriminations. After realizing that convincing a majority of Justices to this position was unlikely, she tweaked her plea to be more conservative and suggested a middle tier that would be more rigorous than rational basis but less stringent than strict scrutiny. Ginsburg never settled for simply arguing that the sex-discriminatory statutes failed the rational basis test; these arguments always read as secondary in her briefs for the Court. Cases like *Reed v. Reed* (1971), *Frontiero v. Richardson* (1973), and *Weinberger v. Wiesenfeld* (1975), among many others, represented small, but crucial, steps in her litigation strategy of inching the Court closer and closer to enunciating a new test.<sup>8</sup>

#### INTERMEDIATE SCRUTINY AND *CRAIG V. BOREN*

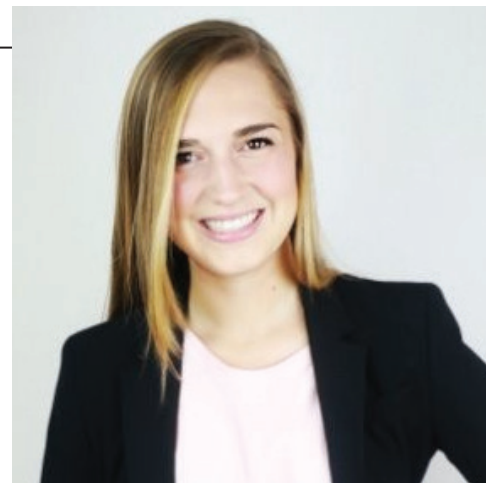
Ginsburg realized her goal of establishing a middle tier of review in 1976 through *Craig v. Boren*. The case, about an Oklahoma law that set a different age of majority for the purchase of beer for males and females, was neither special nor particularly convincing in nature. In fact, fraternity brothers, upset that they needed a middleman to buy beer for their parties, were the first people to formally complain about the law. The Supreme Court had heard Ginsburg's argument about the detrimental nature of sex classifications enough that they were convinced there needed to be a test other than rational basis to evaluate these claims. However, the Court did not believe this new test needed to be as tough as strict scrutiny, so the Justices enunciated a middle tier, known as intermediate scrutiny. Specifically, sex classifications must be proven to "serve important governmental objectives and must be substantially related to achievement of those objectives."<sup>9</sup> It is not clear where on the scale between rational basis and strict scrutiny the intermediate test lies. It is clear, however, that the test only applies to sex-based discrimination claims under the equal protection clause, and that the Court does not think all discrimination claims about biological characteristics should be evaluated in the same way. Still, Ginsburg and other female litigators and activists throughout the twentieth century succeeded in providing women a means of legal relief for discrimination by convincing the Supreme Court to establish the intermediate scrutiny test.

## ACKNOWLEDGMENTS

I would like to thank all the people who have helped make my research project possible. First, thank you to Dr. Sarah M. Misemer, Associate Director for Undergraduate Research, and Dr. Susan Fortney at the TAMU School of Law for establishing this new research program. I am honored to be the pilot researcher. Additionally, I would like to thank my advisors, Dr. Katherine Unterman in the Department of History and Dr. Randy Gordon at the School of Law. Your support, encouragement, and guidance is immeasurably valuable.

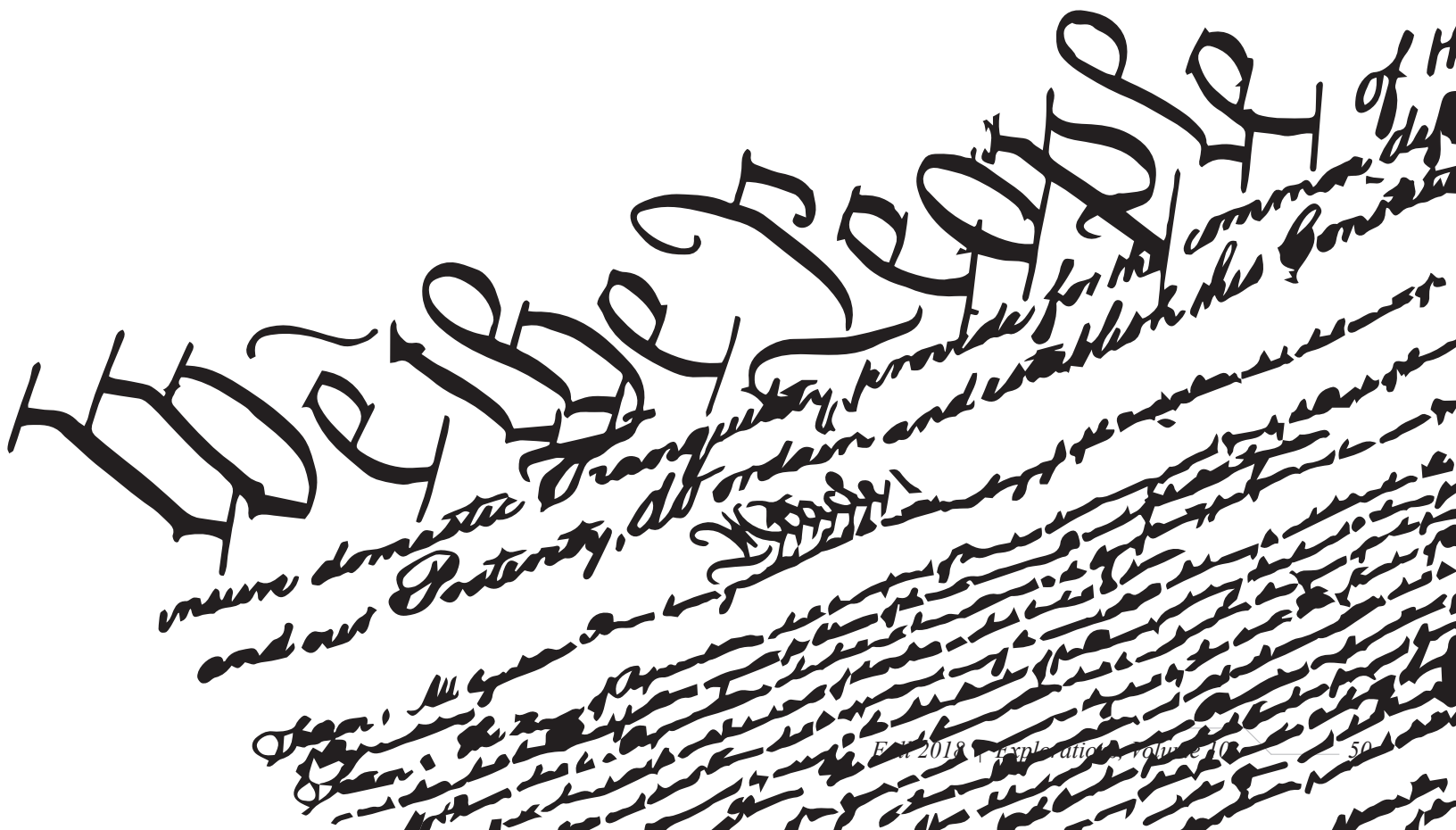
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## Claye Epperson '18

*Claye is a Class of '18 alumna from Lewisville, Texas who studied history during her time at Texas A&M. Claye participated in the 2017–2018 class of Undergraduate Research Scholars, and was the pilot researcher for a new program called Collaboration Among LAUNCH, History, and the Texas A&M School of Law. This interdisciplinary program allowed her to study both history and law under the guidance of Dr. Katherine Unterman (History) and Dr. Randy Gordon (TAMU School of Law). Claye is now a first year law student at the George Washington University Law School in the District of Columbia. She is interested in criminal law, as well as civil rights protections for women and children.*





A microscopic image of Clostridioides difficile bacteria, showing several long, rod-shaped cells with rounded ends. Some cells have thin, hair-like appendages (flagella) extending from them. The background is a soft, out-of-focus blue.

# Epidemic Hospital Pathogens: *A difficile* Problem

By Avery Young

## INTRODUCTION

The evolutionary arms race between humans and the pathogens that call them home has been raging since our ancestral lineages diverged many millions of years ago. For every deadly adaptation a pathogen has acquired, humans have evolved some strategic resistance in response. Lauded as a major medical discovery, Sir Alexander Fleming's 1928 discovery of penicillin afforded humankind an arsenal upgrade against our microscopic foes. Unfortunately, microbes were quick to cultivate antibiotic resistance, and the competition to discover newer and more effective treatments has been contested ever since. Rising virulence in the human intestinal pathogen known as *Clostridioides difficile* (*C. difficile*) has made research about this rapidly evolving bacterium a top priority.

## GENERAL PHYSIOLOGY AND METABOLISM

*C. difficile* is a strict anaerobe, meaning that it cannot grow in the presence of oxygen. It has gained notoriety as a hospital-acquired infection due to its highly contagious nature, toxin production, and antibiotic resistance. In some areas of North America, *C. difficile* infections (CDI) have surpassed methicillin-resistant *Staphylococcus aureus* (MRSA) as the number one hospital-acquired infection.<sup>1</sup> *C. difficile* begins cycles of infection in the colon and travels between hosts via fecal-oral transmission routes. Clinical manifestations of CDI often occur in cycles and range in severity from asymptomatic carrier states to fatal colonic inflammation.<sup>2</sup> Typical signs and symptoms of infection include watery

diarrhea, food refusal, nausea, and painful cramping.

Patients presenting with the highest risk for contracting *C. difficile* infections include the elderly, newborns, and anyone with recent antibiotic exposure. Broad spectrum antibiotic treatments, often prescribed for pre-existing infections, disrupt the naturally healthy and protective microbiome of the colon. This makes treatment of CDI precariously difficult because the medications prescribed to treat other illnesses are often the footholds that provide *C. difficile* the perfect opportunity for colonization.

While many aspects of the *C. difficile* infection cycle remain poorly understood, it is well established that the synthesis of toxins is a large proponent of disease symptoms.<sup>3</sup> Toxins are secreted by *C. difficile* into the host colon and affect the biology of host colonic cells at the cytoskeletal level.<sup>4</sup> Cytoskeletal disturbance results in a loss of the cell's structural integrity and apoptosis (cell suicide).<sup>5</sup> Apoptosis and intestinal inflammation subsequently manifest as the hallmark symptom of infection: diarrhea.

To ensure survival and the successful propagation of disease, *C. difficile* cells will form metabolically dormant and dehydrated endospores in the face of environmental stressors. Researchers and healthcare professionals pay significant attention to spores because of their role in the transmission cycle. Through the process known as sporulation, a vegetative *C. difficile* cell can respond to nutrient deprivation, immune system attacks, or antibiotic therapy by encasing a complete copy of its genome in many layers of thick, protective protein, as depicted in Figure 1.

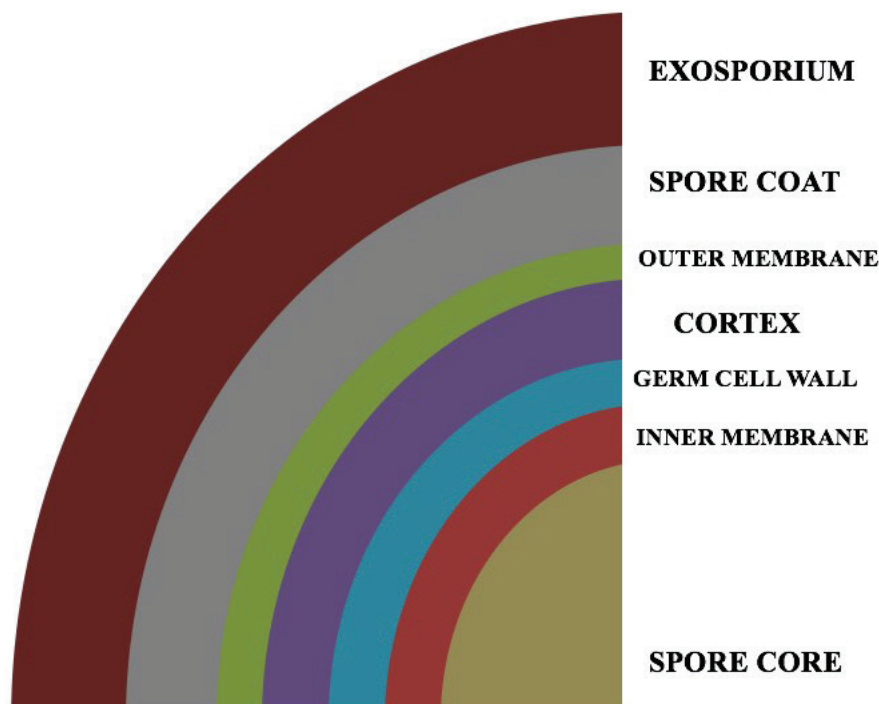
These spores present with remarkable resistance properties and are able to persist in hostile environments.

Spores even demonstrate an extraordinary adherence to stainless steel, a material often used in hospitals for appliances, furnishings, and other items with which patients and physicians come into daily contact.<sup>7</sup> *C. difficile* endospores can withstand exposure to extreme heat, oxygen (*C. difficile* is a strict anaerobe), radiation, antibiotics, and chemicals.<sup>7</sup> This even includes the standard disinfectants utilized by custodial staff. Once shed in the feces of hosts, these infectious and microscopic particles saturate the environment and can remain viable for years until ingestion completes the cycle of transmission.

Each *C. difficile* spore core contains a complete copy of the genome, as well as all proteins necessary for outgrowth upon germination. Once in the small intestine, the presence of specific bile acids will trigger spores to undergo germination, meaning they will transform once again into vegetative cells capable of disease. The specificity of bile acids necessary for germination indicates that a large portion of the spores' fates depends on the secretion activity of the liver and gallbladder. Bile acids are small cholesterol-derived acids that are necessary for the healthy absorption of fats and cholesterol during digestion. Bile acids are divided into two families: cholic acids, which stimulate *C. difficile* spore germination, and chenodeoxycholic acid derivatives (CDCA), which inhibit *C. difficile* spore germination.<sup>8</sup>

## OBJECTIVES

The focus of this research was to characterize a recently identified *C. difficile* ribotype 106 clinical isolate (LC5624). Ribotypes are used by research laboratories to classify strains of the same species; a molecular analysis of rRNA allows bacteria of the same genus and species to be further characterized into what is roughly analogous to a subspecies. Ribotyping as a technique has further classified the 180 validly described *C. difficile* species into 6 phylogenetic clades, with pathogenic strains dispersed throughout each clade. Notably, instances of CDI caused by strains of ribotype 106 have overtaken the historically prevalent ribotype 027 in cases of active circulation in healthcare communities across the globe. Using a well-studied ribotype 027 strain as a standard of comparison, investigations into a ribotype 106 clinical isolate were conducted to better understand the current evolutionary state of this pathogen. As a snapshot of this pathogen's community progression, this research high-



**FIG 1.** The main structural layers of a bacterial endospore, not drawn to scale. Figure adapted from Paredes-Sabja.<sup>6</sup>

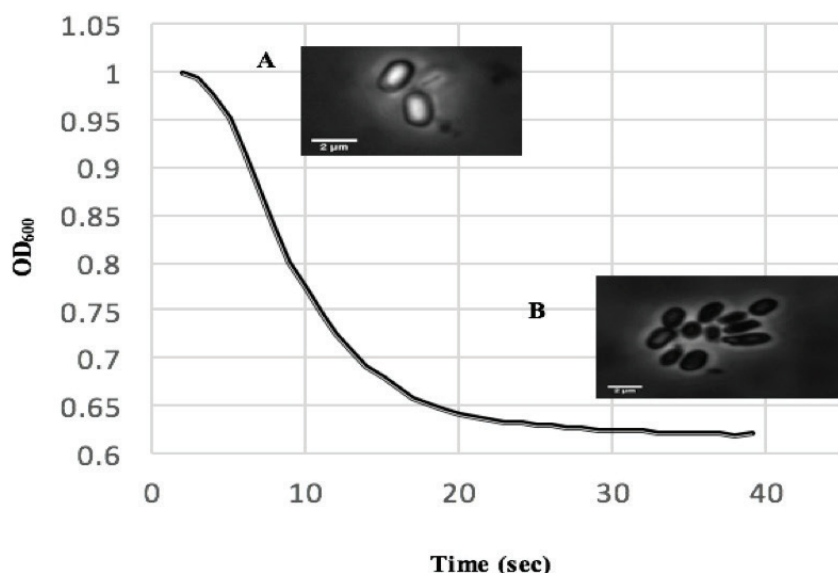
lights trends of evolution between current and historical strains and potentially serves to curtail any further advancements in pathogenicity. Through assessments of sporulation and germination assays in the presence of germinants and inhibitors, I compiled a detailed physiological profile of *C. difficile* LC5624. Bridging this molecular understanding of laboratory physiology to a range of clinical severities aids scientific research aimed at eliminating this human pathogen.

## METHODOLOGY

In order to identify the novel germination phenotype of clinical isolate LC5624 (ribotype 106), the thoroughly studied *C. difficile* strain R20291 (ribotype 027) was used as a control and standard of comparison throughout all experimentation. Optical density and dipicolinic acid (DPA) release assays were used to study the effective rates of growth and germination in *C. difficile* strains in the presence of known germinants (taurocholate and a glycine cogerminant) and inhibitors (chenodeoxycholic acid) at various concentrations.

### PRINCIPLE BEHIND OPTICAL DENSITY ASSAY

Upon germination, an endospore will rehydrate its core and shed its thick, protective spore coat and exosporium (Figure 1), culminating in the outgrowth of a living cell. This transition from a dense spore into a vegetative cell is monitored through changes in optical density at 600 nm over time and is commonly seen as a transition from a bright to a dark phase under contrast microscopy, as seen in Figure 2. An ideal graphical representation of optical density as a function of time is



**FIG 2A-B.** (A) Ungerminated, phase bright *C. difficile* spores suspended in buffer. (B) Germinated, phase dark spores after exposure to 10 mM TA and 30 nM glycine. All images were taken under the 100X objective in phase contract microscopy by Ritu Shrestha.

shown. The optical density rate of change as a function of time varies with the amount and identity of germinant or inhibitor present in solution.

#### PRINCIPLE BEHIND TERBIUM ASSAYS

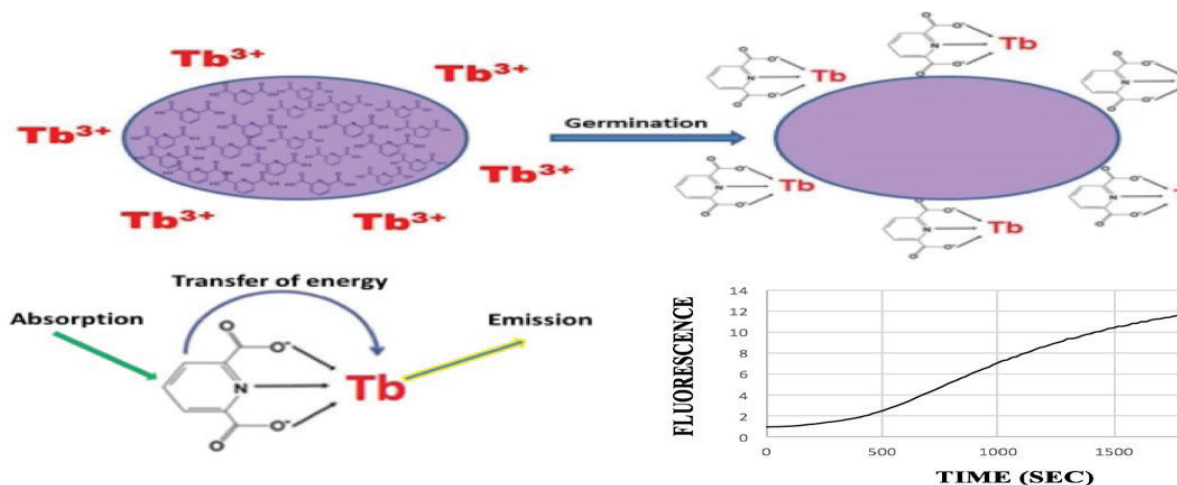
A large component of spore resistance is attributable to a DPA chelate found packaged in the spore core. The DPA chelate is a complex layer of calcium ions coordinately bound to the ligand DPA and is thought to be primarily responsible for the endospore's core dehydration and impressive heat tolerance. During germination,

this DPA chelate is released to allow the spore core to rehydrate and develop into a vegetative cell. In the laboratory, DPA release can be monitored in real time because DPA readily binds to terbium ions added to the solution and results in a fluorescent signal. An ideal graphical representation of fluorescence as a function of time is shown in Figure 3.

#### QUANTIFYING THE KINETICS OF THE MULTI-ENZYME GERMINATION PROCESS

As mentioned previously, taurocholate (TA) and glycine are potent activators of *C. difficile* spore germination and CDCA is a potent inhibitor. The concentration of a compound that results in the half-maximum germination rate is known as the effective concentration 50%, or  $EC_{50}$ . From the  $EC_{50}$ , the interaction of an inhibitor of germination can be quantified as  $K_i$ . Concentration values for glycine and TA are reported as  $EC_{50}$ , and CDCA is reported as  $K_i$ . Spores with a decreased sensitivity for germinants or inhibitors present with higher  $EC_{50}$  or  $K_i$  values respectively.

The kinetics of the DPA release across a range of TA concentrations (0 mM–50 mM) and a constant concentration of glycine were used to calculate TA  $EC_{50}$  values for both strains. Similarly, a range of glycine concentrations (0–30 mM), and a constant concentration of TA were used to determine a glycine  $EC_{50}$  value for both strains. To calculate CDCA  $K_i$  values, a range of TA concentrations (0–50 mM) and a constant concentration of CDCA were tested in terbi-



**FIG 3.** Dehydrated spore cores are rich in a DPA chelate that is released upon initiation of germination. Upon this release, DPA can form a complex with terbium ions that is excitable at 270 nm.



um assays.  $EC_{50}$  and  $K_i$  experiments were designed to include constant concentrations of a co-germinant or inhibitor to ensure the range of TA or glycine concentrations was the sole independent variable.

## RESULTS

In the calculations reported in Table 1, a lower  $EC_{50}$  value for LC5624 indicates a more potent interaction with substrate and, subsequently, more efficient germination. Wildtype R20291 spores require greater than 9 times the concentration of TA and 2.2 times the concentration of glycine than do *C. difficile* LC5624 spores to induce half maximal germination rates (Table 1). In regard to inhibitor CDCA, *C. difficile* R20291 spores were inhibited at approximately 1.6 times greater concentrations of CDCA than were *C. difficile* LC5624 spores (Table 1).

Arguably the most notable aspect of the *C. difficile* LC5624 germination profile is the fact that LC5624 spores show a significantly heightened sensitivity to both bile acid germinants and inhibitors. Based on a comparison of calculated  $EC_{50}$  values, LC5624 spores are more sensitive to the bile acid germinant taurocholate (TA) and amino acid co-germinant glycine than are R20291 spores. This aspect of the germination profile may be misleading if not viewed in the context of a typical transmission cycle. Inside a host colon, a typical endospore will naturally be exposed to TA, glycine, and CDCA. For R20291 spores, the  $K_i$  of the CDCA inhibitor is less than that of the  $EC_{50}$  of both primary germinant TA and co-germinant glycine. This means lesser concentrations of CDCA are required to inhibit germination in R20291, and greater concentrations of TA and glycine are necessary to initiate germination. In contrast, *C. difficile* LC5624 spores require lower concentrations of TA and glycine to initiate germination, and greater concentrations of CDCA to inhibit germination. Such variance in spore germination sensitivities carries impactful consequences in regard to infection; a spore derived from *C. difficile* strain LC5624 may be more likely to germinate in the presence of physiological concentrations of bile acids than are spores of *C. difficile* R20291. At the same concentration of TA, glycine, and even CDCA, *C. difficile* LC5624 spores appear to germinate into viable, disease-causing organisms at faster rates than *C. difficile* R20291 spores.

**TABLE 1.** Comparison of  $EC_{50}$  and  $K_i$  values for known germinants and inhibitors between *C. difficile* strain R20291 and clinical isolate LC5624.

	R20291 (Ribotype 027)	LC5624 (Ribotype 106)
$EC_{50}$ Taurocholate (mM)	$1.20 \pm 0.13$	$0.127 \pm 0.02$
$EC_{50}$ Glycine (mM)	$0.550 \pm 0.10$	$0.250 \pm 0.05$
$K_i$ Chenodeoxycholic Acid (mM)	0.423	0.268

*Note: Values represent the average from three independent experiments  $\pm$  the standard error of the mean. Statistical analysis was performed as a paired t-tests between replicates.*

## DISCUSSION

*C. difficile* R20291 (ribotype 027) was isolated during an epidemic outbreak of CDI in the early 2000s; LC5624 (ribotype 106) was a clinical isolate identified in 2017. In little more than a decade, ribotype 106 evolved with rates of germination that are more than double that of historical strains. This increased sensitivity to the presence of natural, host-derived germinants may have contributed to the spread of ribotype 106 within hospital and healthcare communities.

The clear advance in the spread of this strain also raises questions pertaining to other active strains of the same genetic ribotype. Are heightened sensitivities to germinants conserved among all ribotype 106 strains? Have the minimum concentrations for germination inhibitors risen in all strains? While it is not appropriate to suggest this trend is pervasive in all actively circulating strains of ribotype 106, there is no evidence to indicate such an increase would not also be modeled in other strains. Further investigations into other strains would certainly prove beneficial in this regard and would better guide the physicians who are providing treatment to patients afflicted with CDI.

The characterization of phenotypes seen in *C. difficile* clinical isolates allows for a deeper understanding of the pathogen faced by physicians and patients in healthcare today. A clear picture of the pathogen in its current evolutionary state could curtail potential increases in virulence through better informed treatments of active cases. Further investigations into clinical isolates, their unique phenotypes, and levels of disease severity allow for a greater understanding of the pathogen in its community evolution and provide physicians with an edge over the evolutionary rival found in *C. difficile*.

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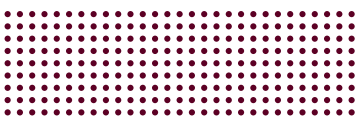


## Avery Young '19

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