SRI International – Summer REU Program 2016

Student Research Projects and Accomplishments:

Below is a summary of each student's project at SRI International during the summer of 2016 in their own words with some editing of the text as appropriate.

Photo Credit: Field trip- REU Students at the Department of Applied Physics, Stanford University, with Prof. Byer and Dr. Brett Shapiro.

[1] Student: David Thorne (Central Connecticut State University); Mentor: Dr. Jason White

Project Title: Modeling of Reactive Gas and Pyrolysis Interactions with Hot Carbon Chars

Heat shields use different types of thermal protection system (TPS) materials. Ablative heat shields are required for when you expect to encounter extremely high temperatures during entry into an atmosphere. Ablative TPS materials are composed of carbon fiber and phenolic resin. When exposed to high temperatures and reacting atmospheres, the material undergoes a process called pyrolysis, which is a chemical reaction at high temperatures in which gaseous products are generated. Ablative heat shields function to protect the craft by generating a boundary layer of pyrolysis gases in front of the heat shield during entry into an atmosphere. This boundary layer protects the craft from convective heat and carries heat away.

Modern design of heat shields involves the use of ablation models, which simulate the ablative process. These models however are dependent on experiments performed in the 1960's, and the limited set of data collected based on outdated techniques during that time. Any effort to improve the physics and chemistry of ablation models must reference that set of data, because few new experiments have been performed since that time. As a result of the use of subpar models, ablation rates are typically overestimated, calling for more ablative material than necessary during heat shield design. Lighter heat shields are of course desired to make the craft lighter, allowing for more equipment to be stored on board. The purpose of the project I was involved in was to collect modern experimental data that not only could be used to evaluate the performance of ablation models currently in use, but could also be used for the development of new models.

The experimental setup used to collect this data was designed to be simple, and easy to simulate using fluid dynamics and material response codes. It is simply a quartz tube through which a carbon fiber plug is fitted, and reactants at various temperatures are passed through. We collect temperature and pressure data at different points across the tube, and detect products of the reactions with the plug using two spectrometers downstream of the plug. This data is then sent to the University of Kentucky, where they are developing their KATS program (Kentucky Aerothermodynamics and Thermal Response System) in order to simulate the ablative process.

As for the choice of which reactants are experimented with, pyrolysis gases and oxygen are the core of the experiments. Oxygen because it is very reactive with carbon, easy to model, and commonly found in planetary atmospheres, and pyrolysis gases because they are involved in the ablative process. Various experiments have to be performed because of experiments with oxygen. For instance, CO and CO_2 are products of the reaction of oxygen with carbon and continue to react with the plug as they pass through, so individual experiments must be performed for each of them. Experiments with O atoms must also be performed, because O is found in the presence of O_2. In order to create these O atoms, either we could run O_2 through the discharge, or we can perform a titration of NO with N ($NO+N \rightarrow O+N_2$). Because we would like to perform this titration, individual experiments with NO are required in order to distinguish observed interactions with the plug due to O from those due to NO.

Signal intensities that the spectrometers receive do not immediately allow us to know the quantity of a product detected. In order to quantify reaction products detected downstream of the plug, we must perform calibration experiments. These experiments involve varying the mass flow of a specific gas directly into a spectrometer (in another words, without passing through a plug first), and then correlating the mass flow of the gas with the intensities detected. Then, any product detected downstream of the plug that we have performed calibration experiments for can be quantified based on signal intensity alone because we have established intensity's relationship to mass flow.

As for the gases I got to work with this summer, NO was the focus both in experiments and during analysis. About 9 total experiments were performed with NO at varying temperatures, and I have analyzed the data received in terms of things like detected products and their quantities, and reaction mechanisms going on through the plug. Experiments with O atoms using both the titration technique and microwave discharge were also performed.

However, we could not get the O atoms to react with the plug in either case, probably because of recombination of the O atoms with themselves before they reach the plug, or the O atoms getting stuck on the tube walls. I believe I was involved in about a total of 20 experiments this summer (including calibration experiments). Most of my time was spent in the lab this summer, while data analysis was performed whenever I was not in the lab. For the last three or so weeks however, I had been working mainly on both my presentation and analysis of NO experiments, as well as on a paper for NO. A lot of progress was made this summer for this project and I loved being involved.

[2] <u>Student</u>: Justine Walker (The College of Wooster); <u>Mentors</u>: Drs. Hua Lin and Thomas Shaler

Project Title: Breaking Down the Secrets of the Human Hair

This summer I worked on a biochemistry project with Hua Lin and Tom Shaler, as well as with Sophia Chen. It was my first time in 5 years doing anything biology or chemistry related (outside of thermal physics) so it was a bit of a slow moving journey. Overall, though, I feel like I accomplished a decent amount of what I aimed to do with my project.

My project is based in the field of forensics. In crime shows, we often see our investigators find a strand of hair at a crime scene, they quickly do a bunch of science stuff in the lab, and suddenly they are able to figure out whom the hair belongs to. Thus, they quickly find the culprit of the crime. In actuality, current techniques require much more time and the root of the hair. The root is required because that is where the DNA used for analysis is held. Unfortunately, most hair samples found at crime scenes do not have the root attached since the hair needs to be pulled out for the root to be attached. Thus, a technique for figuring out whom a sample belongs to is required for more efficiently solving crimes and even for ancestry analysis. That is what Hua and Tom aim to do with their Hair Proteomics project.

The goal of this project is to allow us to use proteins inside of any section of hair from any location on the body to acquire protein sequences in place of DNA sequences in order to identify whom the sample belongs to. Currently, though, it takes a long time to do this type of analysis and the markers in the amino acid chains that show variations to the scale of DNA analysis still need to be researched further.

At the start of the summer we had multiple buffer methods from previously published papers from other groups that we wanted to compare and find the most effective from. One of the buffers was immediately discarded because it was way less effective than the other buffers. The three other buffers were then compared in further experiments and we found that the most consistent buffer was our lab's THGH buffer solution. We also, replaced the recommended reducing reagent, DTT, with a more efficient one, TCEP. We found that way less TCEP is required to do the same work as a larger amount of DTT.

Additionally, we cut out some superfluous steps thus making our experiment efficient. Unfortunately, we have yet to make the process of cutting hair faster and less messy. We started off cutting the hair using rulers for exact measurements but this was extraneous so we ended up switching to eyeballing approximate 1mm pieces. Then, we attempted creating a multiple razor chain to make multiple cuts at one but it was too difficult to control the cutter and hair for this to be efficient at all. We also tried freezing the hair and then shaving it with cheese graters but the size variations were too large and it took much longer than simply cutting the hair so we stuck to cutting it with razor blades.

An accomplishment from this summer is that we figured out that we are able to use a Nanodrop device over BCA to figure out protein concentrations because of consistent ranges of concentrations between samples and the fact that the two give proportionally similar results. Therefore, we can choose to use the quicker, cheaper method – Nanodrop. Lastly, we were also able to decrease the size of sample needed to get accurate results from our techniques and we hope to get even smaller for commercial uses. Hopefully, the process will be streamlined further and more ground will be covered in identifying significant amino acid chains thus making this technique more useful.

[3] <u>Student</u>: Kelly Neubauer (Gustavus Adolphus College); <u>Mentors</u>: Drs. Konstantinos Kalogerakis and Yingdi Liu

Project Title: Laboratory Studies Relevant to Earth's Upper Atmosphere

Through this summer I worked on two projects. The first experiment was studying the decay of hydrogen atoms generated through photolysis initiated from an Excimer laser beam at 193 nm. Hydrogen atoms were generated from HCl for most of the experiments we ran. The atoms reacted with molecular nitrogen and oxygen, whose concentrations were varying in order to determine a rate constant. The rate constant was determined as the decay of hydrogen atoms to HO_2. Our goal was to determine a rate constant at low temperature, where no previous studies have been done. We were able to determine a rate constant at 173 K, but our result is much faster than the NASA and IUPAC projections. These preliminary results may actually fit the projections between NASA and the IUPAC despite their divergence at this temperature, once the corrections for temperature are done, but we are not able to explain the observed behavior so far.

This first experiment taught me how to think critically and troubleshoot many different unexpected results. We worked to optimize our system, which was far from perfect. Our lasers lost energy very quickly, which meant that time could not be wasted once we began warming up and running experiments in the morning. I also learned a lot about the lab and the science behind the experiment as the weeks went on. I came in very overwhelmed, this being at the far end of the project's lifetime, needing to understand the results we were getting without being a part of the many steps that led up to them.

The second experiment began by setting up a cavity ring-down spectroscopy (CRDS) apparatus. I analyzed many different mirrors, from different laser heads, using a spectrometer. We eventually got high quality CRDS mirrors, which we used in the cavity. I built and mounted the cavity, set up the optics to direct the beam, and set up gas lines to reach our cavity. With good alignment using back reflections, the ring-down was not hard to obtain. While not difficult to obtain, it was difficult to optimize at times and strongly depended on the energy of the laser beam and the cleanliness of the mirrors. The nature of the pulsed dye laser resulted in the inability to stabilize a single mode, causing unsmooth exponential decays. We found that despite this odd shape we were able to generate good results. We studied the characteristic absorption lines of oxygen between 627 nm and 630 nm. We also varied the oxygen concentration in the cavity and saw that the ring-down time varies linearly as expected.

I enjoyed this experiment a lot, being accountable for all aspects of it. I got to set up the apparatus, do all of the alignment, and run all of the experiments on my own. This was very exciting and also helped me fully understand the experiment. I learned a lot about the steps that are taken when just being an experiment, starting first verifying results that have previously been measured and then moving closer and closer to new, unstudied areas.

Reflecting on my goals from midsummer, I believe I have improved my laboratory skills and gained confidence in what I have learned. I also learned about my own interests.

[4] Student: Victoria Kong (Carroll College); Mentors: Drs. Gregory Faris, Sanhita Dixit, and Yingdi Liu

Project Title: Imaging in Real- Time: Droplet Kinetics and Biological Samples

This summer, I had the opportunity to work on both the hyperspectral imaging and droplet interface lipid bilayer projects. The hyperspectral imaging project was an incredible experience, allowing me to work with technology that is completely new in the field of imaging. At the beginning of the summer, I spent quite a bit of time just learning about the Fourier-transform interferometer microscope setup. I had never had any prior exposure to Fourier transforms, and did not even know what a Michelson interferometer was, so the learning curves felt steep.

After taking some time to figure out the conceptual side of things, I then moved onto actually looking at the programs. I also had never used LabView or MATLAB, so I spent a bit of time looking at all the programs that were used for the interferometer and microscope setup. After I reached an understanding of the experiment as a whole, I was tasked with looking at the MATLAB code and trying to figure out what exactly was taking the program so long to run. While Yingdi worked on optimizing the Labview, I looked at some of the individual MATLAB steps and tried to figure out where the rate-limiting steps were occurring.

I was able to compile a list of some of the MATLAB steps, and how long each of them took. Because I still did not feel quite as comfortable optimizing a code, considering I had just learned *how* to code a few weeks prior, the MATLAB took a bit of a backseat and I focused more on the physical instrumentation setup. The Labview program uses a laser in order to do some calibration steps, and so we worked on changing out the laser as well as fixing some of the mounts and screws to help make the setup and alignment of the interferometer easier.

Disassembling and reassembling the interferometer was a very beneficial exercise to help me understand that actual mechanistic working of our setup. I was able to put the interferometer back together fairly independently, and align everything rather quickly. While I waited for the GPU to come in, as well as for the code to be completed by Gabriel, I started working on the interface lipid bilayer project.

I spent a bit of time reading and taking notes about what an interface lipid bilayer was, and exactly what we were trying to accomplish. Since I worked with lipid bilayers last summer, I caught on to what we were trying to do pretty quickly. Besides the wet lab techniques of making the lipid solutions and pulling the tips, I was able to work primarily with the microscope and work on trying to use the mechanized tip to form the drops under oil. There were some difficulties with learning how to use the programs and making sure that our fluorescence filters were correct for both NBD and DiD.

Assembling and disassembling filter cubes also helped me learn quite a bit about the techniques and the overall microscope setup we were using. I came into this summer knowing basic microscope setups, because of my previous biology experience, but I had never used such an extensive setup with fluorescent filters.

And then, on the second to last day at SRI I was able to form the lipid bilayer! This was a very exciting day, and I was able to make the drops rather consistently. I showed Greg and he confirmed that I was definitely forming lipid bilayers, which was very encouraging.

Overall, I think I accomplished quite a bit. I am very pleased with how the summer turned out, and I am very happy that I chose to work on the projects that I did. Though I started out feeling a little over my head with the hyperspectral imaging project, I learned so much so quickly that I feel very proud for catching on so quickly. I also think that adding on the lipid bilayer project was a good balance for me, and since I want to pursue imaging/inorganic chemistry for graduate school, the two projects together gave me a good comprehensive view of imaging science and what we can do with it.

I am very happy that I was able to work here at SRI for the summer, and will always remember the mentors and advisors that made it so great. I am excited to see where my life takes me in the future. Thanks for a great summer!

[5] Student: Emanuel Dallas (Brown University); Mentors: Drs. Sanhita Dixit, and Gregory Faris

Project Title: Platform design for Rapid PCR

The goal of my project was to design and create a platform for conducting rapid PCR. This would potentially shorten the length of PCR done in labs from several hours to several minutes. In order to create a usable platform, we had to first ensure that the DNA was heated to temperatures necessary for conducting PCR. This became a challenge in its own right, and occupied most of my efforts over the summer.

I came into the summer with little research experience. I wanted to not only learn but also witness how the scientific process manifested itself in everyday work. Not only did I learn how to solder, carry out some organic reactions, and use tabletop lab equipment and microscopes, but I also learned how failures shape research and how intuition and experience serve incredibly useful in the lab.

I started off by familiarizing myself with the lab equipment and literature on rapid PCR. I learned how to carry out the necessary organic syntheses and use a variety of lab equipment to manipulate platforms and PCR solutions. I also learned how to use the microscope and fluorescence setup used to carry out temperature calibration for our platforms. From there, I set out creating platforms, testing their temperature profiles, changing designs, and testing them again. By frequently speaking with Greg and Sanhita, I tried out a number of entirely distinct platform prototypes, most of which ended up displaying deficiencies after several trials.

By the end of the project, we had a platform that looked promising but still displayed some flaws. My summer ended before I had time to investigate these flaws further and work on refining the design to prevent DNA solution from evaporating or overheating. There also remained the issue of uniformity across platforms, which was far from resolved by the time I left. That is to say, for a platform design to be successful, it has to be precisely reproducible. Otherwise, it will lack consistency and thus lack the trustworthiness that one expects in such a normally reliable process.

I had an incredible summer at SRI. The program was a blast, I learned a ton about my research topic and science in general, and Greg and Sanhita were incredibly helpful and encouraging mentors. I also loved exploring the Bay Area on the weekends.

[6] Student: Gabriel Barajas (Stanford University); Mentors: Dr. Gregory Faris

Project Title: Hyperspectral *Imaging*

The first few weeks of my REU experience introduced me to the main project I would work on throughout the summer— an FPGA implementation of hyperspectral imaging analysis— and had me aid in a related project, which included a software-based implementation. I completed the necessary basic safety training for the work I was to do, which only put me at minor risk, since I did not directly deal with biological samples or dangerous chemicals. My supervisor then gave me some reading materials to acquaint me with the hardware description language VHDL I would be using later. The language proved not too difficult to learn, as I had previously worked with a similar language, Verilog. While I was learning VHDL, my supervisor also briefed me on the software project and outlined goals for me to accomplish. My main goal was centered on translating a MATLAB program into C++ with the same functionality. The program performed a Fourier transform on image data through time and subsequent phase correction to remove noise. This was a didactic project for me because it honed my skills in both Fourier analysis and computer programming.

I came across a significant stumbling block early on because implementing the C++ program meant I had to install third-party libraries on my computer to access complicated functions. Although I had substantial coding experience prior, I had never built a program from scratch (I had always been provided with starter libraries installed), and I soon realized there was no clear-cut solution to this issue, as it depended on many variables (e.g. operating system, programming environment, library type). I eventually solved the issue after consulting many— at times conflicting— sources. Over the next several weeks, I recreated the MATLAB program step-by-step, and soon had a functioning program that approximated the original code fairly well. The main purpose of my work on this project was to drastically reduce the run time of the code. I made significant progress toward this, reducing the required time from over five minutes to less than ten seconds. A current goal for this project is to adapt the C++ code to a lab computer with a GPU to reduce the run time even further.

As for the FPGA-based project, this was more complicated to grasp at first. The main problem my supervisor faced with this project was that a significant amount of data seemed to be lost on its way through the FPGA device, which was meant to perform operations on the data and output transformed results. Although I learned an immense amount throughout my time working on this project, I did not see significant results until later in the summer. I was to examine the code for the FPGA written by a previous intern and locate the area that was causing the loss of data. The previous intern had successfully implemented much of the hyperspectral imaging design, but unfortunately did so in a fairly roundabout way and without comments indicating his intentions for different sections of code. We came up with some ideas as to which lines may have been causing the issues, but these led to dead-ends. The main obstacle I had when making modifications to the code was the incredibly long time it took to test whether I had succeeded. As the code for this project was extensive, it took upwards of 45 minutes for the computer to synthesize it into a file that was readable by the FPGA. This made the trial-and-error process long and frustrating, but I soon learned several more efficient methods of testing modifications, including a software simulation of the code, which ran instantly. Eventually, we discovered the problem had been caused by even older code that we had not considered earlier— code that was more deeply imbedded within the project. Once we fixed this issue, I worked on several other modifications to the code to optimize its functionality, including maximizing the size of the images we were taking.

The presentation component of my REU was also tremendously useful in gaining understanding of my projects. I researched more thoroughly the background of my projects, including some of their intended applications, and my specific role in the projects as a whole. I learned about the complex pipeline of the hyperspectral imaging I was contributing to— incorporating a spectrometer coupled with a microscope to image a biological sample, which produced data that would be processed by the FPGA to extract spectral information from the image, and then analyze the data using LabView and other applications. I greatly value the experience I gained through the REU as well as the people I met.

SRI REU Program Activities:

Regular meetings with the REU students were scheduled to gauge student progress and address any concerns. In addition, several activities were included in the 12-week program to provide a well-rounded and fun-filled REU experience. These are described below.

1. Field Trips:

- 07-18-2016: Stanford University/ LIGO Engineering test facility - The REU students accompanied by the program PI's Drs. Dixit and Faris visited Dr. Byer's labs at Stanford University. Our, host, Dr. Byer, gave the REU students an overview about his research interests and then took the students on a tour of two facilities on Stanford's campus. We were excited to have the opportunity to see the labs which housed large vacuum isolation systems at the LIGO Engineering test facility that were used on Advanced LIGO (http://ligo.stanford.edu/lvc/) to detect *gravitational waves*! Dr. Brett Shapiro gave a wonderful introduction to the LIGO effort. Dr. Byer showed the students research work from the laser accelerator test facility that makes laser driven dielectric accelerator structures.
- 08-01-2016: SLAC - The REU students accompanied by the program co-I Dr. Dixit, and SRI scientist, Dr. Daniel Matsiev, visited the SLAC laboratories. Our group was hosted by Dr. Thomas Weiss (group leader) and Dr. Ivan Rajkovic who assist users at the beam line 4-2, the SSRL station that works on Biological Small Angle Scattering/Diffraction (http://ssrl.slac.stanford.edu/~saxs/index.htm). The students were able to see the instrumentation inside the hutch and it was a very informative tour!
- 08-04-2016: Impossible Foods - The REU students accompanied by the program PI's Drs. Faris and Dixit visited the labs of a fascinating startup company in the San Francisco Bay Area called Impossible Foods. Our group was hosted by Dr. Ranjani Varadan who is a Director (Protein Discovery) at the startup. Dr. Varadan gave the students an overview of her research career, and described the mission of Impossible Foods.

2. Lab Tours at SRI International:

- The REU students visited the facilities of the Materials Research Labs on campus that are involved in doing applied research in the area of CO_2 capture and were hosted by Dr. Indira Jayaweera.
- The REU students visited the FAST lab (https://www.sri.com/newsroom/video/fast-fiber-optic-array-scanning-technology) and were hosted by Dr. Janey Snider who is the product specialist on the instrument. The students were given a tutorial on the optics behind the instrument and a peek at the software that is used to image biological cells.

3. Innovation Speaker Series at SRI International:

This seminar series was started in 2016 by the Advanced Systems and Technology Division at SRI International, and the REU students had the opportunity to attend these seminars.

- 07/20/2016: Speaker - Pascal Finette, Vice President, SU Labs, Entrepreneurship Chair and Global Evangelist at Singularity University.
- 08/31/2016: Speaker - Dr. David Soderblom is an astronomer from the Space Telescope Science Institute. His talk focused on how the new James Webb Space Telescope will help reveal the origins of our universe, our galaxy, and our world. NASA's James Webb Space Telescope (JWST) will be the largest telescope ever put in space when it is launched in October 2018.

4. REU Student Presentation:

Around the 11th week of the program, each REU student gives a presentation outlining the research they conducted over the summer. Staff members and the CEO attend these seminars schedules permitting. Presentations last approximately 20 minutes with an additional 10 minutes reserved for questions and discussion. Prior to these presentations, each student hosts the remaining group for a tour of their lab and experimental set up. The 2016 REU students gave the following presentations:

8/15/2016	Seminar Title
Kelly Neubauer	Laboratory Studies Relevant to Earth's Upper Atmosphere
Emauel Dallas	Platform Design for Rapid PCR
David Thorne	Collecting Experimental Data for the Modeling of Reactive Gas and Pyrolysis Interactions with Hot Carbon Chars
8/16/2016	
Justine Walker	Breaking Down the Secrets of the Human Hair
Gabriel Barajas	Implementing High-Speed Bio-Image Processing Using an FPGA and High-Level Programming Alternatives
Victoria Kong	Imaging in Real-Time: Droplet Kinetics and Biological Samples

5. Graduate School Application information:

A one hour group discussion was organized by Drs. Faris and Dixit to help answer questions from the REU students regarding graduate school applications, graduate school study abroad options and, helping students understand that a variety of career options are available in the STEM disciplines.

The program coordinators also encouraged our REU students to attend webinars on the website hosted by the Institute of Broadening Participation (http://www.pathwaystoscience.org/) and to navigate the IBP's website for information on fellowships and graduate school applications.

- **8/3/2016 at 3pm Eastern: Making the Most of your STEM Graduate Program - free Webinar**: 1 hour including 3 guest speakers, Q&A and captioning for the hearing impaired.

6. Ethics Training

A formal mechanism to train the students in the ethics of scientific research was put in place in the summer of 2010. As part of this training, the students were required to take an online course to educate themselves about ethics in a research environment. The online course is available freely at: http://ori.dhhs.gov/education/products/montana_round1/issues.html#intro. The study of the following three sections was mandatory; Section One: Ethical issues in Research, Section Two: Interpersonal Responsibility, and Section Four: Professional Responsibility. At the end of their study of each section, this website provided a test. The students were asked to take the test and furnish copies of their scores to Dr. Sanhita Dixit.

7. Social Events

Students were invited to attend SRI events during the course of the REU program.

- A welcome party for the REU students was organized at the start of the summer. An end of program party was organized to declare the Peterson Award Winner and to celebrate the successes of the REU students!
- Breakfast with the CEO Dr. Bill Jeffery: The students participated in a breakfast event with the CEO along with other campus interns.
- Division All Hand meeting: The students attended the All Hands Meeting for the Biosciences Division during the summer.
- Summer Concert Series: The students enjoyed lots of good music and California sunshine during the summer concert series on campus which featured a great band line up and each act features at least one SRI employee or alumnus.

8. James R. Peterson Award for Excellence in Undergraduate Research

During its 50th anniversary reunion in 2006, the former Molecular Physics Program at SRI International, announced the creation of the James R. Peterson Award for Excellence in Undergraduate Research. This award is given to the summer undergraduate student participating in SRI's NSF-supported Research Experiences for Undergraduates (REU) program that best combines Jim Peterson's technical excellence and spirit of friendliness and cooperation.

REU student nominations determine the winner of the Peterson Award. The 2015 winner was Brendan Marsh of University of Missouri, Columbia. Previous winners include Anand Oza, Princeton University (2006), Zachary Geballe, University of Michigan (2007), Brad Hartl, University of Wisconsin, LaCrosse, (2008), Aya Eid, Illinois Institute of Technology (2009), Alejandro Ceballos, Northern Arizona University (2010), Michael Rodriguez, California Lutheran University (2011), Stefan Mellem, St. Olaf College (2012), Timothy Weber, Columbia University (2013), Collen Werkheiser, Reed College (2014), Brendan Marsh, University of Missouri-Columbia (2015), and Gabriel Barajas, Stanford University (2016).